Oberlin College Carbon Neutrality Resource Master Plan, Implementation Strategy, and Economic Approach

October 2016

EVER-GREEN ENERGY™

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About the Project Team

The project team of SSOE, Inc. and Ever-Green Energy led the development of the Oberlin College Carbon Neutrality Resource Master Plan, Implementation Strategy, and Economic Approach. Each organization is briefly described below.

SSOE Group

SSOE Group is a project delivery firm for architecture, engineering, and construction management. SSOE is prominent in both industrial and institutional environments and make their clients successful by saving them time, trouble, and money through their innovative design solutions. SSOE strives to return 100% of their fees through savings and over the last 3 years, SSOE has returned 111% of its fee to clients in the form of project savings. SSOE understands its clients' expectations for buildings that are durable, flexible, easy to maintain, and energy efficient. SSOE's architects and engineers include LEED® accredited professionals experienced in sustainable design and energy reduction opportunities.

Ever-Green Energy

At Ever-Green Energy, we take pride in being one of the country's premier district energy system experts, with decades of experience in developing, operating, and managing community energy systems. Our unique combination of technical expertise, business acumen, and operations experience has helped communities, colleges and universities, health care campuses, and government organizations advance the study, development, and operation of community energy systems. The Ever-Green team applies its depth of knowledge through every step of a system's development and implementation, finding sustainable solutions that are reliable and financially viable to secure a campus or community's energy future.

Acknowledgements

The Project Team would like to express its gratitude to the Oberlin College Staff, students, and stakeholders for their support in the development of this project. In particular, Jeff Baumann, Steve Dupee, Bridget Flynn, Mike Frandsen, Cindy Frantz, Julian Geltman, Sean Hayes, Jim Klaiber, Doug McMillian, Julia Murphy, Dave Pastorius, John Petersen, Meghan Riesterer, Sal Talarico, and Darrel Tremaine provided a great deal of support and guidance as we navigated through this project. In addition, we appreciate the guidance that was provided by the Carbon Neutrality Subcommittee of the Board of Trustees and its members, along with the detailed feedback they offered throughout this process. The team from Oberlin College and the community stakeholders displayed an immense dedication to this project and the pursuit of the environmental, societal, and economic goals that were established. This commitment has made all the difference in the success of these efforts.

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Oberlin College Carbon Neutrality Master Plan

1. Introduction

In 2006, Oberlin College (Oberlin) signed the American President's Climate Commitment and committed to achieving carbon neutrality by 2025. In 2016, Oberlin turned to Ever-Green Energy (Ever-Green) to lead the development and implementation of a plan to fulfill this commitment. Ever-Green, along with its subconsulting partner SSOE Group (SSOE), collectively known as the "Project Team," developed this Carbon Neutrality Resource Master Plan, Implementation Strategy, and Economic Approach (Plan) to identify actionable, implementable, and financeable steps to bring Oberlin closer to carbon neutrality in a meaningful manner.

Oberlin has recently implemented several significant actions to reduce its carbon profile. The most meaningful action was the conversion of its central utility plant from coal to natural gas, which has reduced carbon emissions by over 30%. By way of its partnership with the local municipal electric utility, Oberlin Municipal Light and Power System (OMLPS), Oberlin has been able to leverage the 2012 installation of a 2.27 MW solar PV array and a broader fuel-switching initiative within OMLPS to approach carbon-neutral electricity consumption on the campus. While these recent steps have aided Oberlin's progress toward carbon neutrality, a range of additional steps and strategies will be necessary to achieve Oberlin's commitment. The two key strategies in the next phase focus on energy and water conservation measures (ECMs) and a local, renewable waste energy source:

- Implementing ECMs to improve the overall efficiency of the campus, reducing Oberlin's energy and water consumption.
- Converting the campus district energy system from steam to hot water and leveraging waste heat from the Lorain County landfill gas electricity generation station to serve the campus' heating needs through the hot water district energy system.

Implementation of this Plan is projected to reduce Oberlin's annual water consumption by 7.5 million gallons and reduce current level Scope 1 and 2 carbon emissions by 73%, with a 92% reduction from the 2007 baseline. Implementation of these recommended strategies can be accomplished with third-party financing, requiring no capital investment by Oberlin, and is projected to reduce Oberlin's long-term, energy-related costs.

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1.1. Energy and Water Vision and Guiding Principles

In order to align the recommendations in this Plan with the priorities of Oberlin College and its community, the Project Team collaborated with stakeholders to develop the following vision statement and guiding principles to act as a road map for this effort.

1.1.1. Energy and Water Master Plan Vision Statement

Oberlin College will achieve its commitment to carbon neutrality for its campus by 2025 in a meaningful manner, while providing equitable solutions and supporting a culture of learning and engagement for the campus and community.

1.1.2. Guiding Principles for the Energy and Water Master Planning Effort

- Establish a national model for carbon-neutral energy solutions and water conservation serving a college campus.
- Develop an energy program that can efficiently integrate with the neighboring community.
- Create a campus energy program that upholds the sustainability priorities of the campus and is adaptable to changing energy needs, market fluctuations, evolution of regulatory and policy frameworks, and technology advancements.
- Establish a phased implementation plan that carries the work toward the long-term vision and goals.
- Develop a carbon neutrality program that is financeable within the private markets.
- Educate and assist the campus and community on opportunities for behavioral changes that can lead to greater energy and water conservation, waste reduction, and more efficient energy systems.

1.2. Summary of Process

To properly develop this Plan, the Project Team worked to identify the most implementable near-term solutions that can move Oberlin toward carbon neutrality, while simultaneously developing a strategy to achieve Oberlin's overall commitment to carbon neutrality. The Project Team followed an approach that included an early in-depth analysis on energy consumption (on and off-campus), as well as the identification of a coalition of stakeholders to champion the implementation of the most practical solutions.

In May 2016, the Project Team kicked off its effort to engage students, Oberlin staff and faculty, and community stakeholders. The team evaluated the following elements of Oberlin's energy and carbon profile:

- previous campus studies (referenced in Appendix I)
- campus energy density (Figure 1)
- options for energy supply and delivery
- energy efficiency improvement opportunities
- current energy system models (including costs)
- financing strategies

The core activity for the campus evaluation was the survey of 74 campus buildings and eight off-campus community buildings. The Oberlin inventory of facilities indicates a total of 82 buildings and facilities as part of the college, but includes buildings that no longer exist and locations that are not buildings, like the Memorial Arch or Tennis Courts. Some of the buildings were not accessed like the Presidents house and Mercy Hospital due to scheduling conflicts. Of the campus and community buildings surveyed, 58 are connected to the campus district steam heating system and 18 are connected to the campus district cooling system. These buildings were mapped by two of Oberlin's summer intern students (one funded by Oberlin's Environmental Studies Program) using ArcGIS. On-site analysis of the buildings was completed by a team including Ever-Green, SSOE, Oberlin interns, members of the Oberlin College Office of Environmental Sustainability (OES), Oberlin Environmental Studies Program, and Facilities Operations. This on-site analysis enabled evaluation of mechanical and system operations, as well as physical assets and vulnerabilities. The information was critical for outlining priority energy efficiency projects at individual buildings. For all buildings, opportunities were identified to use resource management best practices to reduce energy and water consumption.

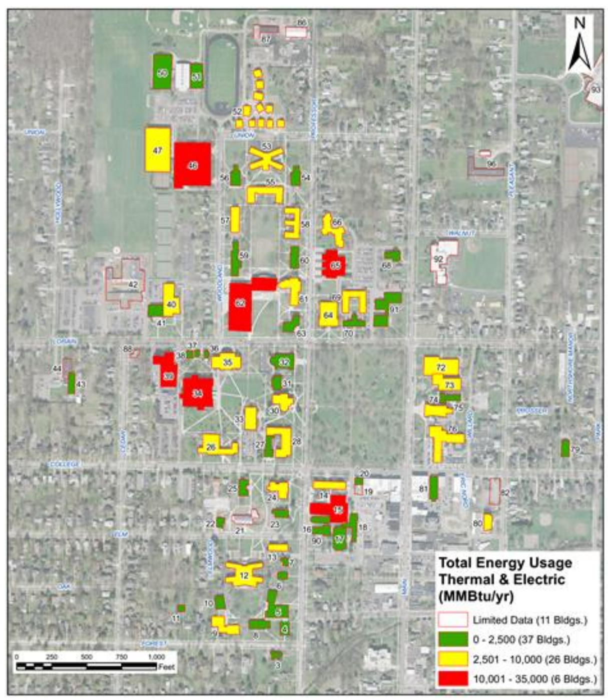


Figure 1. Oberlin campus energy density

In parallel to customer building surveys, the Project Team evaluated the condition of Oberlin's existing central heating system and local options for displacing natural gas consumption with a renewable thermal energy source. In addition, the Project Team evaluated Oberlin's existing electricity consumption profile, present-day management of renewable energy credits and offsets, and the current baseline energy-related costs.

1.3. Basis for Carbon Evaluation

Greenhouse gas (GHG) emissions, and carbon specifically, are measured via different levels of scope. The Greenhouse Gas Protocol[1] is the most widely recognized accounting tool for measuring and managing GHG. The GHG Protocol first defines direct and indirect emissions. Direct emissions include sources owned or controlled by the reporting entity. Indirect emissions are attributed from activities related to the reporting entity, but occur elsewhere. GHG Protocol categorizes this into three primary areas of scope:

- Scope 1: All direct GHG emissions.
- Scope 2: Indirect GHG emissions from consumption of purchased electricity, heat, or steam.
- Scope 3: Other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g. T&D losses) not covered in Scope 2, outsourced activities, waste disposal, etc.

Given the larger carbon profile of Scope 1 and 2 emissions, this phase of the project has been focused on analyzing and establishing an implementation plan to address the impact of only Scope 1 and 2. Ever-Green recommends that the next phase of work begin with an audit that focuses on the Scope 3 carbon categories of commuting, air travel, and solid waste. This will enable Oberlin to establish a current baseline for these emissions and develop a subsequent implementation plan for Scope 3 that could have behavioral, educational, and outreach overlap with Scope 1 and 2.

Carbon evaluation also involves a variety of valuations, including carbon-positive, carbon-neutral, and carbon-free. For the purposes of this report, and in keeping with other formal tracking systems, the term "carbon-neutral" refers to striking a balance between carbon generated by on-campus activities and offset either by off-site carbon-free or carbon reducing activities. For example, purchasing RECs allows Oberlin to have carbon-neutral electricity on campus. However, since the direct source of much of the energy does come from fossil fuels, that energy source cannot be deemed as carbon-free.

1. "Calculation Tools: FAQ." Greenhouse Gas Protocol. 2012. Accessed August 2016. http://www.ghgprotocol.org/calculation-tools/faq.

Similarly, if Oberlin is able to directly use the waste heat from a landfill gas cogeneration process, assuming the landfill gas is seen as 100% renewable, then this source and its energy would be considered carbon-free. These classifications also follow the standard GHG metrics set by the Campus Carbon Calculator, which do not include the carbon impacts of the parts manufactured for wind or solar generation or the transportation costs associated with the waste reaching the landfill in determining their renewable definition or carbon-zero status, for example.

In support of the carbon neutrality efforts, the Project Team recommended a series of continued and new activities to help build community and education values alongside the associated carbon neutrality projects. Oberlin has already realized tremendous success in its campus and community engagement, education, and behavioral programs. These efforts have raised the visibility and awareness for energy and water use. It will be important to build on that momentum and the familiarity students, faculty, and the community have for these issues and the Environmental Dashboard platform, especially as it relates to the behavior change efforts that are necessary to achieve carbon neutrality. Additionally, we suggest that Oberlin should continue developing a robust campus and community energy education and outreach program, with a primary focus on continuation of a student internship program, energy-related curriculum development, collaboration with Oberlin Community Services, a community benefits agreement, and a community engagement forum.

1.4. Stakeholder Engagement

Oberlin set a clear direction for this project to engage a broader set of stakeholders, further described in Sections 1.4.1 through 1.4.4. These stakeholders were involved in the overall process, the vetting of options, and the development of solutions for a carbon-neutral campus. Each stakeholder had the potential to provide a different perspective and guide the project toward a more robust, equitable, and implementable set of solutions. Just as importantly, the solutions are intended to deliver benefits beyond the campus boundary to benefit the city and the broader stakeholders in the community.

In order to accomplish this engagement, efforts were made at the kick-off of the project to bring stakeholders into the conversation and better understand their interests, concerns, ideas, and plans for the future of their organization or representative audience. These stakeholders were updated and asked for feedback throughout this first phase of Plan development.

It is equally important that they continue to be involved and engaged in this effort as it moves forward. Some will have more direct roles in evaluating feasibility and financing, whereas others play a role in representing diverse perspectives and helping the project uphold a strong process that can reach the carbon neutrality goals while helping others along the way. To facilitate this exchange, the Project Team has met with many campus and community stakeholders to better understand local energy needs, conservation opportunities, and energy source opportunities.

Oberlin Student Energy Forum

1.4.1. Students

The Oberlin students have shown a great interest in the Oberlin environmental, energy, and sustainability commitments prior to the start of this current effort. It is an Oberlin priority to create a forum for students to learn more about the project and participate in the development of ideas and solutions. To foster this exchange, a student advisory process was initiated in May 2016. The Student Advisory Group included students representing a variety of academic backgrounds and areas of interest. The group met in person in May and via conference calls throughout the summer. The primary intention of these initial meetings was to provide students with information about previous efforts, the scope of the current work, the progress of research throughout the summer, and to develop student engagement options. Ever-Green team members presented foundational information on energy systems to help set the framework for providing input on the initial areas of focus, including energy efficiency and energy source alternatives. Students also interacted with online tools established by the Project Team to ask questions and share information.

On September 20, 2016, OES co-hosted a student and community forum to discuss progress to-date and give students an opportunity to learn more. Topics included background information on the development of this Plan through the carbon neutrality commitments, the progress that has been made toward initial objectives, and potential solutions that have been identified. The technically-focused presentation was followed by roundtable breakout sessions for students to spend more time discussing the key topics with the OES and Ever-Green teams. Students seemed most interested in the financing mechanisms, the overall equity of solutions and community benefits, as well as the continued development of student engagement and opportunities for students to get directly involved in implementation of the recommended strategies. Given the initial commitment to student and community engagement and interaction, it is clear that this framework should be a part of the future phases. The student advisory group should continue in its capacity throughout future phases of this achieving carbon neutrality, and the basis for these interactions is outlined in Section 10.

Oberlin Student Energy Forum

1.4.2. Faculty and Staff

The Committee on Environmental Sustainability (CES) has been a critical stakeholder group for guiding this project, representing a broad set of technical, social, financial, environmental, and student perspectives, and providing ongoing advice as implementation plans are developed and refined. CES is comprised of teaching faculty, staff, student representatives, a local Oberlin City councilperson, and a representative from the Oberlin Project. The Project Team met with the CES during the kick-off activities in May and followed up with individual committee members throughout the process to get input and guidance on various aspects of research and development of solutions. Multiple members of the CES attended the September campus forum on preliminary findings. A more detailed version of these findings was presented to CES in late September.

In order to better understand Oberlin's operations, challenges, and priorities, the Project Team met with various departments and representatives on campus. The Project Team met with Oberlin's Facilities Operations staff to review project planning, current campus operations and maintenance, and the new steam plant. The steam system is operated with a staff of five and the team operates the overall system effectively. Facilities Operations staff did express concern regarding the maintenance demands of the newer campus building equipment, due to the lack of equipment standardization on campus. The variety of new building equipment requires a larger spare parts inventory to be maintained, along with time-consuming and costly maintenance training for Facilities Operations staff. Concerns were also voiced about the turnover of projects without full check-out of operations. In general, staff has an impressive understanding of the system, particularly with such a lean crew.

The Project Team also met with Capital Planning staff to discuss project development and prioritization. Oberlin is currently implementing a campus-wide spatial-use project to identify underutilized resources and improve the operating efficiency of the campus. Projects implemented as part of this Plan should be closely coordinated with project activities being implemented by Facilities

Operation, Capital Planning, and the Construction Office, and the results of the spatial-use study will be important for developing prudent implementation strategies.

The Project Team also met with Oberlin's Grounds Services team. Staff outlined Oberlin's approach to maintaining the grounds and contributing to Oberlin's carbon neutrality goals. Recent improvements include operating tractors and equipment on waste cooking oils, spot application of fertilizers and herbicides, and reduction of planting beds.

1.4.3. Board of Trustees Carbon Neutrality Subcommittee

At the onset of this Plan, Ever-Green met with the Board of Trustees Carbon Neutrality Subcommittee (Board Subcommittee) to review Plan goals, the process that would be followed, and to better understand the Board Subcommittee's vision of a successful outcome of this effort. Throughout the development of this Plan, the Project Team shared preliminary findings with the Board Subcommittee to obtain feedback, and receive guidance on important areas of focus and investigation. The Board Subcommittee also reviewed financial results and identified those aspects of the Plan that will be most important to address as part of a successful implementation plan.

1.4.4. Community

Understanding energy needs in the community was also a key priority in this effort. The Project Team reached out beyond the campus boundaries to collaborate with organizations and individuals in the local community, including representatives of the Oberlin Public Schools, OMLPS, the Oberlin Department of Public Works, Oberlin Planning and Zoning, the Public Library, The Oberlin Project, and Oberlin Community Services. All stakeholders engaged were extremely supportive of Oberlin's carbon neutrality commitment. Stakeholders expressed an openness to participating as appropriate and were interested to see how the project could be expanded to benefit the broader community. Community stakeholder priorities included reduced energy costs, solutions that reduced carbon emissions and water consumption, and the social equality of the implemented projects. More information is provided about the energy profile of non-Oberlin community institutions in Section 3.3.

2. Analysis of Current Campus Energy Profile

2.1. Campus

2.1.1. Central Plant

The existing central heating and cooling plant contains boilers, chillers, and ancillary equipment. The heating plant generates steam for the campus distribution system and serves 56 buildings on campus, along with two churches. The chilled water plant serves 18 campus buildings. The plant is well-maintained.

Figure 2. Central plant north elevation

The heating plant was rebuilt in 2014, when coal boilers were removed and natural gas-fired boilers were added. Facilities Operations reported an 85% condensate return prior to the 2014 project, but with new vacuum pumps, the campus currently returns less than 50% of the condensate, meaning a significant amount of water and energy is being wasted. All of the boilers are natural gas-fired without current provisions for backup fuel. The new boilers were designed to add oil burners if deemed necessary for fuel diversification or backup. Natural gas is supplied by Columbia Gas and the service is reported to be very reliable. During the first two years of operation, the renovated plant has consumed an average of 170,000 MMBtus of gas and 1,550,000 kWh of electricity per year, the electric consumption is estimated since the electrical meter serves six buildings including the Mudd Center (library) and it is not currently possible to extract an exact usage number. A summary of the heating and cooling plant major equipment is presented in Appendix II.

The heating plant is typically operated from October to April, when the average ambient temperature falls below 50°F. When the average ambient temperature rises above 60°F, the chilled water plant is typically started up. The plant is staffed with a day shift and night shift, where one employee works during the daytime and the other four are on rotating shifts. Employees operate the system and perform routine preventative maintenance while on shift.

2.1.2. Distribution

According to information provided by Oberlin staff, steam is distributed on campus through 14,500 feet of an underground distribution system. This piping is reported to be insulated and installed in a conduit. The steam carrier pipe is steel and that the condensate carrier pipe is predominately steel with some small sections of fiberglass pipe. Based on information available and equipment in use, the majority of the current distribution system was likely installed after 1970. A steam distribution system map and piping schedule is provided in Appendix II.

There are approximately 64 concrete vaults located throughout the system at direction changes and branch connections, and the vaults contain valves, expansion joints, and steam traps. A vault maintenance budget for the next four years was provided by Capital Planning. The budget identified problems with moisture wicking into the pre-insulated pipe at manholes, as well as structural degradation of some vaults and access covers, which will likely increase maintenance and replacement costs in the future.

The chilled water distribution system contains approximately 4,500 feet of underground steel and PVC pipe and 750 feet of steel pipe located in buildings. The chilled water system is reported to be insulated, require minimal maintenance, and buildings are directly connected to the chilled water system, without heat exchangers. A chilled water distribution system map and piping schedule is provided in Appendix II.

2.1.3. Buildings

The campus buildings were surveyed during two site visits. The Project Team toured the majority of the buildings with Oberlin staff. There were a handful of buildings that were not toured, but Oberlin staff provided system descriptions. Additional details were obtained from existing building drawings provided by Oberlin. The primary areas of focus during the site surveys included the building envelope, lighting systems, controls, and mechanical systems including HVAC systems, domestic hot water heating, kitchen hood ventilation, and plumbing fixtures. The Project Team also collaborated with RMF Engineering regarding the findings of their current retro-commissioning effort for the Science Center.

There are 82 buildings and facilities listed on the campus map (see Appendix XIV). The campus survey included the majority of on-campus buildings and facilities, with the exception of the athletic fields, Mercy Hospital, Memorial Arch, Clark Bandstand, Hotel at Oberlin, Ward Alumni Center, Shansi House, Apollo Theater, and the President's House. In addition, the Project Team surveyed five public school buildings, two churches, the wastewater treatment plant, and Oberlin's grounds keeping building to identify opportunities for serving non-college buildings with a district energy system. The site survey ultimately included 83 on and off-campus buildings and a summary of the campus buildings is provided in Appendix III.

The central plant provides steam to a total of 58 of the surveyed buildings for primary space and domestic hot water heating, as well as humidification. Of the building served by the central plant, 56 are owned by the college and two are community buildings. Twenty-two of the remaining buildings use natural gas as the primary heating source and three buildings use geothermal for primary heating and cooling. The central plant provides chilled water to 18 of the surveyed buildings for space cooling. The buildings surveyed contained primary heating and cooling systems, as presented in Table 1.

Summary of Buildings Surveyed by Primary System Type		
HVAC System	**Heating**	**Cooling**
District	58	18
Standalone	22	41
Geothermal	3	3
Note: *Standalone cooling loads include DX units, chillers, and window units. Some buildings may contain multiple cooling sources.*		

Table 1. Summary of buildings primary HVAC system type

The majority of Oberlin's buildings internal heating systems are designed to operate or can be converted to operate with hot water heating supply temperatures ranging from 120°F to 180°F for occupant comfort. The buildings' domestic water heating systems operate at a temperature of 120°F to 140°F, and buildings such as Stevenson, with kitchens and food service facilities, typically use domestic hot water heating at a maximum of 160°F. All of these systems are well-suited to use medium temperature hot water (190°F to 250°F) rather than steam as a thermal energy source and building hot water conversion information is provided in Appendix XII. Figure 3 provides a visual representation of campus and off-campus buildings' compatibility with a medium temperature hot water system.

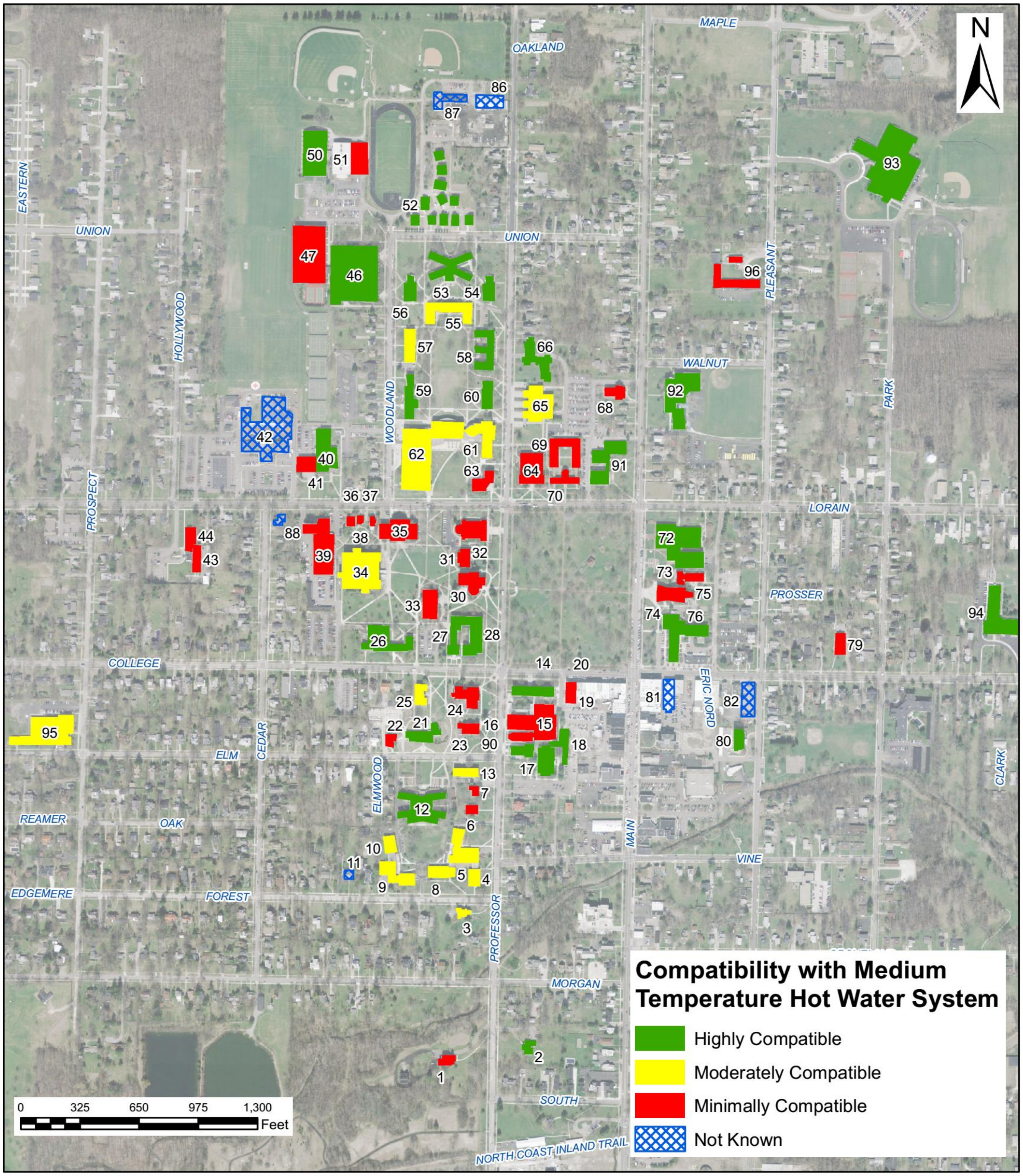


Figure 3. Medium temperature hot water system compatibility

2.1.4. *Campus Cooling*

Approximately one-fourth of Oberlin's buildings contain air conditioning systems. Table 2 represents the various air conditioning systems on campus. Most of the larger buildings have a direct connection to the district chilled water system, meaning there is no heat exchanger to separate the internal building chilled water loop from the district system. Buildings with on-site chilled water production are good candidates for integration with the district chilled water system, but buildings with air cooled chillers, DX units, and window units may not be good candidates for district energy connection. Nearly all of the buildings could benefit from energy efficiency projects to improve their building energy profile. Many buildings contained unitary cooling solutions, such as window units, that are inefficient to operate and provide an avenue for energy loss through gaps in window openings. This is exacerbated if window units are left in place during the winter months.

Building Air Conditioning Systems	
Source	**Building Count**
Central chilled water	18
Localized chiller water to air	7
Localized chiller water to water	2
Local air conditioning (DX) units	32
Geothermal	4
Window units	6
Note *Some buildings may contain more than one air conditioning source.*	

Table 2. Oberlin building air conditioning systems

2.2. Baseline Utility Consumption

The Project Team downloaded the 2013-2015 Oberlin utility data for the campus and other community buildings from SchoolDude, which is an independent third party cloud-based software used by Oberlin to collect, track, and analyze utility data, and trend consumption patterns and costs for their facilities. Figure 4 shows the buildings included in the baseline utility summary. Buildings shown as not included in the model are privately-owned buildings, community-owned buildings, or buildings whose load information was not available.

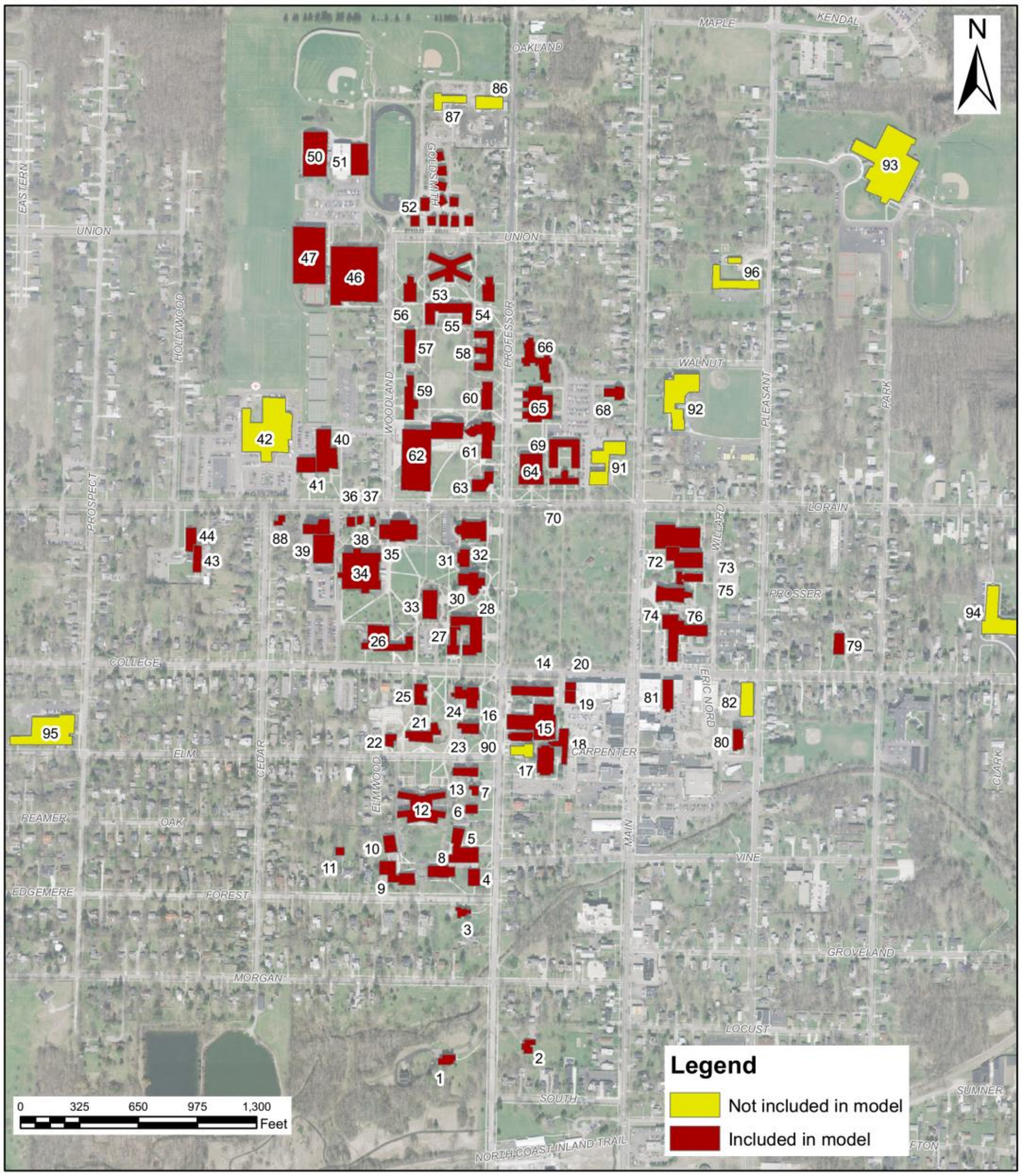


Figure 4. Buildings included in the baseline utility summary

A summary of the average utility consumption data is presented in Table 3. The natural gas values are based on the average of three years of data (2013-2015). Natural gas is normalized by year on a thirty-year basis to account for fluctuations in annual temperatures and then averaged. The central plant coal use in 2013 and 2014 was converted to MMBtu and incorporated into the presented data under the natural gas column. The values presented in Table 3 are considered as the campus consumption baseline for the evaluation of carbon-neutral alternatives presented in Section 6. Table 3 contains the utility consumption for all of the buildings modeled, as indicated in Figure 4.

Baseline Utility Consumption[3]						
Heating System Type	**Area (SF)**	**Natural Gas[1] (MMBtu/yr)**	**Electric (KWH/yr)**	**Water (gals/yr)**	**Sewer[2] (gals/yr)**	**EUI (kBtu/sf)**
Stand alone	272,750	15,032	1,579,348	5,027,971	5,033,058	75
District	2,099,903	188,059	22,723,939	39,734,957	33,336,792	131
Geothermal	130,900	2,148	1,581,873	3,491,086	3,008,301	58
Totals	**2,500,000**	**210,000**	**26,000,000**	**48,000,000**	**41,000,000**	

Notes

1. Includes coal consumption in 2013 and 2014, converted to MMBtu.

2. Sewer utility data shows larger consumption values than water on several buildings.

3. Total of all utilities consumed by buildings classified by heating system type.

Table 3. Baseline campus utility consumption data

The central plant is the largest user of energy on campus and presents the greatest single opportunity to reduce carbon emissions. The high energy use intensity (EUI) indicated in Table 3 for the district energy system buildings is indicative of the high energy consumption for the district energy system and the connected buildings and highlights the opportunity to reduce energy consumption through improvements to the district energy system. Oberlin's thermal energy consumption decreased slightly during the 2013-2015 period, when weather-normalized on a 30-year basis. The thermal reduction at the plant is believed to be a result of the coal to natural gas conversion and the shifting of plant auxiliary loads from steam to electric-driven equipment.

Electricity consumption from the utility grid increased during the 2013-2015 period. The 2015 electricity consumption increased noticeably at the central plant, and also in Buildings 21 (AJLC), 40 (Crane Pool), 51 (Football Stadium), 61 (Wright Physics), and 76 (Oberlin Inn). The increase in electric consumption at the central plant is presumably due to the loss of cogeneration capacity that occurred with the conversion from coal to natural gas and the replacement of steam driven equipment with electric-driven equipment. The increase in consumption could also be driven by new building loads or broader issues in buildings served by the same meter in the central plant. Water consumption at the central plant also increased markedly during the 2014 – 2015 time period. The cause was not identified but the increase in water consumption would be consistent with the reports of increased condensate losses since the new central plant was commissioned. Table 4 presents a summary of 2013-2015 utility consumption at the central plant. The electric billing may include loads from adjacent buildings served by the same meter as the central plant.

Central Plant Utilities (by calendar year)[1]			
Utility	2013	2014	2015
Natural gas (MMBtu)[2]	74,302	63,077	168,354
Coal (MMBtu)[2]	108,958	116,598	0
Total (MMBtu)	**183,260**	**179,675**	**168,354**
Electric (kWh)	5,889,600	6,070,800	6,880,600
Water (kgals)	6,982	7,342	9,933
Sewer (kgals)	5	13	3,370

Notes

1. Data from utility invoicing.

2. Normalized on 30 year basis.

Table 4. Central plant utility consumption

The actual steam consumption at the individual building level is not known due to the lack of steam or condensate metering in the buildings. For purposes of this Plan, we have assumed the distribution of steam is proportioned on a square footage basis for the buildings connected to the steam distribution system. A more accurate analysis of steam consumption is required to size any future energy system alternatives and Oberlin is currently installing meters in individual buildings for this measurement.

2.2.1. Carbon Emissions

Oberlin College has made significant strides in reducing overall Scope 1 and 2 carbon emissions from the 2007 baseline. Table 5 presents the 2007 baseline and 2015 level for Scope 1 and 2 carbon emissions. The greatest carbon emission reductions to date can be attributed to two changes: the increased renewable electrical energy portfolio at OMLPS and the conversion of the central plant from coal to natural gas. Although the conversion of the central plant resulted in a dramatic decrease in Scope 1 carbon emissions, achieving Oberlin's commitment to carbon neutrality will ultimately require that heating and cooling be provided by carbon-free sources of energy.

Campus Scope 1 and 2 Carbon Emissions (M.Tons)		
Source	2007	2015
Thermal production	23,973	11,426
Electricity	20,720	3,030
Total	44,693	14,456

Table 5. Oberlin's Scope 1 and 2 carbon emissions

2.3. Community Energy Profile

In addition to evaluating Oberlin's campus energy profile, the Project Team also evaluated other buildings within the City of Oberlin to identify opportunities for providing carbon-free energy solutions to the greater community.

2.3.1. City of Oberlin

The Project Team met with several representatives of the City of Oberlin (City) to discuss collaborative opportunities that might aid Oberlin and the City in achieving both of their carbon neutrality commitments. The City owns and operates a one million gallon per day wastewater treatment facility east of downtown and adjacent to the landfill. The plant contains an anaerobic digester and biogas from the digester is utilized in a 0.5 MMBtu heater to maintain digester temperature. The excess gas is used to operate a small electrical generator. The City is discussing replacing the digester in the next four years, and the wastewater treatment plant has good potential for connection to a medium temperature hot water system.

There is a small City-owned composting facility adjacent to the wastewater treatment plant that processes 500 tons of organic yard waste annually, this compost is made up of mostly leaves. There may be a possible synergy to process Oberlin's yard and food kitchen waste in a new larger bio-digester, which would increase biogas output.

2.3.2. Public Schools

The Project Team met with the Oberlin Public School District superintendent. The district has been considering consolidation of the schools into fewer buildings. The district is interested in opportunities to reduce energy costs of new and existing facilities. The school district is in the process of implementing an energy audit in the school buildings and indicated that they were interested in district energy collaboration opportunities. The Project Team surveyed the five district-owned school buildings to assess the opportunity for integration with a system designed to meet Oberlin's thermal energy needs. Four of the five school buildings were excellent candidates for inclusion in a medium temperature hot water system.

2.3.3. Churches

The project team surveyed the First Church of Oberlin and the First Methodist Church of Oberlin. Both are currently connected to Oberlin's district steam system. Both churches heating systems are primarily hot water with some steam loads. Both reported being satisfied with the steam service and have good potential for connection to a medium temperature hot water system. The First Church of Oberlin would benefit from an energy audit to improve building efficiency.

2.3.4. OMLPS

OMLPS, a municipally-owned enterprise, is the local electric utility provider and has been supportive of a variety of energy efficiency programs. OMLPS's aggregated customer rates average approximately $0.10 per kWh, and they report their greenhouse gas emissions to be 250 pounds of carbon per megawatt hour (MWh). OMLPS' peak distribution system load is 21 MW and the emergency distribution system capacity is approximately 34 MW, limited by substation capacity. The system is connected through First Energy to the PJM grid. Since 2011, PJM has been providing significant capacity payments to OMLPS. OMLPS purchases RECs and renewable power as part of their supply portfolio and continues to expand the ratio of renewable energy based on direction from the City Council.

3. Energy and Water Conservation Measures

3.1. Process

The Project Team evaluated opportunities to reduce energy and water consumption within campus buildings. Based on the site surveys, the Project Team generated a list of 15 potential ECMs that could be implemented to improve the energy and water efficiency of Oberlin. This list targeted ECMs that would provide the best return on investment and have the greatest environmental benefits. The list is not intended to be all-inclusive or address conservation that could be achieved through behavior change, such as programs that encourage building occupants to turn off lights and computers. Estimates of probable cost and savings were calculated based on an engineer's estimate of performance improvement, taking into account issues that were identified during the site evaluation. A summary of the methodology, assumptions of each ECM, simple payback for each ECM, and a building reference matrix is provided in Appendix IV. Building by building assessments are provided in Appendix XIII.

The Science Center is currently undergoing a long-term detailed recommissioning study by RMF Engineers. The Project Team coordinated with RMF during the field surveys and during the preparation of the Master Plan. It was reported that RMF is evaluating fume hood options, make-up air rates, integrating the building automation system, and other building improvements to reduce energy consumption. RMFs final recommendations were not available during the preparation of this Plan, but their final recommendations should be integrated with the ECM planning recommended in Section 6.

3.2. Findings

For purposes of generating the recommended ECM list, the Project Team selected the items with the greatest environmental benefits, or with the shortest financial payback period. Based on a screening of the 15 ECMs, 12 were selected as ECMs recommended for implementation, and offer the greatest reduction in energy or water consumption. The recommended ECMs include lighting sensors, commissioning of existing lighting controls, demand controls on kitchen ventilation systems, heat recovery from refrigeration systems and site boilers, low flow water fixtures, window replacement, and heat recovery from outside air make up units. A summary of the recommended ECMs and savings is presented in Table 6. A detailed description of each ECM with a location key are provided in Appendix IV. Implementation of all of these recommended ECMs is projected to reduce carbon emissions by 4,506 metric tons per year (10% from the 2007 baseline), with a simple payback of under eleven years.

Recommended ECMs								
ECM Cost Summary				**Projected Annual Utility Reductions**				
Description	**Building Count (Each)**	**Capital Cost (k$)**	**Annual Savings (k$)**	**Natural Gas (MMBtu)**	**Steam (MMBtu)**	**Electric (MWH)**	**Carbon (tons)**	**Water (kgals)**
ECM 1 Lighting Controls	60	$843	$213	0	0	2,051	172	0
ECM 2 Commission Existing Lighting Controls	4	$33	$12	0	0	115	10	0
ECM 3 Demand Control Kitchen Ventilation	12	$644	$25	125	1,608	102	133	0
ECM 4 Walk-in Cooler/Freezer Heat Recovery	11	$133	$3	45	331	0	23	0
ECM 6 Boiler Stack Economizer	4	$312	$91	17,056	0	0	1,010	0
ECM 7 Low Flow Fixtures	12	$171	$42	276	678	0	66	1,709
ECM 9A Mudd HVAC Replacement Option 2	1	$733	$125	0	2,305	653	223	0
ECM 10 Window Replacement	31	$8,117	$508	620	23,486	1,490	1,876	0
ECM 12 HVAC Replacement – Cox, Bosworth, Robertson	1	$405	$36	0	450	204	50	0
ECM 13 Kahn Hybrid PV-Thermal Collectors	1	$163	$5	0	238	28	20	0
ECM 14 Science Center Heat Recovery	1	$858	$107	0	12,045	54	884	0
ECM 15 South Hall Ventilation	1	$54	$8	0	528	10	39	0
Totals		**$12,465**	**$1,174**	**18,121**	**41,669**	**4,705**	**4,506**	**1,709**
Simple payback for recommended ECMs	**11**	**years**						

Table 6. Recommended ECMs

The ECM list is considered dynamic and linked to the overall project timeline. Since some of the ECMs are competing and the implementation of one will affect the benefit from others, the selection of ECMs should be finalized once the project path and schedule are defined. In order to calculate the benefits for this report, we have estimated the impact of the competing ECMs during our analysis and reduced the projected energy savings for each competing ECM. While this does not affect the capital cost, it does increase the payback time and reduce the overall environmental benefit. Depending upon the project implementation schedule, the ECM list may require adjustment and some of the ECMs possibly eliminated. For example, if the renewable energy source that replaces the existing boilers were to operate year-round, installation of stack gas economizers in certain buildings may not be a sensible investment since the boilers would no longer be operated and the payback would not be achieved.

Implementation of the recommended ECMs can provide Oberlin with immediate energy and water cost savings, with a simple payback of the capital investment in 11 years.

4. Energy Sources

For purposes of evaluating carbon-neutral energy supply options, the Project Team separated thermal energy and electricity.

4.1. Thermal

Currently, Oberlin meets the bulk of its thermal needs by burning natural gas for heating and running electrically-driven chillers for cooling. The largest single carbon emitter is the central plant, which generates heating and cooling sources for the majority of the campus buildings.

4.1.1. Process and Description

To evaluate options for a carbon-neutral fuel source for the campus, the Project Team first reviewed the existing reports and studies previously completed for Oberlin. These reports were discussed with a broad group of stakeholders to provide background, understanding, and context of the previous work, along with impediments to implementation. A list of the previous studies reviewed is included in Appendix I.

Based upon a review of the previous studies along with a market assessment, Ever-Green completed a high level evaluation and screening of possible carbon-free fuel and energy source alternatives to serve Oberlin. The metrics for the evaluation and screening included:

- Life-cycle cost of the alternative
- Carbon emissions
- Fuel availability
- Technically feasible
- Simplification of implementation and integration with the campus
- Flexibility of the system to allow for expansion to benefit the broader Oberlin community
- Alignment of the generation source with campus consumption

Once the initial screening process was completed, a model was generated to determine the baseline cost of operating and maintaining Oberlin's current thermal energy supply. The baseline cost was compared to carbon-free alternatives to predict future financial costs and environmental benefits of each alternative.

4.1.2. Baseline

The baseline model developed for Oberlin has inputs for existing fuel, electricity, water consumption and discharge, operations and maintenance expenses, and capital equipment costs. To the greatest extent possible, the information in the model was provided by the Oberlin staff and is based on actual consumption and expenditures. Some information was unavailable and assumptions were set based upon Ever-Green's experience operating similar energy systems. The information provided by Oberlin and assumptions used to generate the baseline model are attached in Appendix V, and Oberlin's current annual energy-related costs without a cost of carbon are roughly $4.2 million.

4.1.3. Carbon-Free Fuel and Energy Source Screening

A comparative high-level screening of carbon-free fuels and energy source options was performed to evaluate options for serving Oberlin's thermal energy needs, with results presented in Appendix VI. Screening was based on NREL[2] and EIA[3] costs for alternative production sources, along with research by the Project Team. The summary of findings for viable options is provided in Table 7. The Project Team has identified that the landfill gas combined heat and power (LFG CHP) solution currently offers the optimal carbon-free heating supply alternative to Oberlin.

Ever-Green met with the landfill power plant operator, Energy Developments, Inc. (EDI), and they are amenable to integration of heat recovery with their operations provided that it does not impact their power generation operations. EDI currently operates eighteen engine-driven electric generators at the landfill. The total electrical capacity for the plant is 26 MW, with an estimated waste heat capacity of 88 MMBtu per hour at a 70% capacity factor for all 18 generators. The engines currently exhaust waste heat from the electric generating process into the atmosphere.

2. "Distributed Generation Renewable Energy Estimate of Costs." NREL: Energy Analysis. February 2016. Accessed August 2016. http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.
3. EIA. *Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2016*. Publication. 2016. Accessed August 2016.Table 8.2 http://www.eia.gov/forecasts/aeo/assumptions/pdf/Table_8.2.pdf.

Screening Analysis Summary for Alternate Technologies				
Technology	**Cost of Implementation (k$)**	**Annual O&M Cost (k$/yr)**	**Annual Life Cycle Cost (k$/yr)**	**Notes**
LFG CHP	$61,200	$700	$4,000	1,2,5,6
Biomass thermal	$55,000	$1,900	$5,400	1,2,5,6
Biogas	$82,200	$900	$6,100	1,2,5,6
Geothermal	$91,700	$1,300	$6,200	1,2,4,6
Wind	$92,800	$1,600	$6,600	1,2
Solar PV	$112,400	$1,400	$6,800	1,3,6
Solar thermal including thermal storage	$142,800	$1,300	$8,700	1,2,3,6
Fuel cells	$137,900	$2,100	$11,000	7
Plasma gasification of MSW	$214,400	$2,600	$16,300	7

Notes

1. Includes cost for existing boiler plant	*$10,770*	*(k$)*
2. Includes cost for hot water distribution system	*$11,500*	*(k$)*
3. Includes cost for electrical system improvements	*$2,112*	*(k$)*
4. Includes cost for building conversions	*$14,400*	*(k$)*
5. Includes cost for building conversions	*$8,300*	*(k$)*
6. Includes system development costs		
Debt service interest rate	*4%*	
Engineering and Design	*10%*	
Project Controls	*8%*	
OH&P	*10%*	
Contingency	*25%*	

7. Estimated production cost based on EIA plant costs.

8. Oberlin has received a quote for carbon offsets for natural gas at $0.181 per MMBtu. The entire natural gas consumption for Oberlin can be offset for approximately $38,000 in 2016 prices.

Table 7. Carbon-free energy supply alternative screening life-cycle cost analysis

Integration of biomass from agricultural residuals or grown for purpose crops could also provide an opportunity to develop a local supply industry, and many district energy systems in Denmark and other European countries currently utilize agricultural residuals in their low-carbon systems. Based on a review of the National Renewable Energy Laboratory (NREL) biomass mapping, there are sufficient potential resources in the greater Lorain County and Cleveland area to serve Oberlin's thermal energy needs.[4]

4. Roberts, Billy J. "Solid Biomass Resources by County." Digital image. NREL.gov. August 4, 2014. Accessed August 2016. http://www.nrel.gov/gis/images/biomass_2014/national_biomass_solid_total_2014-01.jpg.

Solar thermal can also be an effective production source to provide summer capacity when combined with biomass for winter capacity. Given the potential of campus demand for heat and domestic hot water needs, specific to the climate demands of this region, solar thermal could be a strong candidate for Oberlin's future renewable portfolio. This will heavily depend upon the renewable market at the time of development as well as available sites (ground-standing or building mounted). The alternatives require further evaluation if the LFG CHP option becomes unviable or during future phases of implementation as the integration of additional renewables is desired.

A high-level screening was also completed for the following energy sources, and they were quickly excluded due to capital costs, technical complexity, or operating costs: plasma gasification of municipal solid waste, solar photovoltaic, hydrogen generation from electrolysis of water utilizing photovoltaic power, hydrogen fuels cells, and fuel cells.

The purchase of natural gas carbon offsets with the existing facility has a low cost of implementation and lifecycle cost. Oberlin College is currently purchasing a 10% offset with its 2016-2017 natural gas purchase contract. Currently the price for these offsets is fairly low, indicating a low market demand. These types of offsets can be purchased on a ten year term, but the future price is unknown. However, this solution does not meet the original requirement of a tangible carbon-free solution requested by Oberlin stakeholders.

4.1.4. Achieving Carbon Neutral Thermal Energy Supply

District energy is a globally recognized approach to saving energy, reducing carbon emissions, and for creating opportunities to integrate renewables into smart thermal and electric grids. Buildings connected to district energy networks benefit from decreased capital investments for individual building production equipment, decreased maintenance, decreased stress on valuable building space, and ease of use for operations and permitting. District energy networks are also more reliable than stand-alone building systems that rely on limited equipment assets. A network of buildings with diverse uses can help create a balanced energy profile that makes the best use of available equipment and energy in the system, which leads to a lower energy footprint for all buildings and users. When paired with renewable energy sources and efficient technologies, such as combined heat and power, district energy becomes a key approach to lowering carbon in our communities. Among other global experts, the United Nations Environment Programme has taken a strong position on district energy as the key to reducing carbon emissions in cities and has promoted this position through its District Energy in Cities initiative[5].

5. "District Energy in Cities," United Nations Environment Programme, accessed October 5, 2016, http://www.districtenergyinitiative.org/

The most efficient district heating systems utilize hot water as the means for transferring heat. Hot water can be more effectively controlled at buildings to enable optimal energy transfer and occupant comfort. Hot water is also more easily delivered to buildings through a distribution pipeline with fewer losses than are experienced in a steam system. In a steam distribution network, the higher temperatures, difficulties in controlling and containing the gaseous steam, and losses of condensate all are disadvantages when compared to the hot water alternative.

A medium temperature hot water system that serves the Oberlin campus throughout the entire year offers many benefits over the existing steam system. These benefits include a simpler distribution network without condensate return, simplified maintenance by standardization, elimination of individual thermal equipment in buildings required for summer domestic hot water and air conditioning reheat loads, and future system flexibility since a hot water system is extremely effective for utilizing multiple low-grade renewable energy sources such as waste heat salvaged from electrical generation or wastewater treatment.

Based on the high level screening analysis, Ever-Green modeled the LFG CHP thermal energy system to determine its financial viability. LFG CHP involves recovering waste heat generated at the EDI power plant at the landfill and conveying it via hot water in a closed-loop piping system from the landfill to the campus. The hot water system is modeled to operate with a 250°F supply temperature and a 160°F return temperature to meet the projected campus loads. The proposed system, shown in Figure 5, would operate year-round and would displace the majority of natural gas consumption on-campus, as well as eliminate the need to operate and maintain boilers and domestic hot water heaters in individual buildings. The system would be connected to the existing Oberlin central plant boilers for purposes of on-campus redundancy whenever the LFG CHP is unavailable.

Projected capital costs related to implementation of the LFG CHP are approximately $70 million, including the outstanding debt on the existing central heating plant, implementation of the recommended ECMs, and financing costs. A detailed estimate of costs is provided in Appendix VII. The model and assumptions used to generate the LFG CHP alternative are attached in Appendix V.

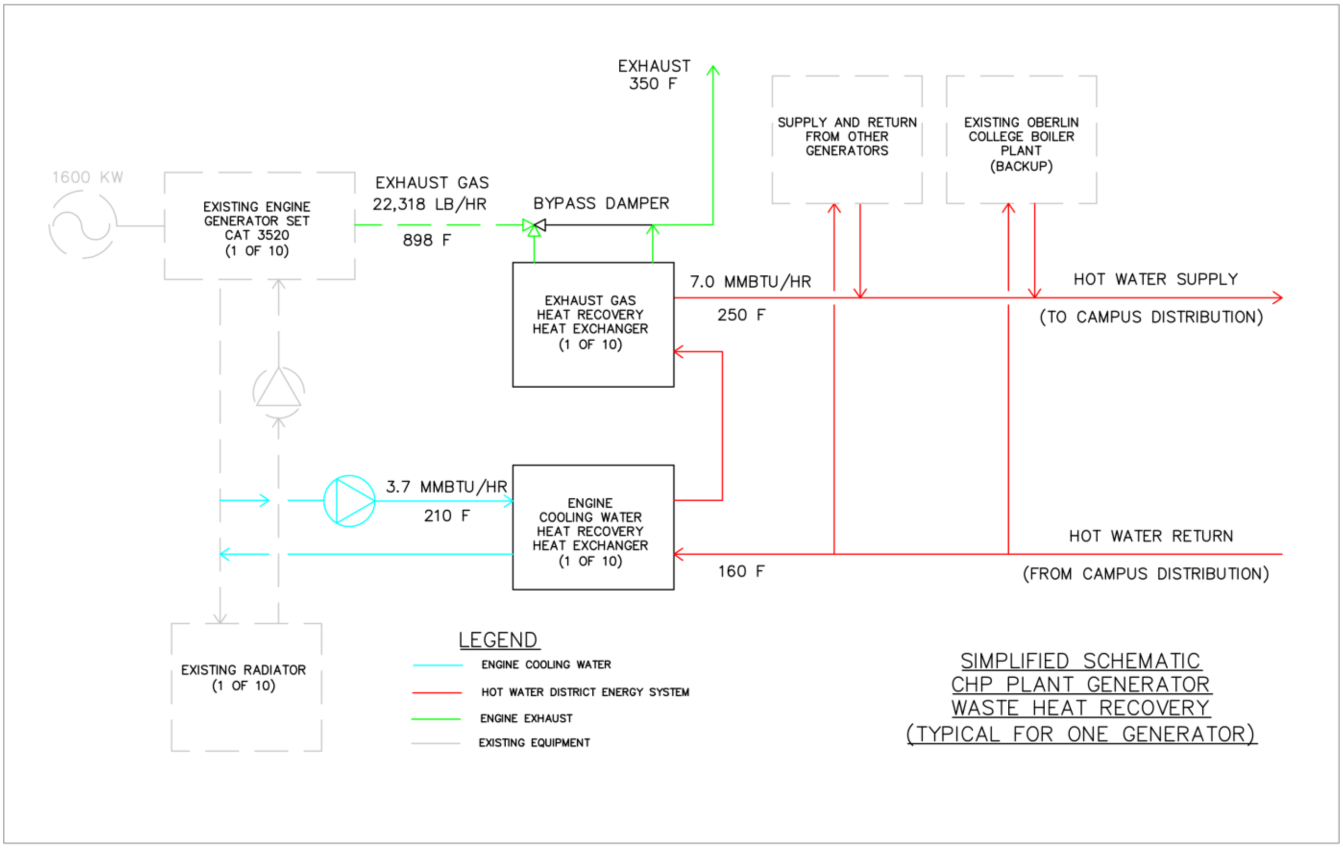


Figure 5. Simplified schematic of LFG CHP waste heat recovery

In the event that LFG CHP cannot be implemented, several more costly options could be implemented. While not fully modeled, the Project Team did perform a high-level analysis of these options. A summary of these options is provided in Table 7, with detailed cost estimates in Appendix VII.

4.1.5. Recommendations

The preferred carbon-free alternative for Oberlin is LFG CHP. This will include converting as many campus buildings as are feasible to accept hot water for domestic and space heating purposes, installing a hot water distribution system on campus, installing a hot water pipeline to the landfill, and installing heat exchangers and pumps at the landfill to recover the waste heat from the engine generators. It may be possible to repurpose sections of Oberlin's existing steam system for hot water, but the Project Team has assumed an entirely new hot water distribution system for the model. Figure 6 provides a general overview of the proposed LFG CHP system, and Figure 7 identifies the buildings that would be initially served by the LFG CHP system. Backup capacity for the system is necessary as EDI is not able to guarantee continuous heat delivery. This backup is assumed to be provided by the boilers at the existing central plant on campus, retrofitted to produce hot water rather than steam. The backup capacity would only be operated to meet peak loads when the temperature falls below -5°F, or when the landfill plant is unavailable due to generation outages or pipeline issues.

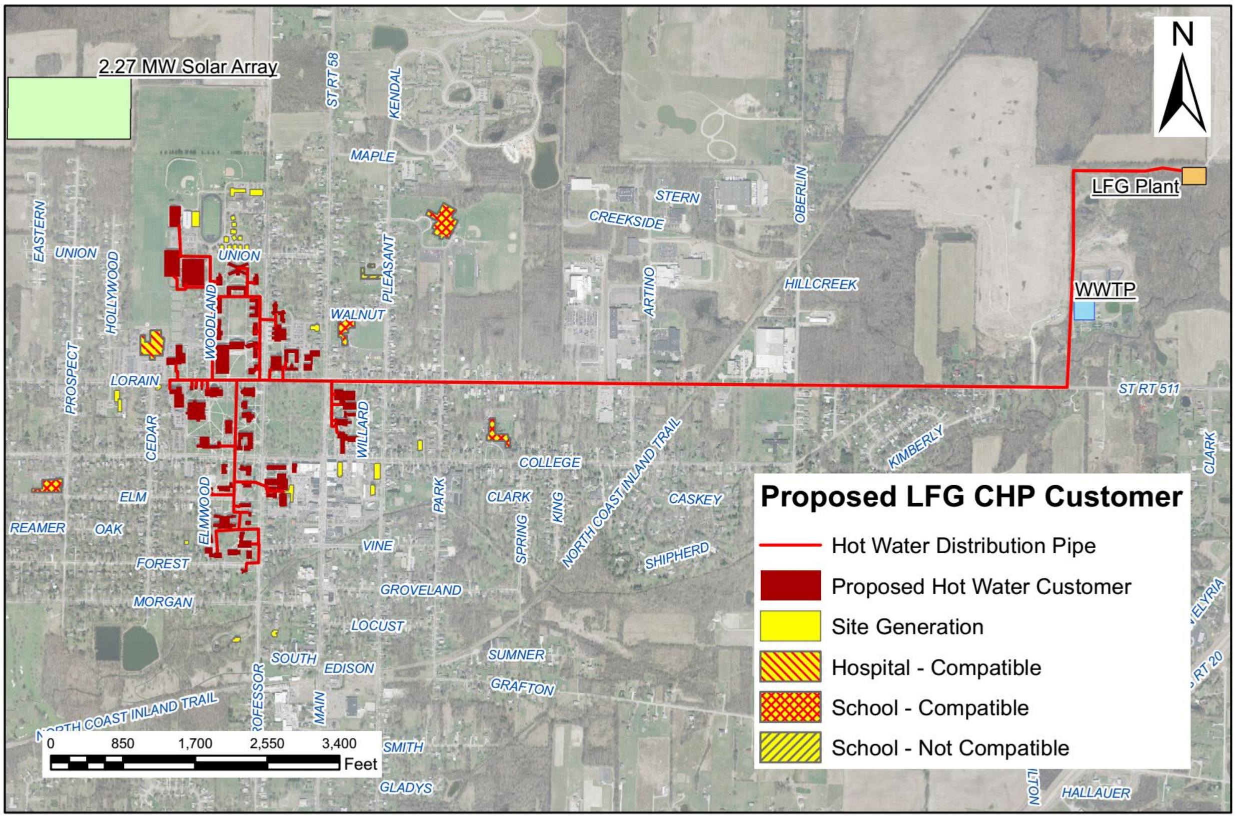


Figure 6. Proposed LFG CHP hot water distribution system overview

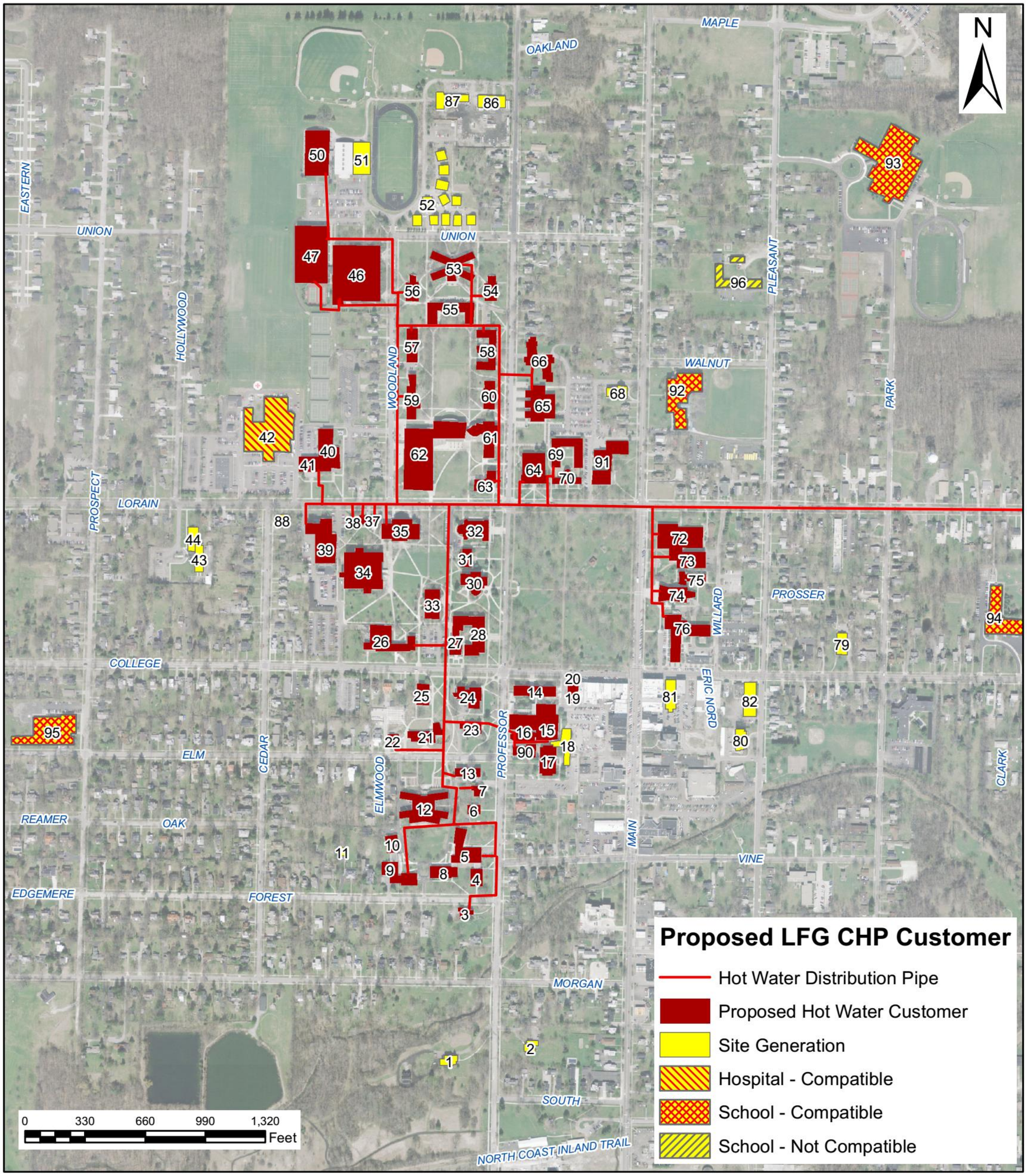


Figure 7. Proposed hot water distribution customers

The estimated landfill gas thermal production by month at the landfill, with corresponding campus load, is presented in Figure 8. The campus load after implementation of the proposed ECMs is indicated by dark blue bars. The base losses for the proposed distribution system are indicated by green bars, assuming that system is operated at a constant temperature. The capacity of the landfill gas with jacket water and exhaust gas recovery is approximately 34,000 MMBtu per month, as indicated by the light blue line. Based on Oberlin's load profile and ASHRAE BIN data for the area, 12 MMBtu per hour of additional heating capacity will be required on a peak day when the ambient temperature is below - 5°F, and the annual probability of the ambient temperature falling below - 5°F is 0.15%.

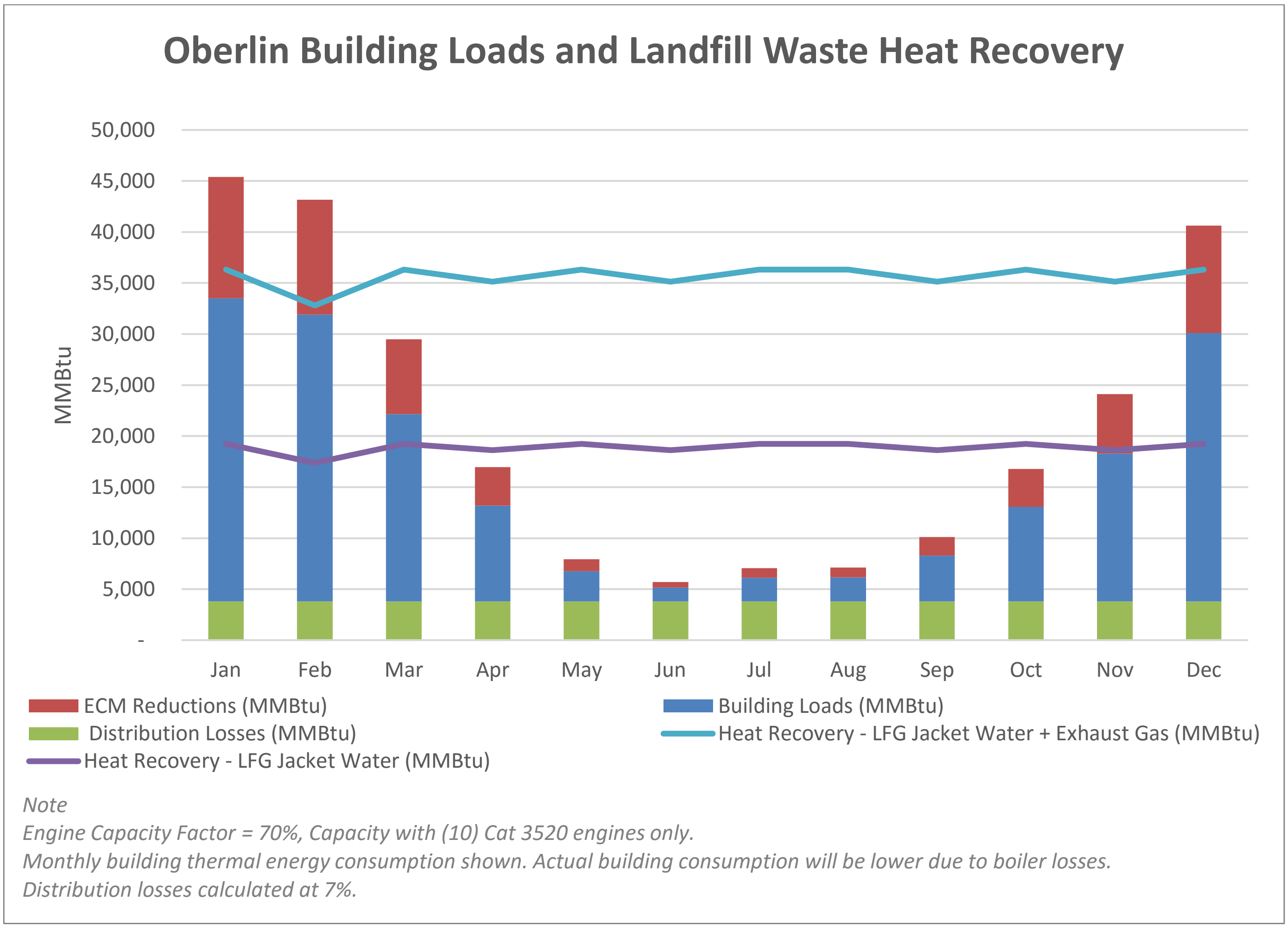


Figure 8. Landfill waste heat recovery and load profile

The landfill, however, may experience issues due to electrical system problems or landfill gas delivery problems, sporadically forcing the generator plant off line. It is assumed that this will occur ten days per year, and another energy source will be required to serve Oberlin's heating needs during those times. Typically forced outages in landfill production are more common in the summer when there is more activity at the landfill and electrical storms, and outages are less common in the winter. Gas production is also typically greater in the winter due to frost sealing the landfill. For purposes of the model in this Plan, natural gas consumed at the central plant has been assumed as the backup fuel during outages at the landfill.

4.1.6. Chilled Water Generation

During the summer, the LFG CHP will generate much more heat than is needed at the campus. This waste heat could be utilized in absorption chillers, which would reduce the campus electricity consumption for cooling, leverage the proposed system's capacity during months when it is operating below capacity, and make the economics for EDI and Oberlin more attractive. This would also enable very cost-effective options for expanding campus cooling to support summer programming and accommodations.

This option would add an additional capital cost to the project of approximately $2.2 million dollars for absorption chillers, and the detailed costs are presented in Appendix VIII. The economic benefits of this solution would be dependent upon the cost of waste heat that EDI would command in the summer, but this option should be considered as negotiations with EDI progress.

4.2. Electricity

4.2.1. Baseline

The campus currently consumes approximately 26,000 MWh per year of electricity. Through behavioral changes on campus, this consumption can decline. However the continued electrification of the campus could place upward pressure on this consumption. OMLPS purchases green electricity from landfill gas generation, wind generation, and hydroelectric generation. OMLPS also purchases Renewable Energy Certificates (RECs) with their renewable electricity supply. A REC is a tradable certificate that represents proof that one MWh of electricity was generated from an eligible renewable energy resource and that the power was fed into the electric grid. A summary of OMLPS' past three years of RECs and total annual electric sales for OMLPS is presented in Table 8. The emission factor reported for OMLPS' electric supply portfolio is 0.250 pounds of carbon per kWh.

OMLPS REC & Energy Summary					
Year	**RECs**			**Energy**	
	Purchased by OMLPS	**Sold to Oberlin College**	**Total Held**	**Total OMLPS Sales**	**Renewable**
	(MWh)	**(MWh)**	**(MWh)**	**(MWh)**	**(%)**
2013	49,562	8,843	40,719	107,760	38%
2014	70,084	9,073	61,011	107,687	57%
2015	69,001	7,800	61,201	107,492	57%

Table 8. OMLPS REC purchase and sale summary by year

4.2.2. Oberlin College's Electrical Carbon Profile

The most effective way to achieve carbon neutrality is to first reduce consumption. With the implementation of the recommended ECMs, Oberlin's electric consumption is projected to be reduced by 4,700 MWh per year.

Oberlin College participates in the RECs Market and uses the PJM Generation Attribute Tracking System (PJM GATS) system as the clearinghouse for the purchase and sale of RECs. Oberlin generates approximately 3,000 RECs annually from the 2.27 MW solar array. These solar RECs are then sold at a price that historically varies between $10 and $815 per REC, and an equivalent amount of wind RECs are purchased. Additional RECs from hydro-electric generators are purchased from OMLPS and held by Oberlin College. One important observation is that the price of RECs is highly volatile and while the cost is currently low, this will likely fluctuate widely as future market demands change. In 2015, Oberlin College also purchased and held 660 RECs from landfill electric generation. In an average year, Oberlin College holds 11,500 RECs in its portfolio, or approximately 44% of the average annual electric consumption for the campus. A summary of Oberlin College's annual RECs held and campus energy consumed is presented in Table 9.

Oberlin College Energy & REC Summary							
Year	OMLPS Delivered to Oberlin College				Oberlin College		
	Total Energy	Renewable	Renewable	Non-Renewable	RECs Held	Remaining Non-Renewable Energy	
	(MWh)	(%)	(MWh)	(MWh)	(MWh)	(MWh)	(% of total)
2013	25,677	38%	9,703	15,974	-11,713	4,261	17%
2014	25,487	57%	14,440	11,047	-12,140	-1,093	-4%
2015	26,715	57%	15,210	11,505	-10,762	743	3%

Table 9. Oberlin College Energy consumed and REC summary by year

Each unit of renewable electricity that OMLPS purchases includes a REC. OMLPS also resells selected high value RECs and purchases wind RECs, but OMLPS does hold one REC for each MWh of renewable energy sold on their distribution system. In an average year, Oberlin College consumes 15,000 MWh of renewable electricity annually, and 11,000 MWh of non-renewable electricity from OMLPS, as shown in Table 9. Implementation of the recommended ECMs will enable Oberlin College to comfortably be in a carbon-negative position regarding its electricity supply.

5. Additional Carbon and Resource Evaluation

Following its charter membership and leading role in the American College and University President's Climate Commitment in December of 2006, Oberlin has committed to eliminate 45,000 tons of carbon emissions per year to achieve carbon neutrality by the year 2025, based upon a 2007 baseline. Implemented projects have already reduced emissions by 30,000 tons, or 68% from 2007 levels.

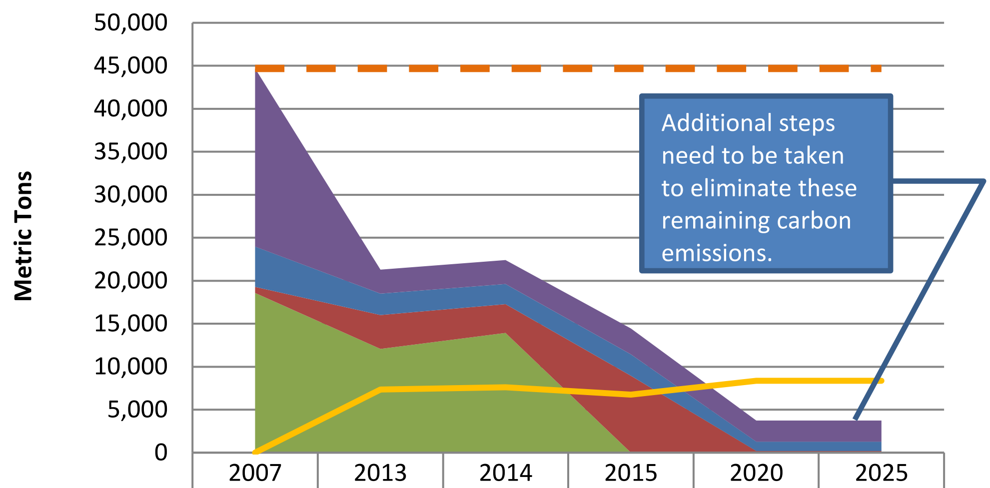
Currently Oberlin purchases RECs roughly equivalent to its non-renewable fraction of grid purchased electricity. With ECM implementation, Oberlin's quantity of RECs purchased will be greater than the non-renewable fraction of its electricity consumed, and the excess RECs could be credited toward Oberlin's remaining carbon budget. Based on the regional United States Environmental Protection Agency (EPA) emission factor for the Reliability First Corporation West region, which is 0.63 metric tons of carbon emitted per MWh, the credit is approximately 7,250 metric tons per year. Further validation of the emission factor is required to resolve emission factor differences between OMLPS and the EPA.

Oberlin also purchased natural gas offsets for the 2016-2017 heating season. The offsets are provided with the natural gas contract and apply to approximately 10% of Oberlin's natural gas consumption. Based on an annual natural gas consumption of 210,000 MMBtu, the annual carbon offset is approximately 1,100 tons. Figure 9 represents the progress Oberlin has made toward carbon neutrality since 2007. The orange line at the bottom of the graph represents the sum of the RECs and natural gas offsets.

While the two recommended actions in this Plan may be implemented together or independently, the Project Team has evaluated their contribution toward Oberlin's carbon neutrality in combination. Figure 9 projects out to 2020, assuming that the ECMs and the LFG CHP are implemented by that point. The orange line indicates the carbon credit due from RECs and natural gas offsets if Oberlin's current trend of purchasing RECs and offsets continues. Thus, with implementation of the recommendations in this Plan, Oberlin's REC purchases will be over double of its remaining Scope 1 and 2 carbon emissions.

Carbon Dioxide Emissions

(As Metric Tons CO2)



	2007	2013	2014	2015	2020	2025
Electric	20,720	2,777	2,790	3,030	2,450	2,450
Natural Gas Other	4,693	2,516	2,333	2,493	1,082	1,082
Natural Gas Central Plant	710	3,943	3,347	8,933	191	191
Coal	18,570	12,054	13,934	0	0	0
Total CO2	44,693	21,288	22,404	14,456	3,724	3,724
2007 Baseline	44,693	44,693	44,693	44,693	44,693	44,693
% Reduction (2007 Baseline)	0%	52%	50%	68%	92%	92%
RECs and Offsets	0	7,328	7,595	6,733	8,361	8,361

Note

1. *2020 levels projected based on implementation of ECMs and LFG CHP alternative. 2013, 2014, and 2015 data not normalized.*
2. *Total carbon does not include scope 3 carbon emissions.*

Figure 9. Oberlin's Scope 1 and Scope 2 carbon emissions per year

5.1. Carbon Reduction from Energy Efficiency and Landfill Gas CHP

Implementation of the ECMs identified in this Plan is estimated to reduce annual carbon emissions by 4,500 tons, or 10% from the 2007 baseline and 30% from current emissions. The proposed ECMs will not only have a positive impact on Oberlin's carbon emissions, they are also estimated to reduce annual water consumption by 1.7 million gallons per year, and sewer discharge by 1.4 million gallons per year.

Oberlin's largest source for Scope 1 and Scope 2 carbon emissions is the central utility plant, which burns natural gas. Coupled with ECM implementation, replacing the combustion of natural gas at the central plant and buildings with waste heat from the LFG CHP is projected to reduce carbon emissions by 10,359 tons per year, a reduction of 73% from Oberlin's current carbon emission level, and 92% from the 2007 baseline. The implementation of LFG CHP will also reduce electric, water, and sewer consumption, as presented in Table 10.

Utility Scope 1 and 2 Emissions Summary[1]				
		2015	**2015 + ECMs**	**Alt 1- LFG + ECMs Heat Recovery**
SUMMARY[3]	Buildings served	73	73	73
	Total natural gas (MMBtu/year)[2]	210,000	131,000	24,000
	Other fuel (MMBtu/year)	0	0	126,000
	Electric (kWh/year)	25,900,000	21,200,000	21,600,000
	Water (gallons/year)	48,620,000	46,376,000	41,140,000
	Sewer (gallons/year)	41,378,152	39,925,413	35,605,878
	Gross square feet	2,503,553	2,503,553	2,503,553
CARBON EMISSIONS	Natural gas (M. tons/year)	11,143	6,951	1,273
	Electric (M. tons/year)	2,935	2,403	2,448
	Water (M. tons/year)	4	4	3
	Sewer (M. tons/year)	13	12	11
	Total (M. tons/year)	14,095	9,369	3,736
REDUCTIONS FROM 2015 BASELINE	Carbon	0%	34%	73%
	Natural gas	0%	38%	89%
	Electric	0%	18%	17%
	Water	0%	5%	15%
	Sewer	0%	4%	14%
	Reduction (2007 baseline)[3]	68%	79%	92%
	Reduction (2007 baseline) (M. tons)[3]	30,599	35,324	40,958

Notes

1.Data normalized and averaged for 2013-2015 period

2.Natural gas savings includes elimination of steam system losses

3.GHG baseline 2007 44,693 (M. tons/year)

Table 10. Utility and emission summary

5.1.1. Recommendations

Implementation of the proposed ECMs, in conjunction with OMLPS's renewable energy portfolio and the solar PV generation on campus provides Oberlin with the infrastructure to achieve carbon-neutral electricity supply on an annual basis. Implementation of the LFG CHP will eliminate a significant amount of natural gas combustion on Oberlin's campus, a number of individual natural gas-fired boilers and furnaces, hot domestic hot water heaters, and kitchen loads will remain for buildings not included in the LFG CHP solution.

As these projects proceed to implementation, a strategy will need to be developed to enhance Oberlin's renewable electricity profile, and offset or eliminate its remaining natural gas combustion.

Oberlin could take the following steps to address its remaining Scope 1 and 2 carbon, and its renewable electricity profile.

- A REC purchasing strategy and annual accounting will create a more transparent process and understanding of the importance of RECs.
- Depending upon how important it is for the carbon RECs to be local, Oberlin could consider eliminating the sale of its solar RECs and procurement of corresponding wind RECs.
- Oberlin could also look for additional opportunities to displace the remaining RECs with local renewable generation such as additional solar PV, wind generation, or other carbon-free electricity sources.
- Further investigation of the coincidence of Oberlin's peak demand and renewable electricity supply should also be performed in the next stage of carbon neutrality planning to identify opportunities for coincidental carbon-free electricity supply.
- Oberlin should consider connecting the new hot water district energy system to outlying campus buildings and other buildings in the community, offering these buildings access to a carbon-free heating source.
- Oberlin could convert additional buildings to geothermal or VRF systems, or purchase pipeline quality biogas from a third party supplier.
- Hot water could be utilized in the summer for purposes of cooling the Oberlin campus, as well as other buildings within the community, offering these buildings access to a carbon-free cooling source.

6. Financial Analysis, Recommendations, and Next Steps

Implementation of the two primary recommendations in this Plan could be done independently or in conjunction with each other. However, for purposes of evaluating the financial viability of each recommendation, it has been assumed that the ECMs will be implemented prior to implementation of the LFG CHP, thus reducing the amount of energy that will need to be delivered to Oberlin and reducing overall costs for the proposed LFG CHP system.

6.1. Baseline Energy Related Costs

To properly evaluate the economic feasibility of the proposed thermal energy solution, Oberlin's current energy-related costs needed to be identified. As Oberlin's current energy-related costs are contained within several different departments and budgets, the Project Team collaborated with Oberlin's Financial Planning and Capital Planning teams to compile a comprehensive assessment of its current campus energy-related costs. Oberlin's current estimated energy-related costs are shown in Table 11.

Oberlin's Annual Thermal Energy Costs[1]		
CAPITAL	Plant and Building Systems	$1,490,147
VARIABLE OPERATING	Natural gas	$1,053,375
	Electricity	$90,211
	Water	$74,060
	Sewer	$31,093
FIXED OPERATING	Labor & benefits	$1,166,158
	Third party maintenance	$304,600
	General & administrative	$32,650
TOTAL	Annual cost[2]	$4,242,294

Notes

1. This table includes only the operating costs for heating and cooling systems in campus buildings. This includes central plant, geothermal, and standalone buildings.

2. Excludes social cost of carbon.

Table 11. Oberlin's annual campus thermal energy costs

The costs presented in Table 11 are based upon information provided by Oberlin staff, and several costs were extracted from larger capital budgets. While Oberlin's actual energy-related costs may vary slightly from these numbers, the overall energy cost per MMBtu appear reasonable for a system with 42% efficiency[6].

6.2. Energy Conservation Measures (ECMs)

Implementation of ECMs can follow a number of frequently-utilized approaches, with the primary funding solutions either being internal financing, utilizing a performance contractor, or obtaining third-party financing. A pros and cons matrix for each of the implementation solutions is provided in Appendix IX.

For purposes of the results presented in this Plan, the Project Team has assumed that independent third-party financing for implementation of the ECMs represents the best and most feasible option. Under this structure, the independent financing entity will provide Oberlin with the capital required for the improvements, and Oberlin would enter into a lease agreement or an assessment for an agreed-upon period of time, which is typically under fifteen years. Payments would be linked to the projected energy savings expected to be realized as a result of the implemented ECMs, and the outside financing entity will only require security of the assets installed as part of the ECMs. At the completion of the agreement term, all future energy savings would be realized by Oberlin.

6.2.1. Financial Results

Implementation of the proposed ECMs can be justified based upon the energy and water savings that will be realized by Oberlin after implementation. The assumptions included in the calculation of the ECM financial analysis are included in Appendix IV, and summary of the financial benefits of the ECMs are shown in Table 12.

6. Reported in "Oberlin Sustainability Study," Professional Supply Inc. (PSI), November 16, 2009 for average annual steam system efficiency.

Summary of Recommended ECMs		
Number of ECMs to implement	12	
Cost	$12,465	(k$)
Projected savings	$1,174	(k$)
Simple payback	11	(years)
Natural gas annual savings	18,121	(MMBtu)
Steam annual savings	41,669	(MMBtu)
Electric annual savings	4,705	(MWh/year)
Water annual savings	1,709	(k gallons)
Sewer annual savings	1,452	(k gallons)
Carbon annual reduction	4,506	(M. tons)

Table 12. Summary of recommended ECMs

Implementation of the recommended ECMs is projected to provide Oberlin with immediate cost, carbon, energy, and water savings, with a simple payback of the capital investment in 11 years.

6.2.2. ECM Implementation

The bundle of ECM projects proposed in this Plan are projected to reduce Oberlin's natural gas consumption by 38%, electricity consumption by 18%, water consumption by nearly 1.7 million gallons per year (5%), and sewer discharge by nearly 1.4 million gallons per year(4%). Implementation of the ECMs is also projected to reduce Oberlin's carbon emissions by 4,500 metric tons per year, and reduce Oberlin's energy and water-related costs by approximately $1.2 million per year. To implement these measures, Oberlin should move forward with third-party engineering validation of the proposed ECMs, coordinate with capital planning and facilities operations, identify applicable energy efficiency rebates that can improve the financial benefits of these measures, and develop a detailed plan to obtain project financing.

6.2.3. Financing

As identified in Section 8.3, the recommended means of financing the ECMs is through a third-party financing structure with a lease program, based upon the projected energy and water savings. Several options exist for purposes of obtaining this financing, with the following programs being the most viable:

6.2.3.1. First American Education Finance Lease Program

First American Education Finance (FAEF) is a City National Bank Company that helps schools achieve their energy goals by offering relatively low-cost, financing mechanisms. FAEF proposes utilizing a finance facility to implement the proposed ECMs through a master lease agreement. This agreement functions in the following manner:

- Each project is funded under the master lease agreement through an amendment specific to each project, with each project having a separate funding and repayment schedule.
- Financing is under an operating lease structure with a defined purchase option outlined in the project amendments to the master lease agreement proposed at a fair market value (FMV) purchase price of 17.7% (under FASB Topic 842 for leases, the new standards will likely require recognizing the assets and liabilities under the master lease agreement). Lease payments are calculated based upon the expected costs savings attributed to the proposed ECMs, and are fixed through the lease term, which can typically be up to 15 years with a FMV purchase option. Excess realized savings can be put to work on other initiatives at Oberlin.
- The debt service to fund each ECM in the portfolio is aligned to the energy savings generated from each individual ECM. This structure minimizes interest expenses across the portfolio by aligning the financing term with the simple payback period for the ECMs.
- The financing would be setup under a no-fee master lease agreement and not require any additional lien or collateral requirements from the school. This financing facility can be increased or extended, making it very easy for Oberlin to add additional measures in the future.

FAEF offers competitive financing terms and is very interested in financing the ECMs at Oberlin, regardless of the total capital cost of the project.

6.2.3.2. Property Assessed Clean Energy Financing

Property Assessed Clean Energy (PACE) financing was established in Ohio in 2010 to support implementation of energy efficiency projects within Ohio. Under the PACE program, property owners access bond funds through an issuing authority to implement energy efficiency improvement initiatives, with the proceeds paid back through a special assessment on the property. Similar to the FAEF model, the payments can be mirrored to the projected energy savings that are projected to be realized through implementation of the ECMs, and would be fixed through the assessment period, which can also be up to 15 years. PACE financing can be for 100% of the capital needed for the ECMs, although there are sometimes caps with the total dollar amount of the project, and the financing rate is typically very competitive.

The Project Team has spoken with the Toledo-Lucas County Port Authority about utilizing PACE financing for implementation of the ECMs, and they have a significant interest in working with the local municipal body to support this project.

6.2.4. ECM Next Steps, Schedule, and Budget

The Project Team developed the recommended ECM list based upon a review of information provided by Oberlin, along with information collected during several weeks of building walks. Not all required information could be collected or was available, and a number of assumptions were made to get to the results provided in Table 12. The following steps should be taken to properly prepare for ECM implementation:

- Oberlin Capital Planning, Financial Planning, OES, and Facility Operations should perform a detailed review of the proposed ECMs to identify any concerns or projects that may already be planned.
- Recommendations from the RMF Science Center recommissioning study should be incorporated into the final ECM list.
- Oberlin should hire an independent engineer to evaluate the findings of the Project Team, and gain confidence in the projected energy savings.
- A detailed implementation schedule should be developed for the ECMs, coinciding with other upcoming work on campus and other important campus events that may be impacted by this work.
- A scope of work should be developed for the preferred ECMs, and construction pricing should be secured to validate the costs presented in this Plan.
- An RFP should be developed for the ECM financing package so that an optimal cost of financing can be obtained.

Development of the ECM implementation strategy is projected to take five months and cost $149,000. A schedule with approximate costs is provided in Figure 10.

	Budget	Month 1	Month 2	Month 3	Month 4	Month 5
Capital Planning and Facility Operations coordination	$ 61,000					
Independent engineering evaluation	$ 18,000					
Implementation planning	$ 37,000					
ECM financing	$ 33,000					
TOTAL	$ 149,000					

Figure 10. ECM implementation schedule and budget

In addition to the ECM implementation steps identified above, Oberlin could also take some steps to improve campus efficiency in the short term. The central plant is the largest energy consumer on campus. There are currently issues with the central plant or distribution system that are causing low condensate return rates. Any condensate that is lost wastes energy, water, and money, and a project is currently underway to improve the condensate return rate. Oberlin would benefit from an operating procedure review, an engineering heat balance study, and field testing to identify opportunities to improve overall steam system performance. Oberlin would likewise benefit from completion of the comprehensive energy metering systems that would allow heating and cooling delivered to each building to be measured so that problems can be more easily pinpointed and addressed in a timely fashion.

6.3. LFG CHP

The Project Team developed a comprehensive financial model for the proposed LFG CHP solution, based upon a third-party energy supply arrangement. Under this scenario, a third party entity would form a non-profit district energy system (DES) for purposes of financing and implementing the proposed solution. The DES would sign a long-term energy supply agreement with EDI, along with a long-term energy services agreement with Oberlin. The DES could leverage these energy agreements to obtain third-party financing for implementation of the project.

As a customer of the non-profit DES, Oberlin would pay for services under a cost-based rate structure. As the primary customer for the DES, Oberlin could also hold a seat on the board of governors of the DES, approving annual budgets and energy rates, as well as providing guidance on the long-term strategies of the business.

6.3.1. Financial Results

Financial results of the proposed LFG CHP district energy system were developed over 25-year and 50-year life cycle cost analyses, compared to Oberlin's energy-related costs if it continued with business as usual. In addition, results are compared to Oberlin's projected energy-related costs after the implementation of the proposed ECMs. The financial model for this comparison is based upon the assumptions provided in Appendix XI, with results provided in Table 13.

Project Cost Summary		2015 Baseline	2015 Baseline + ECMs	Alt 1- LFG CHP + ECMs
COST SUMMARY	Carbon reduction from 2007 baseline	68%	79%	92%
	Annual social cost of carbon (k$/year)	$1,729	$909	$165
	Total annual cost without social cost of carbon (k$/year)	$4,242	$5,215	$6,605
	Net present value without social cost of carbon (k$)(25-year)	$57,429	$60,209	$80,639
	Net present value without social cost of carbon (k$)(50-year)	$80,874	$79,896	$95,181
	Net present value with social cost of carbon (k$)(25-year)	$84,933	$74,677	$83,269
	Net present Value with social cost of carbon (k$)(50-year)	$119,694	$100,317	$98,893

Table 13. LFG CHP financial results

Implementation of a hot water district energy system that captures waste heat from the local landfill electricity generation facility and transports it to the campus is projected to decrease Oberlin's energy-related costs by 2% over a 25-year NPV analysis, and by 17% over a 50-year NPV analysis, when including a social cost of carbon of $122.60 per metric ton and comparing to Oberlin's baseline energy-related costs. Over a 50-year NPV analysis, the break-even social cost of carbon, where LFG CHP energy-related costs are equal to the baseline, is $49 per metric ton. The break-even social cost of carbon for a 25-year NPV analysis is $113 per metric ton.

Implementation of a hot water district energy system that captures waste heat from the local landfill is projected to decrease Oberlin's energy-related costs by 2% over a 25-year NPV analysis, and by 17% over a 50-year NPV analysis, when including a social cost of carbon and comparing to Oberlin's baseline energy-related costs.

6.3.2. Sensitivity Analysis

As part of financial modeling, the Project Team developed a Monte Carlo analysis to analyze the sensitivity of the energy rate results based upon a set of input variables, specifically related to the LFG CHP results. Under this Monte Carlo analysis, 10,000 iterations of the model were run with each of the variables randomly fluctuating independently to understand how significantly the financial results can be affected by fluctuations in those variables. The variables and detailed sensitivity analysis results are provided in Appendix X, and a summary of the results is provided in Table 14.

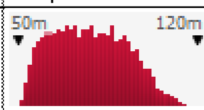
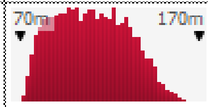
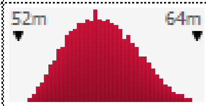
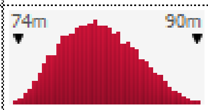
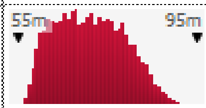
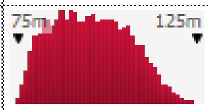
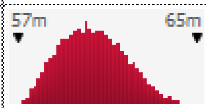
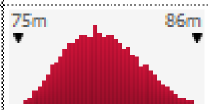
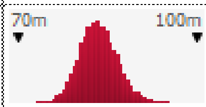
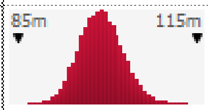
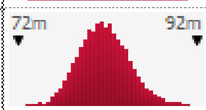
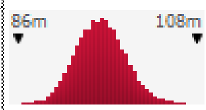
Name	Graph	Mean	5%	95%
25-Year NPV baseline with cost of carbon		$79,122,460	$59,444,890	$100,821,600
50-Year NPV baseline with cost of carbon		$111,519,000	$83,656,160	$142,321,200
25-Year NPV baseline without cost of carbon		$57,784,370	$54,653,110	$61,203,690
50-Year NPV baseline without cost of carbon		$81,403,690	$76,733,800	$86,503,660
25-Year NPV baseline+ ECMs with cost of carbon		$71,660,740	$61,155,680	$83,269,330
50-Year NPV baseline+ ECMs with cost of carbon		$96,076,620	$81,209,050	$112,528,100
25-Year NPV baseline+ ECMs without cost of carbon		$60,435,730	$58,439,190	$62,627,320
50-Year NPV baseline+ ECMs without cost of carbon		$80,233,860	$77,263,360	$83,494,590
25-Year NPV LFG CHP with cost of carbon		$83,826,570	$79,368,220	$88,493,900
50-Year NPV LFG CHP with cost of carbon		$99,275,360	$94,078,780	$104,818,300
25-Year NPV LFG CHP without cost of carbon		$81,785,940	$77,887,940	$85,979,290
50-Year NPV LFG CHP without cost of carbon		$96,395,260	$92,120,760	$100,916,400

Table 14. Sensitivity analysis for financial model results

Implementation of the proposed LFG CHP DES would provide Oberlin with a much more stable energy cost profile. The variability (between the 5% and 95% results) of the 50-year NPV of energy-related costs for the proposed LFG CHP system is projected to be 82% less than the variability of the baseline costs, and 66% less than baseline plus ECM costs. The variables that can have the greatest impact on cost variability are the cost of carbon, energy consumption level, cost of debt, and construction costs.

6.3.3. Landfill Gas Generation CHP Implementation

Implementing a hot water district energy system that leverages waste heat from landfill gas generation to serve the primary heating needs of Oberlin will enable a significant reduction of Oberlin's carbon emissions and water consumption, reducing carbon emissions by over 10,000 metric tons per year and water consumption by over five million gallons per year. Over a 50-year NPV analysis, the shift to this district energy system is projected to reduce energy-related costs by 17% when accounting for Oberlin's social cost of carbon at $122.60 per metric ton. Achievement of these savings will require a significant amount of work, with a primary focus on securing an agreement with EDI, securing a long-term energy services agreement with Oberlin, forming a non-profit district energy business, and developing a plan for integrating with the existing district energy system and campus buildings.

6.3.4. Financing

The proposed non-profit DES structure enables access to a significant number of options related to system financing, without requiring any capital investment by Oberlin. The DES would secure a long-term energy service agreement with Oberlin, whereby Oberlin would commit to purchasing the agreed-upon energy demand. Oberlin has a very favorable credit rating, which will enable the DES to obtain a low cost of debt, based upon this energy service agreement.

Ever-Green has financed over $300 million of district energy system construction projects utilizing this financing method. In conversations with past financing partners, a number of these institutions have a high level of interest in funding the proposed solution, including:

- U.S. Bancorp
- Bremer Bank
- Coady Diemar Partners
- Piper Jaffray Companies
- Dougherty & Co.
- Goldman, Sachs & Co.
- BMO Harris Bank

6.3.5. Next Steps, Schedule, and Budget

The proposed conversion of Oberlin's campus from steam to hot water, with CHP integration at the Lorain County landfill, will require a significant amount of planning, along with some robust contractual discussions with Oberlin and EDI. If Oberlin leadership chooses to proceed with this recommendation, the following actions should be taken to prepare the system for implementation.

- The organizational structure of the DES should be agreed upon, along with its governance and rate structure.
- EDI must be engaged to secure a mutually beneficial agreement that captures waste energy from their landfill gas generators.
- An energy service agreement must be developed between the new DES and Oberlin for supply of energy to the campus.
- The new DES organization will require a franchise agreement or easement with the City of Oberlin, enabling it to route distribution pipes from the landfill to the campus. A routing plan will also need to be developed in collaboration with the City's Public Works department.
- A plan should be developed for how cooling service may also be supplied to the campus through absorption chillers, along with how the system could provide heating to privately-owned buildings within Oberlin that are compatible with a hot water district energy system.
- A detailed campus conversion plan should be developed, in collaboration with Oberlin Capital Planning, Financial Planning, and Facility Operations. This plan should also be coordinated with the ECM implementation plan, along with the completion of building metering at Oberlin
- A financing strategy and detailed implementation plan should be finalized.

While a number of other detailed actions will need to be completed to achieve system financing, the strategies listed above should establish a clear pathway to success for the proposed DES. The next phase of DES implementation is projected to take ten months and cost $726,000. A schedule with approximate costs is provided in Figure 11.

	Budget	Month									
		1	2	3	4	5	6	7	8	9	10
Organizational strategy	$ 117,000										
EDI negotiations	$ 163,000										
Energy service agreement	$ 58,000										
City engagement	$ 63,000										
Customer base expansion	$ 20,000										
Campus conversion planning	$ 251,000										
DES financing	$ 54,000										
TOTAL	$ 726,000										

Figure 11. LFG CHP implementation schedule and budget

6.4. Existing Central Heating Plant

Oberlin recently invested in the central heating plant, replacing a coal-fired boiler with new packaged natural gas-fired steam boilers. These boilers were debt financed at a cost of approximately $10.8 million, and the debt is not set to be retired until 2038. Within the current DES model, the Project Team has assumed that the new Oberlin boilers at the central heating plant would be utilized for purposes of providing redundancy to the system. Under this scenario, these gas-fired boilers would be retrofitted to generate hot water, and the system would be served by these boilers on-campus when there is a disruption at the landfill. At project financing, Oberlin would receive a payment of approximately $10.5 million for the transfer of ownership of these boilers, retiring the existing debt.

7. Opportunities and Risks

The following opportunities have not been included in the assumptions in the financial model developed for this Plan, and could have a positive impact on the financial viability and overall success of DEC growth.

- A lower cost of capital would increase the savings realized by existing and new DEC customers.
- Coordinating construction with other infrastructure improvements would reduce up-front capital costs and reduce customers' energy rates.
- Securing new developments and renovated buildings as they are built to grow the customer base could enhance the benefits of being connected to DEC.
- Expanding the DES system customer base further across campus and into the City could reduce energy rates for Oberlin and all customers.
- Integrating recent advancements in piping technology and packaged substations can reduce capital costs and customers' energy rates.
- There is a significant amount of unused heat in the summer that could be leveraged for chilled water generation on campus with absorption chillers.

The following risks have not been included as assumptions in the financial model of this Master Plan, but could have a negative impact on the financial viability and overall success of DEC growth.

- A higher cost of capital would reduce energy-related savings experienced by existing and new DEC customers.
- Noise abatement at the landfill has not been included. If additional silencers are required as part of the project, the energy cost will increase.
- The financial assumptions do not include a franchise fee for routing the distribution pipes from the landfill to the campus. If this fee is required, the energy costs would increase.

8. Additional Activities to Support Implementation

The strategies identified in this Plan will bring Oberlin significantly closer to carbon neutrality, and will require a focused effort on two primary initiatives. In addition, Oberlin should continue development of a campus and community outreach program and continue looking at its Scope 3 carbon emissions and waste.

8.1. Outreach

To support the priorities identified by students, faculty, community members, and other stakeholders, it is recommended that a multi-faceted education, engagement, and outreach plan be developed and piloted through summer 2017. These activities and initiatives are intended to create opportunities for students to leverage Oberlin's commitment to carbon neutrality as a unique and important learning experience. The education-based experiences could range from internships, to service learning projects, to capstone immersive projects to develop community-facing solutions. The goal is to scope these activities at the end of 2016 and put some test activities into motion in 2017 to better understand their value and function. Based on the lessons learned, these may be recommended for continuation or for restructure and relaunch.

- **Continuation of an internship program (technical and programmatic).** The technical internships could work on metrics, tracking, and other implementation efforts. The programmatic internships could work more closely on behavioral programming, engagement, or sharing lessons learned with other community stakeholders as noted in other concepts.

  This project offers an incredibly unique opportunity for education as programs, infrastructure, and technologies are developed to support the carbon neutrality goal. These programs will include opportunities to learn about technology, earth and environmental science, geology, policy, economics, construction, community and city planning, stakeholder engagement, education, sociology, environmental psychology, and other affairs that have been identified as important to faculty and students. Through the internship and curriculum development, efforts to move the project forward should be transparent and build on existing successes with the Environmental Dashboard and other behavior change and information gathering initiatives.

- **Curriculum and student programming development.** We suggest working with specific faculty to identify areas of interest for private readings and potential coursework or capstone approaches to student experiences. Ever-Green can partner with interested faculty to develop time and topic appropriate experiences for students, related to the carbon neutrality efforts.

Projects could include research, campus or community engagement, metrics and benchmarking, policy and program evaluation, or implementation shadowing.

- **Work with Oberlin Community Services to develop opportunities through their Economic Development Education and Outreach program to match women in the WISE program or other broader program participants in the implementation work for Oberlin.** This could be required as part of a community benefits agreement, as noted in concept 4. (OCS program description noted below.) Alternatively, students could develop additional topics of interest, such as local food or water savings, depending on areas of interest and supportive programming available through community partners.
- **Develop a community benefits agreement to be structured for all carbon neutrality related work on campus (energy efficiency, plant optimization, distribution projects, etc.)**. This agreement could have base requirements offering preference to businesses owned by women or people of color, or require participation in OCS programming. These businesses could also be asked to support energy efficiency programming described in concept 5.
- **Develop a community engagement forum to offer community members information about energy efficiency, or other sustainability topics of interest or concern.** Lessons learned on campus about saving energy or reducing waste in multi-unit residential (residence halls) could be shared with landlords and tenants. Lessons learned about saving energy in classroom buildings could potentially be shared with commercial building owners. Best practices for engaging individuals in behavior change could be shared with local schools, community groups, and homeowners/tenants. Forums could be coordinated with the local gas and electric utility, potentially paired with rebate programs. To offer greater connection between Oberlin and the community, these forums and educational outreach efforts could be developed by interested students, potentially interns. This could potentially be a partnership between Oberlin, the Oberlin Project, and Oberlin Community Services, as well as utilities and local firms that do energy efficiency work.

8.1.1. Next Steps, Schedule, and Budget

Development of the student engagement implementation strategy is projected to take 10 months and cost $60,200. A schedule with approximate costs is provided in Figure 12.

	Budget	Month 1	2	3	4	5	6	7	8	9	10
Internship program development and management	$6,000	■	■	■	■	■	■	■	■	■	■
Intern salaries	$8,000	■	■	■	■	■	■	■	■	■	■
Curriculum & program development	$10,800	■	■	■					■	■	■
Curriculum & program execution	$7,500			■	■	■	■	■			
Development of community sustainability jobs & programming	$1,800					■	■	■	■	■	■
Community sustainability forum	$9,000	■	■	■	■	■	■	■	■	■	■
Community benefits agreement framework	$1,500	■	■	■	■						
On-site consultations (travel + staff time)	$15,600		■			■		■			■
TOTAL	$ 60,200	■	■	■	■	■	■	■	■	■	■

Figure 12. Student engagement implementation schedule and budget

8.2. Scope 3 and Waste

Given the previous efforts to define the waste profile for the campus, the Project Team recommends three key steps for the next phase of work.

The first step is to refine the scope of the waste profile for the campus and determine which areas are most important to track and address. Some areas of this profile (ex. wastewater) could be challenging to track and reduce, so they could be addressed in a future phase or removed from the scope of the inventory.

The second step is to review the 2016 data collection to set a basis for an audit of the methodologies and inputs used. This audit would focus only on the currently measured Scope 3 categories of Commuting, Air Travel, and Solid Waste. The results of that audit will be very useful to define future action to reduce Scope 3 emissions.

The third step is to prioritize activities and recommend next steps based on financial and technical viability and carbon reductions. Given the other priorities for Oberlin, including overall sustainability and education, it will be important to determine the balance of the factors to define the path forward.

9. Conclusion

Oberlin College has been successful in carbon emission reductions moving toward its commitment to achieving a carbon-neutral future. Carbon neutrality can be achieved by establishing a foundation of environmentally sustainable behavior, more efficient energy practices, integration of renewable energy sources, and incorporation of meaningful carbon offsets. The actions recommended in this Plan were crafted to align with the commitments and principles established for the project, as well as reflect the input received from stakeholders and potential partners along the way. Oberlin is well-positioned to reach the ambitious carbon-neutral goals for the campus, with the most prominent opportunities centered on energy conservation and a local, green energy source in landfill gas combined heat and power (LFG CHP). These opportunities are technically and financially feasible and implementable in the near-term. Looking forward, additional phases will also need to address further Scope 2 emissions and begin to make progress on Scope 3 carbon emissions, as well as identify and implement new opportunities to engage the campus and community throughout this program.

As 2025 is a little more than eight years away, implementation of the recommendations in this Plan must start as soon as possible. Leadership at Oberlin will need to make decisions in the near future regarding how to implement preferred strategies, and the structure with which strategies should be implemented. While these recommendations are projected to reduce Oberlin's Scope 1 and 2 carbon emissions when compared to the 2007 baseline, to achieve carbon neutrality by 2025 Oberlin must still address the ongoing electricity generation, its remaining natural gas consumption, carbon offsets, Scope 3 carbon, travel, waste, and ongoing behavioral change. A proposed schedule for achieving this commitment is provided in Figure 13.

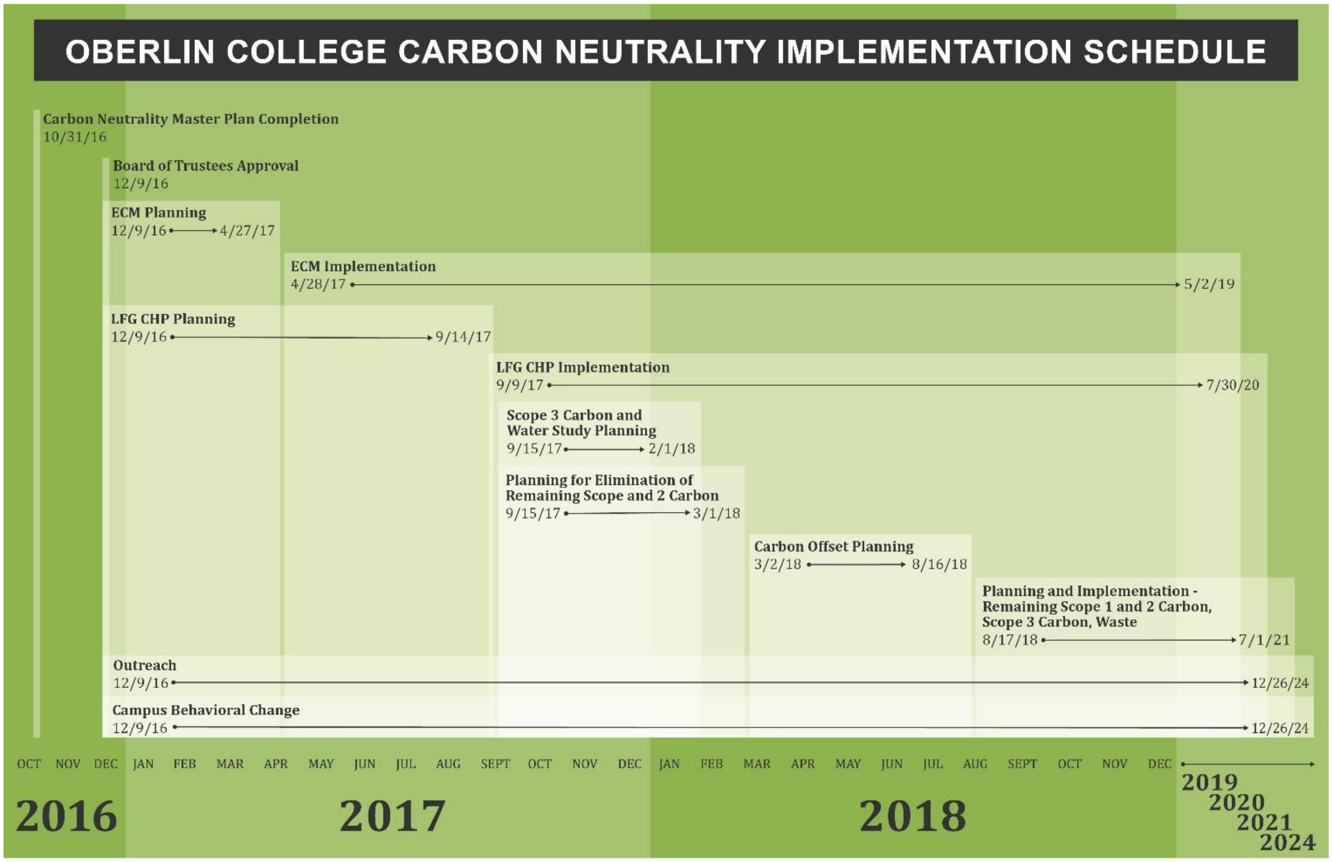


Figure 13: Carbon neutrality implementation schedule

Oberlin College Carbon Neutrality Resource Master Plan, Implementation Strategy, and Economic Approach

Appendices

October 2016

Appendix I – Previous Studies and Reference Materials

"Detailed Energy Analysis for Central Heating Plant and Steam and Distribution Systems," Technical Resource Management Division of the Energy Resource Management Company (THERM), July, 1980.

"Wastewater Treatment Plant Anaerobic Digestion Study," Stand Associates, May 2010.

"Oberlin College: A Plan to be Carbon Neutral," Oberlin College, 2009.

"Oberlin Sustainability Study," Professional Supply Inc. (PSI), November 16, 2009.

"Oberlin College Black and Veatch Study, PSI Study Review," PSI, January 27, 2011.

"Campus Sustainability Best Practices," Massachusetts Executive Office of Energy and Infrastructure, August 2008.

"The City of Oberlin Climate Action Plan," City of Oberlin, 2011.

"Achieving Carbon Neutrality: An Appraisal of Options for Oberlin College," Energy Ventures International (EVI), March 2009.

"Oberlin College Clean Air Cool Planet Greenhouse Gas Inventory Inputs 2007, 2013, 2014," Oberlin College, January 28, 2016.

"Oberlin College Campus Map," Oberlin College Office of Communications, 2011.

"Chilled Water Site Plan," Oberlin College Drawing Number 100222.Site.Drawing, undated.

"Steam Site Plan," Oberlin College Drawing Number 100222.Site.Drawing, undated.

"Beyond Boundaries in Oberlin Ohio: A community collaborates for sustainable, resilient living," Oberlin Office of Sustainability, undated.

"Oberlin College: Climate Neutral by 2020," Rocky Mountain Institute, January 18, 2002.

"Waste Heat Utilization Study for Oberlin College," Brown and Caldwell, December 14, 2012.

"The Economic Feasibility of Power Production form Utility Scale Wind Farms at Oberlin College," Michael Roth, May 2010.

"Oberlin College and Conservatory (Summary of Options)," Black and Veatch, December 2010.

"Oberlin College: Heating and Cooling Plant HVAC Compensation," Oberlin College, September 2016.

"Oberlin College Steam Plant Replacement Study- Final Report," Stantec, April 18, 2012.

"Oberlin College Zone 5 Project," Stantec, August 1, 2014.

"Oberlin College Steam Vaults Priority Assessment, 2016-2019," Oberlin College FP&C, May 26, 2016.

"Oberlin College Energy Transmission and Infrastructure Northern Ohio Department of Energy, National Energy Technology Laboratory Grant- Final Report," Solutions in Sustainability, LLC, August 2011.

"Report of SPRITE Task Force on Building Operating Systems," Oberlin College, March 2013.

"Oberlin College Stars Reporting Tool," Sierra Club, March 20, 2015.

Appendix II – Heating and Cooling Major Equipment

The following summarizes the primary components of Oberlin's district heating and cooling systems.

Major Equipment Inventory						
Item	**Manufacturer**	**Fuel**	**Capacity**	**Operating Pressure**		**Year**
			(PPH/Tons)	**Equipment (psig)**	**Distribution (psig)**	
Boiler 1	Babcock & Wilcox	Natural Gas	50,000	130	15	1970
Boiler 2	Cleaver Brooks	Natural Gas	27,600	35	15	2014
Boiler 3	Cleaver Brooks	Natural Gas	27,600	35	15	2014
Chiller 1	York	Electric	700	60	60	2008
Chiller 2	York	Electric	700	60	60	2008
Chiller 3	York	Electric	450	60	60	1980

Notes

Steam system operates at 8-15 psi. Return temperature varies, but 140°F to 180°F was reported.

Chilled water system operates with a supply and return temp of 43°F and 54°F.

Chiller 1 has a VFD drive.

Primary Chilled Water Pumps: (3) 40 hp

Secondary Pumps: (2) 200 hp with VFDs

Condenser Pumps: (3) 60 hp

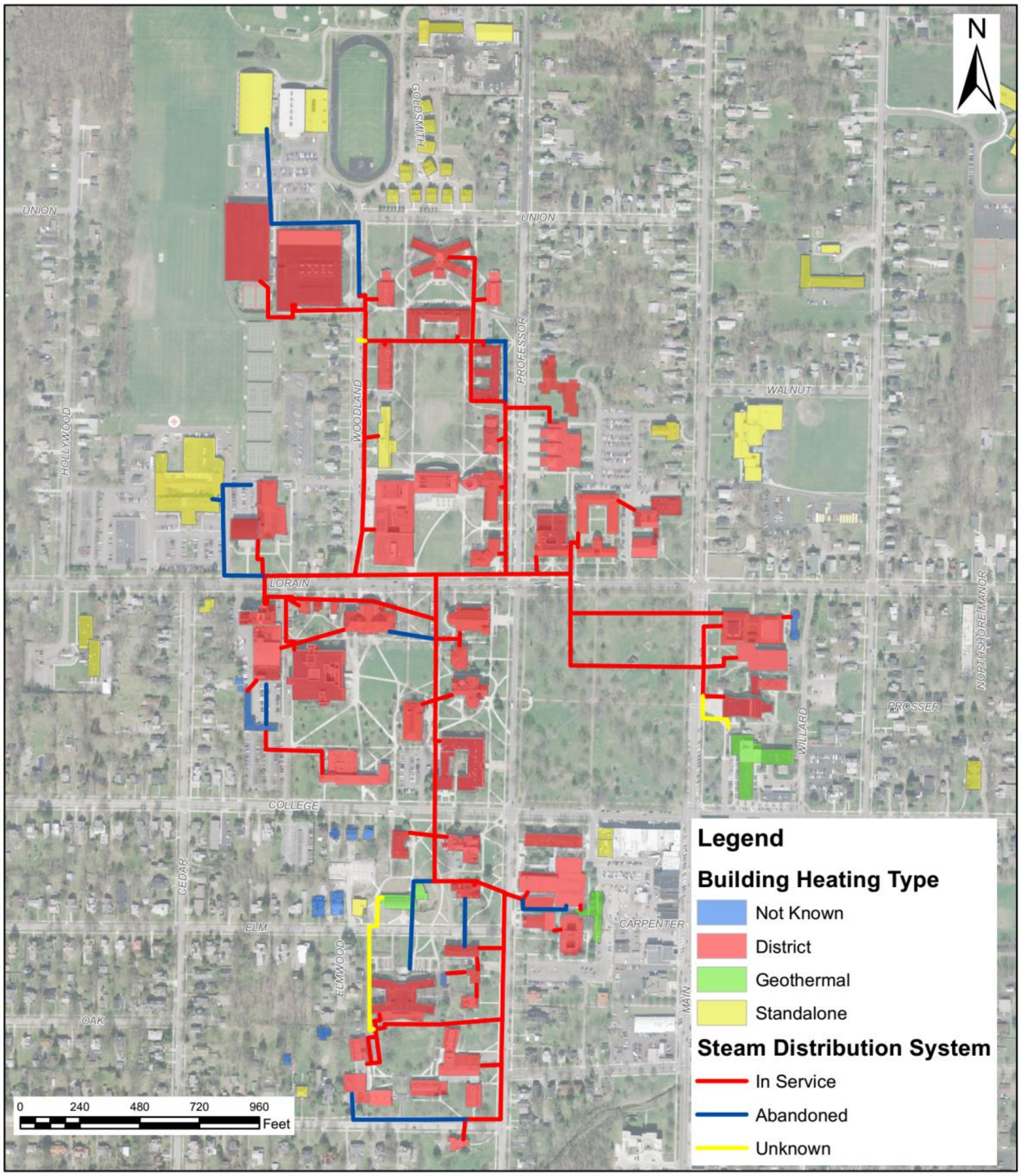
Cooling Towers: (1) BAC, 2 cells, 2000 tons; (1) Evapco, 4 cells, capacity not known

Existing Steam Distribution System Piping									
	Active			Abandoned			Unknown		
Size	**Steam**	**Condensate**	**Vacuum Condensate**	**Steam**	**Condensate**	**Vacuum Condensate**	**Steam**	**Condensate**	**Vacuum Condensate**
1.0			600						224
1		193							
1.5		531			1026				
2	173	278			236				
2.5		1605						163	
3	306	1993			521				
4	1103	2027	121	1026	246		163	127	
5	1007	2164			554				
6	2216	5384		221			372	153	
8	5657	106		1336			219		
10	3769						61	372	
12									
Totals	14,230	14,282	721	2,583	2,583	0	815	815	224

Note
Extracted from AutoCAD file 100222.Site.Drawing

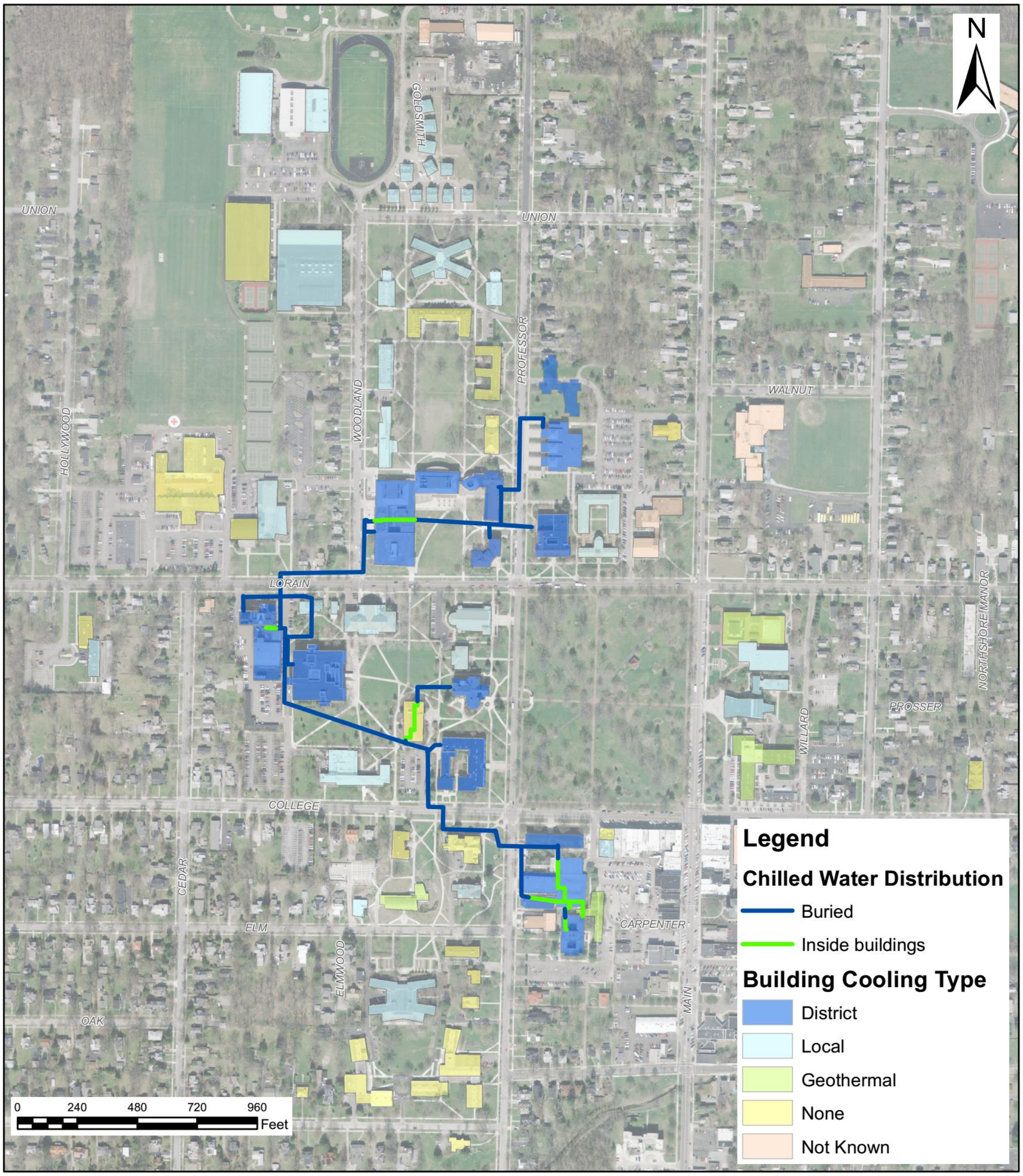
Existing Chilled Water Distribution System Piping				
	Active		Abandoned	
Size	Below Grade	Above Grade	Below Grade	Above Grade
1.0				
1				
1.5				
2				
2.5				
3				
4	52			
5				
6	575			
8	1661	747	221	146
10	1298			
12	948			
Totals	4,535	747	221	146
Note *Extracted from AutoCAD file 100222.Site.Drawing*				

The following maps represent the steam and chilled water distribution systems.



Notes:
1) Data from OC site plan. Imported from AutoCAD.

OBERLIN COLLEGE
Carbon Neutrality Project
Existing Steam Distribution



Notes:
1) Data from OC site plan. Imported from AutoCAD.

OBERLIN COLLEGE
Carbon Neutrality Project
Chilled Water Distribution

Appendix III – Building Survey Results

Pre-1900 Buildings

One element of the site survey was to assess the condition of existing mechanical equipment on campus. The campus includes 11 buildings constructed before the turn of the century. Seven of these buildings were originally constructed as private residences and later converted for college use as dormitories and office space, and the other four buildings are stone structures originally built for college use as dormitories and education. The majority of these building still have single pane windows and parts of the original steam heating system, including the distribution piping and radiators. Three of the buildings are air-conditioned, and three of the buildings have systems that provide fresh air without opening the windows. With the exception of Peters Hall, Lewis Annex, and Daub House, the majority of mechanical equipment in this category of buildings is well beyond its useful life. All buildings have some amount of pneumatic controls, which often leak air and operate inefficiently. These controls should be replaced with direct digital controls to improve reliability and reduce energy consumption from air leaks.

Buildings Built between 1900 and 1925

There were 11 buildings constructed between 1900 and 1925. Three of these building were originally constructed as private residences and later converted for college use as dormitories and security. The other eight buildings are stone structures originally built for college use. The majority of these buildings still have single pane windows and parts of the original steam heating system. Six of the buildings are air-conditioned. Only four of the 11 buildings have systems that provide fresh air without opening the windows. With the exception of Allen Art Museum, Carnegie, and Rice, the majority of mechanical equipment in this category of buildings is well beyond its useful life. All buildings have some amount of pneumatic controls, which often leak air and operate inefficiently. These controls should be replaced with direct digital controls to improve reliability and reduce energy consumption from air leaks.

Buildings Built Between 1926 and 1950

There were ten buildings constructed by the college between 1926 and 1950 for use as dormitories, education, office, athletics and maintenance. The majority of these building still have single pane windows and parts of the original steam heating system including the distribution piping and radiators. Four of the buildings are air-conditioned. Five of the ten building have systems that provide fresh air without opening the windows. With the exception of Creative Writing, the majority of mechanical equipment in this category of buildings is well beyond its useful life. All buildings have some amount of pneumatic controls, which often leak air and operate inefficiently. These controls should be replaced with direct digital controls to improve reliability and reduce energy consumption from air leaks.

Buildings Built Between 1951 and 1975

There were twenty-five buildings constructed between 1951 and 1975. One of these buildings was originally constructed as senior living facility and later converted to a dormitory for college use. This age category includes dormitories, assembly, education, athletics, a library, and a music conservatory. Half of these building still have single pane windows and the majority of these building still have the original heating and cooling equipment. Twenty-one of the buildings have systems that provide fresh air without opening the windows. With the exception of Williams Field House, Bibbins, Bailey and Zechiel, the majority of mechanical equipment in this category of buildings is well beyond its useful life. All buildings have some amount of pneumatic controls, which often leak air and operate inefficiently. These controls should be replaced with direct digital controls to improve reliability and reduce energy consumption from air leaks.

Buildings Built Between 1976 and 2000

There were eight buildings constructed between 1976 and 2000. These buildings serve the music library, offices, education, athletics, and dining. All of these buildings have double pane windows, and in most cases the original heating and cooling equipment. All of the buildings have systems that provide fresh air without opening the windows. During the 2002 renovation, the Sperry mechanical equipment was not replaced and it is at the end of its useful life. Adam Joseph Lewis Center (AJLC) has heating issues that need to be resolved by modifying the occupancy to allow for morning warm-up or the addition of floor radiant heat. Six of these buildings have some amount of pneumatic controls, which often leak air and operate inefficiently. These controls should be replaced with direct digital controls to improve reliability and reduce energy consumption from air leaks.

Post-2000 Construction

There were eight buildings constructed since 2000. These buildings serve as dormitories, office space, educational space, and athletic facilities. All of these buildings have double pane windows and the original heating and cooling equipment. All of the buildings have systems that provide fresh air without opening the windows. In most cases the mechanical equipment is mid-life and of above average energy efficiency. One of these buildings has some amount of pneumatic controls which should be replaced with direct digital controls to improve reliability and reduce energy consumption from air leaks.

Building Mechanical Systems

The Facilities Operations staff reported that there was not a clearly defined standard for HVAC, lighting, safety, and security equipment installed on campus. The repair and maintenance of various different types of equipment and systems places a significant demand on the Facilities Operations staff when equipment malfunctions. The operation and maintenance of the older mechanical systems requires a different technician skill set than does maintenance of newer equipment. As highlighted in the 2013 SPRITE committee findings, coordination between Facility Operations and Capital Planning on equipment standardization could reduce maintenance training, budgets, and spare parts inventory, allowing the college to do more with less.

HVAC Performance

During discussions with students, Facilities Operations, and faculty, there were numerous occupant comfort references related to lack of adequate temperature and humidity control in the summer and winter. These comments are indicative of building performance issues. Overheating and overcooling conditioned spaces is inefficient and consumes more energy than a well-performing building. The cause of the issues vary by building, but are primarily related to building envelope sealing, limited functionality of HVAC controls, inherent limitations of steam as a heating source, mechanical system commissioning and balancing, HVAC system design limitations, and others.

Appendix IV – Energy Conservation Measures

This section contains the Energy Conservation Measures (ECMs) for the Oberlin Carbon Neutrality Project. The methodology and assumptions used to determine the project cost and savings are provided for each ECM. A building summary matrix is provided to cross reference buildings with each ECM. A summary table of the recommended ECMs is provided. It should be noted that some of the ECMs will compete with each other. Depending upon which ECMs are pursued, the total savings will vary.

Utility Assumptions

The following utility rates were utilized to determine the ECM savings.

[redacted]

ECM Financial Summary

The following is a financial summary of all ECMs evaluated.

ECMs – Cost Summary				
Description	**Building Count (Each)**	**Capital Cost (k$)**	**Annual Savings (k$)**	**Simple Payback (yrs)**
ECM 1 Lighting Controls	60	$843	$213	4
ECM 2 Commission Existing Lighting Controls	4	$33	$12	3
ECM 3 Demand Control Kitchen Ventilation	12	$644	$25	26
ECM 4 Walk-in Cooler/Freezer Heat Recovery	11	$133	$3	44
ECM 5 Photovoltaic Skylight	1	$1,405	$3	434
ECM 6 Boiler Stack Economizer	4	$312	$91	3
ECM 7 Low Flow Fixtures	12	$171	$42	4
ECM 8 Direct Digital Controls	47	$6,818	$36	189
ECM 9A Mudd HVAC Replacement	1	$733	$125	6
ECM 10 Window Replacement	31	$8,117	$508	16
ECM 11 HVAC Replacement – Cox, Bosworth, Robertson	4	$2,964	-$21	-139
ECM 12 Conservatory HVAC Replacement	1	$405	$36	11
ECM 13 Kahn Hybrid PV-Thermal Collectors	1	$163	$5	34
ECM 14 Science Center Heat Recovery	1	$858	$107	8
ECM 15 South Hall Ventilation	1	$54	$8	7
Totals		**$23,652**	**$1,191**	

ECM Projected Annual Utility Savings Summary

The following is a summary of the projected utility savings for all of the ECMs evaluated.

ECM - Projected Annual Utility Reductions					
Description	Natural Gas (MMBtu)	Steam (MMBtu)	Electric (MWH)	CO2 (tons)	Water (kgals)
ECM 1 Lighting Controls	0	0	2,051	172	0
ECM 2 Commission Existing Lighting Controls	0	0	115	10	0
ECM 3 Demand Control Kitchen Ventilation	125	1,608	102	133	0
ECM 4 Walk-in Cooler/Freezer Heat Recovery	45	331	0	23	0
ECM 5 Photovoltaic Skylight	0	94	24	9	0
ECM 6 Boiler Stack Economizer	17,056	0	0	1,010	0
ECM 7 Low Flow Fixtures	276	678	0	66	1,709
ECM 8 Direct Digital Controls	0	0	348	29	0
ECM 9A Mudd HVAC Replacement Option 2	0	2,305	653	223	0
ECM 10 Window Replacement	620	23,486	1,490	1,876	0
ECM 11 HVAC Replacement – Cox, Bosworth, Robertson	0	2,853	-372	177	0
ECM 12 Conservatory HVAC Replacement	0	450	204	50	0
ECM 13 Kahn Hybrid PV-Thermal Collectors	0	238	28	20	0
ECM 14 Science Center Heat Recovery	0	12,045	54	884	0
ECM 15 South Hall Ventilation	0	528	10	39	0

ECM Building Matrix

BUILDING ENERGY CONSERVATION MEASURE (ECM) SCHEDULE									
		Lighting Controls	Commission Lighting Controls	Control Kitchen Ventilation	Cooler or Freezer Heat Recovery	PV Skylight	Boiler Stack Economizer	Low Flow Fixtures	Direct Digital Controls
BUILDING		ECM 1	ECM 2	ECM 3	ECM 4	ECM 5	ECM 6	ECM 7	ECM 8
1	JOHNSON (HEBREW HOUSE)	X	-	-	-	-	-	-	-
2	OLD BARROWS	X	-	-	-	-	-	X	-
3	ALLENCROFT	X	-	-	-	-	-	X	X
4,5,8	LANGUAGE - KADE, HARVEY, PRICE	X	-	-	-	-	-	-	X
6	TRANSGENDER HOUSE	X	-	-	-	-	-	-	-
7	LEWIS HOUSE	X	-	-	-	-	-	-	-
9,10	LORD SAUNDERS	X	-	X	X	-	-	-	X
11	PRESIDENT'S HOUSE	X	-	-	-	-	-	-	-
12	SOUTH	X	-	X	X	-	-	X	X
13	FAIRCHILD	X	-	X	X	-	-	X	X
14	BIBBINS	X	-	-	-	-	-	-	X
15	CONSERVATORY WARNER CENTRAL	X	-	-	-	-	-	-	X
16	CONSERVATORY LIBRARY	X	-	-	-	-	-	-	X
17	ROBERTSON	X	-	-	-	-	-	-	X
18	KOHL	-	X	-	-	-	-	-	-
19,20	ANNEX(INCLUDES BOOKSTORE)	X	-	-	-	-	-	-	-

BUILDING ENERGY CONSERVATION MEASURE (ECM) SCHEDULE CONTINUED									
		Lighting Controls	Commission Lighting Controls	Control Kitchen Ventilation	Cooler or Freezer Heat Recovery	PV Skylight	Boiler Stack Economizer	Low Flow Fixtures	Direct Digital Controls
BUILDING		ECM 1	ECM 2	ECM 3	ECM 4	ECM 5	ECM 6	ECM 7	ECM 8
21	ADAM JOSEPH LEWIS CENTER	-	-	-	-	-	-	-	-
22	LEWIS ANNEX	X	-	-	-	-	-	-	-
23	BALDWIN	X	-	X	-	-	-	X	X
24	TALCOTT	X	-	X	X	-	-	-	X
25	HARKNESS	X	-	X	X	-	-	X	X
26	DASCOMB	X	-	X	X	-	X	X	X
27	RICE	X	-	-	-	-	-	-	-
28	KING	X	-	-	-	-	-	-	X
30	PETERS HALL	X	-	-	-	-	-	-	X
31	COX	X	-	-	-	-	-	-	X
32	FINNEY CHAPEL	X	-	-	-	-	-	-	X
33	WARNER CENTER	X	-	-	-	-	-	-	X
34	MUDD LIBRARV	X	-	-	-	-	-	-	X
35	WILDER HALL (STUDENT UNION)	X	-	X	X	-	-	-	X
36	BONNER CENTER	X	-	-	-	-	-	-	-
37	CREATIVE WRITING	X	-	-	-	-	-	-	-
38	SECURITY	X	-	-	-	-	-	-	X

BUILDING ENERGY CONSERVATION MEASURE (ECM) SCHEDULE CONTINUED									
		Lighting Controls	Commission Lighting Controls	Control Kitchen Ventilation	Cooler or Freezer Heat Recovery	PV Skylight	Boiler Stack Economizer	Low Flow Fixtures	Direct Digital Controls
BUILDING		**ECM 1**	**ECM 2**	**ECM 3**	**ECM 4**	**ECM 5**	**ECM 6**	**ECM 7**	**ECM 8**
39	SERVICE BLDG/CENTRAL PLANT	X	-	-	-	-	X	-	X
40	HALES ANNEX	X	-	-	-	-	-	-	X
41	HALES GYM	X	-	-	-	-	-	-	X
43	PROFESSIONAL BUILDING	X	-	-	-	-	-	-	-
46	PHILIPS GYM	X	-	-	-	-	-	-	X
47	HEISMAN FIELD HOUSE	X	-	-	-	-	-	-	X
50	WILLIAMS FIELD HOUSE	X	-	-	-	-	-	-	X
51	KNOWLES STADIUM/ALUMNI CLUB	X	-	-	-	-	-	-	-
51	STADIUM LOCKER ROOM	X	-	-	-	-	-	-	-
52	UNION STREET HOUSING	X	-	-	-	-	-	-	-
53	NORTH / LANGSTON	X	-	-	-	-	-	-	X
54	BAILEY	X	-	-	-	-	-	-	X
55	BURTON	X	-	-	-	-	-	X	X
56	ZECHIEL	X	-	-	-	-	-	-	X
57	NOAH	X	-	-	-	-	-	-	X
58	EAST	X	-	-	-	-	-	-	X
59	BARROWS	X	-	-	-	-	-	-	X

BUILDING ENERGY CONSERVATION MEASURE (ECM) SCHEDULE CONTINUED									
		Lighting Controls	Commission Lighting Controls	Control Kitchen Ventilation	Cooler or Freezer Heat Recovery	PV Skylight	Boiler Stack Economizer	Low Flow Fixtures	Direct Digital Controls
BUILDING		**ECM 1**	**ECM 2**	**ECM 3**	**ECM 4**	**ECM 5**	**ECM 6**	**ECM 7**	**ECM 8**
60	BARNARD	X	-	-	-	-	-	X	X
61	WRIGHT PHYSICS	X	-	-	-	-	-	-	X
62	SCIENCE CENTER, KETTERING, SPERRY	-	X	-	-	-	-	-	X
63	SEVERANCE	X	-	-	-	-	-	-	X
64	CARNEGIE (ADMISSIONS)	X	-	-	-	-	-	-	X
65	STEVENSON DINING	X	-	X	X	X	X	-	X
66	KAHN HALL	-	X	-	-	-	-	-	-
68	KEEP	X	-	X	X	-	-	X	X
69	ASIA HOUSE	X	-	X	X	-	-	-	X
70	BOSWORTH	X	-	-	-	-	-	-	X
72	ALLEN ART MUSEUM	-	X	-	-	-	-	-	-
73	ART ADDITION	X	-	-	-	-	-	-	X
74	HALL AUDITORIUM	X	-	-	-	-	-	-	X
75	HALL ANNEX	-	-	-	-	-	-	-	X
78	CHARLES MARTIN HALL	-	-	-	-	-	-	-	-
79	TANK	X	-	X	X	-	-	X	X
80	FIRELANDS	X	-	-	-	-	X	X	-
	TOTAL	60	4	12	11	1	4	12	47

BUILDING ENERGY CONSERVATION MEASURE (ECM) SCHEDULE CONTINUED											
		Mudd HVAC Option 2	Mudd HVAC Option 3	Mudd HVAC Option 4	Mudd HVAC Option 5	Window Replacement	HVAC Cox, Bosworth, Robertson	Conservatory HVAC Replacement	Hybrid PV-Thermal Collectors	Science Center Heat Recovery	South Hall Ventilation
BUILDING		ECM 9a	ECM 9b	ECM 9c	ECM 9d	ECM 10	ECM 11	ECM 12	ECM 13	ECM 14	ECM 15
1	JOHNSON (HEBREW HOUSE)	-	-	-	-	X	-	-	-	-	-
2	OLD BARROWS	-	-	-	-	X	-	-	-	-	-
3	ALLENCROFT	-	-	-	-	X	-	-	-	-	-
4,5,8	LANGUAGE - KADE, HARVEY, PRICE	-	-	-	-	-	-	-	-	-	-
6	TRANSGENDER HOUSE	-	-	-	-	X	-	-	-	-	-
7	LEWIS HOUSE	-	-	-	-	-	-	-	-	-	-
9,10	LORD SAUNDERS	-	-	-	-	-	-	-	-	-	-
11	PRESIDENT'S HOUSE	-	-	-	-	-	-	-	-	-	-
12	SOUTH	-	-	-	-	X	-	-	-	-	X
13	FAIRCHILD	-	-	-	-	-	-	-	-	-	-
14	BIBBINS	-	-	-	-	-	-	-	-	-	-
15	CONSERVATORY WARNER CENTRAL	-	-	-	-	-	-	X	-	-	-
16	CONSERVATORY LIBRARY	-	-	-	-	-	-	-	-	-	-
17	ROBERTSON	-	-	-	-	X	X	-	-	-	-
18	KOHL	-	-	-	-	-	-	-	-	-	-
19,20	ANNEX(INCLUDES BOOKSTORE)	-	-	-	-	-	-	-	-	-	-
21	ADAM JOSEPH LEWIS CENTER	-	-	-	-	-	-	-	-	-	-

BUILDING ENERGY CONSERVATION MEASURE (ECM) SCHEDULE CONTINUED											
		Mudd HVAC Option 2	Mudd HVAC Option 3	Mudd HVAC Option 4	Mudd HVAC Option 5	Window Replacement	HVAC Cox, Bosworth, Robertson	Conservatory HVAC Replacement	Hybrid PV-Thermal Collectors	Science Center Heat Recovery	South Hall Ventilation
BUILDING		ECM 9a	ECM 9b	ECM 9c	ECM 9d	ECM 10	ECM 11	ECM 12	ECM 13	ECM 14	ECM 15
22	LEWIS ANNEX	-	-	-	-	-	-	-	-	-	-
23	BALDWIN	-	-	-	-	-	-	-	-	-	-
24	TALCOTT	-	-	-	-	X	-	-	-	-	-
25	HARKNESS	-	-	-	-	-	-	-	-	-	-
26	DASCOMB	-	-	-	-	X	-	-	-	-	-
27	RICE	-	-	-	-	-	-	-	-	-	-
28	KING	-	-	-	-	X	-	-	-	-	-
30	PETERS HALL	-	-	-	-	X	-	-	-	-	-
31	COX	-	-	-	-	X	X	-	-	-	-
32	FINNEY CHAPEL	-	-	-	-	X	-	-	-	-	-
33	WARNER CENTER	-	-	-	-	X	-	-	-	-	-
34	MUDD LIBRARV	X	X	X	X	X	-	-	-	-	-
35	WILDER HALL (STUDENT UNION)	-	-	-	-	X	-	-	-	-	-
36	BONNER CENTER	-	-	-	-	-	-	-	-	-	-
37	CREATIVE WRITING	-	-	-	-	-	-	-	-	-	-
38	SECURITY	-	-	-	-	-	-	-	-	-	-
39	SERVICE BLDG/CENTRAL PLANT	-	-	-	-	X	-	-	-	-	-

BUILDING ENERGY CONSERVATION MEASURE (ECM) SCHEDULE CONTINUED		Mudd HVAC Option 2	Mudd HVAC Option 3	Mudd HVAC Option 4	Mudd HVAC Option 5	Window Replacement	HVAC Cox, Bosworth, Robertson	Conservatory HVAC Replacement	Hybrid PV-Thermal Collectors	Science Center Heat Recovery	South Hall Ventilation
BUILDING		ECM 9a	ECM 9b	ECM 9c	ECM 9d	ECM 10	ECM 11	ECM 12	ECM 13	ECM 14	ECM 15
40	HALES ANNEX	-	-	-	-	X	-	-	-	-	-
41	HALES GYM	-	-	-	-	X	-	-	-	-	-
43	PROFESSIONAL BUILDING	-	-	-	-	-	-	-	-	-	-
46	PHILIPS GYM	-	-	-	-	X	-	-	-	-	-
47	HEISMAN FIELD HOUSE	-	-	-	-	-	-	-	-	-	-
50	WILLIAMS FIELD HOUSE	-	-	-	-	-	-	-	-	-	-
51	KNOWLES STADIUM/ALUMNI CLUB	-	-	-	-	-	-	-	-	-	-
51	STADIUM LOCKER ROOM	-	-	-	-	-	-	-	-	-	-
52	UNION STREET HOUSING	-	-	-	-	-	-	-	-	-	-
53	NORTH / LANGSTON	-	-	-	-	X	-	-	-	-	-
54	BAILEY	-	-	-	-	X	-	-	-	-	-
55	BURTON	-	-	-	-	-	-	-	-	-	-
56	ZECHIEL	-	-	-	-	-	-	-	-	-	-
57	NOAH	-	-	-	-	X	-	-	-	-	-
58	EAST	-	-	-	-	X	-	-	-	-	-
59	BARROWS	-	-	-	-	-	-	-	-	-	-
60	BARNARD	-	-	-	-	X	-	-	-	-	-

BUILDING ENERGY CONSERVATION MEASURE (ECM) SCHEDULE CONTINUED											
		Mudd HVAC Option 2	Mudd HVAC Option 3	Mudd HVAC Option 4	Mudd HVAC Option 5	Window Replacement	HVAC Cox, Bosworth, Robertson	Conservatory HVAC Replacement	Hybrid PV-Thermal Collectors	Science Center Heat Recovery	South Hall Ventilation
BUILDING		ECM 9a	ECM 9b	ECM 9c	ECM 9d	ECM 10	ECM 11	ECM 12	ECM 13	ECM 14	ECM 15
61	WRIGHT PHYSICS	-	-	-	-	X	-	-	-	-	-
62	SCIENCE CENTER, KETTERING, SPERRY	-	-	-	-	-	-	-	-	X	-
63	SEVERANCE	-	-	-	-	X	-	-	-	-	-
64	CARNEGIE (ADMISSIONS)	-	-	-	-	X	-	-	-	-	-
65	STEVENSON DINING	-	-	-	-	-	-	-	-	-	-
66	KAHN HALL	-	-	-	-	-	-	-	X	-	-
68	KEEP	-	-	-	-	X	-	-	-	-	-
69	ASIA HOUSE	-	-	-	-	-	-	-	-	-	-
70	BOSWORTH	-	-	-	-	X	X	-	-	-	-
72	ALLEN ART MUSEUM	-	-	-	-	-	-	-	-	-	-
73	ART ADDITION	-	-	-	-	-	-	-	-	-	-
74	HALL AUDITORIUM	-	-	-	-	X	-	-	-	-	-
75	HALL ANNEX	-	-	-	-	X	-	-	-	-	-
78	CHARLES MARTIN HALL	-	-	-	-	-	-	-	-	-	-
79	TANK	-	-	-	-	-	-	-	-	-	-
80	FIRELANDS	-	-	-	-	-	X	-	-	-	-
	TOTAL	1	1	1	1	31	4	1	1	1	1

ECM Descriptions

Energy Conservation Measures (ECM) 1: Lighting Controls

Description: Add wall and/or ceiling mounted vacancy sensors for manual on-automatic off lighting control in all spaces.

Assumptions:

1. Classrooms/offices savings are based on cutting "on" time by 25%.
2. Dormitories savings are based on cutting "on" time by 50%.
3. Installation cost for a vacancy sensor is assumed to be $0.25 per square foot (sf). Assumes a 1,000 sf coverage area for each sensor at an installation cost of $250 each.
4. Based on Electric Power Research Institute (EPRI) National Database, U.S. Colleges and Universities lighting is 47% of total building electrical usage.
5. ASHRAE Lighting Power Density allowances used to estimate usage where no metering data was provided. Dormitory lighting assumed to be in use 8 hours per day. Academic buildings assumed to be in use 12 hours per day. Assembly assumed to be in use 4 hours per day.

ECM 2: Commission Existing Lighting Controls

Description: Commission the existing lighting controls to operate as designed to optimize energy savings.

Assumptions:

1. Cost to commission existing whole building lighting control systems is assumed to be $5,000
2. Re-commissioning savings estimated at 10% of the estimated annual lighting power consumption.

ECM 3: Demand Control Kitchen Ventilation

Description: Installation of a complete kitchen hood demand control ventilation system equal to Melink Intellihood. Make-up air and exhaust fans' speeds are modulated based on smoke or heat generated by cooking equipment under the hood.

Assumptions:

1. Based on Melink case study data, demand ventilation control reduces exhaust and make-up airflow by 35% annually.
2. Hours of operation:
    a. Stevenson: 7 am to midnight, 7 days per week, September thru April (36 weeks); 7 am to 7pm, 5 days per week, May thru August (14 Weeks).

b. Dascomb: 7 am to midnight, 5 days per week, September thru April (36 weeks).
c. Lord-Saunders: 4 pm to midnight 5 days per week, September thru April (36 weeks).
d. Wilder: 4 pm to midnight, 7 days per week, September thru April (36 weeks).
e. Co-op: 6 am to 6 pm, 5 days per week, September thru April (36 weeks).
f. South: 9 am to 4 pm, 5 days per week, year-round (50 weeks).

3. Dining halls of the central steam system can only heat from October thru April.
4. The cost to retrofit existing hoods is assumed to be $2 per cfm based on Melink case study data.
5. Heating and cooling load calculated per cfm of savings using the ASHRAE Bin Tables for temperature and enthalpy for Cleveland, OH.

ECM: 4 Walk-in Cooler or Freezer Heat Recovery

Description: Install heat recovery module for each refrigerant circuit and storage tank to recover heat for domestic water heating.

Assumptions:

1. Based on manufacturer case study, cooler/freezer operates for 16 hours per day resulting in an average of 244 thousand btu per day of domestic water heating.
2. Projected to eliminate or reduce fan energy currently used to cool compressors.

ECM 5: Photovoltaic Skylight

Description: Replace existing skylight glass with a low E photovoltaic glass. The glass generates electricity and still allows natural light in and the low E glass coating reduces radiant heat loss through the skylight glass.

Assumptions:

1. Based on manufacturer's case study, HVAC energy demand is projected to be reduced by 17%.
2. Electricity is generated at 2.645 kW per sf per year based on manufacturer's case study for Cleveland, OH.
3. Installed cost based on Means and Manufacturer's case study.
4. Baseline heating and cooling conduction load of existing glass based on ASHRAE Bin Tables. Cooling Solar gain reduction was not included in the cooling savings.

ECM 6: Boiler Stack Economizer

Description: Install boiler stack economizer packages in several buildings with boilers serving the summertime building loads. The package includes a heat exchanger, pumps, and the piping required to recover stack heat for preheating boiler feedwater or domestic hot water.

Assumptions:

1. For the central plant, annual steam and condensate generation is based on data in the PSI 2009 study. Make-up water is assumed to be 15%.
2. For the boiler installed in the Firelands building, the annual building heating load was estimated using the ASHRAE Bin Tables. To allow for diversity, only 70% of the building's connected load was included in the savings calculation.
3. For the boiler installed in the Stevenson building, the boiler is considered to be in use from May through September. The boiler is assumed to be loaded at 100% capacity for 17 hours per day. The energy savings will increase if the central plant is converted from steam to hot water and the local steam boiler will operate year-round to serve the kitchen equipment loads.
4. For the boiler installed in the Dascomb building, the boiler is considered to be in use from May through September. The boiler is assumed to be loaded at 100% capacity for 17 hours per day. Energy savings increase if the central plant is converted from steam to hot water and the local steam boiler will operate year-round to serve the kitchen equipment loads.

ECM 7: Low Flow Fixtures

Description: Replace lavatory faucets and shower heads in dormitories.

Assumptions:

1. Existing showerheads are 3 gpm or greater.
2. Existing lavatory faucets are 1 gpm or greater.
3. Based on ASPE data, dormitory domestic hot water usage is 22 gallons per person per day.

ECM 8: Direct Digital Controls

Description: Replace pneumatic controls with electric or digital controls.

Assumptions:

1. Installed cost equals $5,000 for building control panel, $3,000 for local control panels, and $1000 per point. The number of points is based on existing control diagrams.
2. Assumes 4,380 hours per year of compressor operation due to air leaks, as the majority of the systems are well past their useful life.

3. Air compressor estimated hp varies from 0.5 to 20, depending on the size of the building and system types.

ECM 9: Mudd Library HVAC System Option 1

Description: The building HVAC systems include air handlers, zone reheat, and 34% outside make-up air. Cooling during periods when the central plant is not operating is provided by local DX units and a large water to air chiller. Cooling is provided by the Central Plant when the facility is operating. The Mudd air handling systems are at the end of their useful life and there are more energy efficient replacement systems that can be used to reduce energy consumption. Existing air handling systems include constant volume air handlers with chilled and hot water coils, and steam humidification. Air side economizers are not installed on the air handling system. The baseline for equipment replacement includes 33 air handlers and 73 reheat coils located in the building. The baseline equipment replacement does not include the replacement of chilled water or hot water production equipment. All of ECM 9 proposed system costs are based on the premium cost for system upgrade above direct equipment replacement. Energy savings for each ECM system is calculated based on the percent savings from the baseline energy consumption which was calculated using existing connected building equipment capacity and ASHRAE Bin Tables.

Assumptions:

1. Baseline equipment replacement involves one-for-one air handler replacements with chilled water cooling, hot water heating, and steam humidification, and one-for-one reheat coil replacement.
2. The existing system has no economizer control per the original control drawings. The air handling system operates 24/7 year-round.
3. Installed cost based of $5 per cfm for air handlers and $2 per cfm for reheat coils.

ECM 9A: Mudd Library HVAC System Option 2

Description: This ECM includes the consolidation of the buildings air handling units to take advantage of the building’s load diversity. The AHUs will be changed from constant volume to variable volume. The hot water reheat coils will be replaced with VAV terminal units with hot water reheat coils. Airside economizers will be added to take advantage of free cooling. The addition of demand control ventilation (DCV) will reduce the outside air make up and air conditioning energy consumed. All equipment will be equipped with DDC controls. This ECM assumes no change to the central chilled water and hot water system.

Assumptions:

1. Reuse existing ductwork mains and air distribution.
2. Building diversity of 90%.
3. Installed cost based on $6 per cfm for air handlers and 150 terminal units at $4,000 each.
4. Fan power reduction calculated based loads using ASHRAE Bin Tables.
5. Economizer and DCV energy based on Honeywell savings calculator.

ECM 9B: Mudd Library HVAC System Option 3

Description: For this ECM, the airside improvements will be the same as ECM 9A. In addition to the airside improvements, this ECM involves replacing Mudd’s central chilled water and hot water system with a central geothermal system with chiller-boiler heat pumps to provide hot water and chilled water to the HVAC systems.

Assumptions:

1. Reuse existing piping mains.
2. Central geothermal plant installed cost is $10 per sf
3. Geothermal system - 20% improvement in system efficiency above existing central plant systems.

ECM 9C: Mudd Library HVAC System Option 4

Description: Elimination of all existing air handlers and reheat coils. Installation of four rooftop dedicated outdoor air system (DOAS) units with energy recovery using exhaust air to pre-condition outside air. DOAS units include supply and exhaust fans, heat recovery thermal energy wheels, chilled water cooling, hot water heating, and steam humidification. Outside air is distributed through the existing mechanical rooms to fan powered terminal units with sensible cooling coils and reheat on the perimeter. All equipment will be equipped with DDC controls. This ECM involves no change to the central chilled water and hot water system.

Assumptions:

1. Reuse existing duct main for outside air distribution to fan-powered terminal units.
2. Reuse existing piping mains.
3. DOA and terminal units installed cost of $19 per sf.

ECM 9D: Mudd Library HVAC System Option 5

Description: The air-side system will be the same as ECM 9C. In addition to air-side replacement, this ECM replaces the central chilled water and hot water system with a central geothermal system with chiller-boiler heat pumps to provide hot water and chilled water to the HVAC systems.

Assumptions:

1. Reuse existing piping mains.
2. Central geothermal plant installed cost of $10 per sf
3. Geothermal system rating for cooling: 18 EER (energy efficiency ratio); heating: 3.5 coefficient of performance (COP)

ECM 10: Window Replacement

Description: Replace single-pane windows with double-pane windows. Windows typically have the largest Btu per sf heat gain or loss of all exterior building components.

Assumptions:

1. Replacement windows to comply with current State of Ohio energy code for U-value, SHGC, and leakage rate.
2. For simplicity, only conduction gains or losses are considered since the majority of the buildings are only heated.
3. Heat gains and losses are calculated per sf of glass using the ASHRAE Bin Tables for Cleveland, OH.
4. The area of glass is estimated based on exterior elevations in existing drawings.
5. Infiltration was included in the calculation.

ECM 11: HVAC Replacement Cox, Bosworth, and Robertson

***Cox*:** The building HVAC system includes steam radiators and window air conditioning (AC) units. There is no outside air supplied to the building and the majority of the windows can't be opened because the window AC units are installed year-round. The systems in this building are at the end of their useful life, and there are more energy efficient replacement systems that can be used. Steam radiators and window units would be removed and replaced by a VRF heat recovery system. The addition of a DX DOAS unit installed in the basement will provide outside air through the central core of the building and include energy recovery. All equipment will be equipped with DDC controls. Removal of the window units will eliminate the cold air drafts in the winter time and reduce air infiltration in the summer and winter. In addition to the energy savings, these system upgrades will improve the building's indoor air quality and space temperature control, improving the work environment.

Bosworth**:** The building HVAC system includes steam radiators, dx split systems, and window AC units. There is no outside air supplied to the building and the majority of the windows can't be opened, because the window units are installed year-round. The systems in this building are at the end of their useful life, and there are more energy efficient replacement systems that can be used. Steam radiators and window units would be removed and replaced by a VRF heat recovery system. The addition of a DX DOAS unit will provide outside air to the building and include energy recovery. All equipment will be equipped with DDC controls. Removal of the window units will eliminate the cold air drafts in the winter time and reduce air infiltration in the summer and winter. In addition to energy savings, these system upgrades will improve the building's indoor air quality and space temperature control, improving the work environment.

Robertson**:** The building HVAC system includes a 100% outside air unit and room induction units. The systems in this building are at the end of their useful life and there are more energy efficient replacement systems that can be used. Due to excessive pressure drops, the induction system consumes considerably more fan energy than a present day DOAS. This ECM assumes replacement of the air handling units with DOAS units with energy recovery, and replace room induction units with chilled beams units. All equipment would be equipped with DDC controls.

Assumptions:

1. The DOAS would be sized to provide outside air per the Ohio Mechanical Code.
2. DOAS would be equipped with an air cooled heat pump.
3. The VRF system would consist of wall cassettes for the indoor unit and ground-mounted condenser.
4. Annual heating and cooling loads are calculated using the ASHRAE Bin Tables for Cleveland, OH.
5. The existing piping and OA ductwork is good shape and of adequate size.

ECM 12: Conservatory HVAC Replacement

Description: The building HVAC systems include multi-zone air handlers, constant volume air handlers, and the heating and ventilating units. The air handling systems are at the end of their useful life and there are more energy efficient replacement systems that can be used. Consolidate AHUs to take advantage of building diversity by converting from constant volume to variable volume. Replacement of multi-zone zones with VAV terminal units with hot water reheat. Addition of an airside economizer to take advantage of free cooling. Addition of demand control ventilation to reduce outside air conditioning energy consumed. All equipment would be equipped with DDC controls. This ECM includes no change to the central chilled water and hot water system.

Assumptions:

1. Existing system has no economizer control.
2. Air handling system operate 24/7 year round.

ECM 13 Kahn Hybrid Photovoltaic-Thermal Collectors

Description: Installation of 767 sf hybrid PV-Thermal collectors on the existing structures on the Kahn roof included in this ECM. These hybrid units generate electricity more efficiently because the thermal portion removes heat that would normally reduce the PV panel efficiency. Thermal energy will be used to pre-heat domestic hot water. The new system will include collectors, glycol, piping, pumps, and storage tanks.

Assumptions:

1. The basis of design is Solimpeks Volther PowerVolt. Solar data and costs are utilized from manufacturer's literature.
2. Storage tanks will be installed in the location where tanks were originally intended per the building design drawings.

ECM 14 Science Center Heat Recovery

Description: Add a runaround heat recovery loop to each of the three 100% outside air handling units and corresponding exhaust systems to move energy back and forth between the two airstreams. Each heat recovery loop would include two coils, pumps, accessories, and packaged glycol make-up units.

Assumptions:

1. Coils in the exhaust air will be coated to prevent corrosion.

ECM 15 South Hall Ventilation

Description: There are two, 20,000 cfm, 100% outside air heating and ventilation units that originally served the kitchen and dining area on the first floor. The dining area has been converted to a dance studio and fitness center. A small section of the kitchen is used daily for the Bake Shop. The dormitory floors have no positive means of outside air. The air handling systems are at the end of their useful life and there are more energy efficient systems that can be used. Properly-sized ventilation units would provide make-up for the hoods used by the bake shop. Also included is a DOAS unit with energy recovery to provide fresh air to the fitness center, dance studio, and dormitory corridors.

Assumptions:

1. The Bake Shop operates 8 hours per day; 5 days per week

Appendix VI – Carbon-Free Energy Source Evaluation

A comparative high-level screening of carbon-free fuels and energy source options was performed to evaluate options for serving Oberlin's thermal energy needs. Screening was based on NREL[6] and EIA[7] costs for alternative production sources, along with research by the Project Team. The summary of findings for viable options is provided in Table 7. The Project Team has identified that the landfill gas combined heat and power (LFG CHP) solution currently offers the optimal carbon-free heating supply alternative. Below is a comparative analysis of fuels and energy sources. For the purposes of this section of analysis, fuels and technologies were analyzed as separate solutions, although both have the possibility to displace gas or electricity and reduce carbon profile.

Fuel Source Screening

A high level fuel cost screening was completed to identify and rank carbon-free fuel source options. The purpose was to identify and rank fuel sources that have the highest potential to displace natural gas combustion. Plant operating efficiency is included to determine the unit cost of energy output from the fuel source. Based on the screening, the least-cost carbon-free fuels are biomass from wood residuals and biomass from agricultural residuals. The least cost liquid fuel is ethanol at $23 per MMBtu. From Oberlin's current baseline energy production, burning ethanol would add between $3 million and $4 million dollars per year to the current operating budget. A summary table is provided below.

The NREL Biomass maps indicate that there is sufficient agricultural residue and wood waste in the region to supply a proposed facility. High Btu landfill gas is currently unattractive due to large demand for alternative vehicle fuels increasing the cost significantly and the local landfill gas is under a long term contractual commitment, and thus unavailable.

6. "Distributed Generation Renewable Energy Estimate of Costs." NREL: Energy Analysis. February 2016. Accessed August 2016. http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.
7. EIA. "Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2016." Publication. 2016. Accessed August 2016.Table 8.2 http://www.eia.gov/forecasts/aeo/assumptions/pdf/Table_8.2.pdf.

Alternative Fuel Cost Comparison					
Fuel	Energy Content	Unit	Unit Cost[3] ($/unit)	Combustion Efficiency (%)	Delivered Energy Unit Cost ($/MMBtu)
LFG CHP[1]	1.0	MMBtu	$2.50	85%	$3
Biomass - wood residual	15.5	MMBtu/ton	$50.00	75%	$4
Biomass - agricultural residuals	16.0	MMBtu/ton	$55.00	75%	$5
Natural gas (for comparison)	1.0	MMBtu/mscf	$4.90	85%	$6
Ethanol (E100)	84.0	kBtu/gallon	$1.62	85%	$23
Landfill gas - high-Btu	1.0	MMBtu/mscf	$21.00	85%	$26
Vegetable oil	120.0	kBtu/gallon	$2.96	85%	$29
Rendered animal fat	125.0	kBtu/gallon	$3.11	85%	$29
Electric (RFCW region[2])	3,413.0	Btu/kW	$0.10	98%	$30
Biodiesel-B100	117.1	kBtu/gallon	$3.40	85%	$34

Notes
1. Estimated cost. Not a fuel, included for cost comparison.
2. EPA Emission Factors, https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf.
3. USDA National Weekly Ag Energy Round-Up, September 9, 2016. https://www.ams.usda.gov/mnreports/lswagenergy.pdf

Carbon-Free Energy Source Screening

In order to evaluate competing carbon-free energy sources, the Project Team considered methods to heat the buildings as the basis of the high level energy source screening. The existing campus heat load after implementation of the ECMs was set as the basis for the campus's thermal load, set at 148,700 MMBtu per year and 54 MMBtu per hour peak demand. For Solar PV, the required system capacity is 32 MW which is required to supply the annual electrical energy production required for Oberlin. Reference material was used from EIA[8] and NREL[9] for alternative energy source costs, and operating variables are adjusted to reflect costs in Oberlin. The capital cost for the existing boiler plant is included in each alternative.

8. "Distributed Generation Renewable Energy Estimate of Costs." NREL: Energy Analysis. February 2016. Accessed August 2016. http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.
9. EIA. "Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2016." Publication. 2016. Accessed August 2016.Table 8.2 http://www.eia.gov/forecasts/aeo/assumptions/pdf/Table_8.2.pdf.

Summary of Probable Costs for Alternate Technologies				
Technology	**Cost of Implementation (k$)**	**Annual O&M Cost (k$/year)**	**Annual Life Cycle Cost (k$/year)**	**Notes**
LFG CHP	$61,200	$700	$4,000	1,2,5,6
Biomass thermal	$55,000	$1,900	$5,400	1,2,5,6
Biogas	$82,200	$900	$6,100	1,2,5,6
Geothermal	$91,700	$1,300	$6,200	1,2,4,6
Wind	$92,800	$1,600	$6,600	1,2
Solar PV	$112,400	$1,400	$6,800	1,3,6
Solar thermal including thermal storage	$142,800	$1,300	$8,700	1,2,3,6
Fuel cells	$137,900	$2,100	$11,000	7
Plasma gasification of MSW	$214,400	$2,600	$16,300	7

Notes

1. Includes cost for existing boiler plant	*$10,770*	*(k$)*
2. Includes cost for hot water distribution system	*$11,500*	*(k$)*
3. Includes cost for electrical system improvements	*$2,112*	*(k$)*
4. Includes cost for building conversions	*$14,400*	*(k$)*
5. Includes cost for building conversions	*$8,300*	*(k$)*
6. Includes system development costs		
Debt service interest rate	*4%*	
Engineering and Design	*10%*	
Project Controls	*8%*	
OH&P	*10%*	
Contingency	*25%*	

7. Estimated production cost based on EIA plant costs.

8. Hess quoted carbon offsets for natural gas at $0.181 per MMBtu. The entire natural gas consumption for Oberlin can be offset for approximately $38,000 in 2016 prices.

Landfill Gas Generation Combined Heat and Power

The landfill to the east of Oberlin contains an existing electrical production facility with eight 1,300 kW generators and ten 1,600 kW generators. This alternative proposes to recover the waste heat from the engines and exhaust stacks and pipe the thermal energy via hot water to the campus. There is sufficient thermal energy available to supply the campus and some community loads. Discussions with EDI, the power plant owner and operator, indicated that they are willing to discuss and pursue possible heat recovery as part of a broader concept.

The technology is mature, simple, and feasible. Heat exchangers are installed in the cooling water loop and the stack gas exhaust to recover the waste energy and transfer it to the district hot water system.

A hot water-based system is easily maintained by HVAC technicians and plumbers without significant training, as hydronic systems are widely utilized and the concepts are easily understood. The landfill permit is valid through 2035 but Republic Services, the landfill operator, owns large parcels to the north of the existing landfill and they are currently excavating soils for daily cover, which typically results in landfill expansion once soils are excavated.

The heat recovery alternative would require conversion of campus buildings to accept a hot water energy source instead of steam, construction of a 14,500 foot pipeline from the landfill to campus, modifications to the central plant, addition of heat exchangers and pumps at the landfill to capture the energy and the construction of approximately 8,000 feet of campus hot water distribution piping. The existing boiler plant would serve as backup in the event the landfill power plant is unavailable.

The technology is proven and will allow for the recovery of an energy source that is currently wasted. The hot water system can be expanded in the future to benefit the broader community and integrate other energy sources as they become viable. The connection of the City-owned waste water treatment plant to the hot water system will free the digester’s biogas to generate electricity for plant use. Once the distribution system is installed, other energy sources could be added to the system. Biomass, other waste heat recovery, solar thermal, and thermal storage can all be added to increase the reliability and diversity of the system. Heat loss from the distribution system is managed through the use of pre-insulated pipe and is typically less than 7% for a medium temperature hot water system.

There are several primary risks associated with this alternative. The risks of infrastructure construction cost overruns are real. A second risk is the landfill operator, EDI. We have had discussions related to heat recovery and they were amenable to the idea, but until an agreement is solidified, they could decide not to pursue this opportunity. While the risk of landfill closure in the immediate future is not seen as a risk, the long lifecycle of the district energy system infrastructure requires some mitigation strategies to alleviate that risk. Potential strategies include development of alternative heating source at or near the landfill.

Biomass

The second most attractive alternative is the utilization of biomass. The technology is mature and offers many of the same benefits of a hot water system similar to the LFG CHP option. The operation of a solid fuel facility, while more complicated than a gas-fired facility or landfill gas heat recovery, but is being done by a number of campuses. This alternative has been addressed in several previous Oberlin studies (Appendix I).

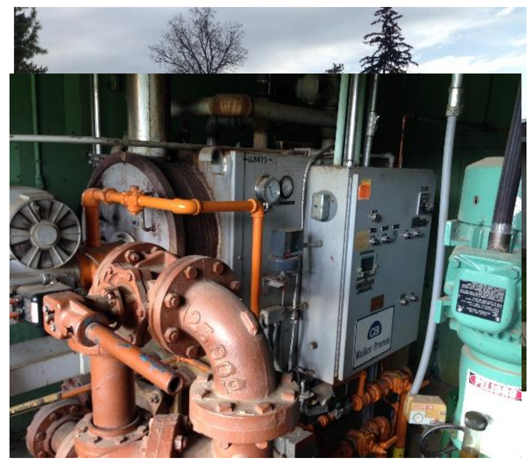
A small biomass hot water plant sited adjacent to the solar farm along North Professor Street is one option. The grounds keeping facility could also be repurposed for this option. The facility located outside of the city's core business district allows for vehicle access from the north. The facility could combust wood residuals, urban wood waste, agricultural residuals, or as a byproduct of grown-for-purpose crops. Burning of agricultural residuals is done in Europe for district heating system and provides a benefit for the community due to additional income source for local farmers. NREL biomass maps of the region indicate that there is an adequate local supply of biomass within a 30 mile radius of Oberlin to provide the approximately 14,000 tons required per year to heat the campus, but the Project Team was not able to confirm a source or cost during the process and the market may require further review and development. Five to six trucks per day would be required to deliver the fuel with the plant operating at full-load and a storage area for the fuel would also be required. Ash could be utilized in the local agricultural community as a soil additive.

The plant would have a fairly small footprint and approximately one acre site would allow for adequate truck access and offloading, fuel handling equipment, and plant equipment (see figure to left of agricultural residual boiler and fuel handling equipment). The hot water pipeline to serve the loads would be substantially shorter at approximately 5,400 feet, but similar to the pipeline for the LFG CHP alternative. The existing Oberlin boilers could be converted to provide backup capacity, or the boilers could be relocated to the new facility and the space repurposed. A campus hot water distribution system similar to the LFG CHP alternative would also be required.

Risks for this alternative are similar to the LFG CHP alternative. The fuel source requires identification and contractual commitment, and there are construction risks that could affect overall costs.

Biogas

This alternative involves the use of an anaerobic bio-digester to produce thermal energy to serve Oberlin's needs. The technology is mature and fully implementable. The Project Team has considered the installation of the bio-digester and equipment, utilization of biogas directly in the existing boiler plant with minor modifications, natural gas as a backup fuel, and the conversion of the campus to a hot water distribution system to improve the operating efficiency and reduce the size of the required digester. It is assumed that a suitable feedstock can be secured at a reasonable cost.



The implementation of biogas requires the identification of a feedstock to fuel the digester. During meetings with the City of Oberlin Public Works Department, the concept of anaerobic digestion was discussed. The City plans to replace the existing digester (see figure) at the wastewater treatment plant within the next 10 years. Currently the biogas from the digester is used to heat the digester using a 0.5 MMBtu heater, and any excess gas is used to fuel a small electric generator when the gas is available. As the wastewater treatment plant uses a lot of electricity to process waste water, producing electricity behind the meter with a nearly free fuel source is of economic benefit. The current waste water treatment plant is rated for approximately one-million gallons per day. Biogas is typically produced at a production rate of 1 $ft.^3$ per 100 gallons of waste water and the typical heat content of biogas is approximately 600 Btu per cubic foot. As such, the plant will produce approximately 6 MMBtu per day, or roughly two thousand MMBtu per year. This is approximately 1% of Oberlin College's annual natural gas consumption. Significant upsizing of the digester and a more robust feedstock would need to be secured to enable this technology to meet Oberlin's thermal needs.

Biogas can be utilized directly in boilers as a fuel in natural gas engines with minimal treatment, or injected into the natural gas pipelines with more extensive treatment. The Project Team discussed biogas opportunities with Montauk Energy, an industry leader in biogas development. According to Montauk, the current biogas market is driven by the demand for renewable vehicle fuels as a high Btu product. Typically the biogas is processed to remove impurities like nitrogen, carbon dioxide, oxygen, residual hydrocarbons, and hydrogen sulfide and sulfur compounds. The treatment brings the biogas up to pipeline specifications and the high Btu gas is injected directly into the natural gas pipeline system. A Renewable Identification Number (RIN) is generated in accordance with the EPA's renewable fuel standard. The RINs are sold in markets where there is a high demand for biogas as a vehicle fuel. Current RIN pricing is around $21 per MMBtu.

While the biogas concept is technologically feasible and implementable, the size of the facility required to serve Oberlin's natural gas consumption, the cost to implement, and sourcing an attractive feedstock, make this alternative marginally practical for implementation in Oberlin. If larger regional project(s) to generate biogas can be identified, Oberlin's best option might be to work with a developer and purchase a stake in the project or purchase the biogas directly from the developer as high Btu biogas. Due to the current high value of RINs, it is anticipated that the fuel will be valued at approximately $16-21 per MMBtu.

The risks of this alternative include securing a suitable feedstock and construction risks. Locating a feedstock may be possible but the Project Team did not identify one during the development of this plan.

Geothermal

This involves conversion of the existing buildings to ground source heat pumps. The concept has been outlined at length in other studies, including partial campus conversion to full campus conversion. The proposed solutions involve heat pumps in individual buildings or clusters of buildings heated and cooled by small plants. This technology is mature and implementable. The conversion of the majority of campus to a geothermal source will require a well field of approximately 7-8 acres in close proximity to the campus or a distribution system from a remote well field. The campus buildings will require a significant retrofit to allow for heating with lower temperature sources and a boiler plant will likely be required still to meet peak demands in the winter time. The campus electricity consumption will also increase proportional to loads.

For evaluating this alternative, it is assumed that a wellfield would be located to the north of the campus and the water would be pumped from the wellfield to the campus in 5,200 feet of pre-insulated piping. The 4,500 ton heat pump equipment would be located in the existing central plant, with an electrical demand of approximately 4.5 MW at a COP of 4.0. The conditioned water from the plant would be pumped to the buildings in 8,000 feet of pre-insulated pipe. The estimated water temperature is 140°F to 160°F. The plant can also be leveraged to provide chilled water during the summer months, with the excess heat rejected back to the earth. The buildings would be converted to receive the water from the central plant, and the required conversion would be significant.

There are risks associated with this alternative. The risks include the conversion of the buildings to operate on the conditioned water loop. The cost to convert the buildings will be significant since many of the buildings are set up with steam and hot water radiators designed to operate at a higher temperature, and building retrofits will be expensive. Design and construction risks also exist.

Wind

This alternative considers generating an equivalent amount of electricity from wind turbines to offset Oberlin's annual thermal energy consumption. The technology is mature and implementable. Since the average wind speeds are typically higher during the winter, the energy production and Oberlin's thermal demand are more closely aligned than other alternatives utilizing electrical production sources. Based on a consumption of 148,700 MMBtu per year (43,570 MWH), a wind turbine capacity of approximately 20-22 MW is required to generate an equivalent amount of energy. This was determined by using the 23% capacity factor for the Bowling Green Wind Farm project cited by OMLPS. For purposes of comparing this option, the Project Team has assumed that Oberlin will install 22 MW of wind turbine capacity, install a 16 MW electric boiler (54 MMBtu) to generate steam in the existing central plant, and that the campus steam system will remain in service.

During discussions with OMLPS related to the distribution system capacity, the peak distribution system demand is approximately 20-23 MW. The system currently experiences a peak in both the summer and winter. The maximum OMLPS substation capacity was reported to be 34 MW under emergency conditions. As such, the addition of a 16 MW electric boiler to the OMLPS distribution system will possibly require electrical substation and distribution upgrades, or a dedicated service from the transmission system to the central plant to power the new load. These costs have not been evaluated.

This alternative contains significant risks. The risks include unidentified electrical system capacities, construction risk, and project development risks. In order to further evaluate this alternative, additional engineering design work would need to be completed.

Rather than Oberlin developing a wind project, a more attractive solution may be to identify a wind project developer and purchase the power directly from a proposed project. US energy was contacted by the Project Team to discuss current projects under development. US Energy is currently developing to two large offshore wind projects in Maryland and New Jersey and the power from the proposed projects will be delivered to the PJM grid. US Energy reported that any power delivered to any point on the PJM grid can be extracted at any point without incurring transmission charges across the system. The cost of the power was quoted at $0.19 per kilowatt hour or approximately $55 per MMBtu. The energy cost coupled with the campus conversion to a hot water system makes the offshore wind appear to be an untenable solution due to the high cost. If a local wind project can be implemented in the $30 per MWH range, the project may prove economically attractive.

Solar Photovoltaic

Solar Photovoltaic (PV) is a technically viable solution for Oberlin. The concept is to generate the equivalent electric capacity, plus a small reserve to account for losses, and use the power to generate thermal energy in an electric boiler to serve the existing steam system. The technology is mature and implementable. Since the solar insolation is higher during the summer, the energy production and Oberlin's thermal demands are not closely aligned but the principle would be to offset summer electric production with winter consumption on a net annual basis. This considers the installation of a 32 MW solar array to generate an annual equivalent energy content of 148,700 MMBtu as currently consumed by Oberlin. The plant would require approximately 145 acres.

This alternative contains significant risks. The risks include unidentified electrical system, construction risk, and project development risks.

Solar Thermal including Thermal Storage

This alternative considers the installation of solar thermal panels and thermal storage to supply the Oberlin's consumption of 148,700 MMBtu per year. The technology is mature and feasible but there are design and operational challenges that will need to be overcome during the project design. The Project Team has based this evaluation on the installation of a 22 MW solar thermal array located in the vicinity of the existing solar PV array. The solar thermal array will require approximately 80 acres to supply the January thermal load at a design solar insolation rate of 190 BTUs per square foot. An insulated thermal storage tank will be required to store the thermal energy overnight and we have estimate the size to allow for a total of two days storage for periods when the sun is not shining. The tank capacity is estimated to store 2,000 MMBtu and this will require a capacity of eight million gallons at a design supply temperature of 160°F and a design return temperature of 130°F. A small pumping station will be required to pump the hot water to campus and a 5,200 foot pre-insulated pipeline to convey the hot water from the solar facility to the campus. The campus will require an 8,000 foot hot water distribution system. The buildings will require modification to receive the hot water at a 160°F supply temperature.

This alternative poses significant risks. The risks from construction include the conversion of the buildings to operate with a 160°F hot water supply temperature. Since many of the buildings currently operating with 250°F steam, significant variations in building conversion cost could result from what is estimated. The conversion cost requires further definition and engineering evaluation to further refine conversion costs and scope. The solar array will also require shielding, draining, or some method to prevent overheating during the summer months since the system design is for a peak day in January when the solar insolation rate is lowest. A significant amount of heat it will be generated during the summer and this will require rejection. Some of the heat can be rejected to the buildings for HVAC reheat, domestic hot water, and possibly absorption chillers if the system is designed to operate a temperatures up to 250°F. The balance of panels will require shielding to effectively remove the panels from operation during the summer months in order to prevent damage to the solar array. Depending upon the design, this could be an operational and maintenance challenge.

While the system is feasible, it poses challenges due to the installed cost and the heat rejection issue during the summer months. And more plausible installation is a smaller array with thermal storage to serve Oberlin's baseline summer loads. This type of system is utilized in Europe. A 4 MMBtu array supplying 3,000 MMBtu per month could be installed to supplement a biomass or other low carbon thermal energy source that would only be operated in the winter. The array size would be reduced to approximately 4 acres and the thermal storage tank reduced to 1.25 million gallons. This size system could provide the campus with hot water from April through September and reduce the operating cost and hours of the winter thermal heat source. This would complement a biomass or a biogas resource.

Hydrogen Fuel Cells and Solar PV- Solar Hydrogen

This concept involves installing fuel cells on campus to generate electricity, and capturing the waste heat for thermal loads. The fuel cells could be located at a central boiler plant. Natural gas or hydrogen could be used as a fuel source but natural gas's carbon footprint limits the attractiveness for use. Current methods for hydrogen generation are energy and environmentally intensive and come with a high carbon footprint so for the screening, we considered hydrogen generated by PV as the fuel source. The hydrogen would predominately be generated during summer months and stored as a pressurized gas. While it is also possible to store as a cryogenic liquid, the cost and technical complexity of operating a cryogenic storage plant is extremely high and was not considered. The utilization of highly flammable hydrogen gas is technically complex and would require a high level of operations staff training. The Project Team evaluated the cost to install a 30 MW solar array, a hydrogen generator to electrolyze water to hydrogen, compressed hydrogen storage, a pipeline to convey the hydrogen to the existing plant, and the conversion of the existing boilers to operate on hydrogen. The campus steam distribution system would remain in place. The solar array would require approximately 145 acres and the hydrogen storage approximately seven acres, although this could be installed vertically underground. The large volume of hydrogen storage would have to be vetted further with the local authority having jurisdiction for flammable storage facilities. The high capital cost for this alternative, the possible competition with OMLPS, and potential impacts on the broader community eliminated this alternative from consideration.

Natural Gas Fuel Cells

This concept involves installing fuel cells on campus to generate electricity, and capturing the waste heat for thermal loads. The fuel cells could be located throughout the campus. Natural gas would be used as a fuel since hydrogen is extremely flammable and poses a high safety risk on a distributed basis. Buildings would be converted to hot water to utilize the waste heat from the fuel cells. The high capital cost for this alternative, competition with OMLPS, inclusion of natural gas combustion, and potential impacts on the broader community eliminated this alternative from consideration.

Plasma Gasification of MSW

The destruction of municipal solid waste (MSW) or other organic waste using plasma gasification is a technology that converts organic matter into a synthetic gas and slag. The synthetic gas can power generators and produce electricity and waste heat. The technology is promising but has not been successfully implemented to date in the United States or Europe. Projects have faltered due to high capital costs and technological problems after commissioning, typically resulting in shut down of the facility. The cost and technical complexity preclude this alternative from further analysis.

Landfill gas generation

The utilization of landfill gas in a CHP application with waste heat recovery to heat the campus has been evaluated in several previous studies. The landfill gas is currently under contract with EDI and is not available for procurement now or in the future. Therefore, this is not an option for consideration.

Appendix IX – ECM Financing Pros and Cons

Third-Party Financing Structure with a Lease Program

Pros

- Very low cost of capital for the projects (~3%).
- Once Oberlin has accepted the projected paybacks of the ECMs, no measurement is required to facilitate lease payments on the capital (although measurement is advised).
- Potential of off balance sheet financing of projects for Oberlin.
- Oberlin will have a higher level of involvement in implementation and strategies. More environmentally responsible projects with longer paybacks have a better chance of being implemented.
- Oberlin will have more say over the coordination of the projects with other activities on-campus.
- Shorter payback period on selected ECMs due to Oberlin taking a higher level of risk.
- Each ECM project can be funded separately under a master lease agreement.
- Flexible repayment schedules up to 15 years.

Cons

- Oberlin takes the risk of actual savings realized from the ECMs.
- Oberlin must be more active in the coordination of implementation of the projects.

Performance Contracting

Pros

- Outside party implements the entire program, which should result in less work for Oberlin.
- Oberlin's risk of the actual amount of realized savings is reduced.
- Off balance sheet financing of projects for Oberlin.

Cons

- Higher cost of implementation. Cost of capital can be as much as 30%.
- Longer payback attributed to the higher cost of implementation.
- Longer payback attributed to risk allocation for actual savings realized.
- Oberlin has less control over the implementation strategy, which could eliminate some environmentally beneficial projects with longer payback periods.
- Greater potential for dispute over measured results.
- Lack of current metering on campus may make it more difficult to set a proper baseline.
- Oberlin will have less say over the coordination of the projects with other activities on-campus.

Appendix XII – Hot Water System Building Conversion

The conversion of existing buildings from steam to hot water hydronic systems is possible for the majority of the Oberlin and community building stock evaluated. Converting the heating equipment throughout these buildings from steam to hot water will improve the efficiency of those buildings, along with the comfort level experienced by occupants. Conversion from steam to hot water is possible in all Oberlin buildings on the district steam system, and many of the standalone buildings surveyed. The benefits of a hot water system include:

- Lower thermal losses due to lower operating temperatures.
- Occupant comfort is improved since operating temperatures are lower.
- Improved operating performance since distribution and production losses are lower.
- Increased safety due to lower operating temperatures.
- Lower noise levels as water hammer noise is eliminated.
- Reduced maintenance since steam traps are eliminated.
- System life expectancy of 50 to 100 years.

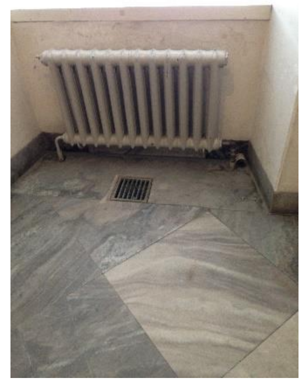
Conversion Process General

Conversion of buildings to hot water should follow a systematic approach. The first step would be for an engineer to review the existing conditions in the building and verify that schematics are correct for the installation. If the schematics require adjustment, these should be completed. The building heat exchangers, coils, and radiation capacities should be verified that they will be able to provide the required capacity with the new system. If any equipment requires special testing, this is identified. Once completed, a simple conversion schematic is generated for each heat exchanger, coil, or radiator, and a general conversion scope of work and specifications would be generated for contractors to bid.

Buildings with Hot Water Internals

Many of the existing buildings currently utilize hot water distribution entirely or for a large percentage of their buildings' thermal loads, and these buildings contain a steam to hot water heat exchanger. To convert these buildings to hot water, the existing heat exchanger would be replaced with two new hot water to hot water heat exchangers; one to serve space heating loads and the second to serve the domestic hot water loads. The building-side system will remain unchanged. The district energy side will contain a flow control valve for space heating, a flow control valve for domestic hot water heating, and a Btu meter to measure the energy delivered to the building. If the heat exchanger is located in a remote area, the steam piping can be reused, but the condensate piping may require replacement if undersized.

Buildings with Perimeter Steam Radiation

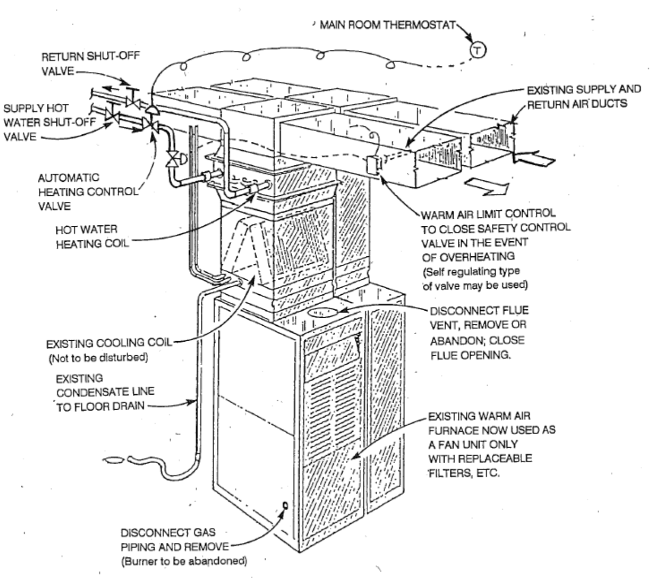


The conversion of buildings with steam radiation is effective for pressurized buildings. Buildings with only perimeter radiation may require additional radiation units or improvements to the building shell, due to the lower operating temperature of the hot water system. For buildings with perimeter steam radiation, the conversion process requires a pressure test of the radiator to verify that it can operate at the higher pressures of a hot water system and the modification of the supply and condensate return system at each radiator. Supply and return piping should also be pneumatically tested to check for leaks. If there are significant leaks in the piping, replacement may be warranted. If the piping and radiator pressure test is satisfactory, typically the supply piping for the steam system can be reused. If the condensate system is oversized, it can also be reused. It will need to be replaced if the engineer determines that it is undersized. The steam trap at each radiator or terminal is removed and a flow balancing valve installed to prevent overflowing the radiator. A lower cost solution is to replace the steam trap internals with a fixed orifice to limit the flow and an isolation valve to allow the radiator to be maintained while the system is online. The inlet supply piping can remain unmodified if there is an isolation valve installed or a thermostatic valve installed to control the radiator. An air vent is tapped into the radiator at the high point to allow for venting of air. The first figure above shows a cast iron radiator converted to hot water and the second figure shows a typical cast iron radiator installed in one of Oberlin's older buildings that is suitable for conversion to a hot water system.

Air Handling Units with Steam Coils

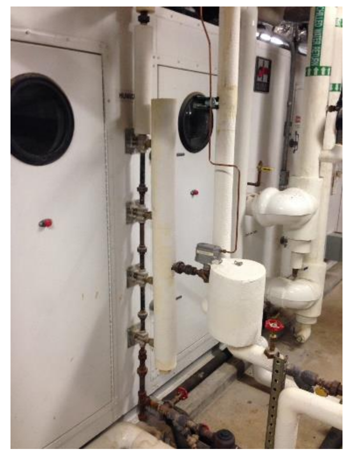
Many of the Oberlin buildings contained air handling units with hot water or steam coils. Steam coils will require conversion to operate with a hot water distribution system. The manufacturer of the air handling with steam coils should be contacted to determine the delivery capacity of the existing coils that would be converted to a hot water supply. If the capacity is determined to be too small, the coil is removed and replaced with a new coil with additional surface area. The existing steam supply piping will require a new hot water control valve and isolation valves to be installed. Condensate piping may require replacement if undersized for hot water flows. The figure below is of an air handling unit with a steam coil (yellow pipe markers) and chilled water coil (green pipe markers). On this one air handling unit steam coil, there are three steam traps that will be eliminated during conversion to a hot water system.

Hot Air Furnaces



Smaller buildings or spaces typically utilize a forced hot air heating system that distributes warm air throughout the occupied space. The conversion process to the hot water district heating system is as shown in the diagram above. A hot water heating coil is mounted in the discharge air plenum of the furnace to replace the natural gas burner as the heat source. The hot water heating coils often consist of multiple-rows of finned tubes or coils. These types of coils are very commonly used in the terminal units in apartment buildings, condominiums, and hotels. The same coils can be utilized to provide air conditioning to the building during the summer months by introducing chilled water to them. This conversion would require modifications to the existing hot air furnace or terminal device, new piping, and the installation of isolation and control valves. If air conditioning is to be added, a condensate drain will be required.

Humidification



Some of the buildings utilize district steam or local boiler steam for humidification of the occupied spaces. The existing humidification of buildings should first be evaluated and eliminated if not necessary. In buildings where humidification is required, the replacement of the humidification system with an electric point of use generator is one possible solution to eliminate natural gas fired boilers and district steam. These units are installed adjacent to the air handler and are connected to the existing dispersion system or a new dispersion nozzle installed in the duct work. The steam generator unit is connected to a water and electric supply. The picture to the right is of an air handling unit with direct steam injection located in the new science building. The installation of a local steam generator to serve loads is fairly straight forward with a connection to the existing steam dispersion system installed in the air handling units.

Non-Convertible Loads

For some of the campus loads, conversion to operation with a hot water system is not possible. These loads are limited to undersized radiator units, column type radiators (see figure below), single pipe steam systems, steam kettles in kitchens, steam fired sterilizers in labs or medical facilities. Single pipe steam systems will require replacement of the radiation units and installation of a new return line from the radiation unit. Column style radiators will require replacement with euro-style radiators (pictures below). Steam kettles in the kitchen and sterilizers will require the installation of small electric steam generators to serve the loads or replacement of the equipment with electrically powered equipment.

Appendix XIII –Building Information Sheets

1 Johnson House (Hebrew House)

Overview

Service	DORM
Year Constructed	1885
Year Last Renovated	2003
Area, SF	13883
Floors	4
Occupancy	29
Hours of Occupancy	24 Hours/
7 Days	

Envelope

The three story building consists of wood wall construction above-grade and stone foundation walls enclosing the basement below-grade. Large single pane wood windows penetrate the exterior envelope along each elevation. The building features a sloped roof system composed of wood and asphalt shingles.

Lighting

The majority of the lighting fixtures have had the incandescent bulb replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated by a gas fired steam boiler in the basement that provides steam to radiators throughout the building. The steam system was upgraded with the last renovation and included the replacement of the boiler. Toilet exhaust fans are controlled by wall switch with time delay. There is no air conditioning or ventilating units to deliver fresh air to the building other than windows (question operability due to age).

Plumbing Fixtures

The bathrooms are equipped with standard residential fixtures.

Domestic Water Heating

Domestic hot water generation was recently replaced with high efficiency instantaneous gas fired water heaters.

Steam Service

This building is not served by the central steam system and would be unaffected by a conversion to hot water.

2 Old Barrows

Overview

Service	DORM
Year Constructed	1901
Year Last Renovated	2003
Area, SF	8006
Floors	4
Occupancy	14
Hours of Occupancy	24 Hours/
7 Days	

Envelope

The three story building consists of masonry wall construction above-grade with sandstone foundation walls enclosing the basement below-grade. Single pane windows penetrate the exterior envelope along each elevation. The building features a sloped hip roof system composed of wood board and asphalt shingles.

Lighting

The majority of the lighting fixtures have had the incandescent bulb replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated by a gas fired hot water boiler in the basement that provides hot water to radiators throughout the building. Toilet exhaust fans are controlled by wall switch. There is no air conditioning or ventilating units to deliver fresh air to the building other than windows (question operability due to age).

Plumbing Fixtures

The bathrooms are equipped with standard residential fixtures.

Domestic Water Heating

Domestic hot water is generated by gas fired water heaters.

Steam Service

This building is not served by the central steam system and would be unaffected by a conversion to hot water.

3 Allencroft (Russian House)

Overview

Service	DORM
Year Constructed	1931
Year Last Renovated	1988
Area, SF	7591
Floors	3
Occupancy	13
Hours of Occupancy	24 Hours/
7 Days	

Envelope

The two story building consists of masonry wall construction above-grade with stone foundation walls enclosing the basement below-grade. Single pane windows penetrate the exterior envelope along each elevation. The building features a flat roof system composed of wood framing and deck with a membrane roofing.

Lighting

The majority of the lighting fixtures have had the incandescent bulb replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam distributed to radiators throughout the building. Radiator valves were replaced in 1988. Most of the HVAC system is original and beyond its useful life. There is no air conditioning or ventilating units to deliver fresh air to the building other than windows (question operability due to age).

Plumbing Fixtures

The bathrooms are equipped with standard residential fixtures.

Domestic Water Heating

Domestic hot water is generated by a steam to hot water steam exchanger. A back-up standard efficiency gas fired hot water boiler generates hot water when steam is not available from the central plant (mid-April thru mid-October). According the utility data, this building has year around gas usage.

Steam Service

This building is served by the central steam system. Conversion of the central plant from steam to hot water would require conversion of 2-pipe steam radiator and domestic hot water heat exchanger from steam to hot water by removing steam traps and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

4 Kade (German House), 5 Harvey (Spanish House) & 8 Price (Third World House)

Overview

Service	DORM
Year Constructed	1968
Year Last Renovated	2008
Area, SF	54779
Floors	4
Occupancy	110
Hours of Occupancy /7 Days	24 Hours

Envelope

These buildings consist of steel wall construction with a brick exterior and concrete foundation walls enclosing the basement below-grade. Double pane metal windows penetrate the exterior envelope along each elevation. The building features a built-up roof system. The three two story dormitories are connected by a single story structure that houses common area including a decommissioned kitchen. There is a basement below the common area that houses the central mechanical systems.

Lighting

Lighting in the common areas comes in the form of electronically ballasted fixtures with T-8 lamps. Lighting in the form of incandescent fixtures has had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam. Heating hot water is generated by a steam to hot water heat exchanger. Heating hot water is distributed to convertors and fan coil units throughout the building. There are a make-up air units with hot water heat and electric backup heat in each dormitory wing that provides fresh air to the corridors. Steam is used directly to heat air in heating and ventilating units serving the common area. Much of the hot water heating system was replaced recently along with the addition of the dormitory ventilating units. The common area ventilating units are original and beyond there useful life. There is no air conditioning in this building.

Plumbing Fixtures

The bathrooms are equipped with low flow commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by central plant steam using a steam to hot water heat exchanger. Standard efficiency gas fired boilers are used to generate domestic hot water when plant steam is not available from the central plant (mid-April thru mid-October).

Steam Service

This building is served by the central steam system. Conversion of the central plant from steam to hot water would require conversion of heating and ventilating steam coils and heating and domestic hot water heat exchanger from steam to hot water by removing steam traps and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler for domestic hot water.

6 Lewis Center for Women & Transgender People (Edmonia)

Overview

Service	OFFICES/DORM
Year Constructed	1857
Year Last Renovated	NA
Area, SF	4136
Floors	3
Occupancy	30
Hours of Occupancy	24 Hours/
7 Days	

Envelope

The two story building consists of wood wall construction above-grade with stone foundation walls enclosing the basement below-grade. Single pane wood windows penetrate the exterior envelope along each elevation. The building features a sloped roof system composed of wood framing/deck and asphalt shingles.

Lighting

The majority of the lighting fixtures have had the incandescent bulb replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam distributed to radiators throughout the building. Toilet exhaust fans are controlled by wall switch. There is no air conditioning or ventilating units to deliver fresh air to the building other than windows (question operability due to age).

Plumbing Fixtures

The bathrooms are equipped with standard residential fixtures.

Domestic Water Heating

Domestic hot water is generated by a standard efficiency tank type gas fired water heater.

Steam Service

This building is served by the central steam system. Conversion of the central plant from steam to hot water would require conversion of 2-pipe steam radiator by removing steam traps and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load.

7 Lewis House (Ombudsperson & Religious Life Center)

Overview

Service	CLASSES/OFFICES
Year Constructed	1894
Year Last Renovated	NA
Area, SF	3143
Floors	3
Occupancy	18
Hours of Occupancy	8 AM-5PM M-F

Envelope

The two story building consists of masonry wall construction above-grade with stone foundation walls enclosing the basement below-grade. Single pane windows penetrate the exterior envelope. The building features a wood gambrel roof system.

Lighting

The majority of the lighting fixtures have had the incandescent bulb replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam distributed to radiators throughout the building. Toilet exhaust fans are controlled by wall switch. There is no air conditioning or ventilating units to deliver fresh air to the building other than windows (question operability due to age).

Plumbing Fixtures

The bathrooms are equipped with standard residential fixtures.

Domestic Water Heating

Domestic hot water is generated by a standard efficiency tank type gas fired water heater.

Steam Service

This building is served by the central steam system. Conversion of the central plant from steam to hot water would require conversion of 2-pipe steam radiator from steam to hot water by removing steam traps and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load.

9 Lord, 10 Saunders (Afrikan Heritage Houses)

Overview

Service	DORM
Year Constructed	1968
Year Last Renovated	2009
Area, SF	35327
Floors	2
Occupancy	72
Hours of Occupancy	24 Hours/7 Days

Envelope

These buildings consist of steel wall construction with a brick exterior and concrete foundation walls enclosing the basement below-grade. Double pane metal windows penetrate the exterior envelope along each elevation. The building features a built-up roof system. The two story dormitories are connected by a single story structure that houses common areas including kitchen/dining hall with basement mechanical space.

Lighting

Lighting in the common areas comes in the form of electronically ballasted fixtures with T-8 lamps. Lighting in the form of incandescent fixtures has had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam. Heating hot water is generated by a steam to hot water heat exchanger. Heating hot water is distributed to radiators throughout the building. There are is a make-up air unit with hot water heat and electric backup heat in each dormitory wing that provides fresh air to the corridors. There is makeup air with steam heat to provide ventilation to the kitchen for hood make-up air. There is no air conditioning in this building.

Plumbing Fixtures

The bathrooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by central plant steam using a steam to hot water heat exchanger. Standard efficiency gas fired boilers are used to generate domestic hot water when plant steam is not available from the central plant (mid-April thru mid-October).

Steam Service

This building is served by the central steam system. Steam is used for kitchen equipment, heating, snow melt and domestic hot water. There is also a local standard efficiency steam boiler that provides steam to the kitchen equipment when central plant steam is not available (mid-April thru mid-October). Conversion of the central plant from steam to hot water would require conversion of make-up air steam coil and heating and domestic hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler for domestic hot water.

12 South Hall

Overview

Service	DORM
Year Constructed	1964
Year Last Renovated	2016
Area, SF	85041
Floors	4
Occupancy	224
Hours of Occupancy	24 Hours/
7 Days	

Envelope

The three story building consists of steel wall construction with a brick exterior and concrete foundation walls enclosing the basement below-grade. Single pane metal windows penetrate the exterior envelope along each elevation. The building features a built-up roof system. The lower level originally housed a large kitchen and dining hall which has been repurposed to fitness center, dance practice studio and a small bake shop. The 3 upper levels are dormitory rooms.

Lighting

Lighting in the common areas comes in the form of electronically ballasted fixtures with T-8 lamps. Lighting in the form of incandescent fixtures has had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam. Heating hot water is generated by a steam to hot water heat exchanger. Heating hot water is distributed to radiators throughout the building. According to Facilities Staff, there are temperature complaints every winter on the third floor. The assumption is that it is due to inadequate pump capacity, in review of the original drawings the system was designed for 30 PSIG steam from the central plant. Since the plant is currently set to provide no more than 12 PSIG at the plant, it is likely a capacity issue. There are 2 make-up air units with hot water heat that provides fresh air to the lower level. There are 2 ground mounted DX package units that provide A/C to the fitness center and dance studio. There is no air conditioning or ventilating units to deliver fresh air to the top three floors other than windows (question operability due to age).

Plumbing Fixtures

The bathrooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by central plant steam uses a steam to hot water heat exchanger. Standard efficiency gas fired boilers are used to generate domestic hot water when plant steam is not available (mid-April thru mid-October).

Steam Service

This building is served by the central steam system. Steam is used for kitchen equipment, heating and domestic hot water. There is also a local standard efficiency steam boiler that provides steam to the kitchen equipment when central plant steam is not available (mid-April thru mid-October). Steam kitchen equipment is not in use. Conversion of the central plant from steam to hot water would require conversion of heating and domestic hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

13 Fairchild House

Overview

Service	DORM
Year Constructed	1950
Year Last Renovated	2010
Area, SF	22889
Floors	4
Occupancy	69
Hours of Occupancy	24 Hours/
7 Days	

Envelope

The three story building consists of masonry wall construction above-grade with concrete foundation walls enclosing the basement below-grade. Multiple double pane windows penetrate the exterior envelope. The building features a sloped roof system composed of wood board and tiles.

Lighting

Lighting in the common areas comes in the form of electronically ballasted fixtures with T-8 lamps. Lighting in the form of incandescent fixtures has had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam distributed to radiators throughout the building. The steam heating system is original to building and beyond its useful life. Kitchen hood make-up air fan system has no heating coil. There is no air conditioning or ventilating unit to deliver fresh air to the building other than windows (question operability due to age).

Plumbing Fixtures

The bathrooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by central plant steam uses a steam to hot water heat exchanger. Standard efficiency gas fired boilers are used to generate domestic hot water when plant steam is not available (mid-April thru mid-October).

Steam Service

This building is served by the central steam system. Conversion of the central plant from steam to hot water would require conversion of 2-pipe steam radiator and domestic hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

14 Conservatory, Bibbins Hall

Overview

Service	CLASSES/OFFICES
Year Constructed	1964
Year Last Renovated	2016
Area, SF	47912
Floors	4
Occupancy	N/A
Hours of Occupancy	8 AM-5 PM M-F

Envelope

The three story building consists of steel wall construction with a quartz-aggregate exterior and concrete foundation walls enclosing the basement below-grade. Floor-to-ceiling double pane hexagonal windows penetrate the exterior envelope along each elevation. There is a glass clerestory at the roof level. The building features a concrete roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is in the process of being converted from a VAV system to a VRF system with dedicated outside air unit with energy recovery. The basement is all that remains to be converted to VRF. The basement air handling units and heating hot water system were still operating. Equipment in the basement was original and beyond its useful life.

Plumbing Fixtures

The bathrooms are equipped with low flow fixtures.

Domestic Water Heating

Domestic hot water is generated by electric tank type water heater.

Steam Service

This building is currently served by the central steam system, but is in the process of being converted to VRF. Drawings were not provided for the final phase, but our understanding is that once the basement is converted to VRF there will be no steam or chilled water usage in this building

15 Conservatory, Central Unit and Warner Concert Hall

Overview

Service	CLASSES/ OFFICES
Year Constructed	1964
Year Last Renovated	2009
Area, SF	32232
Floors	1
Occupancy	645
Hours of Occupancy	8 AM-5PM M-F

Envelope

The single story building consists of masonry wall construction above-grade with concrete foundation walls enclosing the basement below-grade. Double pane windows penetrate the exterior envelope. The building features a concrete roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

The building is conditioned using multi-zone units and single zone units that have been converted to VAV. These units all have chilled water and steam coils, steam humidification and fresh air. There are also heating and ventilating units with steam coils. All equipment is original to the building and beyond its useful life. All systems operate on pneumatic controls.

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by electric tank type water heater.

Steam Service

This building is served by the central steam system. Conversion of the central plant from steam to hot water would require conversion of air coils from steam to hot water by removing steam trap and replacing control valves. Humidification will require the installation of local steam generators and dispersion equipment. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load.

16 Conservatory, Library

Overview

Service	CLASSES/ OFFICES
Year Constructed	1987
Year Last Renovated	2000
Area, SF	11040
Floors	2
Occupancy	N/A
Hours of Occupancy	8 AM-5PM M-F

Envelope
The two story building consists of masonry wall construction above-grade with concrete foundation walls enclosing the basement below-grade. Double pane windows penetrate the exterior envelope. The building features a metal roof system.

Lighting
Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC
The building is conditioned by a multi-zone unit with chilled water and steam coils, steam humidification and fresh air. Variable volume terminal units have been added to each zone. All equipment is original to the building and approaching the end of its useful life. The system operates on pneumatic controls.

Plumbing Fixtures
The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating
Domestic hot water is generated by electric tank type water heater.

Steam Service
This building is served by the central steam system. Conversion of the central plant from steam to hot water would require conversion of air coils from steam to hot water by removing steam trap and replacing control valves. Humidification will require the installation of local steam generators and dispersion equipment. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load.

17 Conservatory, Robertson Hall

Overview

Service	CLASSES/ OFFICES
Year Constructed	1964
Year Last Renovated	1988
Area, SF	32842
Floors	3
Occupancy	N/A
Hours of Occupancy	8 AM-5PM M-F

Envelope

The two story building consists of masonry wall construction above-grade with concrete foundation walls enclosing the basement below-grade. Single pane windows penetrate the exterior envelope. The building features a concrete roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

The building is conditioned by a dedicated outside air handler with chilled water and steam coils and steam humidification that provides conditioned air to inductions units in each space that provide space cooling and heating. All equipment is original to the building and beyond its useful life. All HVAC systems operate on pneumatic controls.

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by electric tank type water heater.

Steam Service

This building is served by the central steam system. Steam is used for heating and humidification. Conversion of the central plant from steam to hot water would require conversion of heating and domestic hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Humidification will require the installation of local steam generators and dispersion equipment. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load.

18 Conservatory, Kohl Building

Overview

Service	CLASSES/ OFFICES
Year Constructed	2009
Year Last Renovated	N/A
Area, SF	38200
Floors	3
Occupancy	N/A
Hours of Occupancy	8 AM-5PM M-F

Envelope

The three story building consists of aluminum curtain wall construction above-grade with concrete foundation walls enclosing the basement below-grade. Double pane windows penetrate the exterior envelope. The building features a concrete roof system.

Lighting

Lighting comes in the form of compact fluorescents, linear fluorescents and LEDs. Light fixtures are controlled by local automatic controls in most area, but a few areas still have manual wall toggle switches. Local automatic lighting controls are overridden by a building lighting control system.

HVAC

This building is conditioned by either radiant heating/cooling panels or water source heat pump. Fresh air is provided room direct by a dedicated outside air geothermal heat pump unit with energy recovery and humidification. Chilled water and hot water are generated by water to water heat pumps using a geothermal field as heat sink. All temperature controls are DDC.

Plumbing Fixtures

The toilet rooms are equipped with low flow fixtures.

Domestic Water Heating

Domestic hot water is generated by a high efficiency tank type gas fired water heater.

Steam Service

This building is not on the central system and would be unaffected by a conversion to hot water.

19 Conservatory, Annex (Admissions)

Overview

Service	CLASSES/OFFICES
Year Constructed	1993
Year Last Renovated	2011
Area, SF	18844
Floors	2
Occupancy	N/A
Hours of Occupancy	8 AM-5PM M-F

Envelope

The two story building consists of steel-frame wall construction with a brick exterior and concrete foundation walls enclosing the basement below-grade. Double pane windows penetrate the exterior envelope. The building features a low sloped roof system composed of wood board and asphalt shingles.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is conditioned using DX rooftop units with gas heat. These units are relatively new and have considerable useful life remaining. These systems operate using DDC controls.

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by electric tank type water heater.

Steam Service

This building is not served by the central steam system and would be unaffected by a conversion to hot water.

20 Oberlin Bookstore

Overview

Service	CLASSES/OFFICES
Year Constructed	1993
Year Last Renovated	2011
Area, SF	18844
Floors	2
Occupancy	N/A
Hours of Occupancy	8 AM-5PM M-F

Envelope

The two story building consists of steel-frame wall construction with a brick exterior and concrete foundation walls enclosing the basement below-grade. Double pane windows penetrate the exterior envelope. The building features a low sloped roof system composed of wood board and asphalt shingles.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is conditioned by a DX split system with gas fired duct heater. This system is relatively new and has considerable useful life remaining. This system operates using DDC controls.

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by electric tank type water heater.

Steam Service

This building is not served by the central steam system and would be unaffected by a conversion to hot water.

21 Lewis Center for Environmental Studies (Adam Joseph)

Overview

Service	CLASSES/ OFFICES
Year Constructed	1999
Year Last Renovated	2009
Area, SF	13700
Floors	2
Occupancy	250
Hours of Occupancy	8 AM-5PM M-F

Envelope

The two story building consists of both aluminum curtain wall construction and masonry wall construction above-grade with concrete foundation walls enclosing the basement below-grade. The masonry walls are composed of CMU, 3" rigid insulation, 1" airspace, and the exterior brick. Double and triple pane windows penetrate the exterior envelope. The building features a concrete roof system except above the atrium where a photovoltaic system is utilized.

Lighting

Lighting comes in the form of compact fluorescents, linear fluorescents and LEDs. Light fixtures are controlled by local automatic controls in most area, but a few areas still have manual wall toggle switches. Local automatic lighting controls are overridden by a building lighting control system.

Electrical

This building has two photovoltaic arrays that provide power to operate the building lights and equipment.

HVAC

This building is conditioned by groundwater source heat pump, heating only fan coil units and radiant floor heating. Fresh air is provided room direct by dedicated heat pump units with energy recovery. Heating hot water is generated by water to water heat pumps using a geothermal field as heat sink. All temperature controls are DDC. There are heating issues that appear to be related to issues with occupancy schedules and warm-ups cycles.

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures, but grey water is used for flushing toilets.

Domestic Water Heating

Domestic hot water is generated by a tank type electric water heater.

Steam Service

This building is not on the central steam system and would be unaffected by a conversion to hot water.

22 Lewis Center Annex

Overview

Service	CLASSES/ OFFICES
Year Constructed	1870
Year Last Renovated	2006
Area, SF	3328
Floors	2
Occupancy	35
Hours of Occupancy	8 AM-5PM M-F

Envelope

The two story building consists of wood wall construction above-grade with sandstone foundation walls enclosing the basement below-grade. Single pane windows penetrate the envelope along each elevation. The building features a low sloped roof system composed of wood board and asphalt shingles.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is conditioned by a gas fired furnace with DX cooling coil. The systems were recently replaced and are in good working order. These systems operate using DDC controls.

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by a tank type electric water heater.

Steam Service

This building is not served by the central steam system and would be unaffected by a conversion to hot water.

23 Baldwin Cottage (Woman's Collective and Third Word Co-op)

Overview

Service	DORM
Year Constructed	1887
Year Last Renovated	2012
Area, SF	17840
Floors	4
Occupancy	32
Hours of Occupancy	24 Hours/
7 Days	

Envelope

The three story building consists of masonry wall construction above-grade with stone foundation walls enclosing the basement below-grade. Double pane wood windows penetrate the exterior envelope along each elevation. The building features a sloped roof system composed of wood board and tile.

Lighting

The majority of the lighting fixtures have had the incandescent bulb replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam. Steam is distributed to radiators throughout the building. There is a make-up air unit with steam coils in the basement that provides fresh air to the kitchen and corridors. The HVAC equipment is beyond its useful life. There is a newer DX split system that serves a small area.

Plumbing Fixtures

The bathrooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by central plant steam uses a steam to hot water heat exchanger. Standard efficiency gas fired boilers are used to generate domestic hot water when plant steam is not available (mid-April thru mid-October). There is also a tank type gas fired water heater that generates 180 deg F water for the kitchen use.

Steam Service

This building is served by the central steam system. Steam is used for kitchen equipment, heating, and domestic hot water. Conversion of the central plant from steam to hot water would require conversion of steam coil, 2-pipe steam radiators and domestic hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

24 Talcott Hall

Overview

Service	DORM
Year Constructed	1887
Year Last Renovated	2011
Area, SF	37005
Floors	4
Occupancy	80
Hours of Occupancy	24 Hours/
7 Days	

Envelope

The three story building consists of masonry wall construction above-grade with stone foundation walls enclosing the basement below-grade. Multiple single pane windows penetrate the envelope along with exterior doors. The building features a sloped roof system composed of wood board and tile.

Lighting

The majority of the lighting fixtures have had the incandescent bulb replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam. Steam is distributed to radiators throughout the building. There is a make-up air unit with steam coil in the basement that provide fresh air to the corridors. There is a make-up air unit with steam coil in the kitchen area that provides make-up air to the kitchen hoods. There are 2 exhaust fans that serve the hoods. There is no air conditioning.

Plumbing Fixtures

The bathrooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by central plant steam uses a steam to hot water heat exchanger. Standard efficiency gas fired boilers are used to generate domestic hot water when plant steam is not available (mid-April thru mid-October). There is an electric booster heater that generates 180 deg F water for the kitchen.

Steam Service

This building is served by the central steam system. Steam is used for kitchen equipment, heating and domestic hot water. Conversion of the central plant from steam to hot water would require conversion of steam coils, 2-pipe steam radiator and domestic hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

25 Harkness House

Overview

Service DORM
Year Constructed 1950
Year Last Renovated 2008
Area, SF 20213
Floors 4
Occupancy 64
Hours of Occupancy 24 Hours/
7 Days

Envelope

The three story building consists of masonry wall construction above-grade with stone foundation walls enclosing the basement below-grade. Double pane windows penetrate the exterior envelope along each elevation. The building features a sloped hip roof system composed of wood board and asphalt shingles.

Lighting

Lighting in the common areas comes in the form of electronically ballasted fixtures with T-8 lamps. Lighting in the form of incandescent fixtures has had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam. Steam is distributed to radiators throughout the building. There is a make-up air unit with steam heating coil in the basement that provides fresh air to the kitchen for hood make-up. There is no air conditioning.

Plumbing Fixtures

The bathrooms are equipped with standard commercial fixtures.

Domestic Water Heating

This building is heated using central plant steam. Steam is distributed to radiators throughout the building. There are make-up units with steam coils that provide fresh air to the corridors. There is no air conditioning.

Steam Service

This building is served by the central steam system. Steam is used for kitchen equipment, heating, snow melt and domestic hot water. Conversion of the central plant from steam to hot water would require conversion of steam coil, 2-pipe steam radiator and domestic hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

26 Dascomb Hall

Overview

Service	DORM
Year Constructed	1956
Year Last Renovated	2016
Area, SF	48308
Floors	3
Occupancy	161
Hours of Occupancy	24 Hours/
7 Days	

Envelope

The three story building consists of masonry wall construction. Single pane metal windows penetrate the exterior envelope along each elevation. The building features a flat concrete roof system.

Lighting

Lighting in the common areas comes in the form of electronically ballasted fixtures with T-8 lamps. Lighting s in the form of incandescent fixtures has had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam. Heating hot water is generated by a steam to hot water heat exchanger. Heating hot water is distributed to radiators throughout the building. There are 2 supply fans that provide unconditioned make-up air directly to the kitchen hoods. There are rooftop DX package units with gas heat that condition the dining hall. There is no air conditioning or ventilating units to deliver fresh air to the three dormitory floors other than windows (question operability due to age).

Plumbing Fixtures

The bathrooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by central plant steam uses a steam to hot water heat exchanger. Standard efficiency gas fired boilers are used to generate domestic hot water when plant steam is not available (mid-April thru mid-October).

Steam Service

This building is served by the central steam system. Steam is used for kitchen equipment, heating and domestic hot water. There is also a local standard efficiency steam boiler that provides steam to the kitchen equipment when central plant steam is not available (mid-April thru mid-October). Conversion of the central plant from steam to hot water would require conversion of heating and domestic hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

27 Rice Hall

Overview

Service	CLASSES/ OFFICES
Year Constructed	1910
Year Last Renovated	2011
Area, SF	29941
Floors	4
Occupancy	N/A
Hours of Occupancy	8 AM-5PM M-F

Envelope

The three story building consists of masonry wall construction above-grade with sandstone foundation walls enclosing the basement below-grade. Double pane windows penetrate the exterior envelope along each elevation. The building features a flat roof system composed of black membrane.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building was recently converted to VAV with new air handling equipment and DDC controls.

Plumbing Fixtures

The bathrooms are equipped with low flow fixtures.

Domestic Water Heating

Domestic hot water is generated in the King basement and piped to Rice.

Steam Service

Hot water is generated from steam in the King basement and piped to Rice. This building would be unaffected by a conversion of the central plant from steam to hot water.

28 King Building

Overview

Service	CLASSES/ OFFICES
Year Constructed	1964
Year Last Renovated	2012
Area, SF	62199
Floors	3
Occupancy	N/A
Hours of Occupancy	8 AM-5PM M-F

Envelope

The three story building consists of steel wall construction with a quartz-aggregate exterior. Large single pane windows penetrate the exterior envelope along each elevation. The building features a flat roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Some renovated areas have LED troffers installed. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is condition by central air handling with zone hot water reheat that was later converted to VAV and skin load perimeter fin-tube heating system. Most of the equipment is original and beyond its useful life.

Plumbing Fixtures

The bathrooms are equipped with low flow fixtures.

Domestic Water Heating

Domestic hot water is generated by a tank type electric water heater.

Steam Service

This building is served by the central steam system. Steam is used for heating only. Conversion of the central plant from steam to hot water would require conversion of heating hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load.

30 Peters Hall

Overview

Service	CLASSES/ OFFICES
Year Constructed	1885
Year Last Renovated	1996
Area, SF	45012
Floors	5
Occupancy	N/A
Hours of Occupancy	8 AM-5PM M-F

Envelope

The four story building consists of masonry wall construction above-grade with stone foundation walls enclosing the basement below-grade. Single pane wood windows penetrate the exterior envelope along each elevation. The building features a sloped roof system composed of wood board and tile.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam distributed to radiators around the perimeter of the building. Air handlers with chilled water coils condition in the interior zones and provide fresh air. A handful unit also have a steam heating coil. The steam radiators are original and beyond there useful life, but air handling units are newer and at mid-life.

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by a tank type electric water heater.

Steam Service

This building is served by the central steam system. Steam is used for heating only. Conversion of the central plant from steam to hot water would require conversion of 2-pipe steam radiators and steam coils from steam to hot water by removing steam trap and replacing control valves. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.
Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load.

31 Cox Administration Building

Overview

Service	CLASSES/ OFFICES
Year Constructed	1915
Year Last Renovated	1985
Area, SF	13947
Floors	3
Occupancy	22
Hours of Occupancy	8 AM-5PM M-F

Envelope

The two story building consists of masonry wall construction above-grade with stone foundation walls enclosing the basement below-grade. Single pane windows penetrate the exterior envelope along each elevation. The building features a sloped roof system composed of wood board and tile.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam distributed to radiators throughout the building. Air conditioning is provided by window A/C units that remain in place year round resulting in cold drafts. Most of the HVAC system is original and beyond its useful life. There is no fresh air delivered to the building other than through windows (question operability due to age).

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

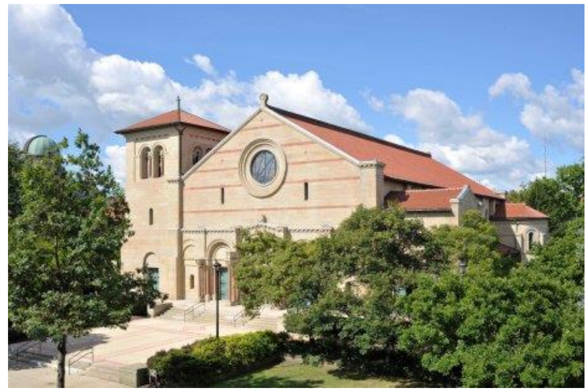
Domestic Water Heating

Domestic hot water is generated by a tank type electric water heater.

Steam Service

This building is served by the central steam system. Steam provides only heating. Conversion of the central plant from steam to hot water would require conversion of 2-pipe steam radiator from steam to hot water by removing steam trap and replacing control valves. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

32 Finney Chapel



Overview

Service ASSEMBLY
Year Constructed 1908
Year Last Renovated 2008
Area, SF 23487
Floors 3
Occupancy N/A
Hours of Occupancy 24 Hours/
7 Days

Envelope

The two story building consists of masonry wall construction above-grade with stone foundation walls enclosing the basement below-grade. Single pane windows penetrate the exterior envelope along each elevation. The building features a sloped roof system composed of wood board and clay tile.

Lighting

Basement and back of house lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches. The sanctuary lighting is incandescent.

HVAC

This building is heated using central plant steam distributed to radiators throughout the building.
The main assembly space has not A/C or ventilation. There is a split system DX unit serving a section of the basement.

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by a tank type electric water heater.

Steam Service

This building is served by the central steam system. Steam is used for heating only. Conversion of the central plant from steam to hot water would require conversion of 2-pipe steam radiators from steam to hot water by removing steam trap and replacing control valves. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

33 Warner Center

Overview

Service	ASSEMBLY
Year Constructed	1900
Year Last Renovated	1975
Area, SF	42197
Floors	3
Occupancy	N/A
Hours of Occupancy	Varies

Envelope

The two story building consists of masonry wall construction above-grade with stone foundation walls enclosing the basement below-grade. Large single pane windows penetrate the exterior envelope along each elevation. The building features a sloped roof system composed of wood framing and clay tile.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam distributed to radiators throughout the building. The HVAC equipment is original and beyond its useful life. There is no air conditioning or ventilating units to deliver fresh air to the majority of the building other than windows (question operability due to age).

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by a steam to hot water steam exchanger. A back-up standard efficiency gas fired hot water boiler generates hot water when steam is not available from the central plant (mid-April thru mid-October).

Steam Service

This building is served by the central system. Conversion of the central plant from steam to hot water would require conversion of steam coils, 2-pipe steam radiator and domestic hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

34 Mudd Center

Overview

Service	LIBRARY
Year Constructed	1974
Year Last Renovated	2012
Area, SF	197000
Floors	5
Occupancy	N/A
Hours of Occupancy	8 AM-12PM/
7 Days	

Envelope

The four story building consists of steel-frame wall construction with a limestone panel exterior. Single pane windows penetrate the exterior envelope along each elevations. The building features a flat built-up roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches. Some exterior light fixtures have been upgraded to LED.

HVAC

The building is conditioned using constant volume units with hot water reheat zoned by exterior elevation or interior. Each air system includes an air handler with supply fan, chilled water coil, hot water coil and steam humidification and a return air fan. OA is supposed to be provided in a fixed quantity using manual balancing dampers. There is computer room HVAC unit with a drycooler that serves the data center. The majority of the equipment is original and past its useful life. There is local standard efficiency gas fired hot water boiler for heating and a tank type electric water heater for back up when central plant steam is not available. There is a local chiller as well.

Plumbing Fixtures

Toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by a steam to hot water steam exchanger. A back-up tanktype electric water heater generates hot water when steam is not available from the central plant (mid-April thru mid-October).

Steam Service

This building is served by the central system. Steam is used for snow melt, heating and domestic hot water. Conversion of the central plant from steam to hot water would require conversion of snow melt, heating and domestic hot water heat exchangers from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

35 Wilder Hall (Student Union)

Overview

Service	ASSEMBLY
Year Constructed	1911
Year Last Renovated	2010
Area, SF	71612
Floors	5
Occupancy	N/A
Hours of Occupancy	8 AM-5PM

Envelope

The four story building consists of masonry wall construction above-grade with stone foundation walls enclosing the basement below-grade. Large single pane wood windows penetrate the exterior envelope along each elevation. The building features a sloped roof system composed of wood framing and clay tile.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam distributed to radiators throughout the building. There are few DX split systems that serve limited spaces. There is a heating & ventilating unit in the basement that provides ventilation for the snack bar kitchen. The majority of the HVAC system is beyond its useful life. There are no ventilating units to deliver fresh air to the majority of the building other than windows (question operability due to age).

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by a steam to hot water steam exchanger. A back-up standard efficiency gas fired hot water boiler generates hot water when steam is not available from the central plant (mid-April thru mid-October).

Steam Service

This building is served by the central system. Steam is used for snow melt, heating and domestic hot water. Conversion of the central plant from steam to hot water would require conversion of steam coils, 2-pipe steam radiators and snow melt and domestic hot water heat exchangers from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

36 Daub House (Bonner Center for Service & Learning)

Overview

Service	CLASSES/ OFFICES
Year Constructed	1862
Year Last Renovated	2009
Area, SF	2500
Floors	3
Occupancy	N/A
Hours of Occupancy	8 AM-5PM

Envelope

The two story building consists of masonry wall construction above-grade with stone foundation walls enclosing the partial basement below-grade. Single pane wood windows with exterior storm windows penetrate the envelope each elevation. The building features a sloped roof system composed of wood board and asphalt shingles.

Lighting

The majority of the lighting fixtures have had the incandescent bulb replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam distributed to radiators throughout the building. Cooling is provided by DX split system. Toilet exhaust fans are controlled by wall switch. There is no air conditioning or ventilating units to deliver fresh air to the building other than windows (question operability due to age).

Plumbing Fixtures

The bathrooms are equipped with standard residential fixtures.

Domestic Water Heating

Domestic hot water is generated by a tank type electric water heater.

Steam Service

This building is served by the central system. Conversion of the central plant from steam to hot water would require conversion of 2-pipe steam radiator by removing steam traps and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load.

37 Creative Writing

Overview

Service	CLASSES/ OFFICES
Year Constructed	1940
Year Last Renovated	N/A
Area, SF	2000
Floors	3
Occupancy	N/A
Hours of Occupancy	8 AM-5PM

Envelope
The two story building consists of wood wall construction above-grade with concrete foundation walls enclosing the basement below-grade. Single pane wood windows with exterior storm windows penetrate the envelope each elevation. The building features a sloped wood roof system composed of wood board and asphalt shingles.

Lighting
The majority of the lighting fixtures have had the incandescent bulb replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC
This building is conditions by a DX split system. Indoor section is a standard efficiency gas furnace with DX coil and duct mounted steam coil. Toilet exhaust fans are controlled by wall switches.

Plumbing Fixtures
The bathrooms are equipped with standard residential fixtures.

Domestic Water Heating
Domestic hot water is generated by a high efficiency tank type gas fired water heater.

Steam Service
This building is served by the central system. Conversion of the central plant from steam to hot water would require conversion of 2-pipe steam radiator by removing steam traps and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load.

38 Security Building

Overview

Service	CLASSES/ OFFICES
Year Constructed	1900
Year Last Renovated	2008
Area, SF	2500
Floors	3
Occupancy	N/A
Hours of Occupancy	24 Hours/
7 Days	

Envelope
The two story building consists of wood wall construction above-grade with concrete foundation walls enclosing the basement below-grade. Single pane wood windows with exterior storm windows penetrate the envelope each elevation. The building features a sloped wood roof system composed of wood board and asphalt shingles.

Lighting
The majority of the lighting fixtures have had the incandescent bulb replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC
This building is heated using central plant steam distributed to radiators throughout the building. Cooling is provided by DX split system and window A/C units. Toilet exhaust fans are controlled by wall switch. There is no air conditioning or ventilating units to deliver fresh air to the building other than windows (question operability due to age).

Plumbing Fixtures
The bathrooms are equipped with standard residential fixtures.

Domestic Water Heating
Domestic hot water is generated by a tank type electric water heater.

Steam Service
This building is served by the central system. Conversion of the central plant from steam to hot water would require conversion of 2-pipe steam radiator by removing steam traps and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load.

39 Service Building

Overview

Service	UTILITY
Year Constructed	1949
Year Last Renovated	2010
Area, SF	31551
Floors	3
Occupancy	N/A
Hours of Occupancy	8 AM-5PM

Envelope

The two story building consists of masonry wall construction. Single pane windows penetrate the exterior envelope. The building features a flat metal built-up roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

The office and shop areas are conditioned by a chilled water VAV air handler with perimeter skin load steam radiation except the print shop that has a rooftop DX system to maintain environmental conditions year round. The majority of the HVAC systems are beyond there useful life.

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by a steam to hot water steam exchanger. A back-up water heater generates hot water when steam is not available from the central plant (mid-April thru mid-October).

Steam Service

This building houses the central steam and chilled water plants. The conversion from steam to high temperature hot water can be done with the existing equipment operating as the primary source or as the backup source to the community landfill plant. Conversion of the central plant from steam to hot water would require conversion of steam coils/radiators and domestic hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up water heater.

40 Hales Annex

Overview

Service	ENTERTAINMENT
Year Constructed	1958
Year Last Renovated	2009
Area, SF	23870
Floors	1
Occupancy	N/A
Hours of Occupancy	6 AM-12 AM (Varies)

Envelope

The single story building consists of steel-frame wall construction with a smooth stone exterior and concrete foundation walls. Single pane windows penetrate the exterior envelope. The building features a concrete roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam. Heating hot water is generated by a steam to hot water heat exchanger. Heating hot water is distributed to radiators throughout most of the building. Cafe is conditioned by DX rooftop unit with gas heat. Window A/C units cool other spaces such as the bowling alley. The majority of the HVAC equipment is beyond its useful life.

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is provided from the system in Hales Gym.

Steam Service

This building is served by the central steam system. Conversion of the central plant from steam to hot water would require conversion of heating hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load.

41 Hales Gymnasium

Overview

Service	GYM
Year Constructed	1939
Year Last Renovated	1958
Area, SF	24647
Floors	3
Occupancy	N/A
Hours of Occupancy	6AM-10PM M-F 9AM-5:00PM Weekends

Envelope

The two story building consists of steel-frame wall construction with a smooth stone exterior and concrete foundation walls. Large single pane windows penetrate the exterior envelope. The building features a metal hangar roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

The gym is conditioned by large heating and ventilating unit with a steam coil. Ancillary spaces are heated by steam radiators. All the HVAC equipment is original and beyond its useful life.

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by a steam to hot water steam exchanger. A back-up standard efficiency gas fired boiler generates hot water when steam is not available from the central plant (mid-April thru mid-October).

Steam Service

This building is served by the central steam system. Conversion of the central plant from steam to hot water would require conversion of steam coils, 2-pipe steam radiators and domestic hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

43 Professional Services, 44 Counseling Center

Overview

Service	OFFICES
Year Constructed	1989
Year Last Renovated	2009
Area, SF	13870
Floors	1
Occupancy	N/A
Hours of Occupancy	8:30AM-4:30PM

Envelope

The single story building consists of masonry wall construction and concrete foundation walls. Double pane windows penetrate the exterior envelope. The building features a flat roof system composed of wood deck and membrane roofing. There is a skylight.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is conditioned using DX rooftop units with gas heat. These units are relatively new and have considerable useful life remaining. These systems operate using electric controls.

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by a tank type electric water heater.

Steam Service

This building is not served by the central steam system and would be unaffected by a conversion to hot water.

46 Philips Physical Education Center

Overview

Service	ATHLETIC
Year Constructed	1971
Year Last Renovated	2007
Area, SF	123873
Floors	3
Occupancy	N/A
Hours of Occupancy	6AM-10PM M-F 9AM-5:00PM Weekends

Envelope

The two story building consists of masonry wall construction and concrete foundation walls. Single pane windows penetrate the exterior envelope. The building features a flat concrete roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated and ventilated with the exception of the pool area that is cooled for dehumidification purposes. Heating hot water is generated by a steam to hot water heat exchanger. Heating hot water is distributed to heating and ventilating units and pool unit in the mechanical mezzanine. The unit has DX coil with an air-condensing unit. The system operate on pneumatic controls. The equipment is original and beyond its useful life.

Plumbing Fixtures

The toilet and locker rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by a steam to hot water steam exchanger. A back-up standard efficiency gas fired boiler generates hot water when steam is not available from the central plant (mid-April thru mid-October).

Steam Service

This building is served by the central steam system. Steam is used for heating, pool heating and domestic hot water heating. Conversion of the central plant from steam to hot water would require conversion of pool heating, heating hot and domestic hot water heat exchangers from steam to hot water by removing steam traps and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

47 Heisman Club Field House

Overview

Service	ATHLETIC
Year Constructed	1992
Year Last Renovated	2005
Area, SF	65895
Floors	1
Occupancy	N/A
Hours of Occupancy	6AM-10PM M-F 9AM-5:00PM Weekends

Envelope

The single story building consists of masonry wall construction and concrete foundation walls. Double pane windows penetrate the exterior envelope. The building features a flat roof system composed of metal and white EPDM.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated by heating and ventilating units with face and bypass steam coils. Equipment is original and appears to be in reasonably good condition. System operates on pneumatic controls.

Plumbing Fixtures

This building shares facilities with Philips

Domestic Water Heating

None

Steam Service

This building is served by the central steam system. Conversion of the central plant from steam to hot water would require conversion of coils from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

50 Williams Field House

Overview

Service	ATHLETIC
Year Constructed	1963
Year Last Renovated	2009
Area, SF	32237
Floors	1
Occupancy	N/A
Hours of Occupancy	Varies

Envelope

The single story building consists of both aluminum curtain wall and masonry wall construction with concrete foundation walls. Double pane windows penetrate the exterior envelope. Windows are shaded by a deep overhang. The building features a metal roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This majority of the building is heated by floor mounted gas fired heating and ventilating units installed during the recent renovation. The physical therapy area has perimeter hot water fin tube and DX roof top unit with gas heat. Hot water is generated by a standard efficiency gas fired boiler. System operates on mixture of pneumatic and DDC controls. Based on Siemens screen shots there appear to be temperature control issues in Physical Therapy.

Plumbing Fixtures

The toilet and locker rooms are equipped with a mixture of standard and low flow commercial fixtures

Domestic Water Heating

Domestic hot water is generated by a standard efficiency gas fired boiler.

Steam Service

This building is not served by the central system and would be unaffected by a conversion to hot water.

51 Savage Football Stadium - Alumni Club

Overview

Service	ATHLETIC
Year Constructed	2014
Year Last Renovated	N/A
Area, SF	16902
Floors	1
Occupancy	N/A
Hours of Occupancy	Varies

Envelope

The building consists of masonry wall construction with concrete foundation walls enclosing the basement below-grade. Double pane windows penetrate the envelope along with exterior doors. The building features a metal roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

Alumni Club is conditioned using VRF with DOAS. Stadium toilet rooms are heated and ventilated using a DOAS with energy recovery and electric heat. The systems are operated by DDC controls. Press Box is heated and ventilated using electric heat and exhaust fans. This is a new facility so all equipment is in good working order.

Plumbing Fixtures

The bathrooms are equipped with low flow fixtures.

Domestic Water Heating

Domestic hot water is generated by electric water heaters

Steam Service

This building is not served by the central system and would be unaffected by a conversion to hot water.

51 Savage Football Stadium - Locker Room

Overview

Service	ATHLETIC
Year Constructed	2014
Year Last Renovated	N/A
Area, SF	16902
Floors	1
Occupancy	N/A
Hours of Occupancy	Varies

Envelope

The building consists of masonry wall construction with concrete foundation walls. Multiple double pane windows penetrate the envelope along with exterior doors. The building features a metal roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

The locker area are heated and ventilated using gas fired rooftop. The office area is conditioned by DOAS with energy recovery, DX cooling and gas heat. Heating hot water is generated by high efficiency condensing boilers to serve unit heaters and zone duct reheat coils. All systems operate on DDC controls.

Plumbing Fixtures

The bathrooms are equipped with low flow fixtures.

Domestic Water Heating

Domestic hot water is generated by high efficiency condensing water heaters. 180 deg F water for the laundry is generated by an electric booster heater.

Steam Service

This building is not served by the central system and would be unaffected by a conversion to hot water.

52 Union Street Housing Complex

Overview

Service	APARTMENTS
Year Constructed	2005
Year Last Renovated	N/A
Area, SF	57420
Floors	3
Occupancy	130
Hours of Occupancy	24 Hours/7 Days

Envelope

The complex consists of multiple buildings constructed of wood wall construction above-grade with concrete foundation walls enclosing the basement below-grade. Double pane windows penetrate the exterior envelope. The buildings feature sloped roof systems composed of wood deck and asphalt shingles.

Lighting

Lighting in the form of incandescent fixtures has had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This complex has a standalone heating and cooling plant that includes gas-fired boilers and water cooled chiller with single cell cooling tower. The central plant operates on DDC controls. The majority of the central plant equipment appears to be in poor condition even though it is only midway through its useful life. The apartment buildings are conditioned by 2 pipe fan coil units with DDC control. Operable windows are the only means of fresh air ventilation. Toilet exhaust fans are controlled by wall switches.

Plumbing Fixtures

The bathrooms are equipped with standard residential fixtures.

Domestic Water Heating

This complex has a central domestic hot water heating system. Standard efficiency gas fired boiler generates domestic hot water that is stored for distribution to all building upon demand. The boiler is in poor condition enough it is only midway through its useful life.

Steam Service

This building is not served by the central system and would be unaffected by a conversion to hot water.

53 Langston Hall

Overview

Service	DORM
Year Constructed	1963
Year Last Renovated	1987
Area, SF	54787
Floors	3
Occupancy	200
Hours of Occupancy	24 Hours/7 Days

Envelope

The three story building consists of steel-frame wall construction with a brick exterior and concrete foundation walls enclosing the basement below-grade. Single pane windows penetrate the exterior envelope along each elevation. The building features a flat concrete roof system.

Lighting

Lighting in the common areas comes in the form of electronically ballasted fixtures with T-8 lamps. Lighting form of incandescent fixtures has had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam. Heating hot water is generated by a steam to hot water heat exchanger. Heating hot water is distributed to radiators throughout the building. Dedicated outside air units with energy recovery and steam heat provide fresh air to the corridors of each dormitory wing. There is a roof top DX unit that serves a small area and a few window A/C units otherwise the building is not air-conditioned. All systems operate on pneumatic controls.

Plumbing Fixtures

The bathrooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by central plant steam using a steam to hot water heat exchanger. Standard efficiency gas fired boilers are used to generate domestic hot water when plant steam is not available from the central plant (mid-April thru mid-October).

Steam Service

This building is served by the central steam system. Steam is used for heating, snow melt and domestic hot water. Conversion of the central plant from steam to hot water would require conversion of steam coil and heating, snow melt and domestic hot water heat exchangers from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

54 Bailey House (French House)

Overview

Service	DORM
Year Constructed	1968
Year Last Renovated	2013
Area, SF	12191
Floors	2
Occupancy	36
Hours of Occupancy	24 Hours/7 Days

Envelope

The two story building consists of steel-frame wall construction with a brick exterior and concrete foundation walls. Single pane metal windows penetrate the exterior envelope along each elevation. The building features a built-up roof system.

Lighting

Lighting in the common areas comes in the form of electronically ballasted fixtures with T-8 lamps. Lighting in the form of incandescent fixtures has had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam. Heating hot water is generated by a steam to hot water heat exchanger. Heating hot water is distributed to radiators throughout the building. There are is a make-up air unit with hot water heat and electric backup heat in each dormitory wing that provides fresh air to the corridors. There is DX split system that serves the lounge area. These systems have been updated recently. All systems operate on mixture of pneumatic and DDC controls.

Plumbing Fixtures

The bathrooms are equipped with low flow fixtures.

Domestic Water Heating

Domestic hot water is generated by central plant steam uses a steam to hot water heat exchanger. High efficiency gas fired water heater is used to generate domestic hot water when plant steam is not available from the central plant (mid-April thru mid-October).

Steam Service

This building is served by the central system. Conversion of the central plant from steam to hot water would require conversion of heating hot water and domestic hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. The availability of hot water year around would eliminate the need for the back-up water heater.

55 Burton Hall

Overview

Service	DORM
Year Constructed	1946
Year Last Renovated	2009
Area, SF	57887
Floors	5
Occupancy	185
Hours of Occupancy	24 Hours/7 Days

Envelope

The four story building consists of steel-frame wall construction with a brick exterior and concrete foundation walls enclosing the basement below-grade. Double pane windows penetrate the exterior envelope along each elevation. The building features a hip roof system composed of wood board and wood shingles.

Lighting

Lighting in the common areas comes in the form of electronically ballasted fixtures with T-8 lamps. Lighting in the form of incandescent fixtures has had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam. Steam is distributed to radiators throughout the building. There are make-up units with steam coils that provide fresh air to the corridors. There is no air conditioning. Steam radiators is the only equipment original to the building so it likely that control valve and trap replacement is needed. All systems operate on mixture of pneumatic and DDC controls.

Plumbing Fixtures

The bathrooms are equipped with low flow fixtures.

Domestic Water Heating

Domestic hot water generation system was recently replaced with high efficiency instantaneous gas fired water heater.

Steam Service

This building is served by the central steam system. Steam is used for heating and snow melt. Conversion of the central plant from steam to hot water would require conversion of 2-pipe steam radiator and snow melt heat exchanger from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load.

Recommendations

Energy conservation recommendations for future renovations include:

- Heated only – conversion to hot water. Complete conversion to DDC controls.
- Heated and cooled - conversion to water source heat pump

56 Zechiel House

Overview

Service	DORM
Year Constructed	1968
Year Last Renovated	2014
Area, SF	12056
Floors	2
Occupancy	40
Hours of Occupancy	24 Hours/7 Days

Envelope

The two story building consists of steel-frame wall construction with a brick exterior and concrete foundation walls. Double pane metal windows penetrate the exterior envelope along each elevation. The building features a built-up roof system.

Lighting

Lighting in the common areas comes in the form of electronically ballasted fixtures with T-8 lamps. Lighting in the form of incandescent fixtures has had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam. Heating hot water is generated by a steam to hot water heat exchanger. Heating hot water is distributed to radiators throughout the building. There are is a make-up air unit with hot water heat and electric backup heat in each dormitory wing that provides fresh air to the corridors. There is DX split system that serves the lounge area. All systems operate on mixture of pneumatic and DDC controls.

Plumbing Fixtures

The bathrooms are equipped with low flow fixtures.

Domestic Water Heating

Domestic hot water is generated by central plant steam uses a steam to hot water heat exchanger. High efficiency gas fired water heater is used to generate domestic hot water when plant steam is not available from the central plant (mid-April thru mid-October).

Steam Service

This building is served by the central steam system. Conversion of the central plant from steam to hot water would require conversion of heating hot water and domestic hot water heat exchangers from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up water heater.

57 Noah Hall

Overview

Service	DORM
Year Constructed	1932
Year Last Renovated	2008
Area, SF	29370
Floors	5
Occupancy	100
Hours of Occupancy	24 Hours/7 Days

Envelope

The four story building consists of steel-frame wall construction with a brick exterior and stone foundation walls enclosing the basement below-grade. Single pane windows penetrate the exterior envelope along each elevation. The building features a sloped roof system composed of wood board and slate.

Lighting

Lighting in the common areas comes in the form of electronically ballasted fixtures with T-8 lamps. Lighting in the form of incandescent fixtures has had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam. Steam is distributed to radiators throughout the building. There is make-up unit with steam coil in the basement that provide fresh air to the corridors. There are a few window units and a DX split system.

Plumbing Fixtures

The bathrooms are equipped with low flow fixtures.

Domestic Water Heating

Domestic hot water is generated by central plant steam uses a steam to hot water heat exchanger. Standard efficiency gas fired water heater is used to generate domestic hot water when plant steam is not available from the central plant (mid-April thru mid-October).

Steam Service

This building is served by the central steam system. Steam is used for heating and domestic hot water heating. Conversion of the central plant from steam to hot water would require conversion of steam coil, 2-pipe steam radiator and domestic hot water heat exchangers from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

58 East Hall

Overview

Service	DORM
Year Constructed	1964
Year Last Renovated	1994
Area, SF	43854
Floors	3
Occupancy	185
Hours of Occupancy	24 Hours/7 Days

Envelope

The three story building consists of steel-frame wall construction with a brick exterior and concrete foundation walls enclosing the basement below-grade. Single pane windows penetrate the exterior envelope along each elevation. The building features a flat metal deck roof system.

Lighting

Lighting in the common areas comes in the form of electronically ballasted fixtures with T-8 lamps. Lighting in the form of incandescent fixtures has had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam. Heating hot water is generated by a steam to hot water heat exchanger. Heating hot water is distributed to radiators throughout the building. There is no air conditioning or ventilating units to deliver fresh air to the building other than windows (question operability due to age). Systems operate on pneumatic controls.

Plumbing Fixtures

The bathrooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by central plant steam using a steam to hot water heat exchanger. Standard efficiency gas fired boilers are used to generate domestic hot water when plant steam is not available from the central plant (mid-April thru mid-October).

Steam Service

This building is served by the central steam system. Steam is used for heating and domestic hot water heating. Conversion of the central plant from steam to hot water would require conversion of heating and domestic hot water heat exchangers from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

59 Barrows Hall

Overview

Service	DORM
Year Constructed	1956
Year Last Renovated	2010
Area, SF	27561
Floors	3
Occupancy	130
Hours of Occupancy	24 Hours/7 Days

Envelope
The three story building consists of steel-frame wall construction with a brick exterior and concrete foundation walls enclosing the basement below-grade. Double pane windows penetrate the exterior envelope along each elevation. The building features a flat concrete roof system.

Lighting
Lighting in the common areas comes in the form of electronically ballasted fixtures with T-8 lamps. Lighting in the form of incandescent fixtures has had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC
This building is heated using central plant steam. Heating hot water is generated by a steam to hot water heat exchanger. Heating hot water is distributed to radiators throughout the building. There is no air conditioning or ventilating units to deliver fresh air to the building other than windows (question operability due to age). Systems operate on pneumatic controls.

Plumbing Fixtures
The bathrooms are equipped with standard residential fixtures.

Domestic Water Heating
Domestic hot water generation system was recently replaced with high efficiency instantaneous gas fired water heater.

Steam Service
This building is served by the central steam system. Steam is used for heating. Conversion of the central plant from steam to hot water would require conversion of heating hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load.

60 Barnard House

Overview

Service	DORM
Year Constructed	1968
Year Last Renovated	1995
Area, SF	12418
Floors	2
Occupancy	40
Hours of Occupancy	24 Hours/7 Days

Envelope
The two story building consists of steel-frame wall construction with a brick exterior and concrete foundation walls. Single pane metal windows penetrate the exterior envelope along each elevation. The building features a built-up roof system.

Lighting
Lighting in the common areas comes in the form of electronically ballasted fixtures with T-8 lamps. Lighting in the form of incandescent fixtures has had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC
This building is heated using central plant steam. Heating hot water is generated by a steam to hot water heat exchanger. Heating hot water is distributed to radiators throughout the building. There are is a make-up air unit with hot water heat and electric backup heat in each dormitory wing that provides fresh air to the corridors. There is DX split system that serves the lounge area. Systems operate on pneumatic controls.

Plumbing Fixtures
The bathrooms are equipped with standard commercial fixtures.

Domestic Water Heating
Domestic hot water is generated by central plant steam uses a steam to hot water heat exchanger. Standard efficiency gas fired water heater is used to generate domestic hot water when plant steam is not available from the central plant (mid-April thru mid-October).

Steam Service
This building is served by the central steam system. Steam is used for heating and domestic water heating. Conversion of the central plant from steam to hot water would require conversion of heating hot water and domestic hot water heat exchangers from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up water heater.

65 Stevenson Hall

Overview

Service	ASSEMBLY
Year Constructed	1989
Year Last Renovated	2007
Area, SF	55300
Floors	3
Occupancy	N/A
Hours of Occupancy	6A-11P 7 Days

Envelope

The two story building consists of masonry wall construction with concrete foundation walls enclosing the basement below-grade. Double pane windows penetrate the exterior envelope along each elevation. The building features a dark gray membrane roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is conditioned by VAV air handlers with hot water reheat or hot water fin tube radiation. The systems operate using a mixture of DDC and pneumatic controls. The make-up air for the general and kitchen exhaust comes in through the air handling. The drawings indicate that the building is negative due to insufficient make-up air which can cause temperature issues at building entry points. Converting the kitchen exhaust hoods to variable volume will reduce fan energy consumption and reduce make-up air requirement when the hood is on, but cooking equipment is not generating heat or smoke. This facility uses a large quantity of hot water and generates a lot of heat. The heat from walk-in cooler/freezer compressors can be recovered to heat domestic water year round. This building has a separate space that is ventilated to reject the heat for these compressors to the outside.

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by central plant steam uses a steam to hot water heat exchanger. Standard gas fired boiler is used to generate domestic hot water when plant steam is not available from the central plant (mid-April thru mid-October).

Steam Service

This building is served by the central steam system. Steam is used for kitchen equipment, snow melt, heating and domestic hot water. There is also a local standard efficiency steam boiler that provides steam to the kitchen equipment when central plant steam is not available (mid-April thru mid-October).

Conversion of the central plant from steam to hot water would require conversion of steam coils and snow melt, heating and domestic hot water heat exchangers from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up domestic boiler.

66 Kahn Hall

Overview

Service	DORM
Year Constructed	2009
Year Last Renovated	N/A
Area, SF	52360
Floors	4
Occupancy	150
Hours of Occupancy	24 Hours/7 Days

Envelope

The three story building consists of steel-frame wall construction with a brick exterior and concrete foundation walls enclosing the basement below-grade. Double pane windows penetrate the exterior envelope. The building features a flat roof system composed of metal decking and membrane roofing.

Lighting

Lighting comes in the form of compact fluorescents, linear fluorescents and LEDs. Light fixtures are controlled by local automatic controls in most area, but a few areas still have manual wall toggle switches. Local automatic lighting controls are overridden by a building lighting control system.

Electric

There is photovoltaic array on the roof generating electric. There are additional support stands for additional arrays.

HVAC

The building is conditioned by a 2 pipe fan coil units with room direct outside air from rooftop dedicated outside air unit with energy recovery. Heating hot water is generated from central plant steam using a heat exchanger and cooling water is generated from central plant chilled water using a heat exchanger. All systems operate on DDC controls

Plumbing Fixtures

The bathrooms are equipped with low flow fixtures.

Domestic Water Heating

Domestic hot water is generated in a storage tank with a steam bundle and a back-up gas fired burner when plant steam is not available from the central plant (mid-April thru mid-October). Original drawings should solar hot water heating which was eliminated due to budget.

Steam Service

This building is served by the central system. Conversion of the central plant from steam to hot water would require conversion of 2-pipe steam radiator and domestic hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

68 Keep Cottage

Overview

Service	DORM
Year Constructed	1913
Year Last Renovated	1988
Area, SF	17286
Floors	4
Occupancy	54
Hours of Occupancy	24 Hours/ 7 Days

Envelope

The three story building consists of wood wall construction above-grade with sandstone foundation walls enclosing the basement below-grade. Single pane windows penetrate the envelope. The building features a sloped roof system composed of wood deck and clay tiles.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using a local steam boiler. Steam is distributed to radiators throughout the building. There is a make-up air unit with steam coil that provides make-up air for the kitchen hoods. The HVAC equipment is beyond its useful life. All systems operate on pneumatic controls.

Plumbing Fixtures

The bathrooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by standard efficiency gas fired boilers. There is also a tank type gas fired water heater that generates 180 deg F water for the kitchen use.

Steam Service

This building is served by the central steam system. Steam is used for kitchen equipment, heating, and domestic hot water. Conversion of the central plant from steam to hot water would require conversion of steam coil, 2-pipe steam radiators and domestic hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

69 Asia House (Quadrangle)

Overview

Service	DORM
Year Constructed	1861
Year Last Renovated	2011
Area, SF	45809
Floors	3
Occupancy	80
Hours of Occupancy	24 Hours/ 7 Days

Envelope
The two story building consists of masonry wall construction with stone foundation walls enclosing the basement below-grade. Double pane windows penetrate the exterior envelope. The building features a sloped roof system composed of wood board and clay tiles.

Lighting
Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC
This building is heated using central plant steam. Steam is distributed to radiators throughout the building. There are new make-up air units with energy recovery and steam coils in the basement that provides fresh air to the corridors. There is a gas fired make-up air that provides makeup for the kitchen hood. There are a few DX split system serving a few apartments. Systems are a mixture of DDC and pneumatic controls

Plumbing Fixtures
The bathrooms are equipped with standard commercial fixtures.

Domestic Water Heating
Domestic hot water generation system was recently replaced with high efficiency instantaneous gas fired water heaters.

Steam Service
This building is served by the central steam system. Steam is used for heating. Conversion of the central plant from steam to hot water would require conversion of steam coils and 2-pipe steam radiators from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load.

70 Bosworth Hall

Overview

Service	OFFICES
Year Constructed	1931
Year Last Renovated	2016
Area, SF	19461
Floors	4
Occupancy	N/A
Hours of Occupancy	8AM-6PM

Envelope

The three story building consists of masonry wall construction with stone foundation walls enclosing the basement below-grade. Single pane windows penetrate the exterior envelope. The building features a sloped roof system composed of wood board and clay tiles.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam distributed to radiators throughout the building. Air conditioning is provided by window A/C units that remain in place year round resulting in cold drafts and DX split systems. There is no fresh air delivered to the building other than through windows (question operability due to age). Most of the equipment is beyond its useful life. All systems operate on pneumatic controls.

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by a tank type electric water heater.

Steam Service

This building is served by the central steam system. Steam provides only heating. Conversion of the central plant from steam to hot water would require conversion of 2-pipe steam radiator from steam to hot water by removing steam trap and replacing control valves. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

72 Allen Memorial Art Museum

Overview

Service	CLASSES/OFFICES
Year Constructed	1917, 1935
Year Last Renovated	2011
Area, SF	43836
Floors	3
Occupancy	N/A
Hours of Occupancy	8AM-5PM

Envelope
The two story building consists of masonry wall construction with stone foundation walls enclosing the basement below-grade. Multiple double pane windows penetrate the envelope along with exterior doors. The building features a sloped roof system composed of wood board and clay tiles.

Lighting
Lighting comes in the form of compact fluorescents, linear fluorescents and LEDs. Display lighting is incandescent. Light fixtures are controlled by local automatic controls in most area, but a few areas still have manual wall toggle switches. Local automatic lighting controls are overridden by a building lighting control system.

HVAC
A dedicated outside air unit preconditions the outside before ducting it the inlet of the 6 HVAC systems used to control temperature and humidity in the Museum. Central plant steam is used for heating and humidification and there is a local backup steam boiler for humidification. There are local chillers, water to water heat pumps, cooling tower and geothermal loop. All systems operate on DDC controls.

Plumbing Fixtures
The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating
Domestic hot water is generated by a tank type electric water heater.

Steam Service
This building is served by the central steam system. Steam is used for humidification, heating and domestic water heating. Conversion of the central plant from steam to hot water would require conversion of 2-pipe steam radiator and domestic hot water heat exchanger from steam to hot water by removing steam trap and replacing control valves. Humidification will require that loop and its local boiler be isolated from the rest of the steam loop. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

73 Allen Art Building

Overview

Service	CLASSES/OFFICES
Year Constructed	1976
Year Last Renovated	2008
Area, SF	36623
Floors	2
Occupancy	N/A
Hours of Occupancy	8AM-5PM

Envelope

The two story building consists of masonry wall construction with stone foundation walls enclosing the basement below-grade. Double pane windows penetrate the exterior envelope. The building features a concrete roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

There are a mixture of system types conditioning this building including VAV, constant volume, fan coil units and fin tube radiation. Heating hot water is generated by a steam to hot water heat exchanger. Central plant steam comes from Hall Annex. Chilled water is generated by the water cooled chillers located in Hall Annex. Air handling units are approaching the end of their useful life. All systems operate on pneumatic controls.

Plumbing Fixtures

The toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by a steam to hot water steam exchanger. A back-up tank type electric water heater generates hot water when steam is not available from the central plant (mid-April thru mid-October).

Steam Service

This building is served by the central steam system. Steam is used for humidification, heating and domestic water heating. Conversion of the central plant from steam to hot water would require conversion of steam coils, heating and domestic hot water heat exchangers from steam to hot water by removing steam trap and replacing control valves. Humidification will require the installation of local steam generators and dispersion equipment. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up water heater.

74 Hall Auditorium

Overview

Service	ASSEMBLY
Year Constructed	1953
Year Last Renovated	1998
Area, SF	35474
Floors	3
Occupancy	N/A
Hours of Occupancy	8AM-5PM (Varies)

Envelope

The two story building consists of masonry wall construction with stone foundation walls enclosing the basement below-grade. Single pane windows penetrate the exterior envelope. The building features a concrete roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is conditioned with a combination of the constant volume air handlers with steam and chilled water coils, fan coil units and steam radiators. Steam is provided by the central plant and chilled water is generated by the Hall Annex water cooled chiller plant. Air handling unit is beyond its useful life. All systems operate on pneumatic controls.

Plumbing Fixtures

Toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by a tank type electric water heater.

Steam Service

This building is served by the central steam system. Conversion of the central plant from steam to hot water would require conversion of 2-pipe steam radiator and steam coils from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load. The availability of hot water year around would eliminate the need for the back-up gas fired boiler.

75 Hall Annex

Overview

Service	CLASSES/ OFFICES
Year Constructed	1959
Year Last Renovated	2012
Area, SF	N/A
Floors	2
Occupancy	100
Hours of Occupancy	8AM-5PM (Varies)

Envelope

The two story building consists of masonry wall construction with stone foundation walls enclosing the basement below-grade. Single pane windows penetrate the exterior envelope. The building features a concrete roof system.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated using central plant steam. Heating hot water is generated by a steam to hot water heat exchanger. Heating hot water is distributed to convertors and fan coil units throughout the building. This building is air conditioned using chilled water for the local chiller plant. Chilled water is distributed to this building as well as the Auditorium and the Allen Art Building.

Plumbing Fixtures

Toilet rooms are equipped with standard commercial fixtures.

Domestic Water Heating

Domestic hot water is generated by a tank type electric water heater.

Steam Service

This building is served by the central system. Conversion of the central plant from steam to hot water would require conversion of air coils from steam to hot water by removing steam trap and replacing control valves. Design would need to confirm the derated capacity of the converted equipment is adequate to meet the load.

78 Charles Martin Hall House

Overview

Service	DORM
Year Constructed	1896
Year Last Renovated	N/A
Area, SF	16559
Floors	4
Occupancy	N/A
Hours of Occupancy	24 Hours/ 7 Days

Envelope

The three story building consists of masonry wall construction above-grade with stone foundation walls enclosing the basement below-grade. Single pane windows with storm sashes penetrate the exterior envelope. The building features a low slope roof system composed of wood board and asphalt shingles.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated by a gas fired hot water boiler in the basement that provides hot water to radiators throughout the building. Toilet exhaust fans are controlled by wall switch. There is no air conditioning or ventilating units to deliver fresh air to the building other than windows (question operability due to age).

Plumbing Fixtures

The bathrooms are equipped with standard residential fixtures.

Domestic Water Heating

Domestic hot water is generated by gas fired water heaters.

Steam Service

This building is not served by the central steam system and would be unaffected by a conversion to hot water.

79 Tank Hall

Overview

Service	DORM
Year Constructed	1896
Year Last Renovated	1986
Area, SF	16559
Floors	4
Occupancy	82
Hours of Occupancy	24 Hours/7 Days

Envelope

The three story building consists of masonry wall construction above-grade with stone foundation walls enclosing the basement below-grade. Multiple double pane windows penetrate the envelope along with exterior doors. The building features a sloped roof system composed of wood board and asphalt shingles.

Lighting

Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

HVAC

This building is heated by a gas fired steam boiler in the basement that provides steam to radiators throughout the building. There are make-up air units with steam coils in the basement that provides fresh air to the kitchen and corridors. The HVAC equipment is beyond its useful life. All systems operate on pneumatic controls.

Plumbing Fixtures

The bathrooms are equipped with standard residential fixtures.

Domestic Water Heating

Domestic hot water is generated by gas fired water heaters. There is an electric booster to provide 180 deg F water to the kitchen.

Steam Service

This building is not served by the central steam system and would be unaffected by a conversion to hot water.

80 Firelands

Overview

Service	DORM
Year Constructed	1963
Year Last Renovated	2016
Area, SF	42606
Floors	7
Occupancy	99
Hours of Occupancy	24 Hours/7 Days

Envelope
The seven story building consists of masonry wall construction above-grade with concrete foundation walls enclosing the basement below-grade. Double pane windows penetrate the exterior envelope. The building features a flat concrete roof system.

Lighting
Lighting comes in the form of electronically ballasted fixtures with T-8 lamps. Any incandescent fixtures have had the bulbs replaced with compact fluorescent or LED bulbs. Light fixtures are controlled with wall mounted toggle switches.

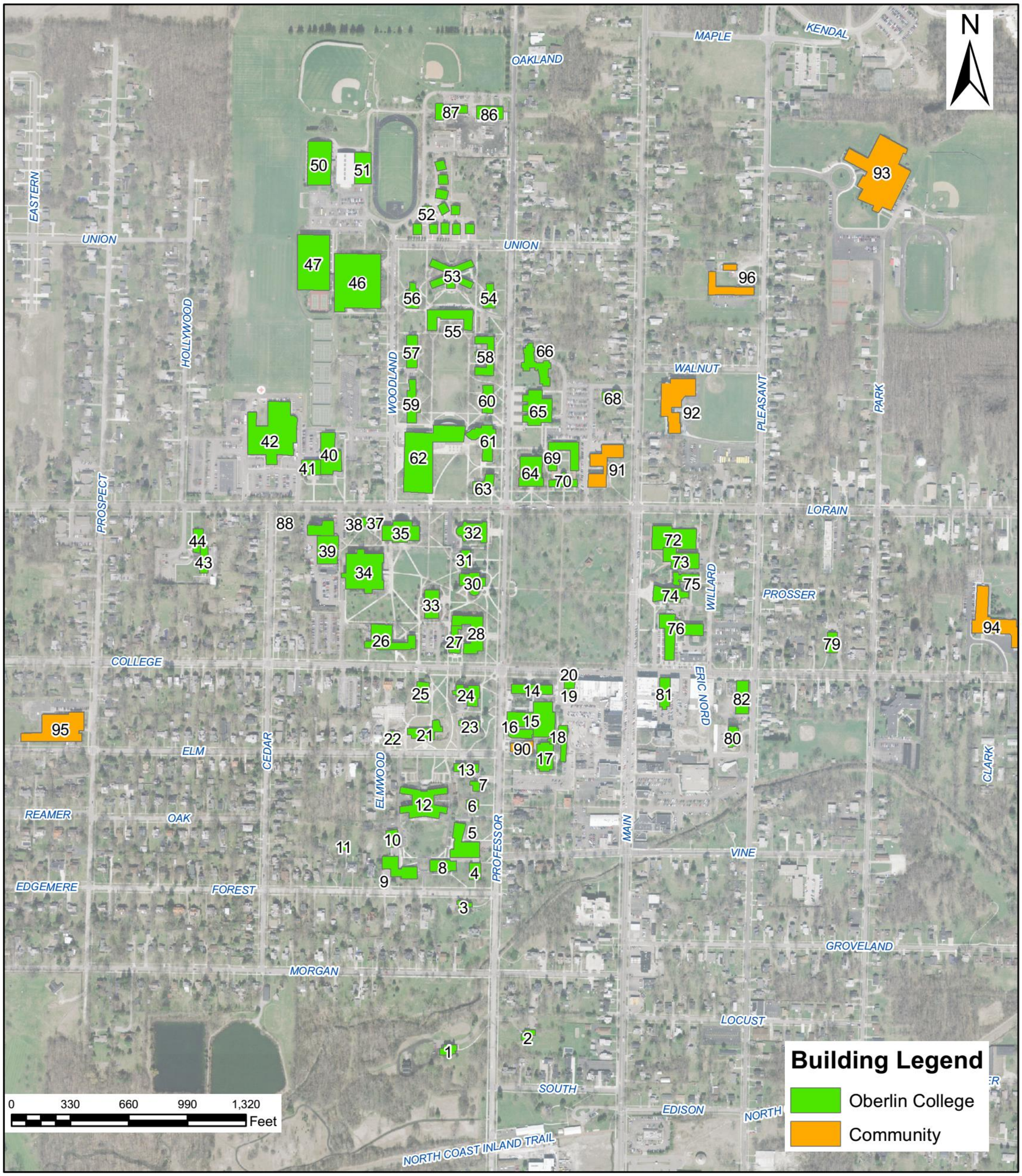
HVAC
This building is heated by a gas fired hot water boiler in the basement that provides hot water to radiators throughout the building. Toilet exhaust is connected to central systems that operate continuously. There is a make-up air unit with hot water coil that provide fresh air to the corridors for toilet make-up. There is a DX split system that conditions the main lobby. Apartment cooling is provided by window A/C units. The air handling equipment is beyond its useful life. All systems operate on electric controls.

Plumbing Fixtures
The bathrooms are equipped with standard residential fixtures.

Domestic Water Heating
Domestic hot water is generated by standard efficiency gas fired water heaters.

Steam Service
This building is not served by the central system and would be unaffected by a conversion to hot water.

Appendix XIV – Campus Map and Building Index



Map #	Building
1	216 S Professor St - Johnson House
2	207 S Professor St - Old Barrows Dorm
3	134 S. Professor St - Allencroft
4	108 S Professor St - Kade Dorm
5	100 S Professor St - Harvey Dorm
6	Lewis Center for Women
7	68 S Professor - Lewis House
8	Price
9	126 Forest St - Lord Saunders Dorm
10	126 Forest St - Lord Saunders Dorm
11	154 Forest St - Presidents House
12	121 Elm St - South Hall
13	93 Elm St - Fairchild House
14	77 W College St - Teaching Unit
15	77 W College St - Conservatory Central
16	Conservatory
17	77 W College St - Robertson Hall
18	77 W College St - Kohl Building
19	Conservatory
20	37 W College St - Oberlin Bookstore
21	122 Elm Street - A J Lewis Center - Enviro Studies
22	132 Elm Street - AJLC Annex
23	30 S. Professor - Baldwin Cottage
24	2 S Professor St - Talcott Hall
25	113 W College - Harkness House
26	140 W College - Dascomb
27	King/Rice
28	10 N Professor St - King Building
29	Memorial Arch
30	50 N Professor St - Peters Hall
31	70 N Professor - Cox Administration
32	90 N Professor St - Finney Chapel
33	30 N. Professor St - Warner Center Gym
34	148 W College - Mudd Learning Center
35	135 W Lorain - Wilder Hall
36	145 W Lorain - Daub House - Bonner Center for S&L
37	Communications Building
38	159 W Lorain St - Security Building
39	173 W Lorain St - Central Heating Plant
40	180 W Lorain St - Hales Gym/Bowling Lanes
41	Hales Gymnasium
42	Allen Medical Center
43	247 W Lorain St - Professional Services Building
44	247 W Lorain St - Professional Services Building
45	Tennis Courts
46	200 Woodland St - Philips Gymnasium
47	202 Woodland -Heisman Field House
48	204 Woodland St - Kahn Track and Concession
49	Shults Field
50	206 Woodland St - Williams Field House

Map #	Building
51	210 Woodland - Knowlton Athletic Field / Alumni Club
52	102 Union Street
53	95 Union St - Langston Hall
54	208 N Professor St - Bailey House
55	194 N Professor St - Burton Hall
56	207 Woodland St - Zechial House
57	167 Woodland St - Noah Hall
58	176 N Professor St - East Hall
59	145 Woodland - Barrows Hall
60	148 N Professor - Barnard House
61	110 N Professor St - Wright Physics
62	119/130 Woodland - Science Center - North Quad
63	120 W Lorain St - Severance Hall
64	52 W Lorain St - Carnegie Building
65	155 N Professor St - Stevenson Hall
66	169 N Professor - Kahn Hall
67	-
68	154 N Main St - Keep Cottage
69	40 W Lorain St - Asia House Quadrangle
70	50 W Lorain - Bosworth Hall
71	Clark Band Stand
72	87 N Main St - Allen Memorial Art Museum
73	-
74	67 N Main St - Hall Auditorium
75	47 N Main St - Hall Auditorium Annex
76	7 N Main St - Oberlin Inn
77	Shansi House
78	Charles Martin House
79	110 E College St - Tank Hall
80	36 S Pleasant - Firelands Dorm
81	19 E College St - Apollo
82	Art Studio (Hobbs)
83	Art Studios
84	Brrell King House
85	Art Studio (Faculty)
86	Athletic Field Quonset
87	Grounds Shop
88	International House
89	Orchard Building
90	First Methodist Church
91	First Church of Oberlin
92	Langston Middle School
93	High School
94	Eastwood Elementary School
95	Prospect School
96	Old Pleasant Street School