Intended for
**SUNY Oswego, New York Power Authority**

Document type
**Plan**

Date
**December 2023 (Final)**

# Clean Energy Master Plan
## Consolidated Report

Bright ideas.
Sustainable change.

# Clean Energy Master Plan
## Consolidated Report

| | |
|---|---|
| Project name | **Campus Energy Master Plan** |
| Project no. | **1950100323** |
| Recipient | **SUNY Oswego, NYPA** |
| Document type | **Consolidated Report** |
| Version | **1.1** |
| Date | **December 2023 (Final Report)** |
| Prepared by | **Joe DiSanto, John Flørning, Rob Neimeier** |
| Checked by | **Michael Kingsley, Rob Neimeier** |
| Approved by | **Tim Erwin, Rob Neimeier** |

Ramboll
94 New Karner Road
Suite 106
Albany, NY 12203
USA

T 518-724-7272
F 315-463-7554
https://ramboll.com

© 2023 Ramboll

## Acknowledgements

The following individuals are acknowledged for their participation in the development of the SUNY Oswego Clean Energy Master Plan:

**SUNY Oswego**
Allen Bradberry
Mitch Fields
Jon Mills
David Pippin
Kate Spector

**New York Power Authority**
Danish Shakil

**Ramboll**
Federico Bava
Tricia D'Agostino
Joe DiSanto
John Flørning
Sebastian Wulff Holtegaard
Sophie Huther
Mai Khuc
Mike Kingsley
Mark McGuire
Rob Neimeier
Kendra Valerius

**Subconsultants**
Trophy Point Construction Services & Consulting

# Contents

**List of Tables**



**List of Figures**

**List of Appendices**

# Acronyms and Abbreviations

| | |
|---|---|
| ACEEE | American Council for an Energy Efficient Economy |
| ACET | Agricultural and Clean Energy Technology Center |
| ASHP | air-source heat pump |
| ASHRAE | American Society of Heating, Refrigerating and Air-Conditioning Engineers |
| ATES | aquifer thermal energy storage |
| BA | building assessment |
| BAS | building automation system |
| BAU | business-as-usual |
| BH | borehole |
| BTES | borehole thermal energy storage |
| CAPEX | capital expenditures |
| CBECS | Commercial Buildings Energy Consumption Survey |
| CEC | Clean Energy Center |
| CEMP | Clean Energy Master Plan |
| CHP | central heating plant |
| CHW | chilled water |
| CLCPA | New York State Climate Leadership and Community Protection Act |
| CM | critical maintenance |
| $CO_2e$ | carbon dioxide equivalent |
| CTs | current transformers |
| DER | deep energy retrofit |
| DH&C | district heating & cooling |
| DHW | domestic hot water |
| EEMs | energy efficiency measures |
| EMIS | energy management information systems |
| EO 22 | Executive Order 22 |
| ETS | energy transfer station |
| EUI | energy use intensity |
| FDD | fault detection and diagnosis |
| GHG | greenhouse gas |
| GSF | gross square feet |
| GSHP | ground-source heat pump |
| HRC | heat recovery chiller |
| HVAC | heating, ventilation, and air conditioning |
| KPIs | key performance indicators |
| LBNL | Lawrence Berkeley National Laboratory |
| LHD | linear heat density |
| LTW | low temperature water |
| MTW | medium temperature water |
| MW | megawatt |
| MWhr | megawatt hour |
| NYSDEC | New York State Department of Environmental Conservation |
| NZC | net zero carbon |
| O&M | operations & maintenance |
| OGS | NYS Office of General Services |

| | |
|---|---|
| OPEX | operating expenses |
| PIP | phasing & implementation plan |
| PEA | Preliminary Energy-Use Analysis |
| Psig | pounds per square inch gauge |
| RTEM | real time energy management |
| SH | space heating |
| SOW | scope of work |
| SPB | simple payback |
| TBtu | trillion British thermal units |
| TM | temperature modulation |
| TMY | typical meteorological year |
| TRM | New York State Technical Resource Manual |
| TTES | tank thermal energy storage |
| WOA | work order assignment |
| WSHP | water-source heat pump |
| WWTP | wastewater treatment plant |

# Executive Summary

**Purpose and Drivers**
State University of New York College at Oswego (SUNY Oswego) is subject to mandates, energy and carbon reduction targets, and directives that include the New York State Climate Leadership and Community Protection Act (CLCPA), Executive Order 22, BuildSmart 2025, and State University Construction Fund (SUCF Directive 1B-2). These drivers have associated energy and greenhouse gas (GHG) emissions reduction goals, including key milestone dates, as further summarized in Section 1.2.

A Clean Energy Master Plan (CEMP) was developed to create a vision for low carbon and renewable technologies and operational strategies to reduce fossil fuel use/dependency, increase electrification of utility operations, and maintain resiliency and reliability. This CEMP provides a roadmap for near-term actions and a decision-making framework for the long-term vision to achieve NYS energy efficiency and GHG reduction, mandates and set a path for carbon neutrality by 2050.

**Approach**
A key focus strategy was identifying a pragmatic and cost-effective approach to achieving the long-term goals of electrification-based energy production technologies while also bridging the short-term needs of critical capital improvements that would ultimately support the long-term campus goals.

**Campus Energy Assessment**
Building energy assessments were performed by Ramboll. Walk-through surveys were performed on buildings exceeding 5,000 GSF at the campus. This effort focused on assessing existing conditions and evaluating current energy consumption profiles following methodologies outlined in ASHRAE's *Procedures for Commercial Building Energy Audits, Second Edition*; summaries were prepared of existing conditions, energy efficiency opportunities, and recommendations for critical maintenance. Energy efficiency measures (EEMs) that were identified and developed include lighting, lighting controls, building automation system control upgrades, variable frequency drive applications, and pool dehumidification.

As shown in Table 1, annual energy cost savings were estimated at about $473,000 (16% of annual campus energy cost); project cost was estimated at approximately $8.8M, with a 19-year simple payback. Numerous capital-intensive projects for equipment and systems that are at or beyond their useful life increase the simple payback period of the entire package of measures. However, these projects can be justified from an infrastructure renewal perspective. For the equipment that is already due for replacement, it could be argued to only include the EEM incremental cost for a high efficiency replacement, rather than the full replacement cost; that was not done here, but it would lower the simple payback considerably.

These measures are estimated to save the campus a total of 66,653 MMBtu /year, accounting for about 46% of the 146,332 MMBtu BuildSmart 2025 reduction target. Annual emission savings are estimated to save the campus over 3,200 MT $CO_2e$ per year, or about 12% of the 1990 campus GHG emissions (26,328 MT $CO_2e$). Measures from this study can be combined in addition to any measures already entered in the BuildSmart 2025 project database, as well as any major renovations that will have at least 30% design documents by December 31, 2025.

**Table 1. EEM Summary**

| | Annual Energy Savings (MMBtu/year) | Annual Energy Cost Savings ($/yr) | Estimated Capital Cost | Simple Payback Period (years) | Annual GHG Reduction ($MTCO_2e$) |
|---|---|---|---|---|---|
| Total | 66,653 | $473,260 | $8,836,129 | 18.7 | 3,242 |
| Total with IRR >= 7% | 42,158 | $293,920 | $997,873 | 3.4 | 2,058 |

**Baseload, Peaking, and Backup Strategy**

Ramboll recommends a clear strategy for establishing heating and cooling technologies that will support baseload, peaking, and backup (emergency) operations. The rationale for serving the annual load with both baseload and peaking technologies is that the peak load occurs in limited hours annually, and it is less cost-efficient to size the relatively expensive baseload technology to meet the peak load when it can effectively meet the majority of the annual load when it is sized much smaller than the peak.

Establishing how much a baseload technology should cover of the total annual heat demand is an optimization exercise. However, as a rule of thumb, if the baseload covers 50% to 60% of the peak heating load, then it will cover approximately 80% to 95% of the annual heating load. This is illustrated in Figure 1 below for the SUNY Oswego heat load. Distinguishing between baseload and peak load will be more cost-efficient and could allow financial resources to be allocated to other projects that economically and environmentally would make better sense. Here are some aspects for planning purposes:

- If baseload is electric based, then backup of the heating system should be another fuel; for instance, a gas (or oil) boiler
- Peaking technology could be electric, fossil fuel, or renewable fuel based, but should consider cost optimization, resiliency, and redundancy aspects
- Backup technology should be highly reliable and have lower installation costs
- Backup fuel supply should be reliable and available
- Backup technology should be well known to the operational staff

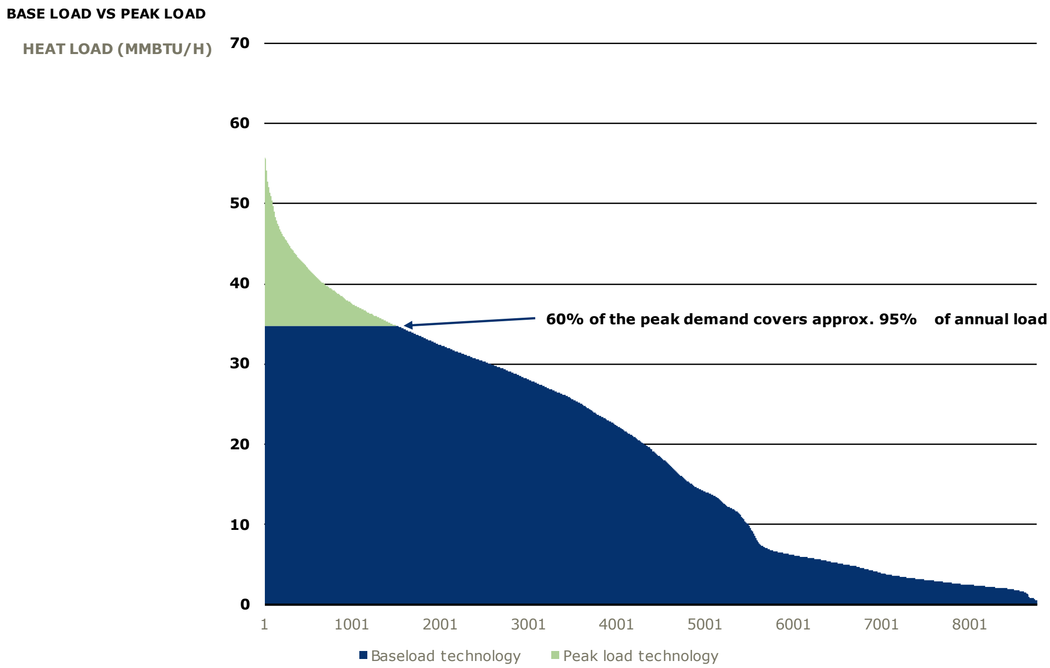



**Figure 1. Baseload and peak load illustration**

## Technology Screening

Technology screening was conducted to identify suitable technologies and storage options for the future production of heating/cooling that support campus alignment with the carbon reduction goals of the CLCPA. Technologies evaluated considered centralized and cluster solutions. The process was conducted through a series of meetings where Ramboll presented descriptions of fossil fuel, renewable, and electrification technologies and their ability to produce baseload and peak load production.

## Scenario Planning

Scenario Planning was performed to develop a suite of scenarios to assess centralized and cluster energy supply scenarios. The scenarios were developed through a combination of quantitative and qualitative screening and considered these aspects:

- Heating and cooling demands for each building on campus
- Production of domestic hot water in winter and summer months
- Best suited technologies and energy systems
- Grouping buildings into geographic clusters

The number of scenarios was established through discussing different variations during the project meetings. The combinations of network configuration, heating and cooling technologies, and storage components that were evaluated are noted below and shown in Table 2.

- Technologies (GSHP, wastewater heat pumps, cascade heat pumps) as centralized technologies
- Fully centralized network versus cluster networks
- Production of domestic hot water (centralized and/or local)

- Geothermal borefield availability and locations

**Table 2. Evaluated scenarios**

| Scenario | BaU | Sc. 2 a), b) | Sc. 4 a), b) | Sc. 5 b) | Sc. 6 a), b) |
|---|---|---|---|---|---|
| **Demand** | Current | Future | Future | Future | Future |
| **Network configuration** | Current system | Cluster 2 pipe | Fully centralized 2 Pipe | Fully centralized 2 pipe | Fully centralized 2 pipe |
| **Baseload technology** | N-gas | Ground Source HP | Ground Source HP | Wastewater HP Ground Source HP | Air Source HP in cascade with Water-to-water HP Ground Source HP |
| **Peaking Technology** | N-gas | a) N-gas, b) Electric | a) N-gas, b) Electric | a) N-gas, b) Electric | a) N-gas, b) Electric |
| **Summer, DHW** | Local gas / central | Local electric | Local electric | Local electric | Local electric |
| **Winter, DHW** | Local gas / central | Centralized | Centralized | Centralized | Centralized |
| **Space cooling** | Local | GSHP Chiller | GSHP Chiller | GSHP Chiller | GSHP Chiller |
| **Backup heat** | N-gas boiler | Boiler: N-gas | Boiler: N-gas | Boiler: N-gas | Boiler: N-gas |
| **Thermal energy storage** | No | Yes | Yes | Yes | Yes |
| **Balancing of BTES** | NA | Heat injection from cooling + Dry coolers | Heat injection from cooling + Dry coolers | Heat injection from cooling + Wastewater | Heat injection from cooling + ASHP |

**Techno-Economic Analysis**

Techno-economic analysis was completed to identify the most cost-efficient mix of technologies to supply the future heating and cooling needs.

Figure 2 below shows the carbon dioxide equivalent ($CO_2e$) GHG emissions for the different scenarios together with the project overall Net Present Value (NPV) (including capital expenditures (CAPEX), operating expenditures (OPEX), and residual value). The total NPV is shown for each of the scenarios by a yellow dot (without including a social cost of carbon for $CO_2e$ emissions) and a green triangle (including a social cost of carbon, as referenced in New York State Department of Environmental Conservation (NYSDEC) guidance).

Overall NPV of the business-as-usual (BaU) scenario shows very high $CO_2e$ emissions compared to the decarbonization scenarios, and the BaU NPV is proportionately affected when applying the social cost of carbon. The alternative scenarios with natural gas peaking show some increase in NPV when adding the social cost of carbon as well. The NPV of the social cost of carbon component depends on:

- The amount of natural gas used in the scenario
- Progressive decarbonization of the electrical grid to align with the EO22 mandate of 100% renewable sources for electricity by 2030 for NYS Agencies (ahead of the CLCPA goal of a 100% carbon free electric grid by 2040)

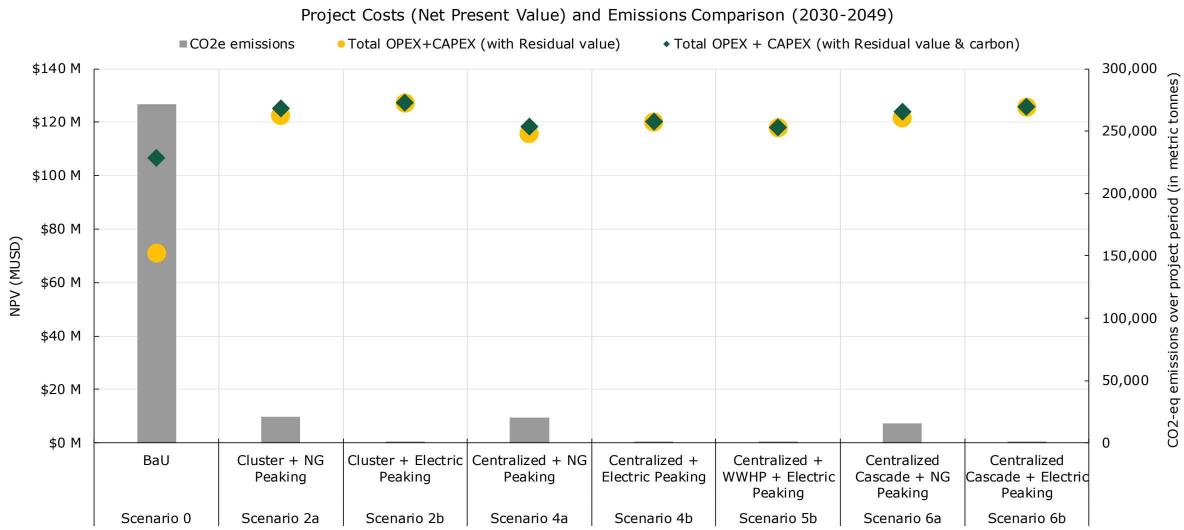



**Figure 2. $CO_2$e emissions and project NPV for the different scenarios**

### Campus Electrical Capacity Assessment

Electrification of the campus will result in increased electric energy use for heating purposes, as well as an increase in the peak electrical demand. The existing peak electrical demands typically occur in August or September. With the shift to electrical heating sources, the electrical peak will occur in the winter months.

Figure 3 summarizes the peak electrical demand impact of each scenario. The existing campus Substation #1, which serves the campus buildings north of Route 104, has two 6,250 kVA transformers. During existing summer peak demand periods, both transformers are required, and at about 76% loaded. This means there is no redundancy in the existing substation during existing peak demand periods. In all scenarios, the substation would need to be upgraded to maintain the desired capacity margin. Building electrical modifications would also be required for the cluster scenario (2a & 2b). The existing Substation #2, which serves the buildings south of Rout 104, has a 25 kVA and a 2,000 kVA transformer. No upgrades would be required for the natural gas peaking scenarios, but the substation would be upgraded with a 3,125 kVA transformer for electric peaking scenarios.

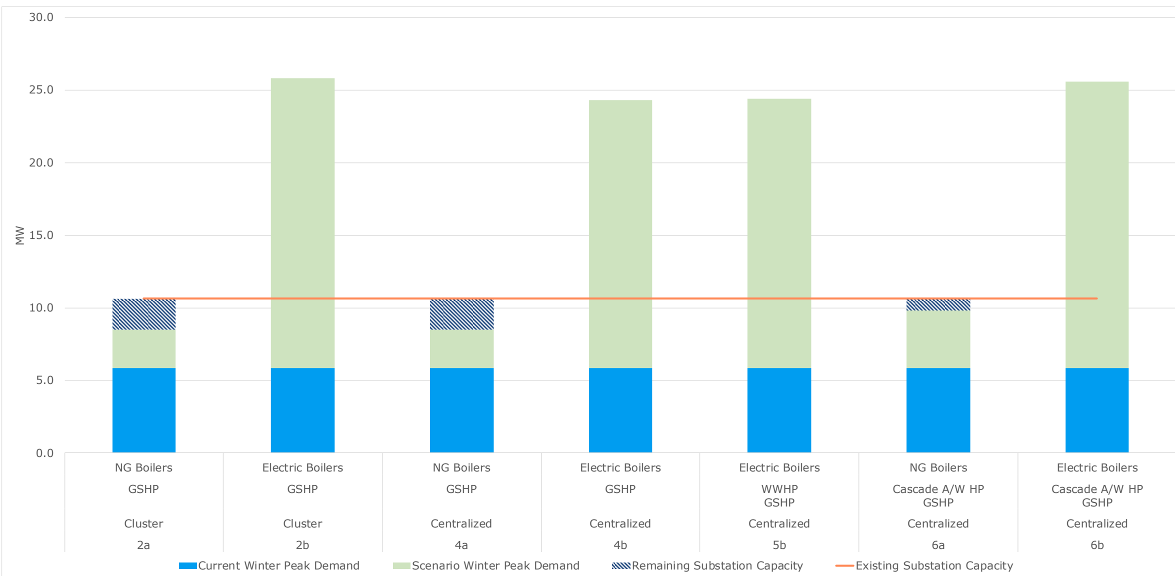



**Figure 3. Estimated electrical capacity per scenario**

## Cost Estimate

Cost estimating was performed by Trophy Point Construction Services & Consulting (Trophy Point). Figure 4 provides a summary of the CAPEX cost estimates, by component, for the BaU and the scenario variants, including building level installations, distribution system, and centralized system components.

The cost estimates include raw labor and material, in addition to the markups listed below:

- General Conditions – 15%
- Overhead & Profit – 10%
- Design Contingency[1] – 20%
- Bid Contingency – 5%
- Phasing – 10%

[1] Design contingency is related to the progress of the project. In early stages before details have been defined, the contingency is higher and typically decreases as the project progresses.

Scenarios using a gas boiler for peaking purposes (Scenarios 2a, 4a and 6a) have less capital investment needs than scenarios using an electric boiler for peaking purposes (Scenarios 2b, 4b and 6b). Utilizing wastewater as a heat source (Scenario 5b) can be compared directly to the centralized GSHP with electric peaking variant (Scenario 4b). A reduced borefield size and elimination of dry coolers for balancing results in a lower CAPEX for Scenario 5b.

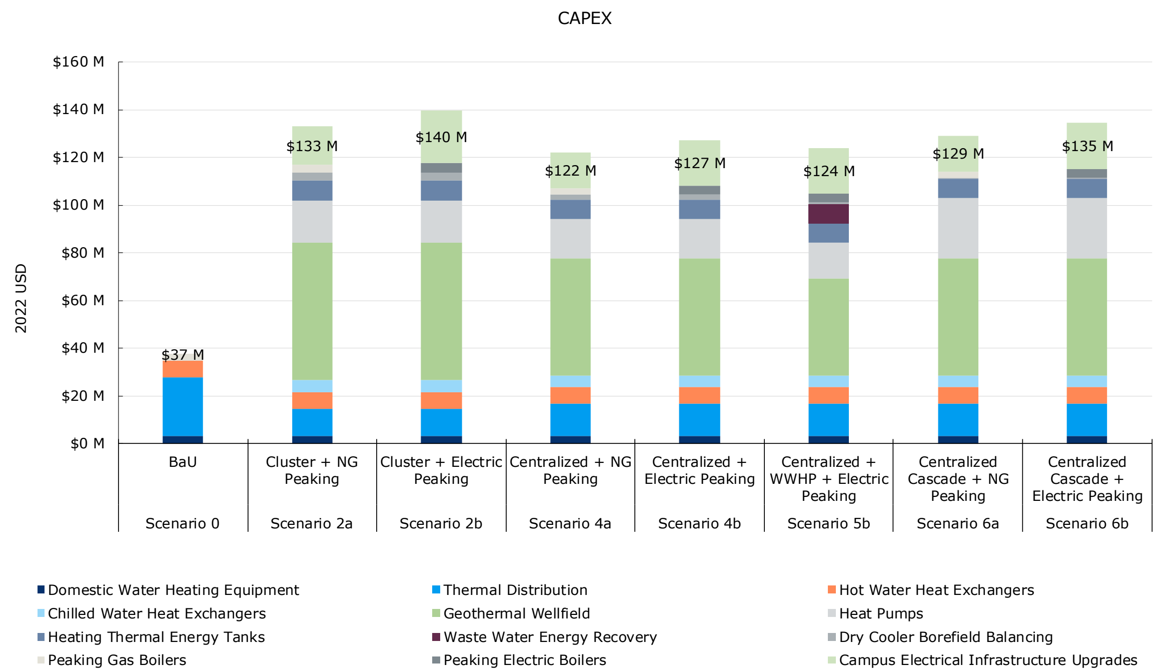



**Figure 4. Scenario cost estimates**

Table 3 presents the cost of modifications to existing buildings that would be required to accept much lower design hot water supply temperature (130°F). The cost estimation basis was Trophy Point cost data for similar work in building types, adjusted for location. Note these modifications are not required in order to implement the decarbonization scenarios; building modification costs that would be required are already in the scenario cost estimates. The costs in Table 3 are for deeper HVAC retrofits or replacements that would allow the buildings to operate at much lower hot water supply temperatures. Lower design supply temperatures improve heat pump efficiency; however, the cost to replace HVAC coils or systems as an early replacement activity should be weighed against the heat pump efficiency gains. The substantial cost of HVAC modifications likely indicate they should not be done as early replacement; only as the systems are due for replacement.

**Table 3. Building modification budgetary cost estimate for 130°F supply temperature**

| Modification | Cost |
|---|---|
| HVAC Renovation | $121.0M |
| Coil Replacement for 130°F Building HW Supply | $45.4M |
| **Total** | **$166.4M** |

**Phasing and Implementation**

Table 4 provides a summary of the phasing strategy and associated key actions towards decarbonization and electrification of campus heating and cooling. It is noted that these actions are based on a centralized scenario approach. When a final scenario has been selected for advancement, phasing and sequencing would be developed specific to the scenario.

**Table 4. Low-carbon electrification phasing strategy**

| Cluster C and W (2025-2040) | Cluster E (2035-2045) | Cluster N and S (2040-2050) |
|---|---|---|
| • Remove Clusters C and W from the steam network<br>• Develop new Energy Center at Lee Hall and potential smaller centers in the western part of campus<br>  ◦ Establish borefields<br>  ◦ Ground source heat pumps<br>  ◦ Dry coolers<br>  ◦ Utilize central heating plant natural gas steam boilers as backup<br>  ◦ Potential ASHP<br>  ◦ Thermal energy storage tank<br>• Develop LTW network and connect to Energy Center<br>• Substation #1 electrical improvements<br>• Potential end of life building renovations/upgrades<br>• Targeted energy efficiency measures for entire campus | • Establish LTW network and connect to main LTW network<br>• Some building renovations/upgrades/hot water coil replacement<br>• Increase centralized energy center capacity to handle additional load of Cluster E | • Establish LTW network and connect Cluster N to main LTW network<br>• Increase centralized energy center capacity to handle additional load of Cluster N<br>• Develop energy center for cluster S<br>  ◦ Establish borefields<br>  ◦ Ground source heat pumps<br>  ◦ Dry coolers<br>  ◦ Potential ASHP<br>  ◦ Thermal energy storage tank<br>• Substation #2 electrical improvements<br>• Some building renovations/upgrades/ hot water coil replacement |

**Key Takeaways**

Table 5 provides a summary of important topics and associated aspects that surfaced during the planning process. These inform the complexities and challenges that will need to be considered and managed as part of the campus energy transition. These aspects intersect to influence and balance carbon reduction, energy efficiency, flexibility, resiliency, and redundancy in a pragmatic and cost-effective manner.

**Table 5. Key takeaways from the clean energy master planning process**

| Electrical Demand Impact | Natural Gas Peaking Benefits | Building Improvements | Infrastructure Scenarios | Emission Reduction |
|---|---|---|---|---|
| In all scenarios, the Substation #1 would need to be upgraded<br><br>Substation #2 would need to be upgraded in full-electrification scenarios<br><br>Significant emergency/stand-by power requirements, without nonelectric-based backup<br><br>High CAPEX with relatively small carbon emissions reduction to electrify peak load in addition to baseload<br><br>Connection of renewables from Hidden Fields to campus electric feeder loop has limitations | Flexibility<br><br>Redundancy for emergency<br><br>Bridging fuel-while electric utility infrastructure catches up<br><br>Manages capital spend<br><br>Future NYS plans of NG to renewable natural gas (RNG) and hydrogen<br><br>Reuse of existing infrastructure and backup power assets | Address steam use in buildings<br><br>Can buildings operate acceptably at lower supply temperatures? (coil replacements or load reductions)<br><br>Renovation approval and timing<br><br>Add cooling to non-cooled buildings/spaces<br><br>Hazardous materials impact | Piping material decisions – temperature and pressure<br><br>Centralized vs cluster<br><br>Property space needs for geothermal | 85% reduction is achievable without 100% electrification |

Figure 5 illustrates the forecasted GHG emissions ($CO_2e$) trend for the campus. 1990 GHG data was taken from the campus' 2012 Climate Action Plan (CAP). Scenario 4a was selected for illustrative purposes.FThe red line represents the forecasted emissions after energy efficiency and beneficial electrification is implemented. This trend shows that even when natural gas is used for peaking purposes, the campus can achieve greater than 85% reduction and would meet the CLCPA reduction goal.

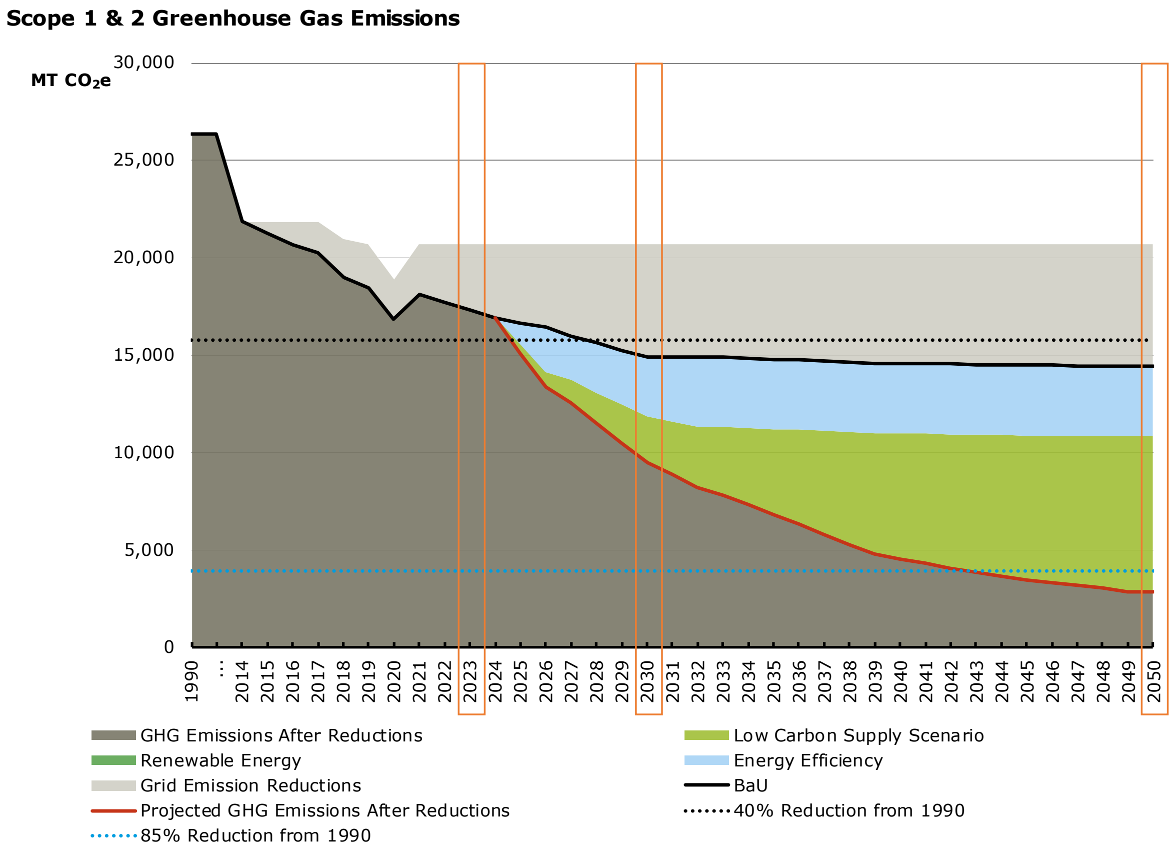



**Figure 5. Projected GHG emissions trend (Scenario 2a)**

## Recommended Next Steps

Ramboll has identified the following recommend next steps to help the campus prioritize enabling projects that can influence future systems designs and demonstrate progress towards campus goals.

1. Implement EEMs that will be cost effective within the time periods that buildings would benefit from the measure
2. Existing geothermal test bore studies previously conducted at the campus can be utilized to inform future borefield design
3. Establish detailed strategy to convert from steam to low temperature hot water, including distribution network piping and impact to specific buildings currently using steam directly
4. Establish a building strategy
   a. Install building level thermal submetering
      i. Most of the campus buildings have electric meters, but some may need to be calibrated or replaced
      ii. Install building-level steam meters
      iii. Submetering is required by BuildSmart 2025 for buildings greater than 25,000 GSF Buildings shall be submetered for all fuels and other energy sources including, but not limited to, electricity, natural gas, steam, chilled water, and oil
      iv. Clamp-on ultrasonic thermal submetering could be cost-efficient option to explore

   b. Monitor building level hot water data and explore lower building supply temperatures on the district loop during the heating season – refer to Section 5.3.3.2.
   c. Steam building conversion
      i. Direct uses need a transition plan
5. Monitor market developments and advancements in heat pump technology and US market availability
6. Some of the preceding recommendations should be completed to help the campus select a preferred scenario, or variation thereof, prior to beginning preliminary design.

# 1. Purpose, Drivers and Approach

### 1.1 Purpose

State University of New York College at Oswego (SUNY Oswego) is subject to New York State (NYS) mandates and SUNY administration directives for aggressive energy and carbon reduction targets, most notably the New York State Climate Leadership and Community Protection Act (CLCPA, also known as the Climate Law). The purpose of this project is to develop a Clean Energy Master Plan (CEMP) that aligns with the mandates and directives.

The intent of the CEMP is to create a vision for low carbon and renewable technologies and operational strategies to reduce fossil fuel use/dependency, increase electrification of utility operations, and maintain resiliency and reliability. This CEMP provides a roadmap for near-term actions and a decision-making framework for the long-term vision to achieve NYS energy efficiency and GHG reduction goals and set a path for carbon neutrality by 2050.

### 1.2 Drivers

A high-level summary of the mandates, energy and carbon reduction targets, and directives that SUNY Oswego is addressing includes the following:

| New York State Mandate | Goals/Targets |
|---|---|
| The Climate Leadership and Community Protection Act (CLCPA) | • Reduce statewide GHG emissions 40% by 2030 and 85% by 2050 (1990 baseline)<br>• 70% renewable energy grid by 2030<br>• 100% carbon free electricity by 2040 |
| Executive Order 22 (EO 22) | • By 2030, 100% of electricity use from renewable sources; see Clean Energy Standard "Eligible Systems"<br>• Beginning Jan 1, 2024, new permitted construction shall avoid infrastructure, building systems, or equipment that can be used to combust fossil fuels |
| BuildSmart 2025 (ties to New Efficiency New York and CLCPA) | • Reduce energy consumption by 11 trillion British thermal units (TBtu) by State Agencies by 2025<br>• 4.4 TBtu reduction assigned to SUNY System<br>• 146,332 MMBtu reduction goal assigned to SUNY Oswego<br>• Energy Master Plan every 5 years if annual utility bill is over $300,000<br>• ASHRAE Level 2 audits for state-owned buildings over 5,000 gross square feet (GSF) |

| SUNY and SUCF Directives/Drivers | Goals/Targets |
|---|---|
| SUCF Directive 1B-2 | • Commitment to clean energy<br>• Net zero carbon (NZC) new buildings<br>• Deep energy retrofits on existing buildings<br>• Energy use intensity (EUI) targets<br>• Replacement building systems and equipment must be electrically powered<br>• Onsite combustion of fossil fuels and biofuels is prohibited in new buildings and deep energy retrofits, except for emergency back-up power, emergency heat, and other special cases |

## 1.3 Approach

A key focus strategy was identifying a pragmatic and cost-effective approach to achieving the long-term goals of beneficial electrification while also bridging the short-term needs of critical capital improvements that would ultimately support the long-term campus goals. The key steps to develop the CEMP are illustrated in Figure 6. Completing these steps allowed for critical discussion around strategic focus areas including energy efficiency, resiliency, renewable energy, stewardship, and engagement.

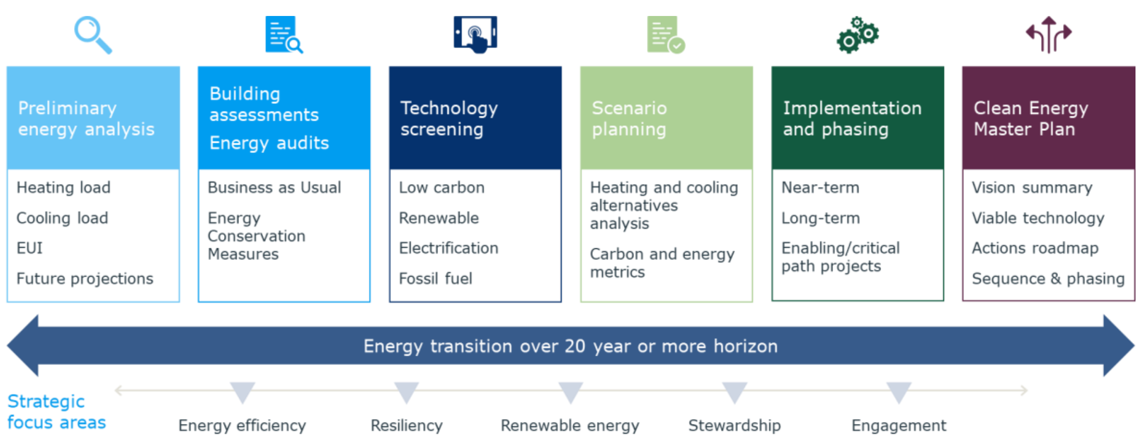



**Figure 6. Clean energy master planning key steps**

# 2. Campus Overview

## 2.1 Description

The SUNY Oswego main campus stretches over 700 acres on the shores of Lake Ontario in Oswego, New York. The campus includes many buildings, athletics fields, service roads and parking facilities.

A high-level summary of buildings and their heating and cooling aspects, as well as unique characteristics of the campus include the following:

- 70 structures – 3.5M GSF
- 54 buildings heated – 3.4M GSF
- 33 Centralized steam
- All buildings have steam to hot water heat exchangers
  - 21 Decentralized (geothermal, natural gas)
  - 38 buildings cooled – 2.3M GSF
  - 4 buildings (300k GSF) on the south side of campus are separated from the main campus by State Route 104

## 2.2 Energy infrastructure

**Central Heating Plant**

The majority of campus buildings are currently supplied with heat from the central heating plant (CHP) located in Lee Hall. The CHP is steam-based, providing steam to the campus buildings for space heating and domestic hot water heating. All buildings are furnished with hydronic heating systems that generate hot water from the steam distribution system through heat exchangers.

The CHP operates primarily on natural gas with No. 2 fuel oil as backup. Portions of the steam line shut down from approximately May 15th through October 1st, islanding buildings that normally generate DHW with steam. During the months the steam lines are dormant, DHW is produced locally for those buildings that otherwise receive steam from the CHP. Thus, the production of DHW in winter months and summer months are treated separately.

**Electrical**

SUNY Oswego receives electrical power from National Grid (through the SUNY Energy Buying Group) for the main campus accounting, which accounts for close to 90% of the annual electricity used at the campus. In addition, the campus has smaller emergency standby generators, many on natural gas.

**Metering**

**Electric:** Most building on campus have electric meters. The metering provides access to usage data at the building level for conditioned buildings. However, the meter readings were unreliable, or data did not exist for much of the buildings. Existing meters should be reviewed for accuracy and connections re-established; this assists with improved operational and scheduling efficiencies, as well as can help highlight the savings potential for energy efficiency measures (EEMs).

**Natural gas:** There are currently 14 natural gas meters on campus and 1 at the Fallbrook Recreation Center. Where feasible, additional sub-metering could assist with operational clarity leading to potential savings.

**Steam:** None of the buildings on campus have steam meters. Where feasible, additional sub-metering could assist with operational clarity leading to potential savings.

## 2.3 Modernization plans

Based on discussions with the campus and the 2013-2023 Facility Master Plan (FMP), the proposed renovation projects include:

- Complete Building Renovations
- Hewitt Hall (under renovation at the time of this study)
- Mahar Hall
- Penfield Library
- Lanigan Hall
- Seneca Hall (cooling to be added)
- Onondaga Hall (cooling to be added)
- Cayuga Hall (cooling to be added)
- Oneida Hall (cooling to be added)
- Adaptive Reuse
- Lonnis/Moreland/Mackin converted to academic buildings (with the addition of cooling)
- Littlepage Dining Hall converted to a student activities building
- Partial Renovation
- Laker Hall to add cooling to offices

# 3. Preliminary Energy Analysis

### 3.1 PEA methodology

Ramboll completed a Preliminary Energy-Use Analysis (PEA) of all buildings at the SUNY Oswego campus to establish current performance and energy savings potential. The PEA was done at two levels: a combined campus level and individual building level. Where available, building-level electric and natural gas meter data as well as campus level electric and natural gas utility billing summaries were provided for the three-year period of January 2018-December 2020. The baseline period for the PEA is three calendar years, with "Year 1" being January 1st, 2018 through December 31st, 2018, "Year 2" being January 1st, 2019 through December 31st, 2019, and "Year 3" being January 1st, 2020 through December 31st, 2020.

As part of the PEA, comparisons were made to peer benchmark buildings as defined in the 2012 Commercial Buildings Energy Consumption Survey (CBECS) database. Benchmark total energy use and end-use allocations for each building were identified based on data from the CBECS database. The percentage of floor area assigned to each CBECS category for each building was based on data provided by the campus and observations from the ASHRAE Level 1 walk-through survey. The energy use benchmark comparison for each building is based on a composite weighted average of the appropriate CBECS peer building types based on the corresponding space type floor area percentages.

Energy data was also disaggregated to estimate the energy allocated to major end uses including lighting, space heating, space cooling, fans, pumps, plug loads, domestic water heating, process equipment, cooking, and refrigeration. The end-use disaggregation is based on end-use data from the CBECS database for similar building types. Future energy use will also be estimated based on planned renovations and changes in building stock.

The fuels (energy inputs) consumed by the campus are electricity and natural gas. Electricity steam, winter DHW, and natural gas are consumed at the individual buildings. The energy use intensity (EUI) for the campus was calculated from utility data obtained through EnergyCAP.

The annual input energy of each fuel source was weather normalized. Regression models were developed from the utility data and actual weather for normalization to typical year weather conditions. Energy use data from Year 3 was excluded in regression calculations to avoid influences of COVID-19 on energy use. The future energy use scenario considers anticipated energy efficiency improvements and changes in building stock (renovations, additions, new buildings, and demolitions).

This section provides an overview of the energy analysis and benchmarking that was completed for the PEA. Table 6 summarizes key results of this PEA for SUNY Oswego over the time periods analyzed.

**Table 6. SUNY Oswego – energy profile summary**

| Year | Total Energy Consumption (MMBTU) | Peak Elec. Demand (kW) | Total Energy Cost (USD) | Total GHG Emissions (MT CO2e) |
|---|---|---|---|---|
| 1990[1] | - | - | - | 26,328 |
| FY2014-15[2] | 421,849 | 7,614 | $4,057,612 | 21,861 |
| 2018 | 405,288 | 8,086 | $3,273,689 | 18,980 |
| 2019 | 400,647 | 7,155 | $2,866,648 | 18,470 |
| 2020 | 364,651 | 6,854 | $2,279,796 | 16,857 |
| Weather Normalized[3] | 408,231 | 7,620 | $2,932,377 | 19,002 |

Notes:

1. 1990 GHG Baseline data from the 2012 Climate Action Plan (CAP)
2. State Fiscal Year FY2014-15 data is presented for comparison but was not part of this PEA. FY2014-15 is the baseline year for BuildSmart 2025.
3. Weather normalized data excluded data from 2020 in the regression to avoid influences of COVID-19 on energy use

## 3.2 Campus information

Table 7 lists each building located on the main campus and Table 8 lists other buildings used by SUNY Oswego that are geographically separate from the main campus. These tables indicate the CBECS building type and size of each building as well as its electric, heating and cooling sources.

**Table 7. Building information – main campus**

| Building | Building Type | GSF | Electric Source | Heating Source | Cooling Source |
|---|---|---|---|---|---|
| 0001 - SHELDON HALL | 100% College/university | 119,211 | 2 | 6 | Chiller |
| 0002 - J C PARK HALL | 100% College/university | 66,979 | 1 | 6 | Chiller |
| 0003 - CAMPUS CENTER | 100% College/university | 185,524 | 1 | 6 | Chiller |
| 003A - I POUCHER HALL | 100% College/university | 40,080 | 1 | 6 | Chiller |
| 003B - REC & CONVOCATION CTR | 100% College/university | 115,421 | 1 | 6 | Chiller |
| 003C - CC STORAGE BLDG | 100% Self-storage | 310 | 1 | N/A | N/A |
| 0004 - M V LEE HALL | 100% College/university | 65,000 | 1 | 6 | N/A |
| 004A - CENTRAL HEATING PLANT | 100% College/university | 21,980 | 1 | 6 | N/A |
| 0005 - SHADY SHORE | 100% Single-Family Detached | 8,754 | 1 | 5 | Heat Pump |
| 0005A - PRESIDENT GARAGE | 100% Self-storage | 576 | 1 | N/A | N/A |
| 0006 - J LANIGAN HALL | 100% College/university | 88,200 | 1 | 6 | Chiller |
| 0007 - J TYLER HALL | 100% College/university | 115,430 | 1 | 6 | Chiller |
| 0008 - RICHARD S SHINEMAN CENTER | 50% College/university 50% Laboratory | 235,860 | 1, 3 | 6 | Chiller |
| 0009 - WILBER HALL | 100% College/university | 108,933 | 1 | 6 | Chiller |
| 0010 - MARY WALKER HEALTH CENTER | 100% College/university | 33,260 | 1 | 6 | VRV |
| 0011 - COMMISSARY BLDG | 100% College/university | 30,836 | 1 | 5 | N/A |
| 0012 - MAINTENANCE BLDG | 100% College/university | 20,664 | 1 | 5 | N/A |
| 0013 - M E MAHAR HALL | 100% College/university | 91,530 | 1 | 6 | Chiller |
| 0014 - RICH HALL | 100% College/university | 53,742 | 1 | 6 | Chiller |
| 0015 - MACKIN HALL | 100% Dormitory/ fraternity/sorority | 41,984 | 1 | 6 | N/A |

| Building | Building Type | GSF | Electric Source | Heating Source | Cooling Source |
|---|---|---|---|---|---|
| 015A - MORELAND HALL | 100% Dormitory/ fraternity/sorority | 29,400 | 1 | 6 | N/A |
| 015B - LONIS HALL | 100% Dormitory/ fraternity/sorority | 32,285 | 1 | 6 | N/A |
| 0016 - OBSERVATORY | 100% College/university | 460 | 1 | N/A | N/A |
| 0017 - J PENFIELD LIB | 100% College/university | 192,298 | 1 | 6 | Chiller |
| 0019 - LAKER HALL | 100% College/university | 196,608 | 1 | 5 | N/A |
| 0020 - GAR-20 | 100% College/university | 14,850 | 1 | 5 | RTU |
| 0021 - ROMNEY FIELD HOUSE | 100% Recreation | 55,000 | 2 | 5 | N/A |
| 0022 - KING HALL | 100% College/university | 7,200 | 2 | 5 | N/A |
| 0026 - CULKIN HALL | 100% College/university | 63,591 | 1 | 6 | Chiller |
| 0028 - SEWAGE PUMP STATION | 100% College/university | 1,881 | 1 | N/A | N/A |
| 0028A - SEWAGE PUMP STATION - SENECA | 100% College/university | 211 | 1 | N/A | N/A |
| 0028B - SEWAGE PUMP STATION - BLG 12 | 100% College/university | 224 | 1 | N/A | N/A |
| 0029 - HEWITT HALL | 100% College/university | 135,010 | 1 | 6 | Chiller |
| 0031 - PATHFINDER DH | 100% Restaurant/cafeteria | 33,827 | 1 | 4 | Chiller |
| 0032 - SENECA HALL | 100% Dormitory/ fraternity/sorority | 152,548 | 1 | 7 | N/A |
| 0033 - CAYUGA HALL | 100% Dormitory/ fraternity/sorority | 105,072 | 1 | 7 | N/A |
| 0034 - ONONDAGA HALL | 100% Dormitory/ fraternity/sorority | 152,548 | 1 | 6 | N/A |
| 0035 - LITTLEPAGE DH | 100% Restaurant/cafeteria | 33,827 | 1 | 6 | Chiller |
| 0036 - ONEIDA HALL | 100% Dormitory/ fraternity/sorority | 105,000 | 1 | 6 | N/A |
| 0037A - TOWNHOUSE A | 100% Dormitory/ fraternity/sorority | 10,260 | 1 | 5 | Chiller |
| 0037B - TOWNHOUSE B | 100% Dormitory/ fraternity/sorority | 8,082 | 1 | 5 | Chiller |
| 0037C - TOWNHOUSE C | 100% Dormitory/ fraternity/sorority | 12,599 | 1 | 5 | Chiller |
| 0037D - TOWNHOUSE D | 100% Dormitory/ fraternity/sorority | 12,599 | 1 | 5 | Chiller |
| 0037E - TOWNHOUSE E | 100% Dormitory/ fraternity/sorority | 15,880 | 1 | 5 | Chiller |
| 0037F - TOWNHOUSE F | 100% Dormitory/ fraternity/sorority | 18,295 | 1 | 5 | Chiller |
| 0037G - TOWNHOUSE G | 100% Dormitory/ fraternity/sorority | 8,082 | 1 | 5 | Chiller |
| 0037H - TOWNHOUSE H | 100% Dormitory/ fraternity/sorority | 10,260 | 1 | 5 | Chiller |
| 0037I - TOWNHOUSE I | 100% Dormitory/ fraternity/sorority | 12,599 | 1 | 5 | Chiller |
| 0037J - TOWNHOUSE J | 100% Dormitory/ fraternity/sorority | 12,599 | 1 | 5 | Chiller |
| 0037K - TOWNHOUSE K | 100% Dormitory/ fraternity/sorority | 16,729 | 1 | 5 | Chiller |
| 0037L - TOWNHOUSE L | 100% Dormitory/ fraternity/sorority | 12,567 | 1 | 5 | Chiller |
| 0041 - JOHNSON HALL | 100% Dormitory/ fraternity/sorority | 79,097 | 1 | 6 | Chiller |
| 0042 - LAKESIDE DH | 100% Restaurant/cafeteria | 27,870 | 1 | 6 | Chiller |
| 0043 - RIGGS HALL | 100% Dormitory/ fraternity/sorority | 58,201 | 1 | 6 | Chiller |
| 0044 - WATERBURY HALL | 100% Dormitory/ fraternity/sorority | 57,464 | 1 | 6 | N/A |
| 0045 - SCALES HALL | 100% Dormitory/ fraternity/sorority | 57,464 | 1 | 6 | N/A |

| Building | Building Type | GSF | Electric Source | Heating Source | Cooling Source |
|---|---|---|---|---|---|
| 0046 - HART HALL | 100% Dormitory/ fraternity/sorority | 114,365 | 1 | 6 | N/A |
| 0047 - COOPER DH | 100% Restaurant/cafeteria | 33,546 | 1 | 6 | Chiller |
| 0048 - FUNNELLE HALL | 100% Dormitory/ fraternity/sorority | 114,365 | 1 | 6 | N/A |
| 0049 - PUBLIC RESTROOM | 100% Other service | 160 | 1 | N/A | N/A |
| 0051 - FM RADIO TRANSMISSION FAC | 100% Other service | 440 | 2 | N/A | N/A |
| 0061 - MAINTENANCE STORAGE | 100% Self-storage | 100 | 1 | N/A | N/A |
| 0082 - PRESS BOX | 100% College/university | 495 | 1 | N/A | N/A |
| 0104 - SECURITY PARKING OFFICE | 100% Office | 2,297 | 2 | 5 | RTU |
| 0106 - VOLATILE STO | 100% Self-storage | 400 | 1 | N/A | N/A |
| 0107 - 1 ROOM SCHOOL HSE | 100% Office | 550 | 1 | 6 | N/A |
| 0108 - POWER STATION 1 | 100% Other service | 216 | 1 | N/A | N/A |
| 0109 - POWER STATION 1A | 100% Other service | 175 | 1 | N/A | N/A |
| 0110 - POWER STATION 2 | 100% Other service | 177 | 1 | N/A | N/A |
| **Total** | **SUNY Oswego Main Campus** | **3,454,048** | **-** | **-** | **-** |

**Table 8. Building Information - off campus**

| Building | Building Type | GSF | Electric Source | Heating Source | Cooling Source |
|---|---|---|---|---|---|
| 0023A - RICE CREEK FIELD STATION | 100% College/university | 7,500 | 2, 3 | VRF | VRF |
| 0024A - BIO FIELD GARAGE | 100% Self-storage | 960 | 2, 3 | N/A | N/A |
| 0081 - RICE CREEK OBSERVATORY | 100% College/university | 550 | 2, 3 | N/A | N/A |
| 0083 - RICE CREEK PAVILION | 100% College/university | 893 | 2, 3 | N/A | N/A |
| FALLBROOK REC CENTER | 100% College/university | 17,167 | -- | 5 | Heat Pump |
| 0071 - POLE BARN (FALLBROOK) | 100% Other service | 17,369 | -- | N/A | N/A |
| **Total** | **SUNY Oswego Off Campus** | **44,439** | **--** | **--** | **--** |

Notes:

1. Electric service from main campus electric service
2. Electric service provided by National Grid utility meter
3. Portion of electricity provided by photovoltaic system
4. Natural gas supplied to the building from main campus natural gas service
5. Natural gas supplied to the building by National Grid utility meter
6. Steam supplied from Central Heating Plant
7. Steam supplied from Pathfinder Dining Hall boiler

### 3.2.1 Utility prices

SUNY Oswego's electricity for the main campus is delivered by National Grid and supplied by the SUNY Energy Buying Group. The National Grid main electric meter accounts for 90% of the electricity used by campus annually. The remaining 10% is from smaller National Grid electric meters on the main campus and buildings off campus.

Natural gas is delivered by National Grid and supplied by NRG Energy, Inc. There are approximately 14 natural gas service accounts in addition to the main gas account for the central heating plant.

Table 9 shows the baseline utility rates by major component. Electric and natural gas fixed monthly costs as well as electric reactive power charges are included in the delivery charges.

**Table 9. Baseline annual average utility prices**

| Fuel | Supply | Delivery | Demand | Total |
|---|---|---|---|---|
| Electricity[1] | $0.035/kWh | $0.009/kWh | $3.903/kW | $0.051/kWh |
| Natural Gas[2] | $0.263/Therm | $0.112/Therm | -- | $0.375/Therm |
| CHP Natural Gas[3] | $0.269/Therm | $0.084/Therm | -- | $0.353/Therm |

Notes:

1. Based on 36-month cost data for all electric accounts
2. Based on 36-month cost data for all natural gas accounts except the Central Heating Plant account
3. Based on 36-month cost data for the main campus gas account (Central Heating Plant account)

### 3.2.2 $CO_2$ emissions

The $CO_2$ equivalent ($CO_2e$) emission factors from all campus fuels are shown in Table 10. The factors were provided by SUNY System Administration.

**Table 10. Emission factors**

| $CO_2e$ Emissions | 2022 | 2030 | 2040 |
|---|---|---|---|
| Electricity[1] | 0.00009573 MT/kWh | 0 MT/kWh | 0 MT/kWh |
| Natural Gas[2] | 0.005311 MT/Therm | 0.005311 MT/Therm | 0.005311 MT/Therm |

Notes:

1. Electric emissions are based off eGrid 2020 values for NYUP subregion. 2022 value is interpolated assuming zero-emission purchased electricity in 2030, per EO22
2. EPA Emissions Factors for GHG Inventories https://www.epa.gov/.../documents/emission-factors_apr2021.pdf

### 3.2.3 Heating values

The heating value for electricity and fossil fuels used on campus is presented in Table 11.

**Table 11. Heating value**

| Fuel | Heating Value | Units |
|---|---|---|
| Electricity | 3,412 | Btu/kWh |
| Natural Gas | 100,000 | Btu/Therms |

## 3.3 Portfolio energy performance

A campus level PEA was developed based on utility data. Key performance indicators (KPIs), such as annual EUI (kBtu/SF), energy cost intensity (ECI; $/SF), and peak demand intensity (W/SF), are presented in Table 12 along with the Weather Normalized Baseline, and the Weighted Average CBECS Benchmark. Fiscal year 2014-2015 (FY14/15), the baseline year for BuildSmart 2025, is presented for comparison.

**Table 12. Overall KPI comparison**

| Data Set | Site EUI (kBtu/SF) | ECI ($/SF) | Peak Demand Intensity (W/SF) |
|---|---|---|---|
| FY14/15[1] | 120.6 | $1.16 | 2.18 |
| 2018 | 115.8 | $0.94 | 2.31 |
| 2019 | 114.5 | $0.82 | 2.04 |
| 2020 | 104.2 | $0.65 | 1.96 |
| Weather Normalized Baseline | 116.6 | $0.84 | 2.18 |
| CBECS Weighted Benchmark | 100.0 | $0.95 | -- |

Notes:

1. EUI calculated using data from EnergyCap for FY14/15.

Figure 7 shows a year-to-year comparison of EUI by fuel source along with the weather normalized baseline and Weighted CBECS Benchmark. FY14/15 is presented for comparison. The FY14/15 breakout by fuel type was estimated using data from EnergyCap.

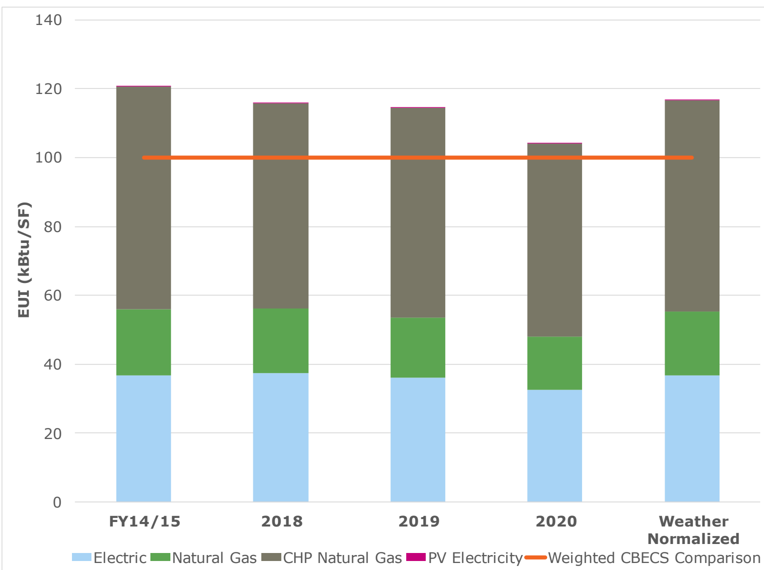



**Figure 7. EUI comparison**

Figure 8 through Figure 11 present weather normalized energy use, cost, and emissions by fuel type for all buildings in the SUNY Oswego portfolio. Figure 8 shows about 69% of the campus energy use is from fossil fuels, and the remaining 31% is from electricity. Of the fossil fuel use, about 92% is for space heating and water heating, with the remaining 8% for cooking, as shown in Figure 9. Of the electric use, about 24% falls under the CBECS "miscellaneous" category, which includes televisions, personal computers, security systems, data center servers, laboratory equipment, and other end uses not accounted for.

Figure 10 and Figure 11 illustrate that while electricity is the largest contributor to campus utility costs, natural gas has the highest energy use and also accounts for about 77% of the emissions. Beneficial electrification will provide significant energy savings and emission reduction but may increase the overall utility costs, depending on the efficiency of the electrification technology.

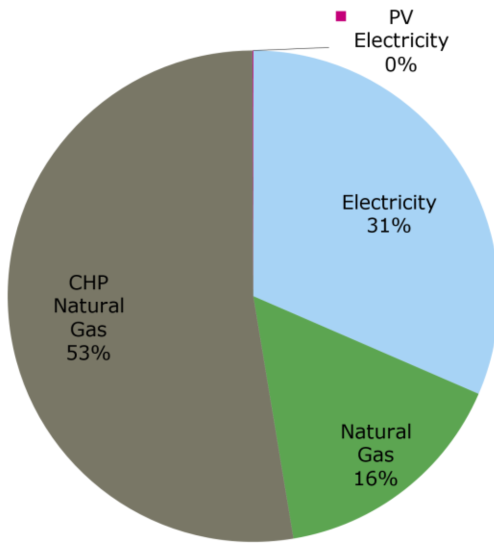



**Figure 8. Energy use by fuel type**

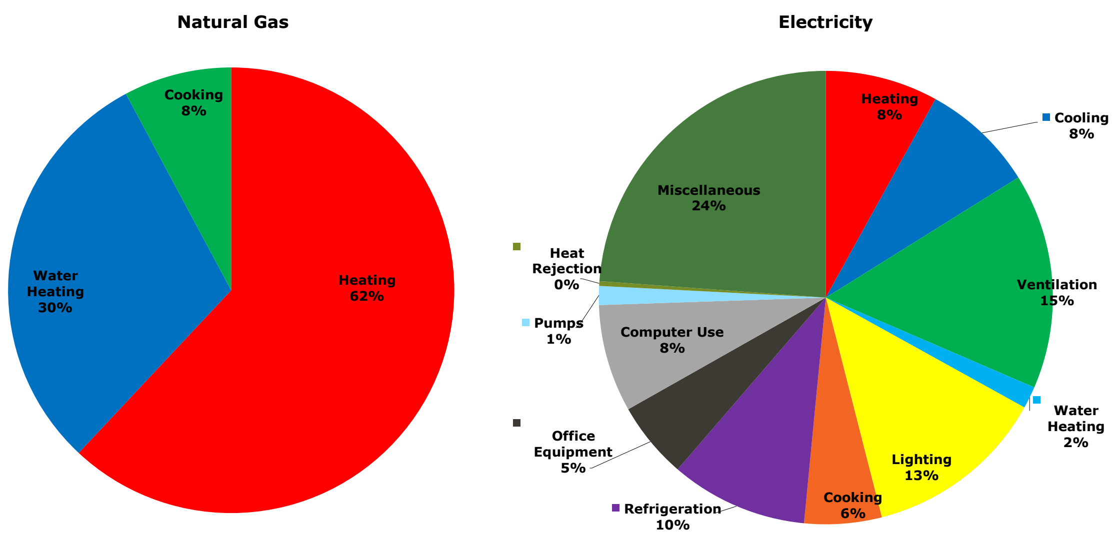



**Figure 9. End use energy**

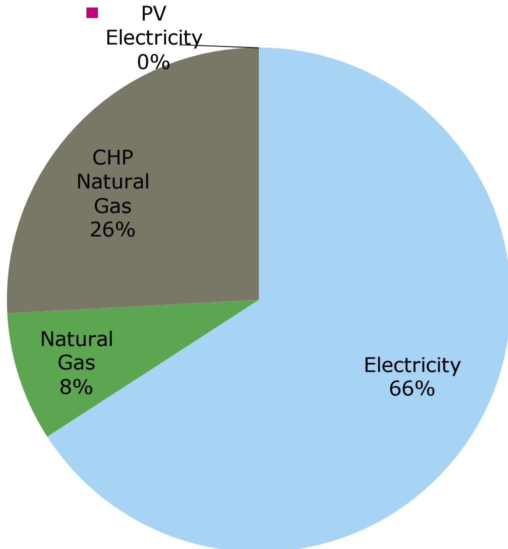



Figure 10. Cost by fuel source

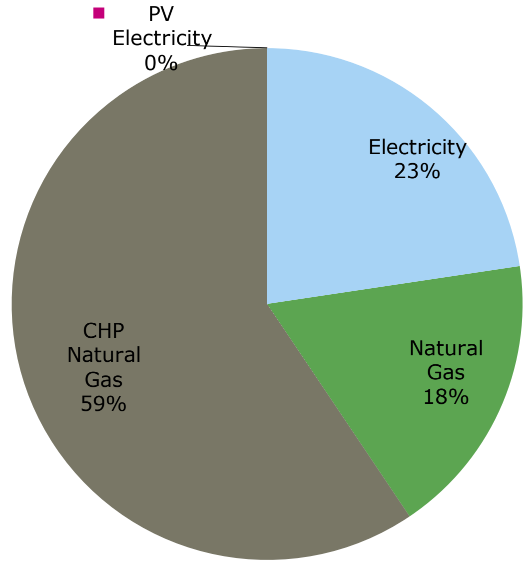



Figure 11. Emissions by fuel source

Appendix A includes more detailed information and monthly profiles for each fuel source. Data include monthly energy and cost for each year as well as an average of the years and a weather-normalized year. Additional KPIs and monthly energy use, demand, and cost were charted and analyzed for each fuel source. Data are also depicted in bar charts along with end use allocation estimates.

### 3.4 Building level current energy performance (benchmarking)

Table 13and Table 14 present the results of the PEA and benchmarking analysis for individual buildings on the main campus and other buildings, respectively. Building EUIs presented are weather normalized and calculated based on available meter data.

Table 13. Building energy consumption comparison to CBECS peer benchmark – main campus

| Building | CBECS Building Type | GSF | EUI[a] (kBtu/SF) | CBECS EUI (kBtu/SF) | Notes |
|---|---|---|---|---|---|
| 0001 - SHELDON HALL | 30% College/university<br>50% Office<br>20% Recreation | 119,211 | 92.1 | 96.4 | 1 |
| 0002 - J C PARK HALL | 60% College/university<br>40% Office | 66,979 | 132.9 | 112.0 | 2 |
| 0003 - CAMPUS CENTER | 30% College/university<br>30% Office<br>15% Recreation<br>25% Restaurant/cafeteria | 185,524 | 184.4 | 150.3 | 2 |
| 003A - I POUCHER HALL | 75% College/university<br>25% Office | 40,080 | 147.9 | 118.5 | 2 |
| 003B - REC & CONVOCATION CTR | 100% College/university | 115,421 | 173.9 | 127.5 | 2 |
| 003C - CC STORAGE BLDG | 100% Self-storage | 310 | 2.8 | 3.8 | 2 |

| Building | CBECS Building Type | GSF | EUI[a] (kBtu/SF) | CBECS EUI (kBtu/SF) | Notes |
|---|---|---|---|---|---|
| 0004 - M V LEE HALL | 10% Office<br>90% Recreation | 65,000 | 83.2 | 67.5 | 2 |
| 004A - CENTRAL HEATING PLANT | 5% Office<br>95% Other service | 21,980 | 55.3 | 47.1 | 2 |
| 0005 - SHADY SHORE | 100% Single-Family Detached | 8,754 | 60.9 | 42.9 | 2 |
| 0005A - PRESIDENT GARAGE | 100% Self-storage | 576 | 2.8 | 3.8 | 2 |
| 0006 - J LANIGAN HALL | 80% College/university<br>10% Office<br>5% Restaurant/cafeteria<br>5% Other service | 88,200 | 164.1 | 129.4 | 2 |
| 0007 - J TYLER HALL | 50% College/university<br>10% Office<br>10% Recreation<br>30% Other service | 115,430 | 121.0 | 94.6 | 2 |
| 0008 - RICHARD S SHINEMAN CENTER | 30% College/university<br>20% Office<br>5% Restaurant/cafeteria<br>30% Laboratory<br>15% Other service | 235,860 | 112.1 | 146.8 | 2 |
| 0009 - WILBER HALL | 40% College/university<br>40% Office<br>20% Other service | 108,933 | 110.5 | 95.5 | 2 |
| 0010 - MARY WALKER HEALTH CENTER | 5% College/university<br>40% Office<br>15% Self-storage<br>40% Other service | 33,260 | 65.5 | 60.9 | 2 |
| 0011 - COMMISSARY BLDG | 10% Office<br>40% Self-storage<br>50% Restaurant/cafeteria | 30,836 | 172.8 | 157.8 | 2 |
| 0012 - MAINTENANCE BLDG | 30% Office<br>10% Self-storage<br>60% Other service | 20,664 | 40.4 | 52.3 | 2 |
| 0013 - M E MAHAR HALL | 50% College/university<br>40% Office<br>10% Other service | 91,530 | 120.4 | 103.8 | 2 |
| 0014 - RICH HALL | 55% College/university<br>40% Office<br>5% Restaurant/cafeteria | 53,742 | 141.9 | 120.5 | 2 |
| 0015 - MACKIN HALL | 30% College/university<br>5% Dormitory/fraternity/sorority<br>15% Office<br>25% Self-storage<br>25% Restaurant/cafeteria | 41,984 | 171.2 | 129.1 | 2 |
| 015A - MORELAND HALL | 90% Dormitory/fraternity/sorority<br>10% Self-storage | 29,400 | 103.3 | 80.9 | 2 |
| 015B - LONIS HALL | 95% Dormitory/fraternity/sorority<br>5% Self-storage | 32,285 | 108.4 | 85.0 | 2 |
| 0016 - OBSERVATORY | 100% College/university | 460 | 40.7 | 56.6 | 2 |

| Building | CBECS Building Type | GSF | EUI[a] (kBtu/SF) | CBECS EUI (kBtu/SF) | Notes |
|---|---|---|---|---|---|
| 0017 - J PENFIELD LIB | 10% College/university<br>10% Office<br>15% Self-storage<br>5% Restaurant/cafeteria<br>60% Library | 192,298 | 94.5 | 87.0 | 2 |
| 0019 - LAKER HALL | 5% Office<br>90% Recreation<br>5% Self-storage | 196,608 | 87.8 | 63.9 | 2 |
| 0020 - GAR-20 | 20% Office<br>50% Self-storage<br>30% Other service | 14,850 | 76.1 | 35.6 | 2 |
| 0021 - ROMNEY FIELD HOUSE | 95% Recreation<br>5% Self-storage | 55,000 | 229.9 | 63.2 | 1 |
| 0022 - KING HALL | 90% Office<br>10% Self-storage | 7,200 | 67.6 | 73.7 | 1 |
| 0026 - CULKIN HALL | 95% Office<br>5% Self-storage | 63,591 | 33.5 | 82.2 | 2 |
| 0028 - SEWAGE PUMP STATION | 100% Other service | 1,881 | 20.0 | 27.8 | 2 |
| 0028A - SEWAGE PUMP STATION - SENECA | 100% Other service | 211 | 20.0 | 27.8 | 2 |
| 0028B - SEWAGE PUMP STATION - BLG 12 | 100% Other service | 224 | 20.0 | 27.8 | 2 |
| 0029 - HEWITT HALL | 35% College/university<br>40% Office<br>5% Recreation<br>20% Other service | 135,010 | 106.9 | 92.7 | 2 |
| 0031 - PATHFINDER DH | 30% Office<br>20% Self-storage<br>50% Restaurant/cafeteria | 33,827 | 223.9 | 177.1 | 2 |
| 0032 - SENECA HALL | 95% Dormitory/fraternity/sorority<br>5% Self-storage | 152,548 | 101.1 | 85.0 | 2 |
| 0033 - CAYUGA HALL | 95% Dormitory/fraternity/sorority<br>5% Self-storage | 105,072 | 102.4 | 85.0 | 2 |
| 0034 - ONONDAGA HALL | 95% Dormitory/fraternity/sorority<br>5% Self-storage | 152,548 | 103.9 | 85.0 | 2 |
| 0035 - LITTLEPAGE DH | 5% Other service<br>5% Office<br>35% Recreation<br>10% Self-storage<br>45% Restaurant/cafeteria | 33,827 | 198.6 | 167.6 | 2 |
| 0036 - ONEIDA HALL | 90% Dormitory/fraternity/sorority<br>10% Self-storage | 105,000 | 99.0 | 80.9 | 2 |
| 0037A - TOWNHOUSE A | 100% Dormitory/fraternity/sorority | 10,260 | 65.1 | 90.7 | 2 |
| 0037B - TOWNHOUSE B | 95% Dormitory/fraternity/sorority<br>5% Self-storage | 8,082 | 63.8 | 86.6 | 2 |

| Building | CBECS Building Type | GSF | EUI[a] (kBtu/SF) | CBECS EUI (kBtu/SF) | Notes |
|---|---|---|---|---|---|
| 0037C - TOWNHOUSE C | 100% Dormitory/fraternity/sorority | 12,599 | 65.1 | 90.7 | 2 |
| 0037D - TOWNHOUSE D | 100% Dormitory/fraternity/sorority | 12,599 | 65.1 | 90.7 | 2 |
| 0037E - TOWNHOUSE E | 100% Dormitory/fraternity/sorority | 15,880 | 65.1 | 90.7 | 2 |
| 0037F - TOWNHOUSE F | 75% Dormitory/fraternity/sorority<br>5% Office<br>20% Library | 18,295 | 64.9 | 88.7 | 2 |
| 0037G - TOWNHOUSE G | 95% Dormitory/fraternity/sorority<br>5% Self-storage | 8,082 | 71.3 | 86.6 | 2 |
| 0037H - TOWNHOUSE H | 100% Dormitory/fraternity/sorority | 10,260 | 72.6 | 90.7 | 2 |
| 0037I - TOWNHOUSE I | 100% Dormitory/fraternity/sorority | 12,599 | 72.4 | 90.7 | 2 |
| 0037J - TOWNHOUSE J | 100% Dormitory/fraternity/sorority | 12,599 | 72.6 | 90.7 | 2 |
| 0037K - TOWNHOUSE K | 100% Dormitory/fraternity/sorority | 16,729 | 72.4 | 90.7 | 2 |
| 0037L - TOWNHOUSE L | 100% Dormitory/fraternity/sorority | 12,567 | 72.6 | 90.7 | 2 |
| 0041 - JOHNSON HALL | 95% Dormitory/fraternity/sorority<br>5% Self-storage | 79,097 | 103.1 | 86.6 | 2 |
| 0042 - LAKESIDE DH | 20% Office<br>30% Self-storage<br>50% Restaurant/cafeteria | 27,870 | 216.1 | 169.3 | 2 |
| 0043 - RIGGS HALL | 100% Dormitory/fraternity/sorority | 58,201 | 109.4 | 90.7 | 2 |
| 0044 - WATERBURY HALL | 100% Dormitory/fraternity/sorority | 57,464 | 107.4 | 89.0 | 2 |
| 0045 - SCALES HALL | 100% Dormitory/fraternity/sorority | 57,464 | 107.4 | 89.0 | 2 |
| 0046 - HART HALL | 100% Dormitory/fraternity/sorority | 114,365 | 120.8 | 89.0 | 2 |
| 0047 - COOPER DH | 25% Recreation<br>25% Self-storage<br>50% Restaurant/cafeteria | 33,546 | 219.3 | 168.4 | 2 |
| 0048 - FUNNELLE HALL | 95% Dormitory/fraternity/sorority<br>5% Office | 114,365 | 119.5 | 88.6 | 2 |
| 0049 - PUBLIC RESTROOM | 100% Other service | 160 | 20.0 | 27.8 | 2 |
| 0051 - FM RADIO TRANSMISSION FAC | 100% Other service | 440 | 2,167.8 | 27.8 | 2 |
| 0061 - MAINTENANCE STORAGE | 100% Self-storage | 100 | 2.8 | 3.8 | 2 |
| 0082 - PRESS BOX | 100% Other service | 495 | 20.0 | 27.8 | 2 |

| Building | CBECS Building Type | GSF | EUI[a] (kBtu/SF) | CBECS EUI (kBtu/SF) | Notes |
|---|---|---|---|---|---|
| 0104 - SECURITY PARKING OFFICE | 100% Office | 2,297 | 165.1 | 86.0 | 1 |
| 0106 - VOLATILE STO | 100% Self-storage | 400 | 2.8 | 3.8 | 2 |
| 0107 - 1 ROOM SCHOOL HSE | 100% College/university | 550 | 40.3 | 62.0 | 2 |
| 0108 - POWER STATION 1 | 100% Other service | 216 | 20.0 | 27.8 | 2 |
| 0109 - POWER STATION 1A | 100% Other service | 175 | 20.0 | 27.8 | 2 |
| 0110 - POWER STATION 2 | 100% Other service | 177 | 20.0 | 27.8 | 2 |

**Table 14. Building energy consumption comparison to CBECS peer benchmark – other buildings**

| Building | CBECS Building Type | GSF | EUI[a] (kBtu/SF) | CBECS EUI (kBtu/SF) | Notes |
|---|---|---|---|---|---|
| 0023A - RICE CREEK FIELD STATION | 60% College/university<br>15% Office<br>20% Laboratory<br>5% Self-storage | 7,500 | 132.8 | 136.9 | 2 |
| 0024A - BIO FIELD GARAGE | 100% Self-storage | 960 | 3.4 | 3.8 | 2 |
| 0081 - RICE CREEK OBSERVATORY | 100% College/university | 550 | 49.5 | 56.6 | 2 |
| 0083 - RICE CREEK PAVILION | 100% College/university | 893 | 49.5 | 56.6 | 2 |
| FALLBROOK REC CENTER | 15% College/university<br>10% Office<br>50% Recreation<br>25% Library | 17,167 | 28.5 | 45.2 | 1 |
| 0071 - POLE BARN (FALLBROOK) | 100% Recreation | 17,369 | 18.0 | 25.0 | 2 |

[a]Weather normalized EUI

Notes:

1. EUI calculated based on utility meter data
2. EUI estimated

Figure 12 and Figure 13 show the estimated annual total energy use and EUI, respectively, for each building by input fuel. The black line represents the relevant benchmark for each building.

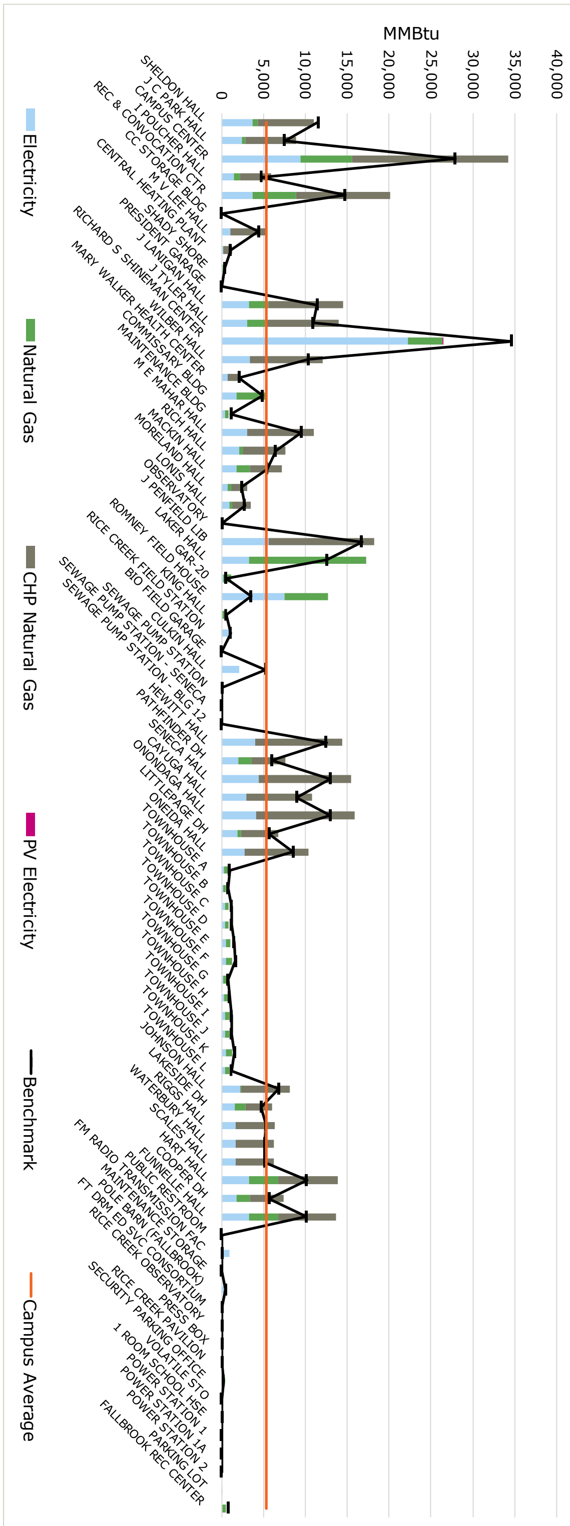



**Figure 12. Building level energy use by fuel, including benchmark comparison**

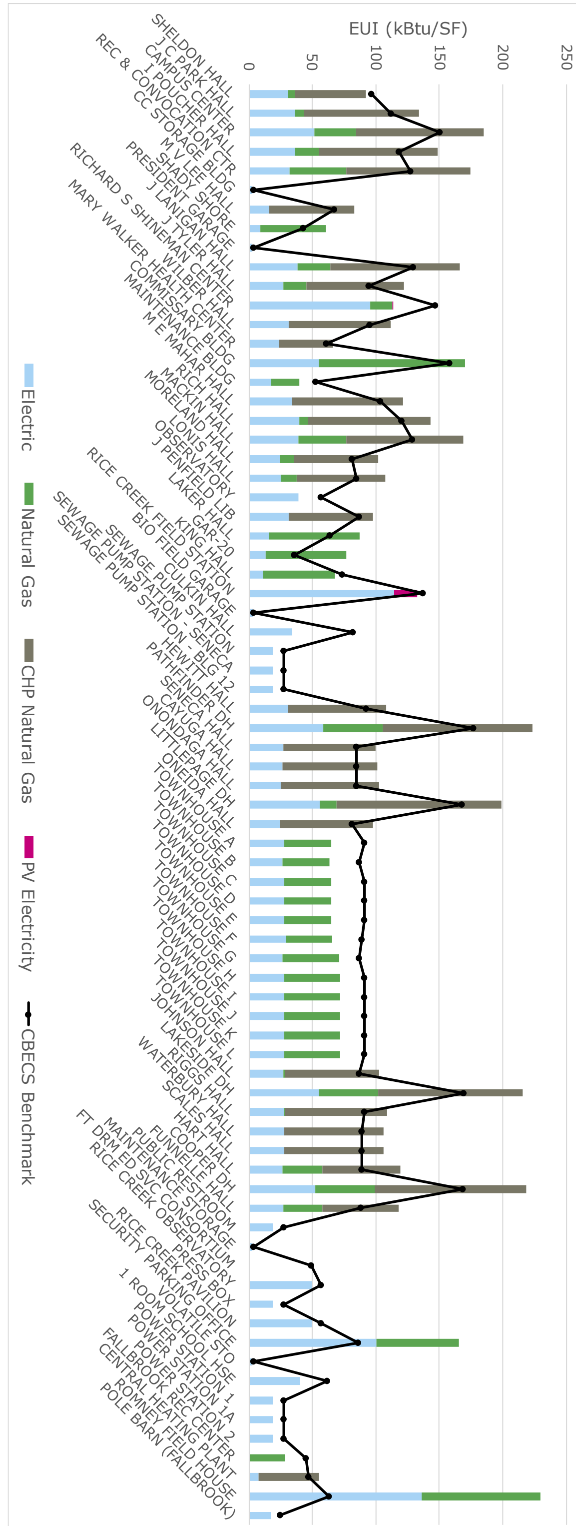



**Figure 13. Building EUI by fuel, including benchmark comparison**

## 3.5 Central heating plant

Natural gas is used at the central heating plant to generate steam. Figure 14 shows monthly natural gas use and steam generation at the plant. The efficiency of steam generation at the plant averages about 67%.

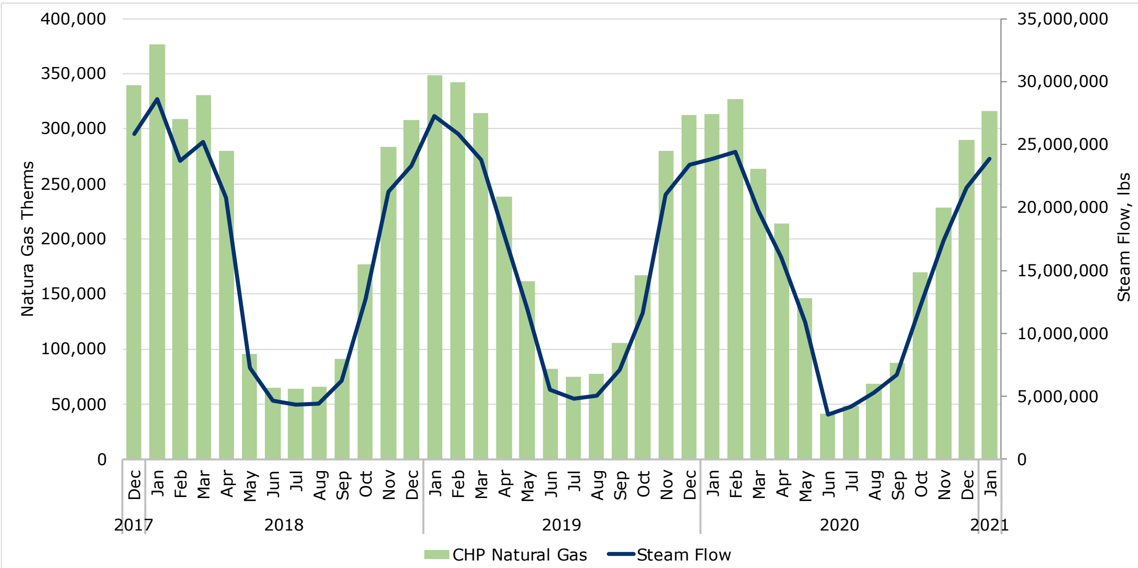



**Figure 14. Central heating plant natural gas use**

Daily steam flow was plotted against heating and cooling degree days and presented in Figure 15. The data shows that the steam production decreases linearly in relation to increasing outdoor air temperature until about 55°F to 60°F. above this inflection point, the steam production is constant, which represents the baseload for any summer domestic hot water loads, building reheat loads, and losses in the steam lines.

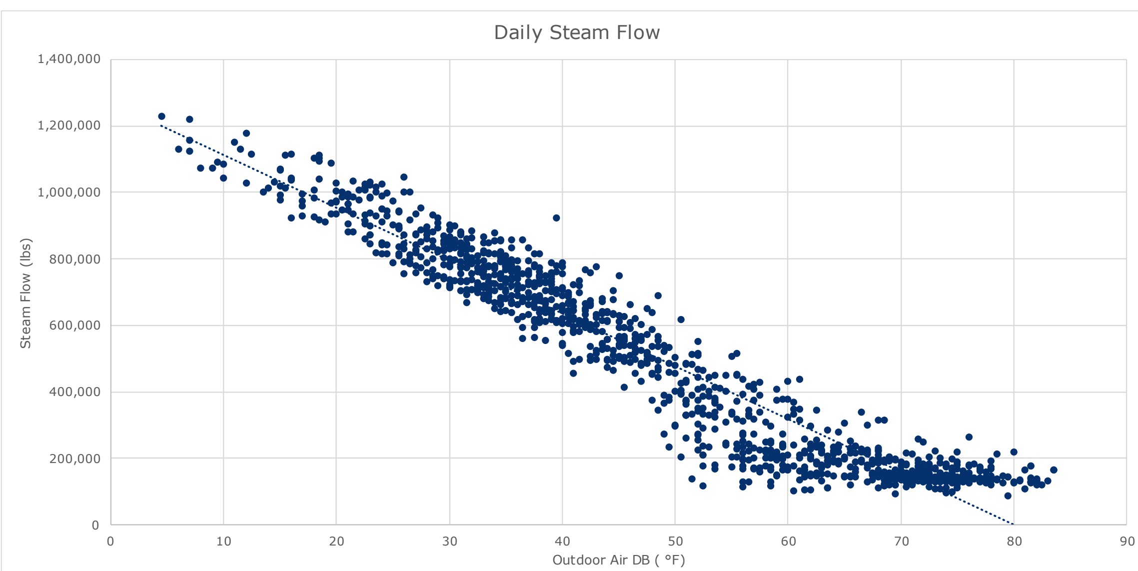



**Figure 15. Steam flow versus outdoor air dry-bulb temperature**

# 4. Campus Energy Assessment

## 4.1 Energy audit methodology

A comprehensive energy assessment was performed so that SUNY Oswego could better ascertain the current state of energy-related matters at the campus, and to identify energy efficiency measures (EEMs) that could be implemented.

### 4.1.1 Building walk-through survey and gap analysis

An ASHRAE Level 1 walk-through survey was performed at the campus. This effort focused on assessing existing conditions and evaluating current energy consumption profiles following methodologies outlined in ASHRAE's *Procedures for Commercial Building Energy Audits, Second Edition*.

The field survey of the buildings listed in Table 15 was conducted from January 12 through February 24, 2022. After meeting with facility staff to review building systems and operations, walk-throughs of mechanical rooms were conducted to assess the physical condition of the systems present. A representative sampling of occupied spaces was also surveyed and observations regarding the condition of building envelope components, electrical plug loads, and other energy systems were recorded. Interior and exterior lighting systems were surveyed to observe general lighting fixture types, lighting levels, and control systems present. Survey observations and general building conditions encountered by the audit team were documented in a Building Assessment (BA) report, which is provided in Appendix B. Based on the on-site walk-through, potential opportunities for reducing energy consumption were identified to support GHG and energy reduction goals. The BA includes a listing of potential energy saving opportunities in the subject building. Additionally, a matrix was developed listing the potential EEMs identified for each building, which is also provided in Appendix B.

In addition to walking through the buildings, interviews were conducted with facilities and maintenance staff to identify potential opportunities and deficiencies that might not be revealed through a physical survey. Facility staff provided their observations and perspective on the operation of the building and its energy systems, which enhanced the understanding of special problems, planned improvements, and maintenance issues and/or practices that impact energy usage.

**Table 15. Level 1 walk-through survey**

| Building | Primary Use | Year Constructed | Building Area (GSF) |
|---|---|---|---|
| 0001 SHELDON HALL | ACADEMIC | 1912 | 119,211 |
| 0002 J C PARK HALL | ACADEMIC | 1933 | 66,979 |
| 0003 CAMPUS CENTER | ACADEMIC | 1963 | 185,524 |
| 0004 M V LEE HALL | ACADEMIC | 1958 | 65,000 |
| 0005 SHADY SHORE | RESIDENTIAL | 1909 | 8,754 |
| 0006 J LANIGAN HALL | ACADEMIC | 1967 | 88,200 |
| 0007 J TYLER HALL | ACADEMIC | 1968 | 115,430 |
| 0008 RICHARD S SHINEMAN CENTER | LABORATORY | 2013 | 235,860 |

| Building | Primary Use | Year Constructed | Building Area (GSF) |
|---|---|---|---|
| 0009 WILBER HALL | ACADEMIC | 1964 | 108,933 |
| 0010 MARY WALKER HEALTH CENTER | ADMINISTRATION | 1965 | 33,260 |
| 0011 COMMISSARY BLDG | ADMINISTRATION | 1966 | 30,836 |
| 0012 MAINTENANCE BLDG | MAINTENANCE | 1965 | 20,664 |
| 0013 M E MAHAR HALL | ACADEMIC | 1966 | 91,530 |
| 0014 RICH HALL | ACADEMIC | 1961 | 53,742 |
| 0015 MACKIN HALL | RESIDENTIAL | 1951 | 41,984 |
| 0017 J PENFIELD LIB | ACADEMIC | 1968 | 192,298 |
| 0019 LAKER HALL | ACADEMIC | 1968 | 196,608 |
| 0020 GAR-20 | MAINTENANCE | 1971 | 14,850 |
| 0021 ROMNEY FIELD HSE | ACADEMIC | 1962 | 55,000 |
| 0022 KING HALL | ADMINISTRATION | 1935 | 7,200 |
| 0023A RICE CREEK FIELD STATION | ACADEMIC | 2013 | 7,500 |
| 0026 CULKIN HALL | ADMINISTRATION | 1967 | 63,591 |
| 0031 PATHFINDER DH | DINING HALL | 1967 | 33,827 |
| 0032 SENECA HALL | RESIDENTIAL | 1967 | 152,548 |
| 0033 CAYUGA HALL | RESIDENTIAL | 1967 | 105,072 |
| 0034 ONONDAGA HALL | RESIDENTIAL | 1968 | 152,548 |
| 0035 LITTLEPAGE DH | DINING HALL | - | 33,827 |
| 0036 ONEIDA HALL | RESIDENTIAL | 1970 | 105,000 |
| 0037A TOWNHOUSE A | RESIDENTIAL | 2010 | 10,260 |
| 0037F TOWNHOUSE F | RESIDENTIAL | 2010 | 18,295 |
| 0037H TOWNHOUSE H | RESIDENTIAL | 2010 | 10,260 |
| 003A I POUCHER HALL | ACADEMIC | 1963 | 40,080 |
| 003B REC & CONVOCATION CTR | ACADEMIC | 2006 | 115,421 |
| 0041 JOHNSON HALL | RESIDENTIAL | 1958 | 79,097 |
| 0042 LAKESIDE DH | DINING HALL | 1959 | 27,870 |
| 0043 RIGGS HALL | RESIDENTIAL | 1960 | 58,201 |
| 0044 WATERBURY HALL | RESIDENTIAL | 1960 | 57,464 |
| 0045 SCALES HALL | RESIDENTIAL | 1961 | 57,464 |
| 0046 HART HALL | RESIDENTIAL | 1963 | 114,365 |
| 0047 COOPER DH | DINING HALL | 1967 | 33,546 |
| 0048 FUNNELLE HALL | RESIDENTIAL | 1965 | 114,365 |
| 004A LEE HALL (HEATING PLANT) | MAINTENANCE | 1958 | 21,980 |
| 015A MORELAND HALL | RESIDENTIAL | 1951 | 29,400 |
| 015B LONIS HALL | RESIDENTIAL | 1951 | 32,285 |

### 4.1.2 Targeted Audits

Targeted audit efforts focused on building upon the results and findings from the Level 1 walk-throughs and EEM matrix. SUNY Oswego and Ramboll identified the following measures for focus during the targeted audit survey, which was conducted from October 25 through October 27, 2022:

- Interior Lighting and Controls
  - MCC interior spine pedestrian pathway
  - Large lecture halls
- Exterior lighting of parking lots and roadways
- Retro-commissioning (RCx)
  - Campus Center
  - Rich
  - Tyler
  - Riggs
  - The Village
  - Waterbury
  - Scales
  - Johnson
- Building automation system (BAS) Control measures
  - HVAC scheduling
  - Occupancy based HVAC controls
  - Pump differential pressure reset controls
  - Multizone VAV static pressure reset controls
  - Demand controlled ventilation
- Kitchen demand controlled ventilation
- Laboratory demand controlled ventilation
- Variable frequency drive (VFD) applications
  - Hot water and chilled water pump VFD
  - Constant volume single zone AHU to single zone VAV retrofit
- Natatorium mechanical dehumidification systems

### 4.1.3 Energy Savings Estimates

Potential energy savings for each measure were estimated, and high-level capital costs for implementation developed. Energy savings were estimated using a variety of methods, including analysis of existing weather-dependent energy use patterns and Ramboll's proprietary custom measure calculators.

Projects selected for implementation may require a more detailed evaluation that would address the impact of peak demand savings and seasonal or time of day variations in utility cost structures. Savings estimates generally do not account for the interaction of different EEMs which may have a positive or negative impact on actual energy savings.

The utility unit costs developed during the PEA, Table 9, are based on average annual energy rates for electricity and fossil fuels that include blended commodity, delivery, demand charges, taxes, and other fees, represented in 2019 dollars. The values shown in Table 16 were used to estimate energy cost savings, simple payback, and savings to investment ratio (SIR) for each

EEM analyzed. The utility rates were escalated to 2022 dollars based on historical consumer price index (CPI) published by the United States Bureau of Labor Statistics[2].

**Table 16. Energy unit costs used in EEM assessments**

| Fuel | Total in 2019 dollars | Total in 2022 dollars |
|---|---|---|
| Electricity | $0.051/kWh | $0.059/kWh |
| Natural Gas | $0.353/Therm | $0.404/Therm |

### 4.1.4 Energy Measure Cost Estimates

Material and labor cost data for the measures were derived from a variety of sources, including R.S. Means Company, Inc., Ramboll's in-house construction cost database, and various published papers and reports as referenced herein. In some instances, budgetary cost estimates were solicited directly from equipment suppliers. Cost estimates were normalized on a square foot basis and were applied to multiple buildings where appropriate. In addition to labor and materials, the following contingencies have been applied: General Conditions (10%), Architectural & Engineering Fees (10%), Construction Management Fees (10%, and Contingency (10%). Major costs associated with environmental abatement issues and infrastructure renovations are generally not accounted for unless they were previously identified and specifically addressed within the EEM.

Capital cost estimates generated for each EEM are preliminary in nature and are intended to reasonably reflect the rough order of magnitude of costs likely to be incurred. Potential grants, incentives, and/or other benefits available through federal, state or local utility programs were not investigated at this stage of project development.

## 4.2 Energy Audit Results

### 4.2.1 EEM Results

Appendix C contains a summary table and detailed writeups for the measures developed as part of the targeted audit effort. Each measure writeup discusses the existing conditions (baseline), recommended actions, estimated energy savings, estimated project costs, and implementation considerations. Detailed assumptions, manufacturers literature, and other supporting documents are also included within the measure writeups.

A Life Cycle Cost Analysis (LCCA) was performed for each option based on the first costs developed for the project and annually recurring energy costs. The LCCA was performed over the expected useful life of each measure (EUL). Annual escalation rates for the utility costs are based on a US Department of Energy (DOE) rate schedule for commercial buildings in the state of New York (Annual Supplement to Handbook 135, Energy Price Indices and Discount Factors for LCC Analysis, NISTIR 85-3273). Annual maintenance costs and replacement costs are not considered in this analysis. Annual costs are discounted back to year zero using a 3% discount rate. The savings to investment ratio (SIR) is calculated as the net present value of lifetime savings

[2] https://www.bls.gov/regions/mid-atlantic/data/consumerpriceindexhistorical_us_table.htm
2019 average CPI = 255.7
2022 average CPI = 292.7
14.47% inflation rate from 2019 to 2022

calculated from the LCCA divided by the first cost. A project is typically considered cost effective if the SIR is greater than or equal to 1.2. Additionally, BuildSmart 2025 considers measures cost effective if the SPB is 10 years or less or it has a 7% or greater internal rate of return (IRR).

Table 17 summarizes energy and economic results for the EEMs addressed in Appendix C. A more detailed table presenting annual utility energy savings and greenhouse gas reductions, is presented in Appendix C. Individual measure savings generally do not account for the interaction of different EEMs. However, the subtotals show in Table 17 are multiplied by a 0.7 interactive factor to account for interaction between measures. If all measures are implemented, the total implementation cost would be approximately $8.8 million with an aggregate simple payback period of 19 years. Numerous capital-intensive projects for equipment and systems that are at or beyond their useful life increase the simple payback period of the entire package of measures. However, these projects can be justified from an infrastructure renewal perspective. For the equipment that is already due for replacement, one could argue to include only the EEM incremental cost for a high efficiency replacement, rather than the full replacement cost; that was not done here, but it would lower the simple payback considerably.

The measure savings identified in Table 17 can be combined in addition to any measures already entered in the BuildSmart 2025 project database as well as any major renovations that will have at least 30% design documents by December 31, 2025.

**Table 17. Summary of energy efficiency measures (EEMs)**

| EEM No. | Potential EEM[1] | Annual Energy Savings (MMBtu/year) | Annual Energy Cost Savings ($/yr) | Estimated Capital Cost | Simple Payback Period (years) | IRR[5] | Annual GHG Reduction (MTCO2e) |
|---|---|---|---|---|---|---|---|
| | **LIGHTING** | | | | | | |
| **EEM-1** | Interior LED Lighting Retrofit | 333 | $7,805 | $414,177 | 53.1 | -13% | 8 |
| **EEM-2** | Parking Lot and Roadway LED Retrofit | 516 | $8,924 | $1,998,482 | 224.0 | -23% | 17 |
| | **LIGHTING SUBTOTAL[4]** | **594** | **$11,710** | **$2,412,659** | **206.0** | **-23%** | **18** |
| | **HVAC AND CONTROLS** | | | | | | |
| **EEM-3** | Retro-Commissioning | 11,039 | $81,472 | $246,586 | 3.0 | 18% | 532 |
| **EEM-4** | HVAC Scheduling | 22,333 | $119,177 | $4,136 | 0.0 | 2845% | 1,144 |
| **EEM-5[2]** | Occupancy Based HVAC Controls | 26,983 | $192,132 | $3,730,696 | 19.4 | -4% | 1,312 |
| **EEM-6** | Pump Differential Pressure Reset Control | 562 | $9,718 | $37,107 | 3.8 | 25% | 19 |
| **EEM-7** | Multizone VAV Static Pressure Reset Controls | 658 | $11,375 | $24,248 | 2.1 | 46% | 22 |
| **EEM-8** | Implement Demand Controlled Ventilation | 6,898 | $27,899 | $40,655 | 1.5 | 65% | 366 |
| **EEM-9** | Implement Kitchen Demand Controlled Ventilation | 2,319 | $14,261 | $192,867 | 13.5 | 1% | 116 |
| **EEM-10** | Implement Laboratory Demand Controlled Ventilation | 17,452 | $148,044 | $503,100 | 3.4 | 28% | 814 |

| EEM No. | Potential EEM[1] | Annual Energy Savings (MMBtu/year) | Annual Energy Cost Savings ($/yr) | Estimated Capital Cost | Simple Payback Period (years) | IRR[5] | Annual GHG Reduction (MTCO2e) |
|---|---|---|---|---|---|---|---|
| **EEM-11** | Install VFD on Pump Motor | 1,004 | $17,355 | $402,611 | 23.2 | -5% | 34 |
| **EEM-12** | Convert CVSZ to SZVAV | 1,284 | $22,201 | $142,040 | 6.4 | 13% | 43 |
| **EEM-13** | Install Pool Dehumidification System | 3,838 | $15,724 | $1,099,423 | 69.9 | -16% | 204 |
| | **HVAC AND CONTROLS SUBTOTAL[4]** | **66,058** | **$461,550** | **$6,423,470** | **13.9** | **-3%** | **3,224** |
| | | | | | | | |
| | **GRAND TOTAL[4]** | **66,653** | **$473,260** | **$8,836,129** | **18.7** | **-6%** | **3,242** |
| | BuildSmart 2025 Reduction Goal[3] | 146,332 | - | - | - | - | - |
| | % of BuildSmart Reduction Goal | 46% | - | - | - | - | - |
| | **Total of IRR >= 7%** | **42,158** | **$293,920** | **$997,873** | **3.4** | **21%** | **2,058** |
| | % of BuildSmart Reduction Goal | 29% | - | - | - | - | - |

Notes:

1. Energy savings will be impacted by interactive effects from other measures. These interactive effects were not considered when calculating energy savings.
2. Measure assumes EEM-3 HVAC Scheduling would be implemented prior to using occupancy based HVAC controls. Measure only accounts for savings during typical building occupied hours.
3. Value provided by NYPA. SUNY has an overall goal of ~4.4 TBtu (4,410,860 MMBTU); SUNY Oswego's goal is 146,332 MMBTU.
4. Subtotals are multiplied by a 0.7 interactive factor to account for interaction between measures.
5. LCCA performed over the expected useful life of each measure (EUL). Annual escalation rates for the utility costs are based on a US Department of Energy (DOE) rate schedule for commercial buildings in the state of New York (Annual Supplement to Handbook 135, Energy Price Indices and Discount Factors for LCC Analysis, NISTIR 85-3273)

### 4.2.2 Measures considered but not analyzed

The building assessments in Appendix B list additional measures for buildings that could be considered but were not analyzed due to limited savings or lengthy paybacks. No cost/low-cost measures listed are not capital improvement measures but are likely to provide energy savings. Implementation may be carried out by contractors or sometimes site staff. Many capital measures identified are not economically justifiable as an early replacement (*i.e.,* adding wall insulation, window replacement, and HVAC replacement). These measures should be considered when the existing systems undergo end-of-life replacement, or the building undergoes a complete renovation.

### 4.2.3 Operations & maintenance

The Federal Energy Management Program's (FEMP) Operations & Maintenance (O&M) Best Practices[3] (*FEMP 2010*) document provides a tool for developing campus O&M strategies and benchmarking best practices against industry standards. Per the FEMP manual, O&M programs targeting energy and water efficiency can save from 5 to 20 percent of annual energy use without significant capital investment.

The Building Assessment (BA) Reports included in Appendix B identify several opportunities for energy and maintenance cost savings. A conservative estimate of 2% annual energy savings is considered achievable through the identified O&M strategies, including replacing missing piping insulation, repairing weather seals, addressing space temperature control and occupant behaviors, and reviewing program space needs.

[3] U.S. Department of Energy's Federal Energy Management Program (FEMP), Operations & Maintenance (O&M) Best Practices – A Guide to Achieving Operational Efficiency, prepared by the Pacific Northwest National Laboratory, Release 3.0; August 2010.

# 5. Energy Master Planning

This section articulates and categorizes conceptual strategies that cover a range of technical approaches to reduce GHG emissions and/or phase out fossil fuel use on campus while maintaining reliable utility services to the campus. Summarized below are completed steps and activities that identify the most suited technologies that could cover forecasted heating and cooling demands for the campus and using that information to develop scenarios for consideration.

## 5.1 Campus energy demand

### 5.1.1 Baseline campus electric demand

Figure 16 presents the monthly electric demand (kW) and energy use (kWh) for the baseline study period of 2018-2020.

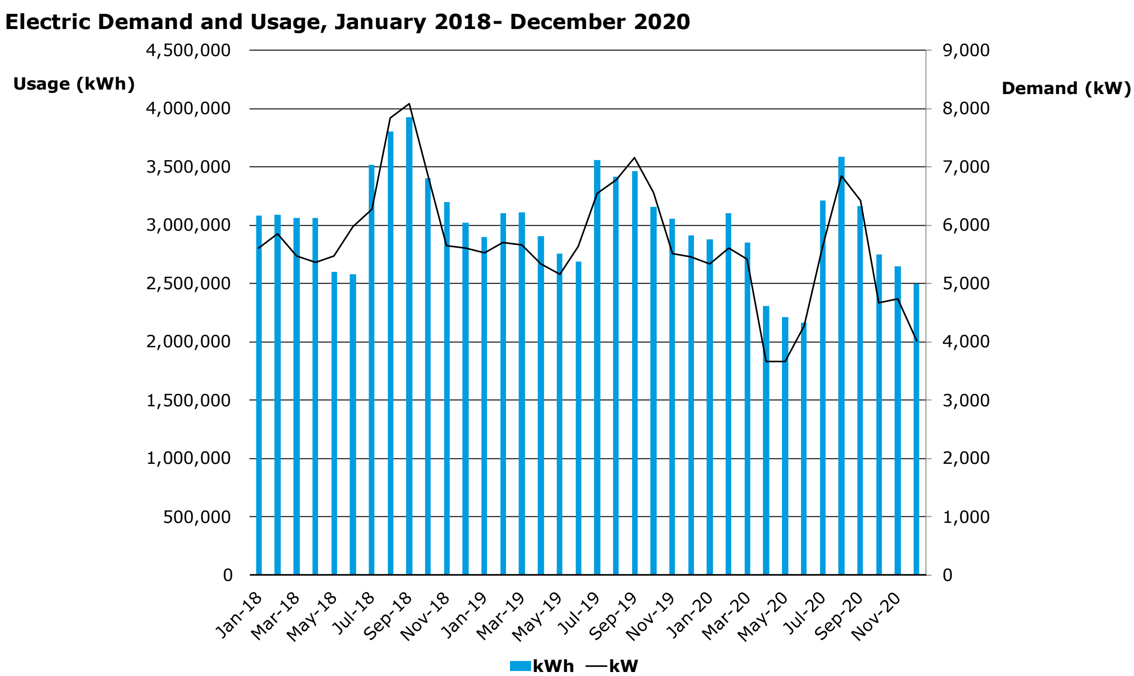



**Figure 16. Monthly electric demand and energy use**

### 5.1.2 Baseline building thermal energy demands

Section 3.4 described the methodology of estimating building level energy use as well as end-use estimates. These estimates are on the input fuel side, just as they are in CBECS and as would be reflected in utility bills. For non-heating/cooling electrical loads (*e.g.*, lights, plug loads), the input fuel (electricity) is essentially equal to the demand or load. For heating and cooling applications, we consider the conversion efficiency.

When considering potential options to serve building heating and cooling demands, the input energy should be determined based on the thermal demands of the building. The heating demands are developed based on the heating input fuel from Section 3 and consider the conversion efficiency of the existing technology; similarly, cooling demands are based on the cooling input fuel and conversion efficiency of the existing cooling technology.

Table 18 contains the estimated annual demand of space heating, domestic hot water heating and space cooling for each building in the baseline scenario. The demands are weather normalized to typical year weather. Note the demand data represents the energy required for the end user; not the input energy, which considers equipment conversion efficiency and on-site distribution losses.

Hourly consumption was derived from dimensionless hourly fractional multipliers developed from daily steam and natural gas data for the central heating plant and similar peer campuses. The profile is shown in Figure 17. In the profile curve, the hour specified on the top horizontal axis denotes the hour from the start of the year. In the load duration curve, the same data are rearranged from the highest to the lowest value. It is noted that cooling is not centralized at the campus, but exists at the building level where applied.

**Table 18. Baseline Demand by building for space heating (SH), domestic hot water (DHW) and cooling**

| Building | Building position | SH (MMBtu/y) | DHW (MMBtu/y) | Cooling (MMBtu/y) |
|---|---|---|---|---|
| 0001 - SHELDON HALL | MAIN | 7,718 | 527 | 1,734 |
| 0002 - J C PARK HALL | MAIN | 4,021 | 451 | 1,870 |
| 0003 - CAMPUS CENTER | MAIN | 9,970 | 4,209 | 5,248 |
| 003A - I POUCHER HALL | MAIN | 2,563 | 520 | 1,121 |
| 003B - REC & CONVOCATION CTR | MAIN | 8,415 | 1,767 | 2,024 |
| 003C - CC STORAGE BLDG | MAIN | 0 | 0 | 0 |
| 0004 - M V LEE HALL | MAIN | 2,855 | 124 | 0 |
| 004A - CENTRAL HEATING PLANT | MAIN | 426 | 261 | 0 |
| 0005 - SHADY SHORE | MAIN | 287 | 79 | 85 |
| 0005A - PRESIDENT GARAGE | MAIN | 0 | 0 | 0 |
| 0006 - J LANIGAN HALL | MAIN | 5,840 | 1,564 | 2,825 |
| 0007 - J TYLER HALL | MAIN | 6,373 | 1,066 | 2,474 |
| 0008 - RICHARD S SHINEMAN CENTER | MAIN | 36,844 | 4,300 | 5,790 |
| 0009 - WILBER HALL | MAIN | 5,156 | 792 | 3,016 |
| 0010 - MARY WALKER HEALTH CENTER | MAIN | 870 | 149 | 674 |
| 0011 - COMMISSARY BLDG | MAIN-SOUTH | 1,182 | 702 | 0 |
| 0012 - MAINTENANCE BLDG | MAIN-SOUTH | 273 | 100 | 0 |
| 0013 - M E MAHAR HALL | MAIN | 4,832 | 641 | 1,972 |
| 0014 - RICH HALL | MAIN | 3,183 | 444 | 1,165 |
| 0015 - MACKIN HALL | MAIN | 1,829 | 807 | 0 |
| 015A - MORELAND HALL | MAIN | 1,055 | 466 | 0 |
| 015B - LONIS HALL | MAIN | 1,216 | 537 | 0 |
| 0016 - OBSERVATORY | MAIN | 0 | 3 | 0 |
| 0017 - J PENFIELD LIB | MAIN | 7,381 | 649 | 4,111 |

| Building | Building position | SH (MMBtu/y) | DHW (MMBtu/y) | Cooling (MMBtu/y) |
|---|---|---|---|---|
| 0019 - LAKER HALL | MAIN-SOUTH | 10,692 | 456 | 0 |
| 0020 - GAR-20 | MAIN | 586 | 173 | 301 |
| 0021 - ROMNEY FIELD HOUSE | MAIN-SOUTH | 4,287 | 184 | 0 |
| 0022 - KING HALL | MAIN | 315 | 15 | 0 |
| 0024A - BIO FIELD GARAGE | MAIN | 0 | 0 | 0 |
| 0026 - CULKIN HALL | MAIN | 855 | 65 | 529 |
| 0028 - SEWAGE PUMP STATION | MAIN | 0 | 15 | 0 |
| 0028A - SEWAGE PUMP STATION - SENECA | MAIN | 0 | 2 | 0 |
| 0028B - SEWAGE PUMP STATION - BLG 12 | MAIN | 0 | 2 | 0 |
| 0029 - HEWITT HALL | MAIN | 6,196 | 927 | 2,896 |
| 0031 - PATHFINDER DH | MAIN | 1,366 | 703 | 741 |
| 0032 - SENECA HALL | MAIN | 5,321 | 2,349 | 0 |
| 0033 - CAYUGA HALL | MAIN | 3,734 | 1,649 | 0 |
| 0034 - ONONDAGA HALL | MAIN | 5,419 | 2,392 | 0 |
| 0035 - LITTLEPAGE DH | MAIN | 1,523 | 667 | 741 |
| 0036 - ONEIDA HALL | MAIN | 3,554 | 1,569 | 0 |
| 0037A - TOWNHOUSE A | MAIN | 210 | 93 | 124 |
| 0037B - TOWNHOUSE B | MAIN | 165 | 73 | 98 |
| 0037C - TOWNHOUSE C | MAIN | 257 | 114 | 153 |
| 0037D - TOWNHOUSE D | MAIN | 257 | 114 | 153 |
| 0037E - TOWNHOUSE E | MAIN | 324 | 143 | 192 |
| 0037F - TOWNHOUSE F | MAIN | 374 | 165 | 221 |
| 0037G - TOWNHOUSE G | MAIN | 194 | 86 | 100 |
| 0037H - TOWNHOUSE H | MAIN | 247 | 109 | 128 |
| 0037I - TOWNHOUSE I | MAIN | 302 | 133 | 156 |
| 0037J - TOWNHOUSE J | MAIN | 303 | 134 | 157 |
| 0037K - TOWNHOUSE K | MAIN | 401 | 177 | 208 |
| 0037L - TOWNHOUSE L | MAIN | 302 | 133 | 157 |
| 0041 - JOHNSON HALL | MAIN | 2,770 | 1,223 | 987 |
| 0042 - LAKESIDE DH | MAIN | 1,043 | 575 | 610 |
| 0043 - RIGGS HALL | MAIN | 2,174 | 960 | 726 |
| 0044 - WATERBURY HALL | MAIN | 2,098 | 926 | 0 |
| 0045 - SCALES HALL | MAIN | 2,098 | 926 | 0 |
| 0046 - HART HALL | MAIN | 4,897 | 2,162 | 0 |
| 0047 - COOPER DH | MAIN | 1,388 | 697 | 516 |
| 0048 - FUNNELLE HALL | MAIN | 4,819 | 2,128 | 0 |
| 0049 - PUBLIC RESTROOM | MAIN | 0 | 1 | 0 |
| 0051 - FM RADIO TRANSMISSION FAC | MAIN | 0 | 396 | 0 |

| Building | Building position | SH (MMBtu/y) | DHW (MMBtu/y) | Cooling (MMBtu/y) |
|---|---|---|---|---|
| 0061 - MAINTENANCE STORAGE | MAIN | 0 | 0 | 0 |
| 0082 - PRESS BOX | MAIN | 0 | 4 | 0 |
| 0104 - SECURITY PARKING OFFICE | MAIN | 102 | 5 | 38 |
| 0106 - VOLATILE STO | MAIN | 0 | 0 | 0 |
| 0107 - 1 ROOM SCHOOL HSE | MAIN | 0 | 3 | 12 |
| 0108 - POWER STATION 1 | MAIN | 0 | 2 | 0 |
| 0109 - POWER STATION 1A | MAIN | 0 | 1 | 0 |
| 0110 - POWER STATION 2 | MAIN | 0 | 1 | 0 |
| **Total** | | **180,859** | **42,809** | **44,052** |

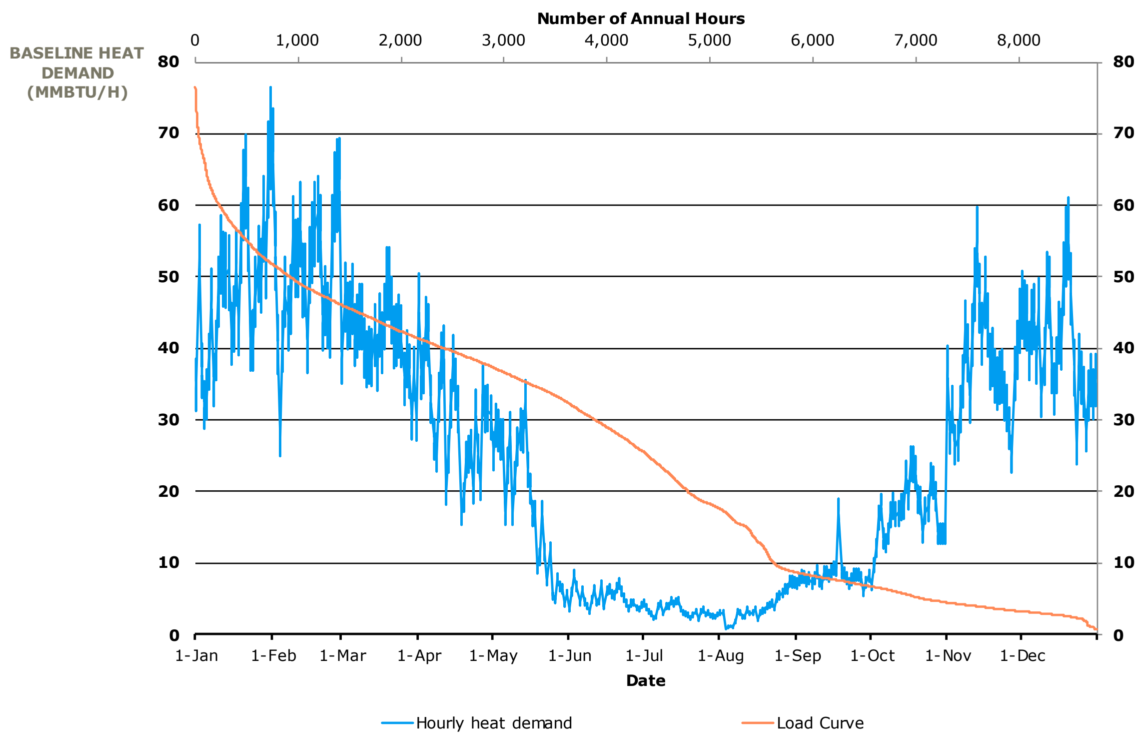



**Figure 17. Baseline heat demand (SH+ DHW)**

### 5.1.3 Future energy demands

The future demand profiles were adjusted to reflect campus renovation plans. The heating and cooling loads for renovated buildings listed in Section 2.3 were estimated based on the building type and cooling loads of similar buildings on campus. Cooling and heating savings for other buildings were estimated based on the results of the energy efficiency measures identified in Section 4.

Table 19 summarizes the effects of the various measures and compares the current to the future estimated use. Even though cooling will be added to a few buildings, through building renovations and implementing EEMs, cooling energy is estimated to decrease by approximately 29% while the heating use is assumed to decrease by 25%. Electricity use for purposes other than heating and cooling is estimated to decrease by 19% through building renovations and implementing EEMs. The impact of electrification on heating and cooling will be assed later in Section 5.7.

**Table 19. Energy conservation and growth estimates**

| | **Cooling** (MMBtu/yr) | **Heating**[1] (MMBtu/yr) | **Electricity**[2] (MWh/yr) |
|---|---|---|---|
| Current Annual Demand[3] | 44,052 | 223,668 | 31,049 |
| Additional Cooling Loads | 1,021 | NA | NA |
| Reductions from EEMs | -13,997 | -55,590 | -5,876 |
| Future Annual Use Estimate | 31,076 | 168,078 | 25,173 |
| Percent Growth over Current | -29% | -25% | -19% |

*1. Heating includes space heating and domestic water heating*
*2. Electricity use excludes any local building electricity consumption for heating or cooling*
*3. The energy demand differs from energy consumption, where consumption accounts for efficiency of the system in converting input fuel to meet the output demand*

Table 20 contains the estimated future annual space heating, domestic hot water heating and space cooling for each building. There is opportunity to serve the heating and cooling loads more efficiently, which is the goal of the scenario analysis.

Note the demand data represents the energy required for the end use; not the input energy, which considers equipment conversion efficiency and on-site distribution losses.

**Table 20. Future energy demand by building**

| **Building** | **Building position** | **SH (MMBtu/y)** | **DHW (MMBtu/y)** | **Cooling (MMBtu/y)** |
|---|---|---|---|---|
| 0001 - SHELDON HALL | MAIN | 7,718 | 527 | 1,734 |
| 0002 - J C PARK HALL | MAIN | 3,176 | 451 | 1,477 |
| 0003 - CAMPUS CENTER | MAIN | 7,178 | 4,209 | 3,779 |
| 003A - I POUCHER HALL | MAIN | 1,845 | 520 | 807 |
| 003B - REC & CONVOCATION CTR | MAIN | 4,292 | 1,767 | 1,032 |
| 003C - CC STORAGE BLDG | MAIN | 0 | 0 | 0 |
| 0004 - M V LEE HALL | MAIN | 2,255 | 124 | 0 |
| 004A - CENTRAL HEATING PLANT | MAIN | 426 | 261 | 0 |
| 0005 - SHADY SHORE | MAIN | 287 | 79 | 85 |
| 0005A - PRESIDENT GARAGE | MAIN | 0 | 0 | 0 |
| 0006 - J LANIGAN HALL | MAIN | 4,614 | 1,564 | 2,231 |
| 0007 - J TYLER HALL | MAIN | 4,589 | 1,066 | 1,781 |
| 0008 - RICHARD S SHINEMAN CENTER | MAIN | 29,107 | 4,300 | 4,574 |
| 0009 - WILBER HALL | MAIN | 4,073 | 792 | 2,383 |
| 0010 - MARY WALKER HEALTH CENTER | MAIN | 870 | 149 | 674 |
| 0011 - COMMISSARY BLDG | MAIN-SOUTH | 934 | 702 | 0 |

| Building | Building position | SH (MMBtu/y) | DHW (MMBtu/y) | Cooling (MMBtu/y) |
|---|---|---|---|---|
| 0012 - MAINTENANCE BLDG | MAIN-SOUTH | 273 | 100 | 0 |
| 0013 - M E MAHAR HALL | MAIN | 1,847 | 245 | 754 |
| 0014 - RICH HALL | MAIN | 2,292 | 444 | 839 |
| 0015 - MACKIN HALL | MAIN | 962 | 131 | 76 |
| 015A - MORELAND HALL | MAIN | 674 | 92 | 53 |
| 015B - LONIS HALL | MAIN | 740 | 101 | 58 |
| 0016 - OBSERVATORY | MAIN | 0 | 3 | 0 |
| 0017 - J PENFIELD LIB | MAIN | 5,679 | 499 | 3,163 |
| 0019 - LAKER HALL | MAIN-SOUTH | 8,447 | 456 | 344 |
| 0020 - GAR-20 | MAIN | 586 | 173 | 301 |
| 0021 - ROMNEY FIELD HOUSE | MAIN-SOUTH | 3,387 | 184 | 0 |
| 0022 - KING HALL | MAIN | 249 | 15 | 0 |
| 0024A - BIO FIELD GARAGE | MAIN | 0 | 0 | 0 |
| 0026 - CULKIN HALL | MAIN | 676 | 65 | 418 |
| 0028 - SEWAGE PUMP STATION | MAIN | 0 | 15 | 0 |
| 0028A - SEWAGE PUMP STATION - SENECA | MAIN | 0 | 2 | 0 |
| 0028B - SEWAGE PUMP STATION - BLG 12 | MAIN | 0 | 2 | 0 |
| 0029 - HEWITT HALL | MAIN | 2,790 | 364 | 220 |
| 0031 - PATHFINDER DH | MAIN | 792 | 703 | 430 |
| 0032 - SENECA HALL | MAIN | 3,491 | 1,541 | 145 |
| 0033 - CAYUGA HALL | MAIN | 2,421 | 1,069 | 100 |
| 0034 - ONONDAGA HALL | MAIN | 3,446 | 1,521 | 145 |
| 0035 - LITTLEPAGE DH | MAIN | 627 | 27 | 107 |
| 0036 - ONEIDA HALL | MAIN | 2,372 | 1,047 | 100 |
| 0037A - TOWNHOUSE A | MAIN | 151 | 93 | 89 |
| 0037B - TOWNHOUSE B | MAIN | 119 | 73 | 70 |
| 0037C - TOWNHOUSE C | MAIN | 185 | 114 | 110 |
| 0037D - TOWNHOUSE D | MAIN | 185 | 114 | 110 |
| 0037E - TOWNHOUSE E | MAIN | 233 | 143 | 138 |
| 0037F - TOWNHOUSE F | MAIN | 269 | 165 | 159 |
| 0037G - TOWNHOUSE G | MAIN | 140 | 86 | 72 |
| 0037H - TOWNHOUSE H | MAIN | 177 | 109 | 92 |
| 0037I - TOWNHOUSE I | MAIN | 217 | 133 | 113 |
| 0037J - TOWNHOUSE J | MAIN | 218 | 134 | 113 |
| 0037K - TOWNHOUSE K | MAIN | 289 | 177 | 150 |
| 0037L - TOWNHOUSE L | MAIN | 217 | 133 | 113 |
| 0041 - JOHNSON HALL | MAIN | 1,994 | 1,223 | 711 |
| 0042 - LAKESIDE DH | MAIN | 605 | 575 | 354 |

| Building | Building position | SH (MMBtu/y) | DHW (MMBtu/y) | Cooling (MMBtu/y) |
|---|---|---|---|---|
| 0043 - RIGGS HALL | MAIN | 1,566 | 960 | 523 |
| 0044 - WATERBURY HALL | MAIN | 1,510 | 926 | 0 |
| 0045 - SCALES HALL | MAIN | 1,510 | 926 | 0 |
| 0046 - HART HALL | MAIN | 3,868 | 2,162 | 0 |
| 0047 - COOPER DH | MAIN | 805 | 697 | 300 |
| 0048 - FUNNELLE HALL | MAIN | 3,807 | 2,128 | 0 |
| 0049 - PUBLIC RESTROOM | MAIN | 0 | 1 | 0 |
| 0051 - FM RADIO TRANSMISSION FAC | MAIN | 0 | 396 | 0 |
| 0061 - MAINTENANCE STORAGE | MAIN | 0 | 0 | 0 |
| 0082 - PRESS BOX | MAIN | 0 | 4 | 0 |
| 0104 - SECURITY PARKING OFFICE | MAIN | 102 | 5 | 38 |
| 0106 - VOLATILE STO | MAIN | 0 | 0 | 0 |
| 0107 - 1 ROOM SCHOOL HSE | MAIN | 0 | 3 | 12 |
| 0108 - POWER STATION 1 | MAIN | 0 | 2 | 0 |
| 0109 - POWER STATION 1A | MAIN | 0 | 1 | 0 |
| 0110 - POWER STATION 2 | MAIN | 0 | 1 | 0 |
| **Total** | | **131,284** | **36,794** | **31,076** |

Figure 18 shows the future hourly profile and load duration curve developed for total net heat demand (SH as well as DHW in both summer and winter) of the buildings which will be connected to the future heating network. Figure 19 shows the future cooling demand for the buildings connected to the future cooling network.

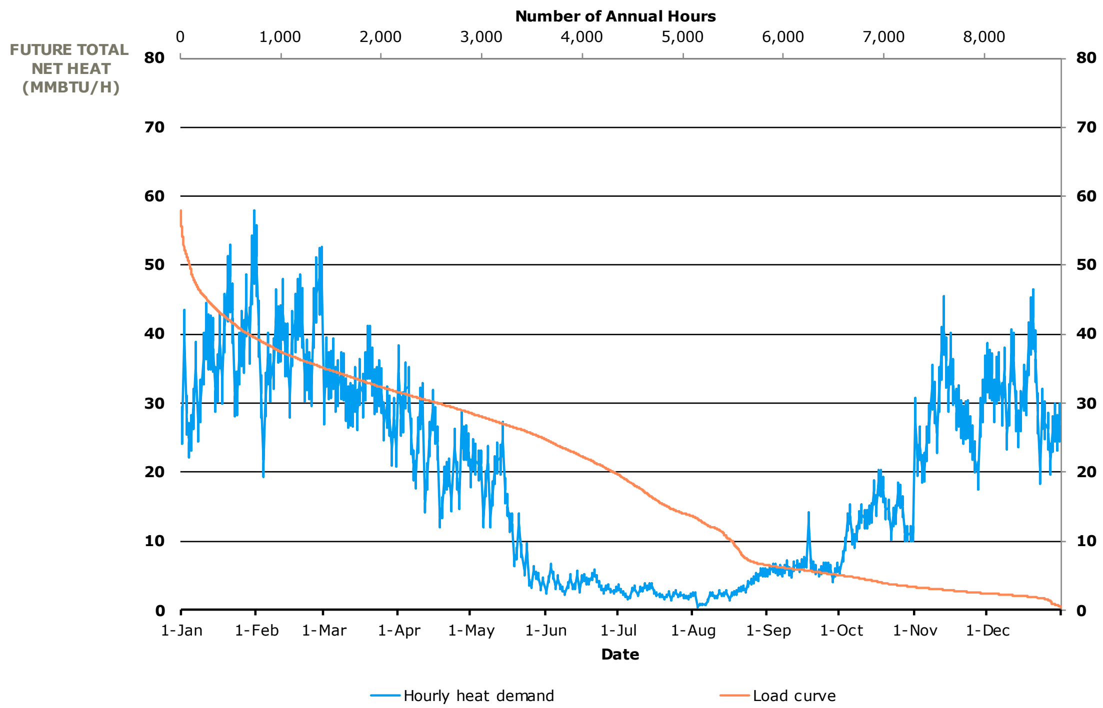



**Figure 18. Future heat demand (SH+ DHW)**

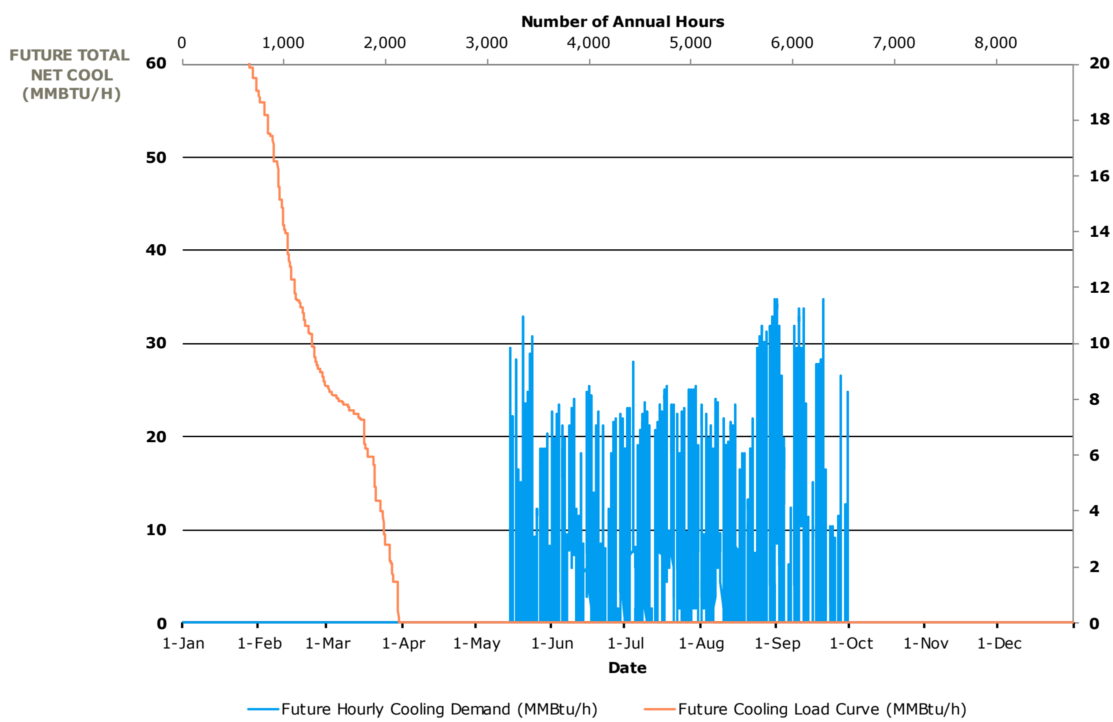



**Figure 19. Future cooling demand**

## 5.2 Campus energy supply

Ramboll analyzed the campus' existing heating, domestic hot water and cooling supply, identifying which buildings are heated and cooled on campus and what types of heating and cooling equipment are used. Understanding the existing campus supply is necessary for modeling potential campus future supply options.

### 5.2.1 Building heating supply

The main campus is mostly centralized with 56 buildings heated covering nearly 3.4M GSF. 33 buildings on campus are heated from the central steam distribution. The Shineman Center is heated with a ground-source heat pump system. The remaining buildings on campus are heated using local natural gas boilers.

The central heating plant generates steam at 110 psig and is reduced to 40 psig for distribution to the buildings. The steam piping is in a mix of concrete trench tunnels and direct buried piping. Individual buildings have pressure reducing valves to reduce the pressure to 12 psig before entering steam to hot water heat exchangers. Each building is equipped with a condensate return unit to pump the condensate back to the steam plant.

Figure 20 is a breakdown of the main campus heating system types as percentages of the campus total gross square footage.

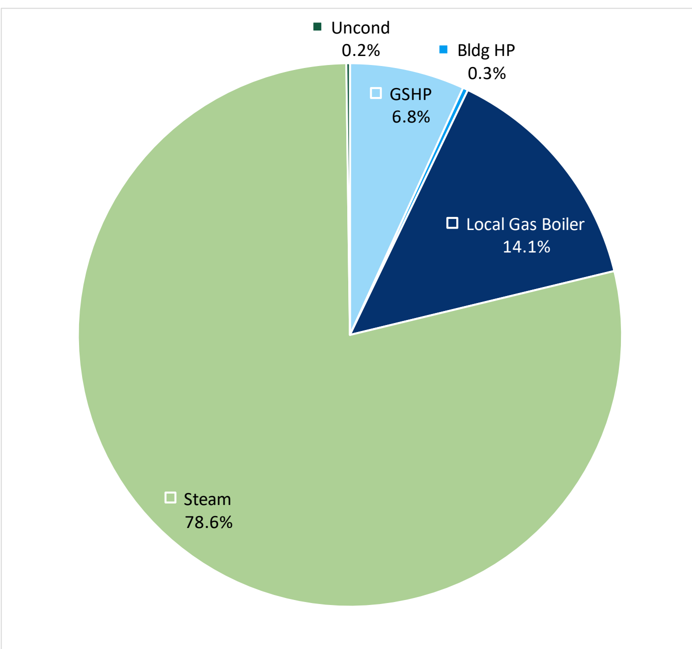



**Figure 20. Heating system type (percent of GSF) by current space heating technology**

### 5.2.2 Building domestic hot water supply

Most of the domestic hot water on campus is produced in steam to hot water heat exchangers. Some buildings on campus have local gas-fired or electric hot water tanks.

Figure 21 presents the percentages of the main campus area served by each DHW supply system type.

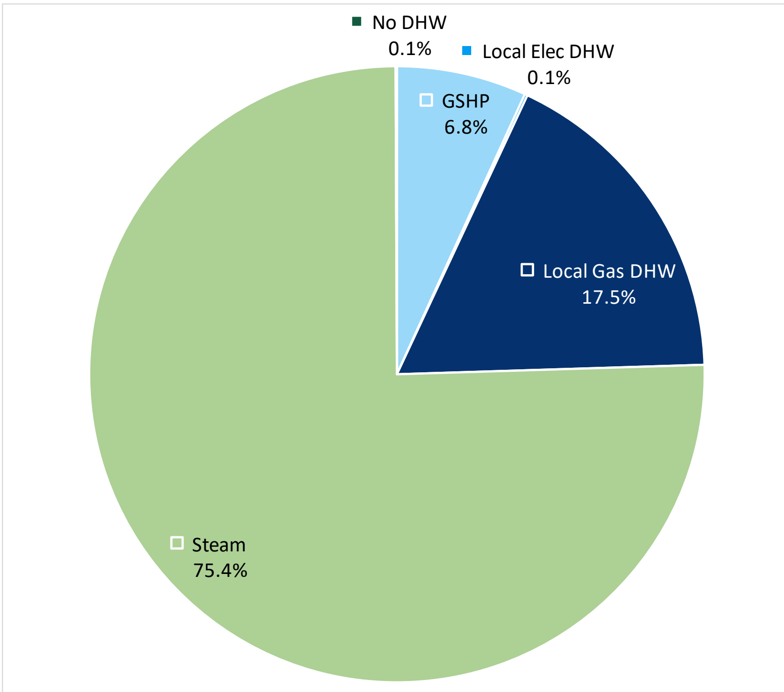



**Figure 21. Domestic hot water type (percent of GSF)**

### 5.2.3 Building cooling supply

Most of the main campus buildings are cooled by a mix of chillers or packaged rooftop units (RTU) with direct expansion (DX) cooling. The Shineman center has a ground-source heat pump system. Hewitt Hall is currently being renovated and will be served with a GSHP system. About 34% of the campus is currently not cooled.

Figure 22 is a breakdown of the main campus cooling system types as percentages of the campus total gross square footage.

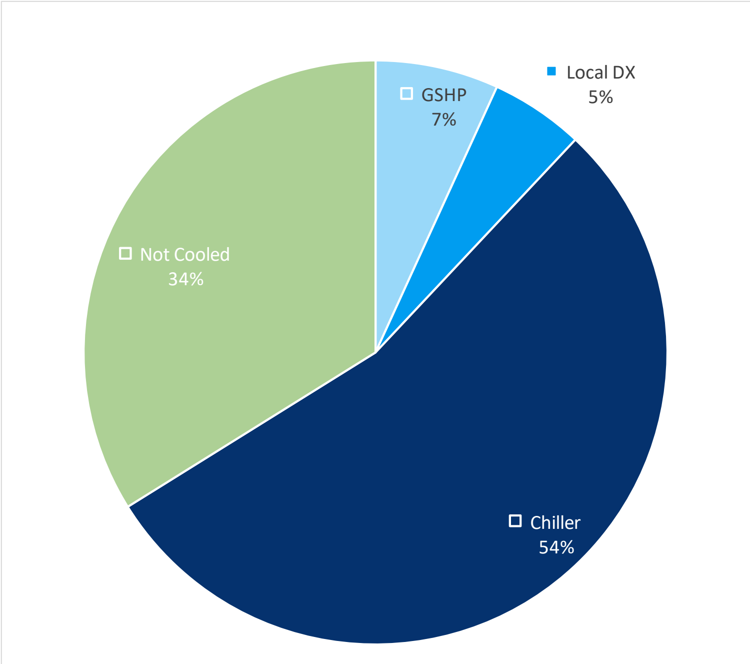



**Figure 22. Main campus cooling system type (percent of GSF)**

## 5.3 Overall design considerations

This section provides some key design considerations when establishing a decarbonization transition strategy.

### 5.3.1 Diversity factor

The peak heating demand in a centralized system will be lower than the sum of the peaks for all buildings since buildings do not have peaks in the exact same hour. The share between the peak heating demand in the central solution and the sum of the peaks in the individual solution is called the diversity factor and is typically estimated between 0.85 and 0.95 depending on the number of buildings. Accounting for the diversity factor provides an economic advantage for a central solution and means that the production capacity requirement in a central solution will be lower than the sum of building level demands. Figure 23 below illustrates the diversity factor for space heating as a function of the number of buildings according to different norms[4]. However, consideration has been given for situations when a central plant trips offline during peak load by sizing the less expensive backup equipment with the capacity to meet the total of all individual building peak loads.

[4] CIBSE CP1 2020 (Heat Network Code of Practice for UK) & Varme Stabi 7th edition, 1st print 2015, published by Praxis-Nyt Teknisk Forlag 2015

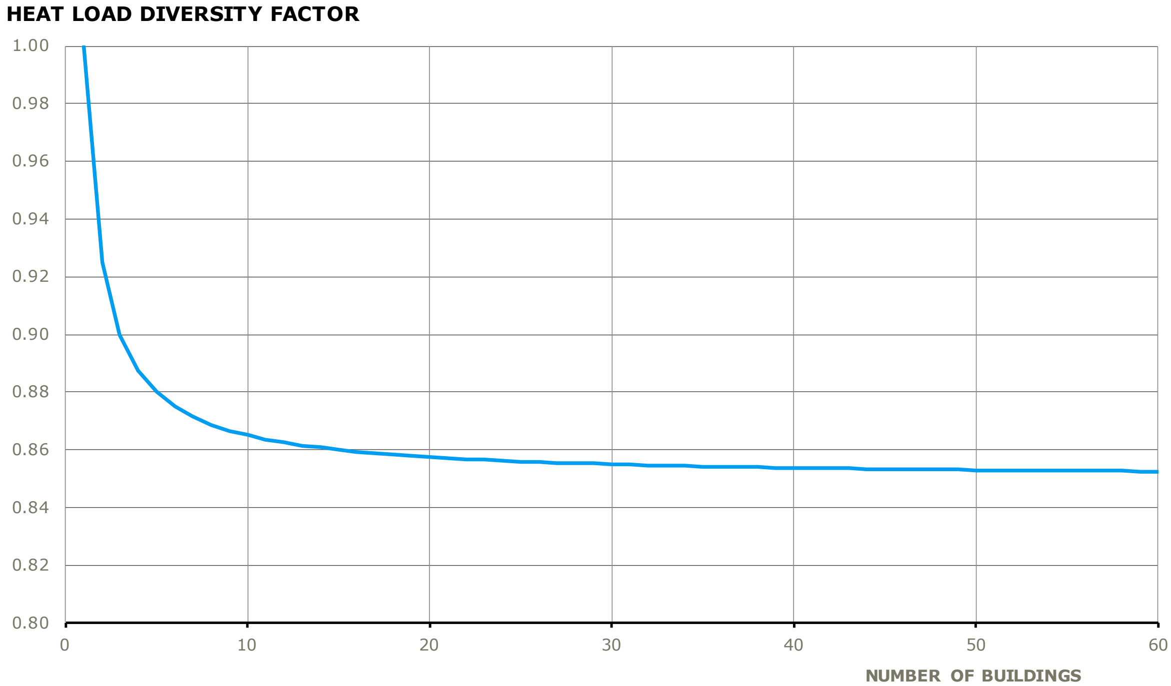



**Figure 23. Diversity factor for space heating**

### 5.3.2 Baseload, peaking, and backup considerations

Typically, base load technologies for electrification strategies (*e.g.*, heat pumps) are costly to install, whereas suitable peak load technologies have limited or even no installation costs. For example, peak load technologies could be existing boilers, which are established assets and often have long remaining lifetime. If they are operated as a peak load technology, the annual operating hours will occur in the coldest times of winter and will be limited in relative comparison to total annual operating hours. Therefore, the technical lifetime for existing boilers will be extended.

Baseload technologies should be in operation for many hours annually and should have a strategy for low operating costs. Since a peaking technology would have limited annual operating hours, potentially higher operational costs will only have limited impact on the overall economy.

The reason for establishing dedicated baseload technologies and peaking technologies is that peaking is only relevant in limited annual hours but requires a high capacity (see Figure 24). Establishing how much a baseload technology should cover of the total annual heat demand is an optimization exercise. However, as a rule of thumb, if the baseload covers 50% to 60% of the peak heating load, then it will cover approximately 90% of the annual heating load. For example, if the baseload technology was a ground heat source system, it would be necessary to nearly double the number of boreholes in the ground to go from approximately 90% to 100% load, but at a significantly higher cost than utilizing existing assets or lower cost peaking technologies, such as natural gas boilers. This could also provide a level of resiliency in both fuel diversification and capital cost management. Therefore, establishing a baseload and peak load strategy will be more cost-effective and could allow financial resources to be allocated to other projects.

The future energy system will increasingly use sources that are more intermittent in nature (i.e., wind and solar) and, therefore, will move from being very stable to being more unstable where electricity backup is crucial. It may also influence the grid reliability and, therefore, heat production backup should be considered. Here are some aspects for planning purposes:

- If baseload technology is electric based, then backup of the heating system should be based on another fuel, as for instance a gas (or oil) boiler
- The backup technology should be highly reliable and have lower installation costs
- The supply of the backup fuel should be non-interruptible and reliable
- The backup technology should be well known for the operational staff

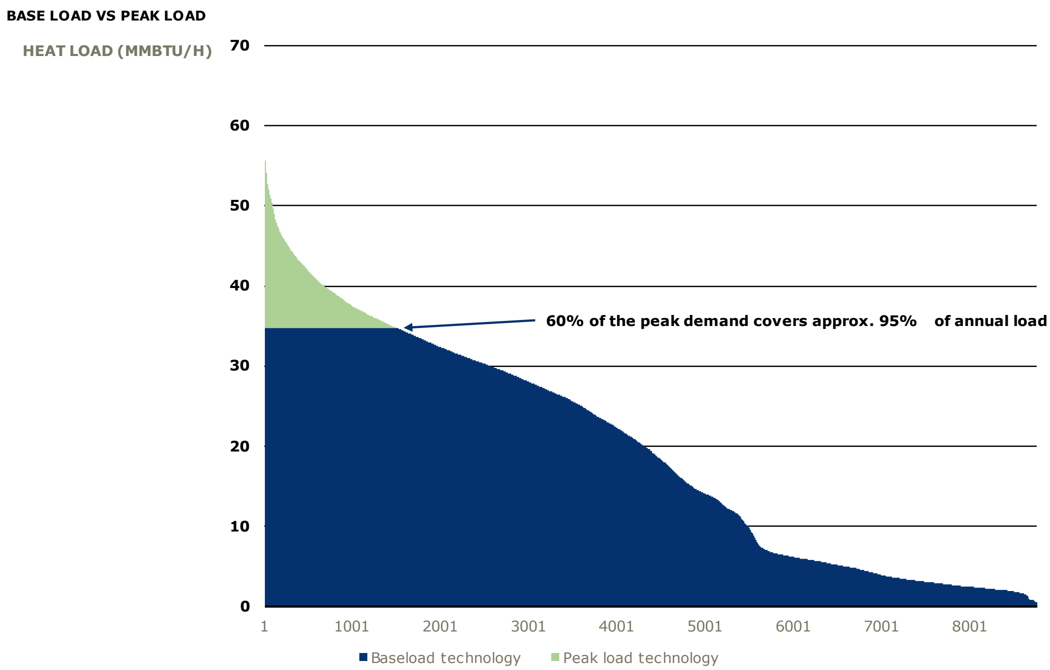



**Figure 24. Baseload and peaking illustration**

### 5.3.3 Supply temperature considerations

To introduce low carbon heating technologies like heat pumps, it is typically necessary to reduce the supply temperature to the systems/buildings since heat pumps have operating temperature limits. Furthermore, the lower the supply temperature of a heat pump, the higher the efficiency of the heat pump.

At this time, industrial heat pumps commonly available in the US can typically only produce district HW temperatures as high as 170°F. There are exceptions, and the market is also developing rapidly to include more multi-stage heat pumps and other refrigerant options that are more common in other parts of the world. High temperature heat pump offerings also tend to be available in larger sizes that are more applicable to centralized solutions rather than individual building scale; although expanded size offerings are a likely future development as well. Market offerings should be monitored within the timeframe for implementation of this study.

There are many benefits of reducing central hot water supply temperatures, including:

- Greater long-term economic benefits of lower temperature systems
- Ability to employ a diversified portfolio of low carbon or renewable technologies including heat pumps, geothermal, waste heat, solar thermal, and thermal storage
- Reduction in heat distribution losses due to a lower temperature difference between the circulating fluid in the distribution pipe and its surrounding
- Reduction in the overall temperature drop from the heat source to the most hydraulically remote building
- Ability to use different piping systems such as PEX or HDPE once the network is completely converted to lower temperature. Steel piping may be required initially to bridge the current high temperature and future low temperature systems.
- Increased efficiency of heat pumps by reducing the amount of temperature lift required
- Reduced reliance on fossil fuel technology by limiting annual peaking operation even further
- Longer life expectancy of steel pipes from reduced thermal stresses
- Increased safety and lower risk of scalding injuries

#### 5.3.3.1 Building design temperature considerations

Steam is currently being supplied to most buildings on campus. All buildings on campus have a steam to hot water heat exchanger to generate 180°F hot water. Since a heat pump efficiency increases through a reduction in supply temperature, consideration should be given to the optimal lowest temperature that could be reached, including reset of the setpoint for off-design conditions.

There should be a focus on increasing the deltaT in the buildings, which will increase the overall energy system efficiency. New buildings should be designed for a low supply temperature (also higher deltaT) at potentially 120°F to 130°F. For buildings that undergo partial renovations where HVAC systems are being updated, SUCF recommends that those systems be designed for supply temperatures of 140°F or less.

#### 5.3.3.2 Building-level temperature monitoring to support low temperature hot water transition

Building-level temperature monitoring is an important action to help inform future design and to help determine and prioritize which buildings need renovations to support the further reduction of hot water supply temperatures. While it is possible for heat pumps to be configured to supply hot water at more conventional design supply temperatures (~180°F), the cost of the heat pump increases, and the capacity and efficiency are reduced as compared to lower design supply temperatures.

If the campus can monitor building hot water supply and return temperatures over the course of at least one heating season, the data could be used to define design parameters of the proposed heat pump solutions in addition to identifying coil retrofits that currently require higher supply temperatures. For example, if the data reveal that most of the buildings can meet design loads with a 160°F supply temperature (and reset lower for off-design conditions), but some buildings still require 180°F supply temperature on a design day, then it may be more cost effective to replace the hot water coils in those buildings to enable a central system to operate more efficiently at a lower supply temperature. Without monitored temperature data the central supply temperature would need to be high enough to meet current building design conditions.

SUNY Oswego has hot water supply and return temperatures in their building automation system for all or most building hot water loops, but the data are not monitored or stored. As part of the monitoring effort, all building hot water supply and return points should be verified for accuracy and set up for trend data collection. It is important that the building hot water supply setpoints be set up for outdoor air temperature reset functionality as well. For a majority of the heating season, the supply temperature can be lower than the design point and heat pump capacity and efficiency will improve significantly.

The original building design hot water supply reset schedules can also be adjusted to optimize the reset, which is much more important for a heat pump application than for fossil fuel supply equipment. For example, the original reset schedule may call for adjusting the supply temperature from 180°F at 0°F outside air temperature down to 120°F at 60°F outside air temperature. This will improve heat pump performance as compared to a constant design supply temperature, but it is likely that the reset schedule can be adjusted and still meet building needs. For example, it may be found that a reset of 160°F at 0°F outside air temperature down to 110°F at 60°F outside air temperature provides sufficient coil capacity. The implications to a heat pump system design and operation are very important, so it is worth the effort of optimizing the reset schedules. A regular review (at least monthly through one heating season) of the data and reset schedule optimization by campus staff and/or outside energy consultants is recommended.

Monitored temperature data would also indicate the system temperature difference (delta T; hot water supply temperature minus return temperature) throughout the season. Knowing the delta-T will help define the design parameters and identify buildings with a low delta T that may benefit from a retrofit. A low delta T can reduce heating capacity, increase pumping power, and/or require larger pipes in the distribution system.

Note that this temperature data monitoring recommendation is different than the energy submetering, which includes heat energy entering each building. The associated energy meters would include supply and return temperature data, but not necessarily temperatures on the building side of the heat exchangers and not necessarily all hot water loops. For instance, a building that uses steam to generate space heating hot water for three zones may only need to install a single energy meter for the steam to meet submetering requirements of BuildSmart 2025. Data from that meter would indicate the total heating load for the building over time, but it would not indicate what supply temperatures are sufficient in the three heating loops. The temperature points needed for this recommendation already exist, and the monitoring effort does not need to wait for energy meter installations.

#### 5.3.3.3 Heating supply temperature recommendations

Heat supplied from a central plant will initially be around 170°F at peak load and operate based on an outdoor air temperature reset schedule to reduce distribution temperatures as outdoor temperature rises, increasing overall seasonal efficiency.

At a supply temperature of 170°F from the central plant and allowing for distribution losses and losses at building heat exchangers, building operating temperatures will be approximately 165°F.

Most building-side heating systems on campus are designed to meet the peak load with 180°F building hot water. As mentioned previously, Ramboll suspects that many buildings on campus could meet design heating loads with lower supply temperatures produced by the heat pumps. However, these temperatures are only required during peak design conditions when the outside air temperature is low, and only occur for a small percentage of the total heating season. For example, Syracuse typical meteorological year (TMY) weather (the closest weather station to Oswego) shows only 697 annual hours (8%) below 20°F outside temperature. Hot water supply temperatures are typically reset to lower temperatures when the outside temperature is higher, which reduces distribution losses and improves temperature control; and in the case of heat pumps, increases efficiency.

An example supply temperature reset schedule is shown in Figure 25 and illustrates that a typical schedule might call for 180°F supply temperature for outside air temperature below 20°F and then decrease that setpoint linearly down to a supply temperature of 120°F at outdoor air temperatures (OAT) above 50°F. The figure shows an outdoor air temperature of 27°F would require 165°F hot-water temperature. Syracuse TMY weather data shows approximately 1,404 hours, or 16% of the year, at or below 27°F OAT.

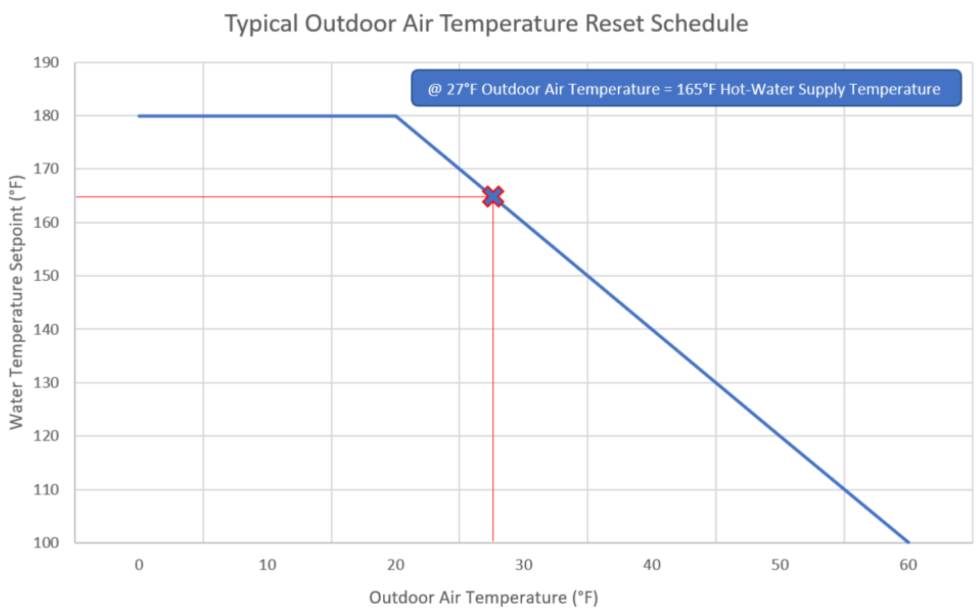



**Figure 25. Example outdoor air temperature reset schedule**

The overall capacity of a distribution network is dependent on the supply and the return temperature in the distribution system. Among the campus buildings, there are differences in the required heat to each building and each building's ability to reduce the temperature of that supplied heat (deltaT). Buildings with a low heat demand and a higher deltaT will have a low influence on the overall deltaT in the distribution network, whereas buildings with a high heat demand and low deltaT will have a high influence on the overall deltaT. When building renovations are planned, focus should be on the buildings with a high influence on the overall distribution system deltaT. Often it may only be necessary to concentrate on a limited number of buildings. This could be assessed through further hydraulic modeling in subsequent phases.

Furthermore, high return temperatures can limit the contribution heat pumps can make to the heating load at higher supply temperatures. If the return temperature at design conditions exceeds the maximum heat pump supply temperature, then the heat pump could not operate, and the peaking technology would need to meet the design load independently. This would have a major impact on peaking technology design capacity and, for electric peaking, required electrical infrastructure requirements. It is possible that NYISO Class Year limits[5] or regional capacity limits may become an issue. Further evaluation, investigation and testing are recommended for buildings which have a high influence on the deltaT.

As mentioned in the previous sections, as campus buildings are modernized and renovated over the long-term, central design supply temperatures will become lower. With consideration to temperature losses in heat exchangers and pipes, heat supplied from the central plant should target a maximum operating temperature of 155° to 160°F on the long-term.

#### 5.3.4 Building upgrade/modification considerations

Determining which buildings can operate at lower design temperatures and implementing reasonable building hot water temperature resets will limit the amount of work that may be required in the buildings to connect them to a low temperature hot water distribution network and allow the campus to start implementing a decarbonization plan sooner. A retro-commissioning study could be conducted on buildings that require higher supply temperatures to assess the issues that cause these buildings to operate at higher supply temperatures.

Ultimately, these buildings may require the heating coils to be replaced with larger coils that have sufficient heat capacity at design conditions with a lower supply temperature (*i.e.,* 130°F at design conditions). If the existing air handling units cannot accommodate larger heating coils, the existing chilled water coils could be valved to the hot water piping to act as a supplementary heating coil.

Some buildings may require complete removal and replacement of the existing HVAC systems. This would likely be required for systems that utilize steam directly for heating (*i.e.,* steam radiators), buildings with no existing hydronic heating/cooling (*i.e.,* rooftop units), or buildings where cooling does not currently exist and is planned to be added.

Initially, the heat pumps will likely need to supply higher hot water temperatures (~170°F), and the system will operate at a lower COP. This may result in peaking technology operating more hours to achieve temperatures higher than the heat pumps may be able to produce. Over time, as buildings are renovated, the distribution temperature could be lowered, allowing the heat pumps to operate at a higher COP.

In this study, building upgrades are not required to implement the scenarios (and serve the building needs with hot water supply temperatures of 170°F or lower). Ramboll also estimated the cost of retrofitting or replacing the HVAC systems in the remaining buildings that would allow them to meet peak heating loads with much lower supply temperatures. The advantage is better heat pump performance, but the retrofit cost is high.

[5] The Class Year study is performed annually by NYISO to evaluate the cumulative impact a group of large projects will have on the NYS transmission system. The process identifies specific system upgrades required at a transmission level and allocates cost. As a result, unpredictable transmission system upgrade costs may be required in addition to the expected high costs to modify the electrical distribution.

The budgetary cost estimate for building upgrades is shown in Table 21. Additional detail of the building upgrades is provided in Appendix D. To achieve a 130°F operating condition, some buildings would require full HVAC system renovation at a cost of $121M because they are at the end of their useful life; others would only need coil replacement at a cost of $45.4M The buildings requiring a full HVAC renovation were identified through discussions with the campus and the 2013-2023 Facility Master Plan (FMP) (Section 2.3).

**Table 21. Building modifications budgetary cost estimate for 130°F supply temperature**

| Modification | Cost |
|---|---|
| HVAC Renovation | $121.0M |
| Coil Replacement for 130°F Building HW Supply | $45.4M |
| **Total** | **$166.4M** |

Overall, it would cost $166.4M for the campus to operate with a 130°F deign temperature at the buildings. These upgrades may allow the LTW distribution temperature to be decreased to improve the heat pump COP. However, replacing coils in HVAC systems that can operate at 170°F under design conditions may not be financially viable. The cost to replace the coil as an early replacement activity should be weighed against the heat pump efficiency gains.

Using the heat load curve in Figure 24, the heat pump would meet about 95% of the annual heating load (162,000 MMBtu/year). If the resulting hot water supply temperature reductions from the $166.4M HVAC upgrades improved the heat pump efficiency by 25%, the annual electrical energy cost of the heat pumps could potentially be reduced by nearly $190,000 ($0.059/kWh from Table 16), resulting in a payback well over 100 years. This high-level analysis would suggest that the building HVAC modifications should not be done as early replacement; rather as the systems are due for replacement.

#### 5.3.5 Piping materials considerations

With lower supply temperatures in the heating network, it is possible to use polymeric materials in the heating network. However, many aspects of the final choice of using a polymeric material should be carefully considered.

- How will the network transition from the higher temperature to the lower temperature? Will it be necessary to maintain the higher temperature for any extended periods, even if that is only to certain portions of the campus?
- What system pressure is necessary? A polymeric material cannot withstand high temperature and high pressure for extended time periods. Are there elevations on the campus which increases the pressure in the system?
- Pipe service life. How long is the service life of the pipe and how is it affected by shorter exceedances in the temperature / pressure gradients?
- Pipes should be insulated, and regardless of material choice, the pipes should be pre-insulated
- Pipes should have leak detection to allow for quick identification and repair of potential issues

Final material choice would be selected in subsequent design phases where the above considerations and costs are further assessed.

### 5.3.6 Energy transfer stations in buildings

This plan considers connecting each individual building to the heating network through an indirect connection. A new heat exchanger would be installed in each building to separate the distribution network from the internal building installations. This is typically referred to as an Energy Transfer Station (ETS), meaning there is hydraulic separation between the two systems.

This has the advantage of being a more secure system than a direct connection in the event of an internal leak where there is risk of getting a large amount of water from the distribution network into the building, potentially causing significant damage. A hydraulically separated indirect connection thus removes this risk. The hydraulic separation also makes it possible to use higher pressures in the distribution network if necessary.

A direct connection, however, has the benefit that temperature loss through the heat exchanger could be avoided, leading to decreasing the central supply temperature and increasing the heat pump efficiency slightly. Furthermore, the return temperature in the distribution network will be lower.

Depending on space availability, the supply of domestic hot water (DHW) can either be instantaneous via a heat exchanger or through stored water in a tank storage. The installation of a DHW hot water storage tank, instead of instantaneous heat exchangers, will reduce the required DHW heating load to the building since the stored water tank volume will act as a buffer to the network. Consequently, this will reduce some of the pipe dimensions of the district heating network, especially the branch connections to each building, although more space will be required in the individual buildings to accommodate the tank. The selection of the type of DHW heater would be based on the DHW demand of the building.

The ETS itself would come as a prefabricated packaged unit solution and depending on the heating demand, will look similar to the unit in Figure 26. A skid mounted unit is suitable for larger demands; for smaller demands, a wall mounted ETS will be more suited. Additional heat exchangers for each building will be necessary to connect to the central cooling network.

Figure 26. Typical ETS installation (source: Danfoss)

**The techno-/economic analysis included CAPEX for installation of hot water and chilled water energy transfer stations for all buildings connected to centralized system.**

### 5.3.7 Resiliency considerations

#### 5.3.7.1 Current resiliency posture

The campus currently has natural gas service through National Grid. The main gas account comes into Lee Hall for the central heating plant and is then distributed to some buildings on campus for space heating, domestic hot water heating, cooking, and natural gas-powered generators. The buildings south of State Route 104 have a separate natural gas service.

The campus receives electrical power from National Grid (through the SUNY Energy buying group). Most buildings receive electricity from the main campus electric service, which accounts for nearly all of the electricity consumed on campus. The buildings south of State Route 104 have separate electric service accounts. Many buildings on campus have natural gas-powered generators for emergency backup power.

#### 5.3.7.2 Future resiliency posture

With an increased focus on electrification of the campus, it is advised to have full heating backup from a secondary fuel. Diversified fuel use can support flexibility and cost resiliency.

For buildings connected to a centralized system, the heating backup would be established in the central plant with boilers. Backup boilers may be supplied from either natural gas or from a liquid fuel. For buildings not connected to the centralized system, it would be necessary to install separate backup boilers within each building. Emergency generators should also be in place for supplying electricity to heat pumps and backup boilers.

Currently, the campus has emergency generators in many buildings. To support the central heating system operations, emergency generation should also supply power to the main circulating pumps for heating and cooling in the central system, as well as to larger circulating pumps within the buildings. Some options to consider increasing the resiliency of the campus include:

- Tank thermal energy storage
- Battery storage

**Tank Thermal Energy Storage**

Tank thermal energy storage (TTES) is an important component in an energy system with fluctuating energy prices. TTES involves storing hot or cold water in insulated tanks to help balance energy demand and supply while ultimately reducing peak demand, energy consumption, carbon emissions and costs. The storage makes it possible to disconnect consumption of electricity from the supply of heat. Thereby, it is possible to capture heat when renewable energy is available and supply heat from the TTES when renewable energy is scarce. Section 5.4.10 provides a broader discussion of this technology and its application.

**Battery Storage**

Battery storage can provide an uninterruptable power supply when the grid power is lost, but the capacity of a battery storage system is limited and often only a few hours of power supply is available. Scale needs to be considered and battery storage would not be cost-effective at campus scale. Often a building or a data center is backed up with an uninterrupted power supply to allow enough time for a generator to be started.

## 5.4 Technology screening – energy generation

The objective of the technology screening process is to identify suited technologies and storage options for the future production of heating/cooling that support campus alignment with the carbon reduction goals of the CLCPA. Technologies evaluated considered centralized and distributed (decentralized) solutions.

The process was conducted through a series of meetings where Ramboll presented descriptions of fossil fuel, renewable, and electrification technologies and their ability to produce either baseload and/or peak load production. Ramboll also discussed the technology’s ability to increase energy system flexibility and resiliency for the campus. Increasing the campus energy system’s flexibility can be advantageous when negotiating the energy utility supply rates and terms.

Technology screening conference calls were held with the campus from May through July 2022. Presentations and meeting minutes were distributed to SUNY Oswego and SUCF for those meetings.

The following subsections document the options considered for each technology category. Conclusions on which specific technologies to proceed with were ultimately made in each technology category during the screening process held with SUNY Upstate and SUCF.

### 5.4.1 Fossil fuel technologies

Table 22 shows the relevant fossil fuel technologies and the result from the screening process:

**Table 22. Technology screening process, fossil-based technologies**

**FOSSIL TECHNOLOGIES**

Scale: 1 2 3 4 5 — 1= poorest performance, 5= highest performance

| Technology | Notes | CO2 neutrality | CAPEX | OPEX | System integration | Go Forward |
|---|---|---|---|---|---|---|
| Gas turbine (simple cycle), Gas turbine combined cycle, rankine steam turbine, gas engines | - Base load technology, well proven<br>- Not carbon neutral if NG is used<br>- High CAPEX | 1 | 2 | 4 | 5 | No |
| Solid oxide fuel cell CHP | - High CAPEX<br>- Base load technology<br>- Not carbon neutral if NG is used<br>- Local use of biogas seems unrealistic<br>- Long start up times, high minimum load % | 2 | 1 | 4 | 4 | No |
| Gas boiler | - Peak / backup technology, very limited operation<br>- Not carbon neutral<br>- Very low CAPEX | 2 | 5 | 3 | 5 | Yes |
| Oil boiler | - Peak / backup technology, very limited operation<br>- Not carbon neutral<br>- Very low CAPEX | 1 | 5 | 2 | 4 | No |
| Grey Hydrogen | - Derived from n-gas and produced from fossil fuels<br>- CO2 is released into the air | 1 | 1 | 2 | 3 | No |

The fossil-based technologies are mentioned in the left column of Table 22 above. The topmost row of the table contains different characteristics or criteria of the technologies in which each technology was evaluated and subsequently scored against on a scale of 1 to 5, with 5 being the best performance. To qualitatively assist in the evaluation of the technologies, color coding is utilized where red is a "low score" and green is a "high score". For example, all technologies in Table 22 have a low score for "CO2 Neutrality" since they are fossil-based. The technology "Gas Boiler" has a high score when evaluated for CAPEX (*capital expenditures, i.e. upfront installation/construction costs and material costs*) since the CAPEX associated with installing a gas boiler system is relatively low in comparison to some other technologies. The column titled "System Integration" considers different characteristics for the technologies (e.g., support to the local energy system [e.g., peak / backup], integration with electricity market, space requirements, potential regulatory impact, etc.). All scores are based on a qualitative evaluation.

As seen from Table 22, only natural gas-fired boilers will continue to the subsequent phases. This is primarily due to their ability to act as reliable and effective peaking and/or backup heating assets, as mentioned previously in Section 5.3.2. While gas boilers would still contribute to carbon emissions if implemented, use of these assets in an emergency back-up case or special case (such as peaking) is permitted per SUCF Directive 1B-2: "On-site combustion of fossil fuel and biofuels is prohibited, except for emergency back-up power and emergency heat, and other special cases (*i.e.*, laboratory process loads, kilns, kitchen equipment) which are submitted for approval to the SUCF Project Coordinator". Gas boilers were not considered for base load applications due to these restrictions in 1B-2.

### 5.4.2 Renewable source technologies

Table 23 shows the relevant renewable source technologies and the result from the screening process:

**Table 23. Technology screening process, renewable sources**

**RENEWABLE SOURCES/TECHNOLOGIES** 1= poorest performance 5= highest performance

| Technology | Notes | CO2 neutrality | CAPEX | OPEX | System integratio | Go Forward |
|---|---|---|---|---|---|---|
| Bio-oil fired turbine (simple cycle) | - Base load technology<br>- High CAPEX<br>- Very high OPEX | 4 | 2 | 1 | 3 | No |
| Bio-oil engines | - Base load technology<br>- Very high OPEX | 4 | 2 | 1 | 4 | No |
| Biomass ORC CHP, wood chips | - Relatively high CAPEX<br>- Low OPEX | 4 | 1 | 4 | 3 | No |
| Biomass ORC, wood pellets | - Relatively high CAPEX<br>- High OPEX | 4 | 1 | 2 | 3 | No |
| Biomass HOB, wood chips | - Low CAPEX<br>- Low OPEX | 4 | 4 | 4 | 5 | No |
| Biomass HOB, wood pellets | - Low CAPEX<br>- High OPEX | 4 | 4 | 2 | 5 | No |
| Bio oil boiler | - Low CAPEX<br>- High OPEX | 4 | 5 | 2 | 5 | No |
| Photovoltaics | - Intermittent source / need backup from grid<br>- Limited production winter / high in summer | 5 | 2 | 5 | 3 | Yes |
| Wind turbine (large scale) | - Relatively low CAPEX<br>- Need backup from grid | 5 | 3 | 5 | 3 | Yes |
| Bio gas production - anaerobic digest | -High CAPEX / OPEX | 5 | 1 | 2 | 2 | No |
| Large Solar Thermal | - High CAPEX<br>- Limited production in winter / high in summer | 5 | 1 | 5 | 3 | No |
| HOB - conversion from n-gas to bio-o | - Very low CAPEX<br>- High OPEX if used in baseload | 4 | 5 | 2 | 5 | Yes |
| Boiler, hydrogen | - High CAPEX / OPEX | 4 | 1 | 1 | 1 | No |
| Cogeneration, hydrogen | - High CAPEX / OPEX | 3 | 1 | 1 | 1 | No |
| Blue Hydrogen | - Derived from n-gas and produced from fossil fuels<br>- CO2 is captures in a CCS process and stored | 4 | 1 | 1 | 2 | No |
| Green Hydrogen | - Produced from electrylyzes<br>- Electricity is based on renewable electricity | 5 | 2 | 1 | 2 | No |
| Run off river - underwater turbine | - Limitation in electricity production<br>- Fully developed? | 5 | 2 | 1 | 2 | No |
| Rooftop solar thermal | | 5 | 3 | 4 | 3 | Yes |

As noted in Table 23, the following technologies continued to the scenario planning phase:

- A boiler converted from natural gas to bio-oil
- Rooftop scale solar thermal (individual buildings)
- Photovoltaics
- Wind turbine

It is noted that per 1B-2 (July 2023 version), "onsite combustion of fossil fuel and biofuels is prohibited, except for emergency back-up power and emergency heat, and other special cases (*i.e.*, laboratory process loads, kilns, kitchen equipment) which are submitted for approval to the SUCF Project Coordinator".

The arguments to why large-scale solar thermal is screened out include the following:

- Production is mainly in the summer season, where there is limited demand for heat
- It will not lead to reduced CAPEX for other technologies since they would be designed for full capacity considering potential for limited sun in the winter months
- High CAPEX technology needing significant available space

### 5.4.3 Electrification technologies

Table 24 shows the relevant electrification technologies and the result from the screening process. Most are heat pumps with different capacities (single building or central) and different heat sources (wastewater, air, or ground).

**Table 24. Electrification technologies**

## ELECTRIFICATION TECHNOLOGIES

1 2 3 4 5
1= poorest performance 5= highest performance

| Technology | Notes | CO2 neutrality | CAPEX | OPEX | System integration | Go Forward |
|---|---|---|---|---|---|---|
| Electric boiler | - Base load or peak load<br>- Very low CAPEX for boiler<br>- High requirement for electric load. Potentially need for larger upgrade of electric feeders<br>- High OPEX | 4 | 5 | 1 | 5 | Yes |
| HP (air-to-water) - large scale | - Air as secondary heat source<br>- Low efficiency in winter period<br>- Reduction in load in winter season | 5 | 3 | 3 | 4 | Yes |
| HP (air-to-water) - small scale | - Standardized product, low CAPEX<br>- Low efficiency in winter period | 5 | 2 | 3 | 3 | Yes |
| GSHP open-loop, deep geothermal | - Base load technology<br>- High risk and high CAPEX | 5 | 1 | 3 | 3 | No |
| GSHP closed-loop, horiz, individual | - Closed loop, baseload technology<br>- Requires high available area | 5 | 1 | 3 | 3 | No |
| GSHP closed-loop, vert | - Closed loop, base load technology<br>- Requires much available space<br>- High CAPEX<br>- Boreholes would require balancing in summer periode | 5 | 2 | 3 | 4 | Yes |
| HP (sewage water-to water) | - Base load technology<br>- Often, relatively low CAPEX compared to benefits | 5 | 3 | 3 | 4 | Yes |
| Heat recovery chillers, electric | - low OPEX considering that heating and cooling is produced simultaneously<br>- higher CAPEX compared to conventional chiller | 4 | 3 | 4 | 4 | Yes |
| Chillers, electric | - low OPEX considering that heating and cooling is produced simultaneously<br>- lower CAPEX compared to heat recovery chillers | 4 | 3 | 3 | 5 | Yes |

### 5.4.4 Borehole thermal energy storage (BTES)

Borehole Thermal Energy Storage (BTES) refers to systems that utilize closed-loop ground heat exchangers that are used as heat source, heat sink, and seasonal thermal storage. Conventional ground source borefields have a reduced seasonal thermal storage capacity as compared to a BTES specifically designed and operated to optimize thermal storage characteristics. Both types exchange heat with the ground and store thermal energy within borefields, and each has its advantages and disadvantages. It is beyond the scope of this study to determine the most economical BTES design for the site, which should be evaluated in follow-up work.

**Number of boreholes**

To estimate the number of boreholes needed to serve the campus heating (or cooling) load, an average heat extraction rate is needed. The scope for this project did not include test bore installation and analysis, but Ramboll did review previous investigation results from the Shineman geothermal project and the Hewitt Hall renovation project. Ramboll applied a heat extraction value of 40 Btu/hr-ft and a heat of rejection value of 68 Btu/hr-ft. Using that assumed value, a borehole depth of 500 feet, and 20 ft spacing between boreholes, the number of thermal of boreholes to cover the baseload heating and cooling for the buildings the district is estimated. This will be covered in detail in Section 5.7.1.

**Borehole balancing**

Using the subsoil as BTES (borehole thermal energy storage) means that the ground temperature for the entire area of the BTES field varies in temperature. Since the campus is heating dominant (a higher demand for heating than for cooling), the demand for cooling is not adequate to re-balance the boreholes and, therefore, the subsoil would eventually get cooler from season to season unless the boreholes are balanced.

The borefield will be at a lower temperature after winter because of high heat demand. Whether the ground temperature can be partly used for direct cooling of the buildings should be further studied. If it is possible, the benefit is that part of the cooling is produced as free cooling with a very high efficiency, where the only electricity needed would be for pumping. The warmer water from the buildings will partly balance the boreholes as the buildings are cooled. When the cooling supply temperature reaches a certain maximum temperature, it would be necessary to operate the heat pumps to meet the cooling load, but also to supply additional heating for the balancing of the boreholes.

Because the campus is heating dominant, it is expected that it will be necessary to add additional heat to the boreholes. Various methods for balancing the borefield for each scenario is discussed in Section 5.7.1. This may either be from direct use of the warmer ambient air in the summer season but may also be from the heat pumps used as conventional heat pumps where cooling is wasted in the ambient air (air source heat pump) and the condenser side of the heat pumps is connected to the boreholes.

### 5.4.5 Wastewater treatment plant heat recovery

Wastewater can be an effective heat source for heat pump technology if its temperatures are at least a few degrees above freezing. The higher the wastewater temperature, the more heat that can be extracted. Ramboll evaluated the economic feasibility of recovering the low temperature heat from a wastewater treatment plant (WWTP) to feed a water-to-water HP, which was compared to a geothermal heat source in the form of vertical boreholes. Both solutions (wastewater and geothermal heat) provide low temperature heat, which can be used by a HP to produce higher temperature heat.

The Oswego Westside Wastewater Treatment Facility is about half a mile from the central heating plant, as shown in Figure 27. The yellow line represents the path of the piping that would connect the two plants. A heat exchanger at the WWTP would capture heat from the effluent as it leaves the plant for use as a heat source in the water-to-water HP.

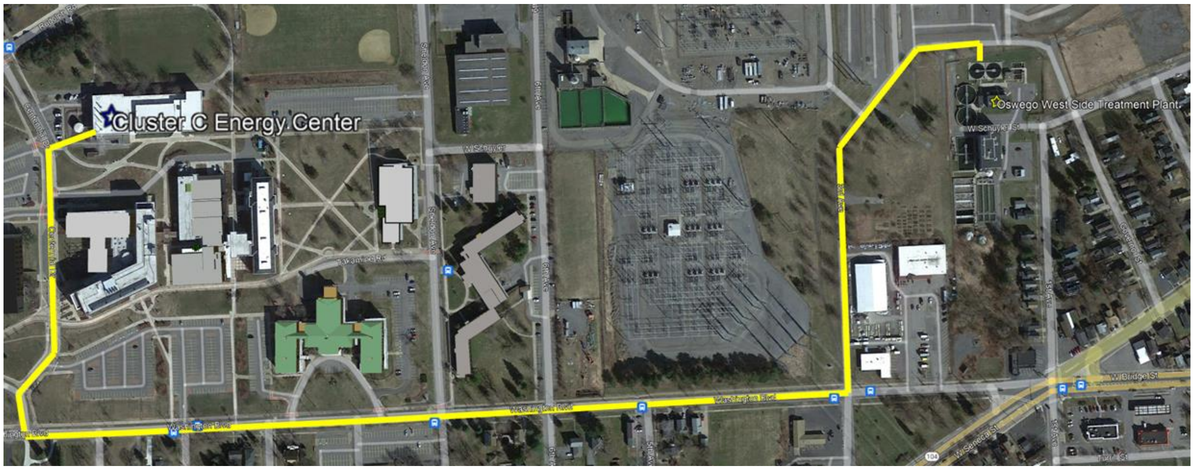



**Figure 27. Oswego westside wastewater treatment facility location**

Ramboll obtained daily flow (in millions of gallons per day) and effluent temperature from the WWTP, illustrated in Figure 28. From this data, the amount of heat that could be extracted from the effluent leaving the plant and the potential heat output of the heat pump was estimated, as shown in Figure 29.

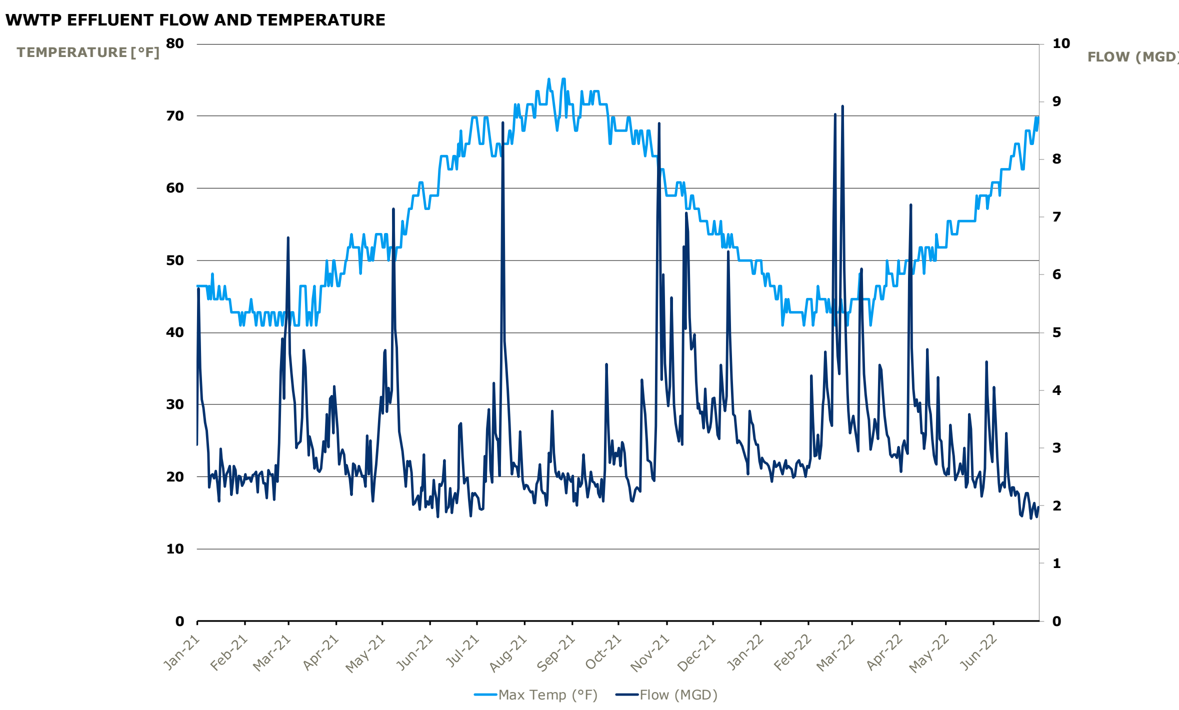



**Figure 28. Oswego westside WWTP data**

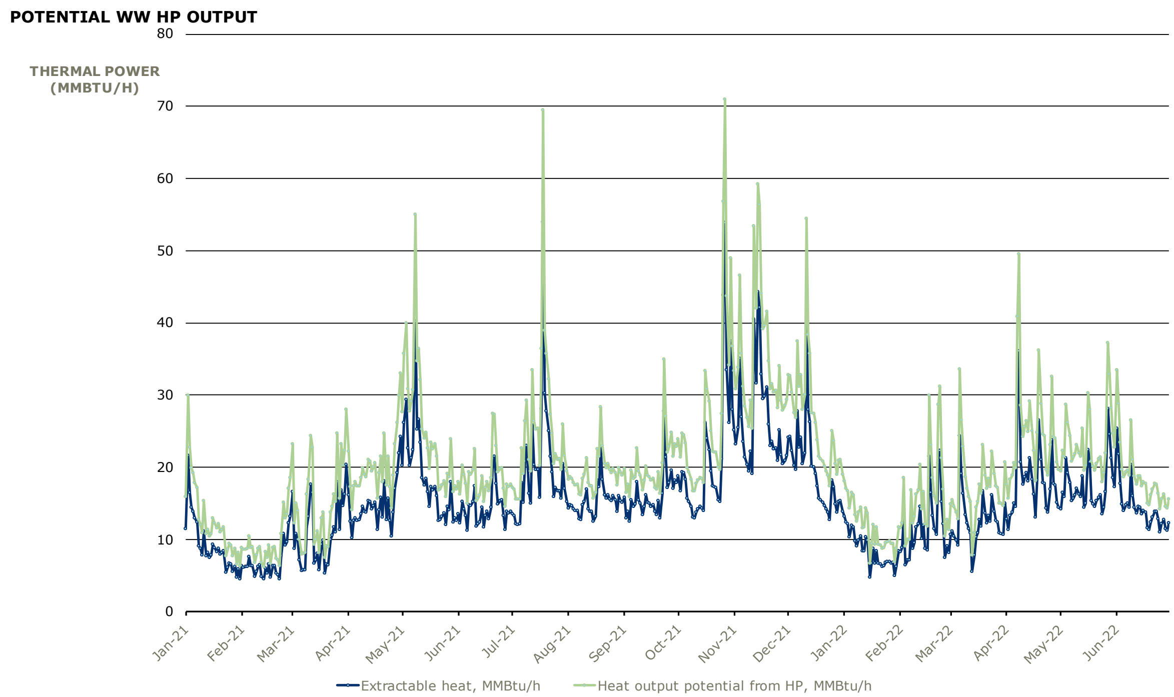



**Figure 29. Extractable heat from WWTP and potential heat output from HP**

Wastewater can potentially cover approximately 67% of the future annual heating baseload, as shown in Figure 30. A secondary baseload technology, such as geothermal, or other heat sources discussed in the subsections that follow, would cover the remaining baseload.

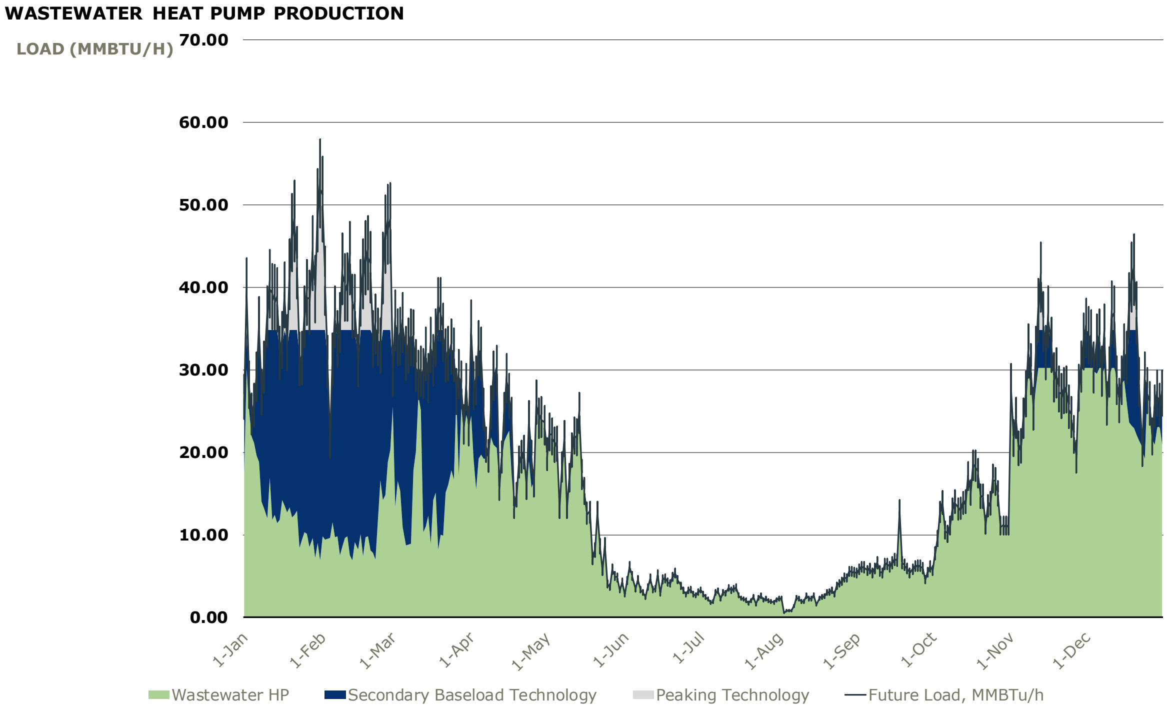



**Figure 30. Wastewater heat pump production**

### 5.4.6 Lake Ontario Heat Source

Utilizing water from Lake Ontario as a heat source was reviewed. Water temperature data at depths ranging from 1 m to 19 m (about 3 ft to 62 ft) was obtained from the Upstate Freshwater Institute. Data during winter months was only available from the 2021-2022 season. Figure 31 shows that the lake water temperature in the winter drops to about 32°F. Lake water temperature data at deeper depths was not available. At the temperatures observed, the heat pump evaporator would experience a very low delta T, which would result in a large flow of lake water, and thereby large pipe dimensions. The hours of operation of the system would be limited to conditions with warmer lake water temperatures to avoid freezing the return lake water. Due to these limitations and likely limited hours of use, installing a dedicated lake water intake would likely be cost prohibitive.

However, the Metropolitan Water Board raw pumping station is adjacent to the campus and takes in raw lake water and pumps it to a treatment facility several miles inland. Ramboll reached out to the Metropolitan Water Board to discuss the existing typical flow of the system and the excess capacity available. The board was not at a point to discuss this information, as they are assessing prior commitments for incoming industry (*i.e.*, Micron) that may utilize a significant amount of water.

A study conducted by The Research Foundation for the State University of New York assessed the potential to use lake water for areas of Central New York[6]. This study indicates that at a depth of 250 feet, the water temperature is approximately 39°F year-round. However, temperatures are

[6] *Assessing the Feasibility of a Central New York Naturally Chilled Water Project*, The Research Foundation, The State University of New York, June 2011

in general lower from the lake than from wastewater, making wastewater a better alternative as a heat source. If wastewater is used as a priority, then lake water will have limited hours in operation (intermediate technology is Figure 30).

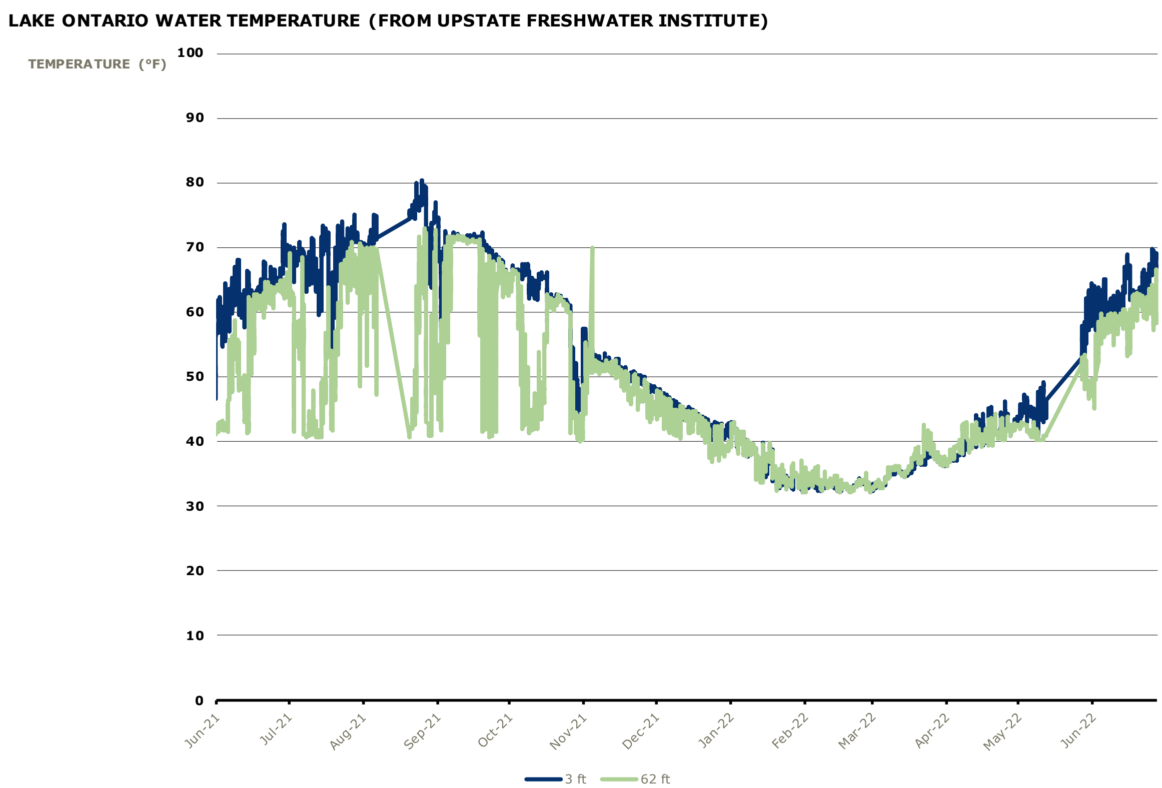



**Figure 31. Lake Ontario water temperature (obtained from Upstate Freshwater Institute)**

### 5.4.7 Substation Transformer Waste Heat

Two electric distribution substations owned by National Grid are adjacent to the campus, highlighted in Figure 32. The transformers are oil cooled, and heat can be captured for use as a heat source for heat pumps. There are two size units, a 115/34.5 kV transformer and a 345/115 kV transformer. Based on transformer loss data provided by National Grid, at full load, Ramboll estimates 400 MMBtu/h could be recovered from the smaller transformer and 2,400 MMBtu/h could be recovered from the larger transformer. A total of 2,800 MMBtu/h could be recovered from the transformers at full load, and about 1,600 MMBtu/h at 50% load. It is unclear what the typical loading of the transformers is. At an average of 50% transformer load versus 100% load, the waste heat would provide about 8% and 14% of the annual heat load, respectively. Ramboll suspects these transformers are around or below 50% loaded on average, limiting any heat recovery potential.

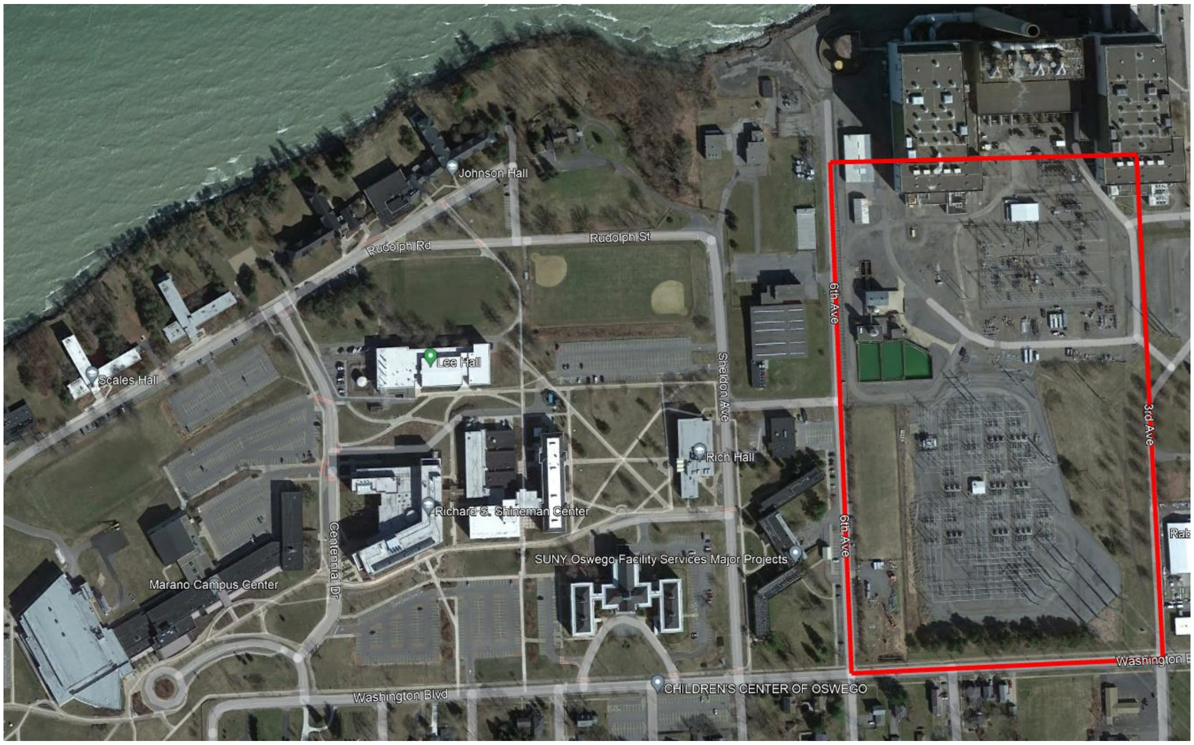



Figure 32. Electric substations

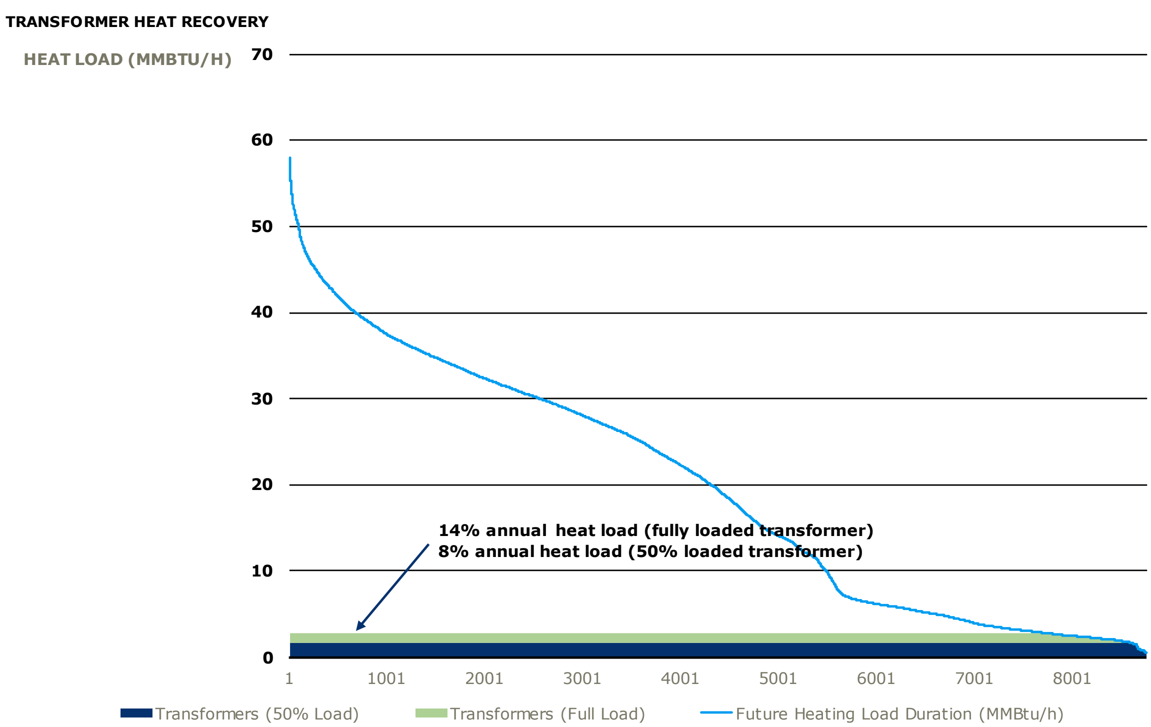



Figure 33. Transformer Heat Recovery

### 5.4.8 Cluster versus centralized

At the time this study was being conducted, SUNY Oswego was also conducting a NYSERDA Community Heat Pump project that looked at a geothermal plant at Hewitt Hall that would provide heating and cooling to a cluster of buildings around Hewitt Hall. SUNY Oswego was interested in building out similar cluster plants around the campus. Ramboll and SUNY Oswego developed the clusters shown in Figure 34. A common energy center for each cluster would be located within existing buildings to provide heating and cooling to the buildings within the cluster. The energy centers were identified by Ramboll and SUNY Oswego based on location within the cluster, available mechanical area, and renovation timeline. The following buildings were identified to house the energy centers:

- Cluster C – Central Heating Plant
- Cluster E – Mackin
- Cluster N – Riggs
- Cluster W – Little Page DH
- Cluster S – Laker Hall

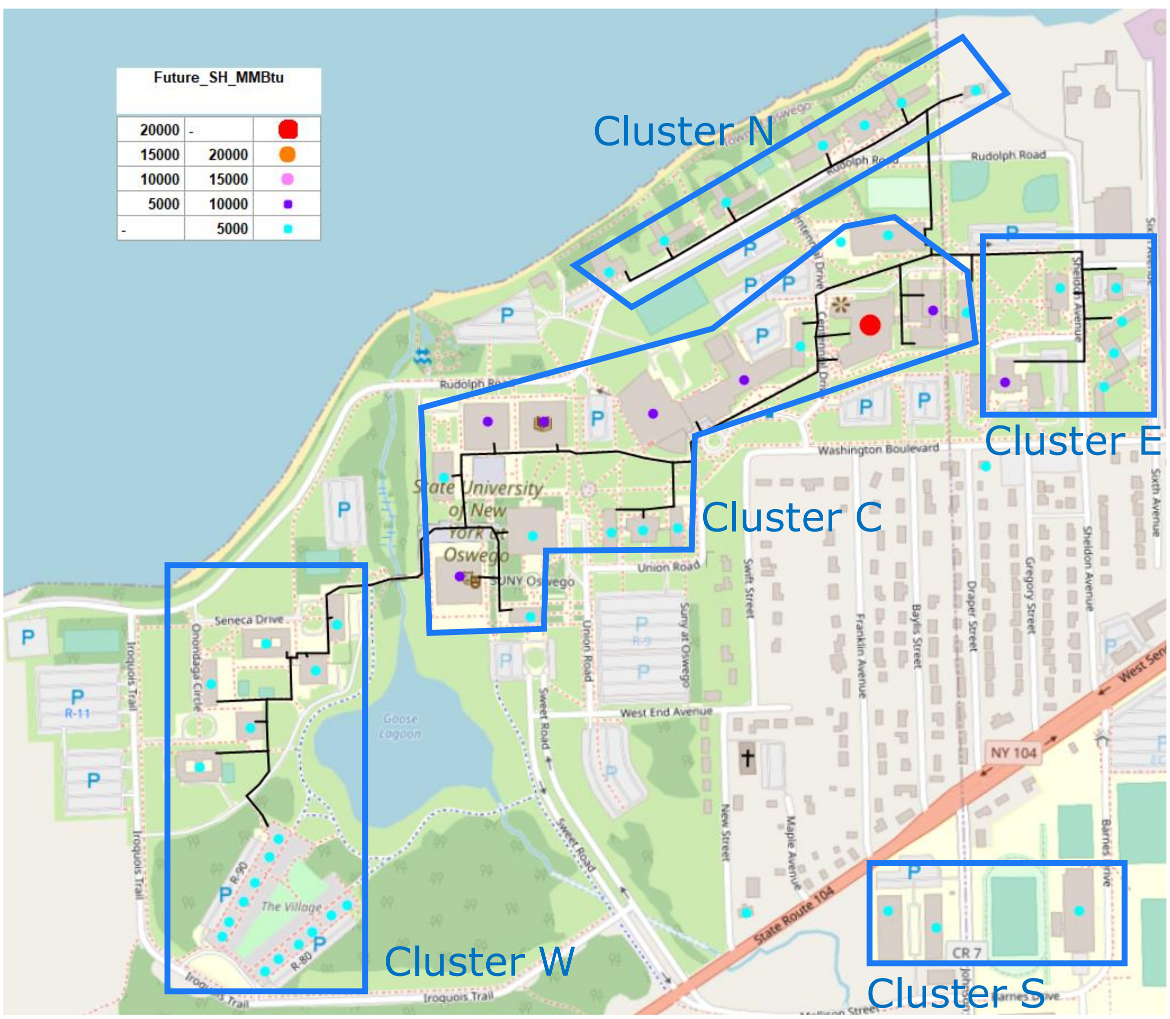



Figure 34. Heating and cooling clusters

Ramboll evaluated the cost difference between individual clusters versus connecting clusters to a single centralized energy center, as illustrated by the highlighted piping in Figure 35.

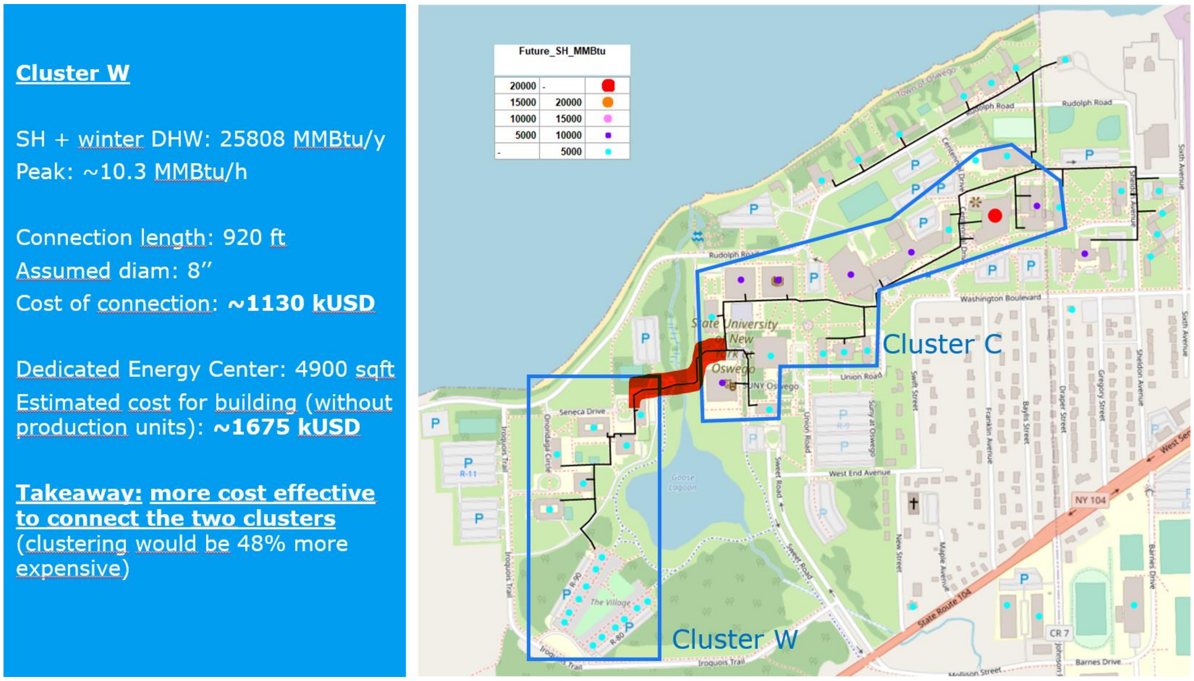



**Figure 35. Cost comparison to connect clusters**

Because of the relatively short piping connections needed to connect the clusters, Ramboll concluded that it was more cost effective to connect the Clusters E, W, and N to cluster C than to build out dedicated energy centers for each cluster. The distance and need to cross NY104 made it more cost effective to leave Cluster S as a stand-alone cluster. The results of the analysis are presented in Table 25.

**Table 25. Cluster versus centralized cost comparison**

| Energy Center | Energy Center Size (GSF) | Energy Center Cost | Connection Pipe Length and Diameter | Cost of Connection | Takeaway |
|---|---|---|---|---|---|
| Cluster W | 4,900 | $1.675 M | 8" Ø x 920' | $1.130 M | Clustering is 1.5 times more expensive |
| Cluster E | 3,600 | $1.230 M | 6" Ø x 577' | $0.530 M | Clustering is 2.3 times more expensive |
| Cluster N | 3,600 | $1.230 M | 6" Ø x 560' | $0.510 M | Clustering is 2.3 times more expensive |
| Cluster S | 2,000 | $0.684 M | 4" Ø x 2,400' | $1.980 M | Clustering is ~65% cheaper |
| Sum of Clusters W, E, N | - | $4.135 M | - | $2.170 M | Clustering is 1.9 times more expensive |

### 5.4.9 Additional technologies and heat sources

Additional technologies and heat sources were discussed and researched during meetings between SUNY Oswego and Ramboll. The technologies are listed below, but further analysis was not performed.

- Heat from composting
- Technical challenges of within-pile heat exchangers
  - Within pile heat exchange tubing can be easily damaged, due to compression from compost settling, loading, or unloading
  - Recirculating the within-pile heat exchange liquid too early or too fast can inhibit the composting process, reducing temperatures and future heat exchange
  - Compost cannot be mixed once the heat exchanger is placed within the pile
  - Energy recovery is limited due to poor heat conduction characteristics of composting feedstocks
  - High uncertainty on system performance
- Very few examples of this technology
- No predictable trend of heat recovery by system type or scale was apparent
- Heat recovery rates varied significantly and were dependent on system scale, type of heat exchange system, composting method, composting feedstocks, continuous versus batch loading, model versus operational data, geographic location, and duration of heat recovery
  - High uncertainty on system costs
- Of the 45 systems reviewed, only eight detailed cost. Without an economic component, comparison between technologies becomes difficult
  - Microhydro
- Based on pre-commercial demonstration project[7]
- Necessary water velocity is 3.3 ft/s or 2 knots (1 m/s)
- Data from Oswego River was not available
- Brookfield Renewable is the operator of hydro dams on the Oswego River
  - Potential to enter into a power purchase agreement (PPA) with Brookfield to purchase hydro power

### 5.4.10 Tank thermal energy storage (TTES)

Tank thermal energy storage (TTES) is a very important component to overall efficiency of energy systems, particularly district heating and cooling. TTES stores hot or cold water in insulated tanks to help balance energy demand and supply while ultimately reducing peak demand, energy consumption, carbon emissions and costs.

TTES is designed as a day-to-day storage, being able to discharge during periods of high electricity prices or charge during periods of low electricity prices. The total storage volume depends on system needs and desired function. TTES helps to level out daily fluctuations, whereas other types of storage are more suited for seasonal fluctuations (as for example, borehole thermal energy storage). TTES can also function as a cooling storage.

[7] Tidal Testing Underway in New York's East River | Department of Energy
Verdant Power deploys three tidal turbines in New York City's East River (hydroreview.com)

The benefits of TTES include the following:

- Lowers energy system operating costs, since the storage enables operation in off-peak hours for electricity
- Reduces the requirements for peak production since the storage can help provide peak. If peak is produced from fossil fuels, it will thereby reduce the GHG emissions
- Can, to a certain extent, provide backup for the system if pumps and ancillary equipment are on a secured electrical supply or emergency generator backup
- Functions as a "virtual battery" in energy systems dominated by intermittent renewable energy production and variability of hourly electrical prices. TTES has similar characteristics as a chemical battery (using electricity at low electricity prices and curtailing consumption of electricity when prices for electricity are high) but provides significantly higher energy content than a chemical battery and at a lower overall cost.

TTES typically can be in the form of cylindrical steel tanks (typically located above ground level) or concrete tanks (which can be partially buried if necessary). The tanks are insulated in both cases. In most installations, the temperature supplied to the storage is the supply temperature in the district heating network. Temperature stratification (i.e., having distinct layers of water at different temperatures within the storage tank rather than a fully mixed tank with a uniform temperature) can be achieved through multiple inlets, which increase the performance of the storage. Figure 36 shows the principles of a TTES:

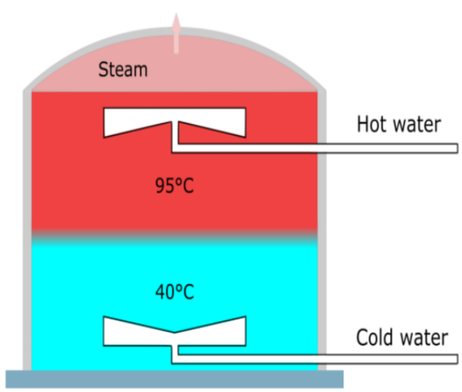



**Figure 36. Principle of a tank thermal energy storage**

There is not a physical separation between the warm and the cold water. The separation is handled by the difference in density between warm and cold water. Since the temperature in the separation layer is in between the supply and return temperatures, it is desired to keep it as thin as possible, typically 6-8 feet. Therefore, to avoid disturbances of the separation layer the inlet and outlet velocities are kept low with diffusers in the top and bottom of the tank. A tall and slim tank is preferred, since it will limit the unusable volume in the separation layer.

To avoid corrosion of the tank (in the case of a steel tank), steam is sometimes used in the space between the water level and the tank structure. More often, nitrogen is used instead of steam, and the nitrogen is produced from a small nearby nitrogen generator. If necessary, tanks can be slightly pressurized, but that will increase the construction costs. Most often, the water temperature will not exceed 212°F (100°C) in new low temperature heating systems, and therefore, the tank will be unpressurized. The temperatures in the example shown are 95°C (203°F) as supply temperature, and 40°C (104°F) as return temperature.

Unpressurized tank storage will serve to maintain minimum static pressure for a district heating network in case of pump failure. Therefore, it is recommended that the water level in the tank is always above the highest point in the district heating system. If the water level is below the highest point, it would be necessary to separate the systems, which will complicate the installation and increase the risk of failures.

The basic structure of connecting the heat storage tank to the district heating system, as a pressure holding vessel, is shown in Figure 37 below. With the heat storage tank included in the system, the instantaneous demand of the heat consumers does not have to equal the heating plant output; instead, the storage component allows flexibility in operation of the system to achieve energy cost and GHG emission savings.

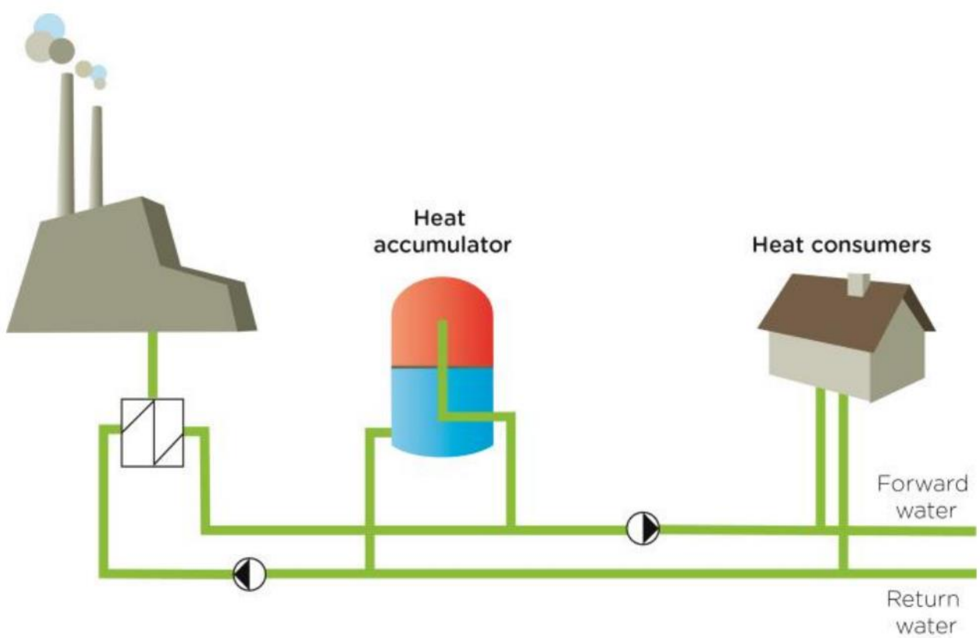



**Figure 37. Connection of a TTES – heat storage**

Figure 38 below is from DN Tanks[8] and illustrates how thermal energy (chilled water in this case) is produced during periods of off-peak electrical periods, collected in a thermal energy storage tank, then withdrawn and distributed to the facility during on-peak periods.

[8] https://www.dntanks.com/what-we-do/thermal-energy-storage/how-tes-works/

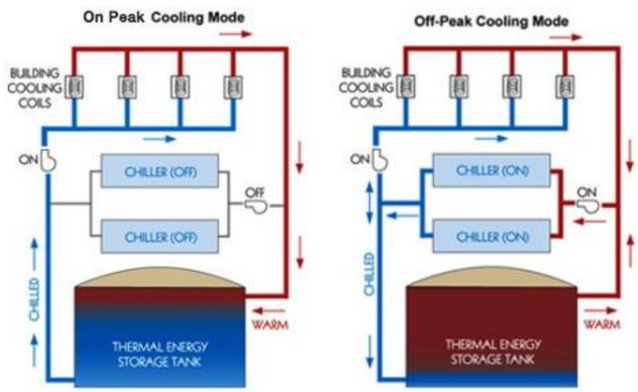



**Figure 38. Connection of a TTES – cooling storage**

#### 5.4.10.1 Preliminary sizing of thermal storage

The TTES should be able to provide heating or cooling to the energy system when there is limited renewable electricity in the grid. Therefore, in principle, it should be designed based on a thorough analysis of the prices for electricity and their fluctuations. However, since the further build out of intermittent renewable energy in NY will occur over many years to meet the goals of CLCPA, for purpose of this analysis, Ramboll assumed that TTES would cover 8 hours of base load operation.

From the load curve described in Section 5.3.2, it is estimated that the 60% of the peak heating demand covers approximately 95% of the heat demand. This load has been used as basis for the preliminary design. The peak heating demand is approximately 58 MMBtu/h, and the maximum baseload is approximately 35 MMBtu/h.

As previously mentioned, it is desired to keep the stratification layer between the warmer (supply) and the colder (return) water as thin as possible. The larger the diameter of the tank storage compared to the height of the tank storage, the more volume there will be in the stratification layer. Therefore, a higher and slimmer tank storage is generally preferred.

For this assessment, Ramboll has estimated a gross tank volume of 500,000 gallons. Based on a diameter/height ratio of 0.6, the water level height is estimated at 61 ft with a diameter of 37 ft (excluding insulation).

### 5.4.11 Aquifer thermal energy storage (ATES)

Aquifer Thermal Energy Storage (ATES) system is an innovative open-loop geothermal technology that relies on seasonal storage of cold and/or warm groundwater in an aquifer. An ATES system requires significantly fewer boreholes than a traditional geothermal borefield of the same capacity. As a result, ATES can have significantly lower CAPEX, should it be a viable option for the site. An ATES system requires suitable geological formations and sufficient water flow extraction rate from the borings.

Ramboll reviewed the hydrogeology of the Oswego area and found that ATES is not a viable option to pursue.

### 5.4.12 Distribution system: 4-pipe versus 2-pipe

When it comes to heating and cooling systems, two popular options for thermal distribution are the 4-pipe system and the 2-pipe system. The main difference between these systems lies in the number of pipes used for circulating hot and cold water. In a 2-pipe system, a single pipe is responsible for both the supply of hot water for heating and chilled water for cooling. On the other hand, a 4-pipe system utilizes separate pipes for hot water and chilled water, allowing simultaneous heating and cooling operations. The choice between a 4-pipe or 2-pipe system depends on factors including energy efficiency requirements and design flexibility, with each system offering unique advantages for heating and cooling applications.

Diagrams representing 4-pipe and 2-pipe systems are shown in Figure 39 and Figure 40, respectively.

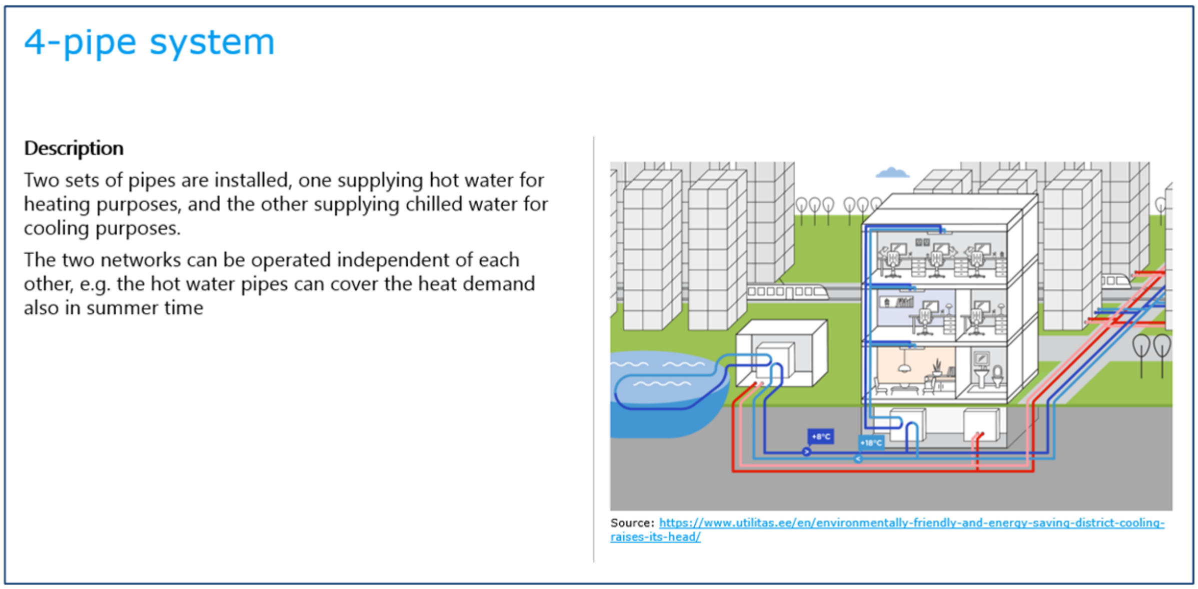



**Figure 39. 4-pipe system**

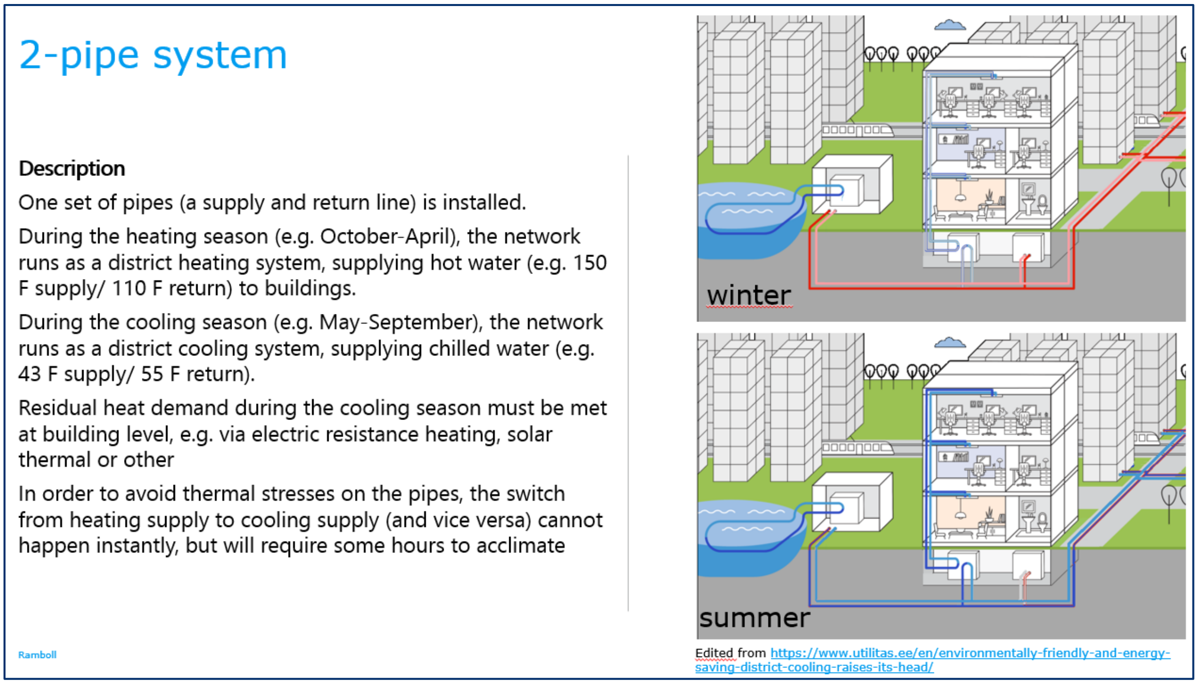



**Figure 40. 2-Pipe system**

The main advantage of a four-pipe system lies in its ability to provide simultaneous heating and cooling, allowing for enhanced comfort and control within a building. However, it is important to note that this system does come with a drawback, namely a higher capital expenditure due to the need for two sets of pipes. In situations where the cooling demand is limited, the implementation of dedicated centralized cooling may not be cost-effective.

On the other hand, a two-pipe system offers a more cost-effective solution as it requires only a single set of pipes to supply both heating and cooling. This streamlined design leads to a lower installation cost, particularly when providing cooling to existing buildings. However, it's worth noting that two-pipe systems lack flexibility as they are unable to provide simultaneous heating and cooling. Switching between dedicated modes takes time and introduces additional thermal stress cycling to the piping system, which can have adverse effects on both reliability and useful life. Moreover, defining the exact switch date can be a challenging task. Cooling and heating demands must be seasonal and easily defined for this type of system to work sufficiently.

The project team considered the advantages and drawbacks of both system types. The campus currently shuts down parts of the steam distribution in the summer and regularly shuts down local chillers and cooling towers for the heating season. As a result, SUNY Oswego was interested in advancing the 2-pipe system into the list of scenarios selected for analysis.

### 5.4.13 Ambient loop

An ambient loop circulates ambient temperature water throughout a district piping network. The low temperature is not suitable for direct heating; however, it is the source water supply for individual water source heat pumps (WSHP's) installed at each building. Building level heat pumps, as opposed to central heat pumps, is the fundamental difference between an ambient loop and a low temperature hot water (LTW) network. Oswego was not interested in exploring an ambient loop due to concerns of maintaining heat pumps at all buildings on campus.

## 5.5 Hydraulic modeling

Hydraulic modeling plays a crucial role in designing and analyzing piping distribution systems, including water supply networks, sewer systems, and energy distribution systems. These systems require efficient and reliable hydraulic performance, and hydraulic modeling enables engineers to predict and optimize fluid flow within them. It assists in determining appropriate pipe sizes, identifying potential pressure losses, predicting temperature differentials, evaluating system capacity to meet demands, and identifying operational issues. With its ability to simulate various scenarios, hydraulic modeling provides engineers valuable insights for informed decision-making to ensure optimal performance of piping distribution systems.

Hydraulic modeling is an efficient way to evaluate the current situation and the impact of changes to the distribution network. For instance, it assesses the impact of modifications such as pipe size alterations, network sectioning through valve operation, or distribution network expansion. Furthermore, the hydraulic model can be used to evaluate different production strategies involving multiple heat sources operating at varying temperatures. It also aids in determining maximum throughput, optimal pipe sizing, and pump requirements.

Ramboll utilized existing steam site piping drawings, flow diagrams, and stated design conditions to determine that the current distribution network cannot be reused for the proposed low-temperature hot water networks considered in this project.

New distribution networks were modeled for the centralized and cluster scenarios to supply low-temperature hot water or chilled water in a 2-pipe distribution using the Termis software package. The centralized distribution systems were modeled with the energy center at the existing Central Heating Plant, as shown in Figure 41. The cluster distribution system assumed the same path for piping distribution but with the pipes connecting the clusters removed, as shown in Figure 42. As mentioned in Section 5.4.8, the following locations were identified for the cluster energy centers:

- Cluster C – Central Heating Plant
- Cluster E – Mackin
- Cluster N – Riggs
- Cluster W – Little Page DH
- Cluster S – Laker Hall

The analysis, based on space heating and cooling demands, as well as domestic hot water demands, provided piping sizes, system pressure drops, and operating pressures for the distribution systems. The models assume direct buried piping throughout the campus. Appendix E contains summaries of the model assumptions and outputs for the three distribution systems. The results from the analysis were used to size the main distribution pumps and determine piping sizes and quantities, which were then incorporated into the scenario cost estimates.

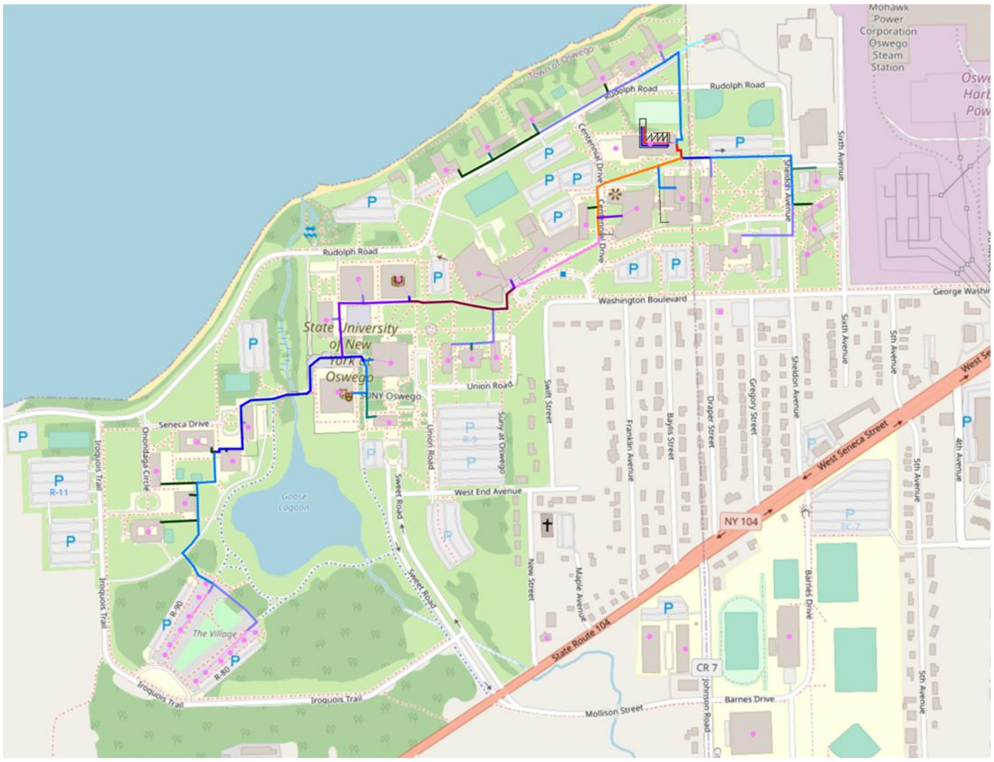



**Figure 41. Centralized 2-pipe distribution network**


**Figure 42. Cluster 2-pipe distribution network**

## 5.6 Conceptual scenario selection and initial screening

The objective of the planning efforts is to develop a group of scenarios to assess centralized and decentralized energy supply alternatives, and to identify those that will be advanced for further assessment. The scenarios are based on the technologies presented in Section 5.4 and consider the aspects below through a combination of quantitative and qualitative screening:

- Heating and cooling demands for each building on the campus
- Domestic hot water production during winter and summer months
- Best suited technologies and energy systems

### 5.6.1 Scenario variations

The number of scenarios was established through the discussion of variations during the project meetings. The following variations were identified in the provision of heating and cooling:

- GSHP, ASHP, natural gas boilers and electric boilers as centralized technologies
- GSHP, ASHP, lake water heat pumps, and wastewater heat pumps as baseload technologies
- Centrally supplied heating and cooling versus cluster heating and cooling
- 4-pipe versus 2-pipe distribution networks
- Production of domestic hot water (centralized and/or local)

The following subsections below describe the additional screening that was conducted and reviewed with the campus and SUCF to select variants considered most practical for each campus.

#### 5.6.1.1 Domestic hot water

Domestic hot water at the campus is mainly produced at the buildings from the central plant steam distribution system. Some steam lines are shut down during the summer, and numerous buildings have electric or natural gas DHW heaters for summertime production of DHW. For the decarbonization scenarios, DHW production from the proposed LTW distribution system via building level heat exchangers was evaluated. For the 2-pipe distribution network scenarios, local production of DHW at each building in the cooling season will be analyzed.

A qualitative comparison of relevant technologies was performed for local production of DHW. Local production units that could be considered to produce DHW are summarized below. Additionally, it could be considered to connect buildings to produce DHW from one unit to several buildings.

- Gas/oil boilers
- Electric boilers
- Smaller heat pumps (air or ground source)
- Solar thermal panels

Critique and observations of the technologies include the following:

- New gas/oil boilers are prohibited from being installed in accordance with SUCF directive 1B-2 and would not comply with the long-term goals for the campus transition away from fossil fuel use.

- Electric boilers have very simple components and are not dependent of a heat source as air or water. CAPEX is low, but OPEX can be high.
- Heat pumps have higher costs ($ per MMBtu/h) compared to electric boilers and have additional complexity. This is important since the operation and the efficiency of the units is highly dependent of the subsequent adjustment after the installation. Heat pumps should predominantly be considered when the unit can achieve many annual operating (more than 3,000 to 4,000 full load hours)
- Solar thermal production is dependent on actual solar radiation. The design of a solar thermal plant should balance the limited demand for DHW in the summer season with the production. Therefore, tank storage for DHW would be necessary. It may be necessary to curtail production in some instances or to utilize excess solar thermal production for balancing geothermal boreholes.

#### 5.6.1.2 Ground-source heat pump (GSHP) versus air-source heat pump (ASHP)

Two potential electrification technologies to serve the baseload demands at the campus have been considered: ground-source heat pumps (GSHP) and air-source (air-to-water) heat pumps (ASHP). The following items were discussed:

- **ASHP fan noise.** The evaporator of the ASHP is equipped with fans to improve the heat transfer rate. When in operation, the fans create noise. Depending on the context, noise reduction/mitigation may be required, which can be challenging and an add cost. However, the fans may be equipped with variable frequency drives to reduce fan speed, which will decrease the noise when operating at reduced speed.

- **Land availability for geothermal.** A GSHP will require a geothermal heat exchanger and access to the subsurface. Vertical boreholes significantly reduce the space requirements compared to a horizontal geothermal heat exchanger. The installation of the boreholes will have substantial surface disruption around the building during the installation phase. Once the boreholes are installed, the soil around the area can still be used, but substantial new building construction would not be possible. Parking lots can be a good application for geothermal borefields, particularly when a parking lot is being replaced or added.

- **Space availability for ASHP evaporator.** The ASHP evaporators will be located outdoors. Smaller units can be installed on the ground or on the top of buildings, but larger units will require dedicated horizontal space for the installation of the air heat exchanger.

- **ASHP performance limitations on cold days.** ASHPs experience lower operating efficiencies during colder periods of the year, namely when ambient temperatures are well below freezing. This limitation is driven by how cold the refrigerant within the ASHP system can get, as the refrigerant must be colder than the air in order to accommodate an effective heat transfer. While innovations in ASHP technology have resulted in systems capable of operating at subzero ambient temperatures, the drop-off in operating efficiency and capacity at colder ambient temperatures is still a crucial issue to consider when evaluating baseload technologies.

### ASHP

ASHPs considered in this study are air-to-water heat pumps that use ambient air as the heat source or heat sink to generate hot water or chilled water, respectively. ASHPs use a refrigeration cycle to facilitate this heat transfer between components. ASHPs can be integrated into either a decentralized (building-level) or centralized system, such as a district thermal system. In either arrangement, ASHPs are best sized to contribute toward the annual baseload heating demand. This is due to the heat pump's cost, inverse relationship between capacity and demand, and efficiency degradation for peak demand operation. In cold climates, application of ASHPs for heating are often more economical when coupled with the use of more conventional heating technologies, such as electric or gas-fired boilers, for supplemental heat for peak demands.

Some additional attributes of ASHPs to consider for implementation into a building-level or district-level hot or chilled water system are:

- ASHPs have higher efficiency than electric boilers, but this efficiency is impacted by ambient air temperatures
- High CAPEX relative to other technologies such as boilers
- Large space requirements for the air coolers
- Generally located on roof space of existing or new buildings, or dedicated open-air mechanical space on the ground
- Will have a noise impact to the immediate surroundings
- Will have a visual impact to a campus's or building's overall aesthetic
- Can be configured achieve hot water supply temperatures of up to 180°F
- The lower the supply temperature, the higher the efficiency of the ASHP
- Outdoor air coolers will pose the risk of icing-over when operating in sub-freezing temperatures
- Defrosting methods/options such as the use of hot refrigerant gas must be taken into account when designing an ASHP system

Figure 43 below represents a pro/con analysis done for ASHPs when compared to other technologies. Some of the attributes of ASHPs discussed previously are reiterated in the analysis.

**Pros**

- Free supply from ambient air
- Unlimited supply of ambient air
- Always accessible
- Scalable
- Less expensive to install when compared to Ground Source or Wastewater Source Heat Pumps

**Cons**

- Low energy content -> large air flows
- Noise
- The efficiency is low when the demand is high (During the years coldest months)
- Water vapor results in condensate and frost when the temperature approaches the freezing point
- The capacity decreases with the outside temperature
  - Overcapacity if designed for winter peak
  - Very few full load hours

**Figure 43. ASHP pro/con chart**

### GSHP

The Shineman Center currently has a GSHP system serving most of the heating loads and all cooling loads of the building. Hewitt Hall is currently under construction and the building will be heated and cooled with GSHPs.

GSHPs as considered in this study are water-to-water heat pumps that use the ground as the heat source or heat sink to generate hot water or chilled water, respectively. In the context of vertical closed-loop GSHP technology screened in Section 5.4.4, heat is exchanged to the earth via an array of vertical closed-circuit boreholes (the borefield) installed underground. The GSHP systems circulate a water or glycol solution through the borefield on one side and the building or central HW or CHW distribution loop on the other side.

Like ASHPs, GSHPs can be integrated into either a decentralized or centralized system, and they are also often most economical when sized to meet baseload heating demand rather than the entire peak heating demand. This is due, primarily, to their relatively high cost but also due to efficiency degradation for ground conditions typical in peak demand operation. In cold climates, application of GSHPs for heating are often more economical when coupled with the use of more conventional heating technologies, such as electric or gas-fired boilers, for supplemental heat for peak demands.

Some additional attributes of GSHPs to consider for implementation into a building-level or district-level hot or chilled water system are:

- Water is pumped in a closed-circuit through the ground to exchange heat with the ground
- Significant civil and ground works would be required to install this type of circuit
- Ground and site characteristics, along with load profiles, should be understood when sizing a GSHP system
- High CAPEX relative to other technologies such as boilers
- Large space requirements to install borefields
- Can achieve hot water supply temperatures of up to 180°F
- The lower the supply temperature, the higher the efficiency of the GSHP

Figure 44 below represents a pro/con analysis done for GSHPs when compared to other technologies. Some of the attributes of GSHPs discussed previously are reiterated in the analysis.

**Pros**

- Free supply from ground
- Scalable
- Stable ground temperatures
- High annual operating efficiency
  - Higher efficiency in coldest months, compared to AHSP

**Cons**

- Risk of imbalances in thermal profile of ground
  - GSHP must be sized correctly to avoid this
- Large space required for borehole arrays
- High CAPEX
- Performance may vary with local geology

**Figure 44. GSHP pro/con chart**

### Conclusion

There are both advantages and disadvantages to GSHP and ASHP technology. As explained later in Section 5.7, Ramboll optimized the advantages of both technologies by using ASHP and GSHP to collectively serve as the baseload in some scenarios.

#### 5.6.1.3 Geothermal borefield locations

The campus has substantial green space and parking area available for geothermal borefields. The shaded areas shown in Figure 45 represent the area that could be used for the borefield installation for each energy center. The potential areas were identified based on discussions with the campus; considerations included planned parking lot or courtyard renovations, intended future use of each area, and required land area for the borefield. The centralized scenario borefield could be placed in the Cluster C area (blue shading), in addition to the Cluster N area (orange shading), and the area to the east of the Cluster N area, if additional land is required.

Additionally, the existing Shineman Center borefield is shown as light blue shading and the borefield for Hewitt Hall is shown in pink shading. At the time of this study, Hewitt Hall was still under construction, but the borefield has been installed.


Figure 45. Potential and existing borefield locations on campus

## 5.7 Final screening and selection

This section contains a summary of the final scenarios that advanced through energy modeling and techno-economic analysis, including their impact on reducing carbon emissions.

### 5.7.1 Final scenarios selected

Through a process of qualitative and quantitative analyses, Ramboll reduced the number for scenarios from around 40 to 7, which advanced to further detailed techno-economic analysis. Table 26 below lists the seven final scenarios for the techno-economic analysis.

The business-as-usual (BAU) scenario considered in this study provides a comparison relative to the proposed modeled scenarios of costs and GHG emissions for the campus heating and cooling systems. In all cases, the scenarios numbered with an “a” indicate natural gas as the peak load technology and “b” indicate electricity as the peak load technology.

**Table 26. Final scenarios for the techno-economic assessment**

| Scenario | 2a | 2b | 4a | 4b | 5b | 6a | 6b |
|---|---|---|---|---|---|---|---|
| **Approach** | Cluster GSHP Variant | Cluster GSHP Variant | Centralized GSHP Variant | Centralized GSHP Variant | Centralized WWHP + GSHP Variant | Centralized Cascade ASHP+WSHP Variant | Centralized Cascade ASHP+WSHP Variant |
| Total number of heated buildings | 54 | 54 | 54 | 54 | 54 | 54 | 54 |
| Total number of cooled buildings | 44 | 44 | 44 | 44 | 44 | 44 | 44 |
| Number of buildings connected to district network | 52 | 52 | 52 | 52 | 52 | 52 | 52 |
| Total heat load of all buildings (SH+DHW), MMBtu/year | 167,647 | 167,647 | 167,647 | 167,647 | 167,647 | 167,647 | 167,647 |
| Heat load covered by DH network, MMBtu/year | 167,277 | 167,277 | 167,277 | 167,277 | 167,277 | 167,277 | 167,277 |
| Baseload | GSHP | GSHP | GSHP | GSHP | WWHP + GSHP | Cascade ASHP+WSHP GSHP | Cascade ASHP+WSHP GSHP |
| Peaking | Natural gas boiler | Electric Boiler | Natural gas boiler | Electric Boiler | Electric Boiler | Natural gas boiler | Electric Boiler |
| DHW | Centralized Local Electric (Summer) | Centralized Local Electric (Summer) | Centralized Local Electric (Summer) | Centralized Local Electric (Summer) | Centralized Local Electric (Summer) | Centralized Local Electric (Summer) | Centralized Local Electric (Summer) |
| Space Cooling | GSHP Chiller | GSHP Chiller | GSHP Chiller | GSHP Chiller | GSHP Chiller | GSHP Chiller | GSHP Chiller |
| Thermal Storage | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

| Scenario | 2a | 2b | 4a | 4b | 5b | 6a | 6b |
|---|---|---|---|---|---|---|---|
| Backup Heat | Natural gas boiler | Natural gas boiler | Natural gas boiler | Natural gas boiler | Natural gas boiler | Natural gas boiler | Natural gas boiler |
| Borefield Balancing | Cooling and ambient air | Cooling and ambient air | Cooling and ambient air | Cooling and ambient air | Cooling and Wastewater | Cooling and ASHP | Cooling and ASHP |
| Location of Borefield | Figure 45 | Figure 45 | Figure 45 | Figure 45 | Figure 45 | Figure 45 | Figure 45 |
| Distribution Network | 2-pipe | 2-pipe | 2-pipe | 2-pipe | 2-pipe | 2-pipe | 2-pipe |

GSHP = ground source heat pump; WWHP = wastewater heat pump; ASHP=air source heat pump

The **Scenarios 2a and 2b** are cluster heating and cooling scenarios, whereas **Scenarios 4a through 6b** are centralized heating and cooling scenarios. **Scenarios 2a and 2b** are identical to **Scenarios 4a and 4b**, except for cluster versus centralized distribution approach, respectively. The centralized scenarios are conceptually identical to each other, except for the different baseload technology mix that is assumed at a new energy center that would supply the centralized district heating & cooling (DH&C) network.

**Scenarios 2b, 4b, 5b, and 6b** consider full electrification, while **Scenarios 2a, 4a, and 6a** consider a natural gas boiler to address peaking during the heating season.

Full electrification scenarios (**2b, 4b, 5b, and 6b**) are equipped with natural gas emergency backup boilers, which are sized to meet the peak heating loads. The natural gas peaking boilers in **Scenarios 2a, 4a, and 6a** can double as emergency backup boilers. All boilers are in their respective energy center.

As shown in Table 26, the centralized scenarios only differ in terms of technology mix used in the energy center supplying the centralized distribution network. In all scenarios, a borefield is used as the heat source and sink for water-to-water HPs. In summer, the GSHPs switch mode, producing cooling for the 2-pipe distribution network and injecting the heat from the condenser back into the borefield to help recharge it before the start of the next heating season. Due to the difference between heating and cooling demand (see Figure 18 and Figure 19), the heat from the cooling production in summer is not sufficient to fully balance the borefield. Methods for balancing the borefield are discussed below.

As shown in Figure 46, the base load technology (heat pumps) will cover approximately 60% of the peak heating load (in MMBtu/h), thereby covering approximately 95% of the annual demand for heat (in MMBtu per year). The heat pumps have the capability to produce cooling but cannot provide 100% of the cooling load when sized for 60% of the heating demand. Additional cooling capacity could be provided by chillers or by additional heat pump capacity sized to handle the cooling load. Additional heat pump capacity would provide redundancy on the heating side but would also require larger geothermal borefields. Based on discussions, SUNY Oswego preferred to analyze the scenarios assuming additional ground source heat pump capacity would be installed to satisfy the cooling load.

While the borefield needs to be larger enough to handle 100% of the cooling load, it is sized based on the cooling capacity and the borehole heat rejection value (68 Btu/h-ft from Section 5.4.4), not the additional heating capacity and borehole heat extraction value (40 Btu/h-ft from Section 5.4.4) that is provided by redundant heat pumps. If the peak heating load were to be covered by 100% electrification sources, it would require 67% more boreholes and only cover an additional 5% of the annual heat load. This would have a significant impact on CAPEX when compared to alternative peaking technologies, as noted above. While the additional cooling capacity of the geothermal heat pumps would require a larger borefield, it only increases the borefield size by about 13%. This comparison is illustrated in Table 27, based on Scenario 4a/4b capacities.

**Table 27. Borefield sizing comparison**

| Geothermal Sizing Scenario | 60% of Peak Heating Load | 100% of Peak Cooling Load | 100% of Peak Heating Load |
|---|---|---|---|
| HP Heating Capacity (MMBtu/h) | 30.2 | 47.0 | 50.3 |
| HP Cooling Capacity (MMBtu/h) | 22.0 | 34.3 | 36.7 |
| Heat of Extraction (MMBtu/h) | 22.0 | 34.3 | 36.7 |
| Heat of Rejection (MMBtu/h) | 26.9 | 41.9 | 44.9 |
| # Boreholes | 1,095 | 1,236 | 1,825 |
| % Increase in Boreholes | 0% | 13% | 67% |

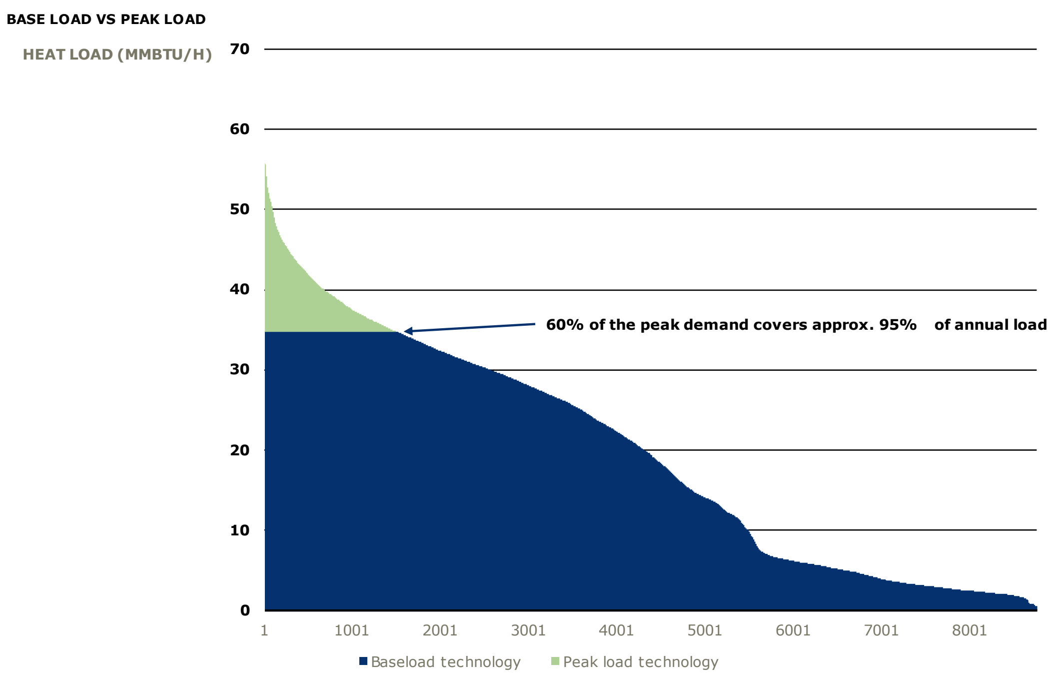



**Figure 46. Heat load curve**

**Business-as-usual (BAU)** scenario considers the existing central heating plant producing to the existing steam network, geothermal at the Shineman Center, and local natural gas-fired boilers at a few buildings on campus. In the BAU scenario, technologies will be renewed when they reach the end of their useful lifetime.

**Scenarios 2a and 2b** each consider a cluster scenario with five energy centers. Each energy center utilizes ground source heat pumps for baseload technology, and the scenarios differ only in terms of peaking technology: natural gas boilers in Scenario 2a and an electric boiler in

Scenario 2b. To maintain balance in the borefield, a dry cooler is used in warmer months to recharge the borefield.

**Scenarios 4a and 4b** each consider a centralized scenario for the buildings north of Route 104. The buildings South of Route 104 are identical to Scenarios 2a and 2b. Like Scenarios 2a and 2b, the energy centers utilize ground source heat pumps for baseload technology, and the scenarios differ only in terms of peaking technology: natural gas boilers in Scenario 4a and an electric boiler in Scenario 4b. To maintain balance in the borefield, a dry cooler is used in warmer months to recharge the borefield.

**Scenario 5b** is identical to Scenario 4b but considers recovering heat from wastewater as a heat source for the centralized energy center heat pumps. Wastewater heat recovery and ground source heat pumps are used as the baseload technologies and electric boilers are utilized for peaking technology. The borefield size is reduced by just over 200 boreholes, or about 25% fewer boreholes than Scenarios 4a and 4b. The wastewater heat recovery reduces the heat extraction of the borefield, likely eliminating any need for borefield balancing. However, the wastewater heat recovery can also be used to help balance the borefield by injecting heat into the borefield if needed.

**Scenario 6a and 6b** use an air-source heat pump in a cascade setup with a water-to-water heat pump as the baseload technology. Ground source heat pumps are utilized as a second baseload technology. The cascade heat pumps do not utilize the geothermal borefield, instead the base heat load is extracted from ambient air. The cascade heat pumps produce part of the base heat load, reducing the heat extraction of the borefield, and eliminating any need for borefield balancing. The two scenarios differ in peaking technology: natural gas boilers for Scenario 6a and an electric boiler in Scenario 6b.

### 5.7.2 Techno-economic analysis

The objective of techno-economic analysis is to identify the most cost-efficient mix of technologies for future supply of heating and cooling.

#### 5.7.2.1 Main assumptions

<u>Tariffs</u>

**Electricity**

The hourly electricity price was developed from an applicable 12-month time series of recent historical day-ahead market prices. The following two cost components were added to the day-ahead market price to reflect other electricity charges:

- a delivery charge
- an add-on to reflect to the annual demand charges (as assessed monthly)

The resulting rate used for the centralized solution analyses is an hourly blended rate that is variable, following the day-ahead market prices, and including demand charges that are blended as an add-on cost to each unit of electrical energy consumed. The result is an assumption that the ratio of monthly peak demand to monthly consumption is the same for the decarbonization scenarios as it is for the BAU. This is a necessary simplification in order to model an optimized sequencing of supply and storage assets within the EnergyPRO models.

The overall hourly price used as input to the EnergyPRO model for the centralized solution evaluation is shown in the Figure 47. The calculated average electricity price of the day-ahead data (with add-ons) is lower than the blended rate derived from historical consumption. This is expected since electricity prices are higher in hours of higher demand. The blended rate can be regarded as a consumption-weighted average electricity price; the straight average of hourly day-ahead pricing is not comparable.

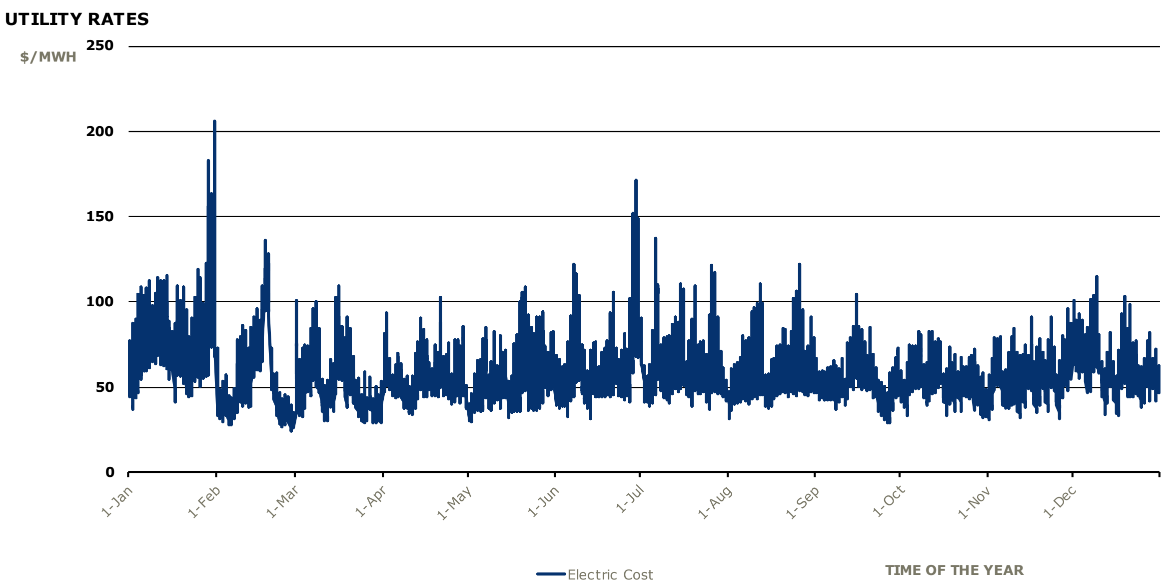



**Figure 47. Overall hourly electricity price used for the centralized production units**

Using an hourly blended rate (Figure 47) for electricity instead of explicitly including a separate demand charge has a consequence that can be described using an example.

Consider a centralized cooling production with thermal storage. If an hourly blended rate (Figure 47) is assumed, the optimal operation strategy (lowest operation cost) for operating the electric chillers would be to operate at full capacity in the hours with the lowest electricity prices to charge the thermal storage and then minimize/avoid operation during the hours with the highest electricity price, where the storage tank would be discharged to cover the demand. If the thermal storage charging ends up occurring during times that are not during the peak time window designated by the utility, or if the chiller demand during these times does not contribute to the monthly total electric peak, then the simplification has no consequence; that is not guaranteed. In practice, the thermal storage implementation would be operated to consider monthly demand peaks.

### Social cost of carbon

The social cost of carbon was estimated based on the New York State Department of Environmental Conservation (NYSDEC) document "Establishing a value of carbon"[9]. Table 28 presents the values used to calculate the social cost of carbon over the life of the project. The NYSDEC guidance document expresses the values in 2020 dollars. Ramboll calculated the social cost of carbon expressed in 2022 dollars based on historical consumer price index (CPI) published by the United States Bureau of Labor Statistics[10].

**Table 28. 2% Average (central rate) social cost of carbon**

| | Carbon | | Methane | | Nitrous Oxide | |
|---|---|---|---|---|---|---|
| **Emissions Year** | **2020$ per metric ton of CO2** | **2022$ per metric ton of CO2** | **2020$ per metric ton of CH4** | **2022$ per metric ton of CH4** | **2020$ per metric ton of N2O** | **2022$ per metric ton of N2O** |
| 2020 | $121 | **$137** | $2,700 | **$3,053** | $42,000 | **$47,492** |
| 2021 | $123 | **$139** | $2,800 | **$3,166** | $43,000 | **$48,623** |
| 2022 | $124 | **$140** | $2,800 | **$3,166** | $44,000 | **$49,754** |
| 2023 | $126 | **$142** | $2,900 | **$3,279** | $45,000 | **$50,884** |
| 2024 | $128 | **$145** | $2,900 | **$3,279** | $45,000 | **$50,884** |
| 2025 | $129 | **$146** | $3,000 | **$3,392** | $46,000 | **$52,015** |
| 2026 | $131 | **$148** | $3,100 | **$3,505** | $47,000 | **$53,146** |
| 2027 | $132 | **$149** | $3,100 | **$3,505** | $47,000 | **$53,146** |
| 2028 | $134 | **$152** | $3,200 | **$3,618** | $48,000 | **$54,277** |
| 2029 | $136 | **$154** | $3,300 | **$3,732** | $49,000 | **$55,408** |
| 2030 | $137 | **$155** | $3,400 | **$3,845** | $50,000 | **$56,538** |
| 2031 | $139 | **$157** | $3,400 | **$3,845** | $50,000 | **$56,538** |
| 2032 | $141 | **$159** | $3,500 | **$3,958** | $51,000 | **$57,669** |
| 2033 | $142 | **$161** | $3,600 | **$4,071** | $52,000 | **$58,800** |
| 2034 | $144 | **$163** | $3,600 | **$4,071** | $53,000 | **$59,931** |
| 2035 | $146 | **$165** | $3,700 | **$4,184** | $54,000 | **$61,061** |
| 2036 | $147 | **$166** | $3,800 | **$4,297** | $54,000 | **$61,061** |
| 2037 | $149 | **$168** | $3,900 | **$4,410** | $55,000 | **$62,192** |
| 2038 | $151 | **$171** | $3,900 | **$4,410** | $56,000 | **$63,323** |
| 2039 | $152 | **$172** | $4,000 | **$4,523** | $57,000 | **$64,454** |
| 2040 | $154 | **$174** | $4,100 | **$4,636** | $58,000 | **$65,584** |

[9] https://www.dec.ny.gov/docs/administration_pdf/vocapp22.pdf

[10] https://www.bls.gov/regions/mid-atlantic/data/consumerpriceindexhistorical_us_table.htm

2020 average CPI = 258.8

2022 average CPI = 292.7

13.1% inflation rate from 2020 to 2022

| Emissions Year | Carbon | | Methane | | Nitrous Oxide | |
|---|---|---|---|---|---|---|
| | 2020$ per metric ton of CO2 | 2022$ per metric ton of CO2 | 2020$ per metric ton of CH4 | 2022$ per metric ton of CH4 | 2020$ per metric ton of N2O | 2022$ per metric ton of N2O |
| 2041 | $156 | **$176** | $4,200 | **$4,749** | $58,000 | **$65,584** |
| 2042 | $158 | **$179** | $4,200 | **$4,749** | $59,000 | **$66,715** |
| 2043 | $160 | **$181** | $4,300 | **$4,862** | $60,000 | **$67,846** |
| 2044 | $162 | **$183** | $4,400 | **$4,975** | $61,000 | **$68,977** |
| 2045 | $164 | **$185** | $4,500 | **$5,088** | $61,000 | **$68,977** |
| 2046 | $166 | **$188** | $4,500 | **$5,088** | $62,000 | **$70,108** |
| 2047 | $167 | **$189** | $4,600 | **$5,202** | $63,000 | **$71,238** |
| 2048 | $169 | **$191** | $4,700 | **$5,315** | $64,000 | **$72,369** |
| 2049 | $170 | **$192** | $4,800 | **$5,428** | $65,000 | **$73,500** |
| 2050 | $172 | **$194** | $4,800 | **$5,428** | $66,000 | **$74,631** |

**Fuels**
Campus fossil fuels rates from Table 16 were escalated to 2022 dollars using the same methodology as described in Section 4.1.3.

- Natural gas: 0.404 USD/therm

Staffing needs and workforce development
The need for staffing is dependent on the complexity of the local energy system. The energy system will transition over time from a fossil fueled steam-based combustion system to a low temperature hot water system with heat pump technology, where combustion fuels are only used for peaking and backup purposes. The operation of the plant will, to a high extent, be automated.

Future operations are expected to be more complicated than todays. With the CLPCA goal of a carbon-free grid by 2040, there will be a broad build out of wind (off-shore, on-shore) and solar. This will result in more intermittent renewable energy as part of the electric grid and a heightened attention to shifting demand away from hours of limited intermittent renewable electricity in the grid. Daily strategies will include operating the heat pumps at the lowest wholesale day ahead prices for electricity and produce to thermal storage. In situations with potential high prices for electricity, it may be more optimal to produce from natural gas boilers.

This techno-economic evaluation does not include differences in workforce and staffing needs between the BAU and the scenarios.

<u>Technical lifetime of assets</u>

Table 29 includes equipment lifetime that have been assumed for estimating CAPEX.

**Table 29. Assumed equipment technical lifetime**

| Item | Technical Lifetime (years) |
|---|---|
| **Building level installations** | |
| Air cooled chiller | 15 |
| ASHP | 15 |
| Building level tank thermal energy storage | 25 |
| Dry coolers | 20 |
| DX cooling | 15 |
| Electric boilers | 15 |
| Electric radiators | 30 |
| Electric domestic hot water heater | 15 |
| Energy transfer station (ETS) | 25 |
| Fossil fuel boilers | 20 |
| Fossil fuel domestic hot water heater | 15 |
| Geothermal borefield | 40 |
| GSHP | 20 |
| Local domestic hot water HP | 15 |
| Rooftop units (RTU) | 15 |
| Water cooled chiller | 20 |
| | |
| **Distribution system** | |
| Ambient network | 50 |
| Condensate lines | 20 |
| Electrical infrastructure upgrades | 50 |
| Low temperature water (LTW) network | 50 |
| Hot water/steam tunnel network | 50 |
| HTW network (direct buried) | 35 |
| MTW network (direct buried) | 30 |
| Steam lines (direct buried) | 25 |
| | |
| **Energy center** | |
| Air cooled chiller | 20 |
| Geothermal borefield | 40 |
| Building for energy center | 50 |
| Dry coolers | 20 |
| Electric boilers | 20 |
| Fossil fuel boilers | 25 |

| Item | Technical Lifetime (years) |
|---|---|
| Heat pump (GSHP, WWHP, HRC) | 25 |
| Heat pump (ASHP) | 20 |
| Tank thermal energy storage (TTES) | 30 |
| Water cooled chiller | 25 |
| Wood chip boiler | 25 |

#### 5.7.2.2 EnergyPRO modeling tool

The operation of the centralized systems has been modeled through EnergyPRO software to assess how the different energy production units, as well as energy storage, would be operated considering technical, economic, and environmental aspects. The layout of an EnergyPRO model for the campus is shown in Figure 48 below.

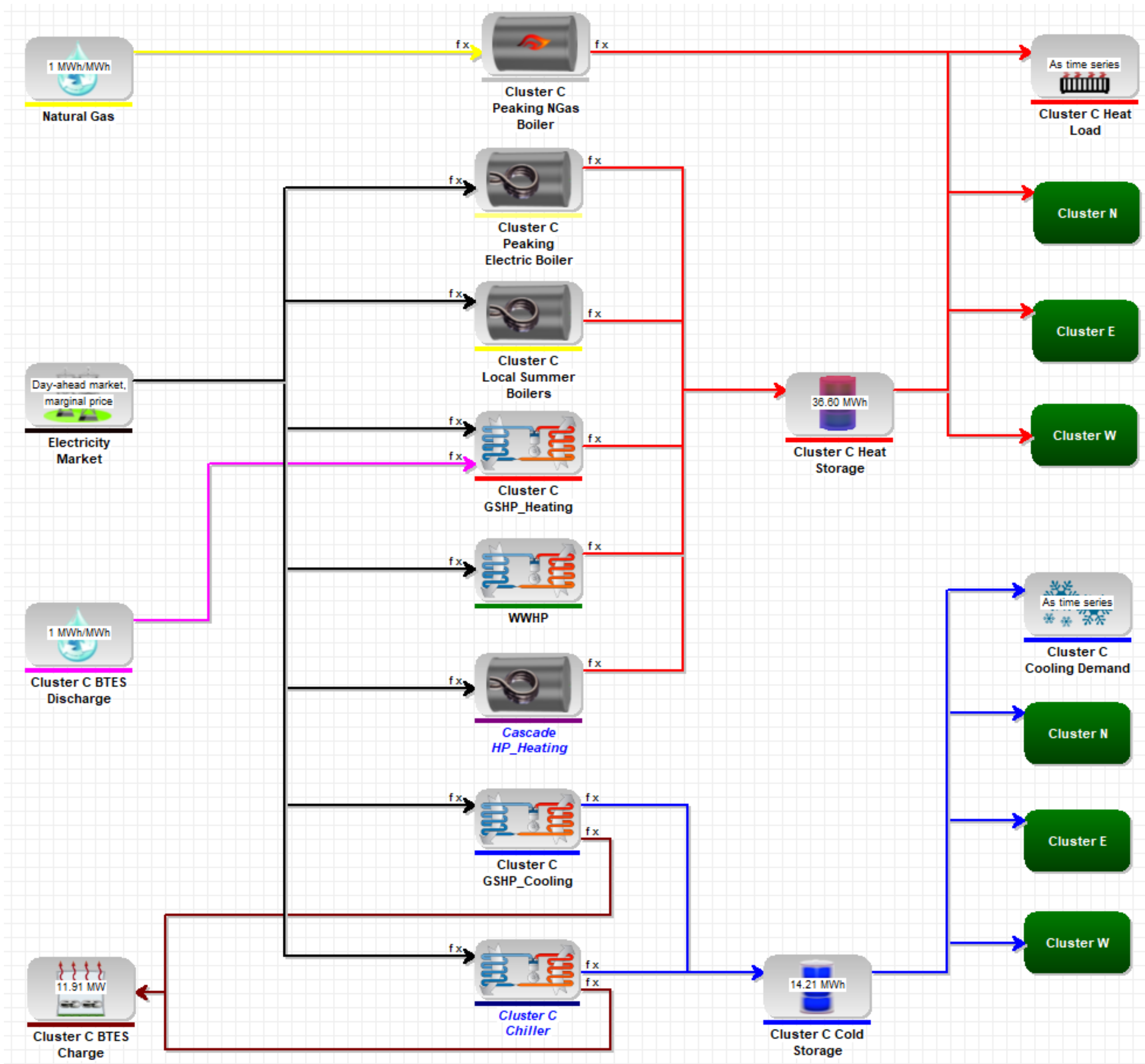



**Figure 48. EnergyPRO model for the campus (centralized system only)**

In EnergyPRO, the different colors of the connectors denote a different type of energy flow:

- Blue: "cooling energy"
- Red: "heating energy"
- Black: electricity
- Maroon: "heat rejected to BTES"
- Pink: "heat extracted from BTES"
- Yellow: natural gas

On the right-hand side, the cluster heating and cooling demand blocks represent the energy demands that must be covered. In the figure, the energy-production units are the following:

**GSHP heating/GSHP cooling** – these units are the same machine (i.e., a ground source heat pump), but need to be modeled as separate units in EnergyPRO to properly simulate the behavior and operation of the machine.

**Chiller** – this is the additional GSHP capacity added to meet peak cooling requirements that can also provide redundant heating capabilities. This is modeled separate from the GSHP units in EnergyPRO to avoid providing more than 60% of the heating baseload from GSHP.

**Cascade HP heating** – This unit is an air source heat pump in a cascade arrangement (series ASHP/WSHP configuration) with a water-to-water heat pump; the ASHP heated water acts as the source for the WSHP to further boost hot water supply temperature. Its performance depends on the outdoor ambient temperature. It is assumed that the unit has a cut-off temperature of 10°F. The operation of the heat pump is dependent on both the electricity price and on the outdoor ambient temperature.

**WWHP** – This unit is the same unit as the GSHP but uses wastewater as the heat source instead of the geothermal borefield. Even though it has the same compressor as the GSHP, it needs to be modeled separately in EnergyPro because of the different heat source. Its performance depends on the wastewater temperature throughout the year. The operation of the heat pump is dependent on both the electricity price and on the assumed performance at different wastewater temperatures.

**Natural gas boiler/Electric boiler** – these units (either of the two, depending on the scenario) work as peak units. These will run a limited number of full-load hours during the year, only in the periods where the heat demand exceeds the capacity of the baseload technology. In this way the more CAPEX-intensive technologies (such as the geothermal borefield) do not have to be sized for peak load, and the investment cost in these technologies can be reduced significantly with minimal impact to GHG emissions reduction. All scenarios (including those with electric boiler as peak production units) assume gas boilers as emergency backup units. This alternative energy source improves the resiliency and reliability of the energy system and supply.

**Local summer boilers** – This unit estimates the energy for summer boilers or domestic hot water heaters located in buildings that handle heating loads when the two-pipe distribution is in cooling mode.

Thermal energy storage ("Heat storage" and "Cold storage") buffers energy supply from energy demand. One physical tank will act as heat storage in the heating season and cold storage in the cooling season but must be modeled as two separate units in EnergyPRO. The presence of thermal storage allows the system to take advantage of lower hourly electricity prices when they occur in the market; operating the electric-drive machines at full capacity to cover instantaneous demand and charging storage(s). During times when the electricity price increases, the stored energy can be discharged to cover the demand, while reducing the output from the energy-production units.

On the left-hand side, two blocks ("BTES charge" and "BTES discharge") are used to model the seasonal thermal energy storage for scenarios equipped with GSHP.

The objective of EnergyPRO is to optimize the yearly operation of the production units so that the energy demands (heating and cooling in this case) are covered at the lowest yearly operational cost. Simply stated, EnergyPRO assigns to each production unit a marginal cost of production in each hour of the year, considering relevant external conditions such as ambient temperature (for the ASHP) and electricity price (for electric-driven machines). The units with the lowest marginal cost of production will be called into operation first. If more production capacity is required to cover demand, units with progressively higher marginal costs of production are called into operation. The optimization process in EnergyPRO also involves the optimal utilization of the energy storages and technical constraints, such as unavailability periods and minimum duration of operation.

EnergyPro can produce an hour-by-hour output of energy-production units. As an example, the heating and cooling production graphic for Scenario 5b is shown in Figure 49, while the state of charge of the thermal energy storage during the heating and cooling season is shown in Figure 50. Note in Figure 49

As seen from Figure 49, the WWHP and GSHP provide the base heating load and the electric boiler is used during peak periods. During the summer, the GSHP and chiller provide the cooling load.

It can be seen how EnergyPRO optimizes the operation of the available technologies, based on the availability of storage capacity and electricity prices. A clearer demonstration of this is shown in Figure 51, where the operation of a chiller is shown together with the state of charge of thermal storage and electricity price. In periods with low electricity prices, the chiller operates at full capacity to cover the cooling demand and recharge the thermal energy storage. Conversely, in hours with higher electricity prices, the chiller stops operating and the cooling demand is covered by discharging the storage.

It is noted that the power unit on the y-axis is megawatt (MW), and the chart starts at the beginning of the heating season (assumed October 1) when the two-pipe system is transitioned to a heating network. The two-pipe system is transitioned to a cooling network on May 15.

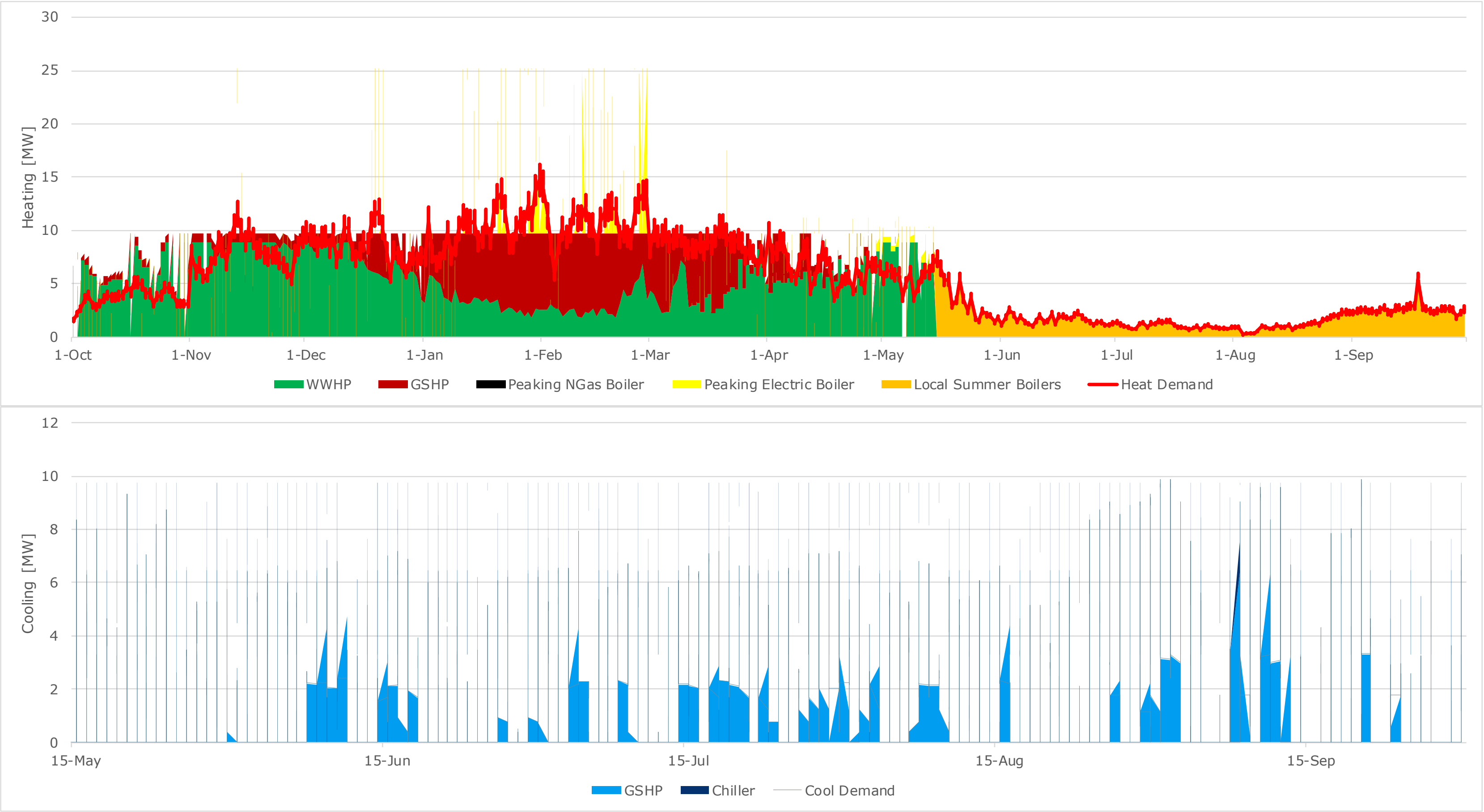



**Figure 49. Hour-by-hour production schedule of the different production units over one year in Scenario 5b for both heating (upper diagram) and cooling (lower diagram)**

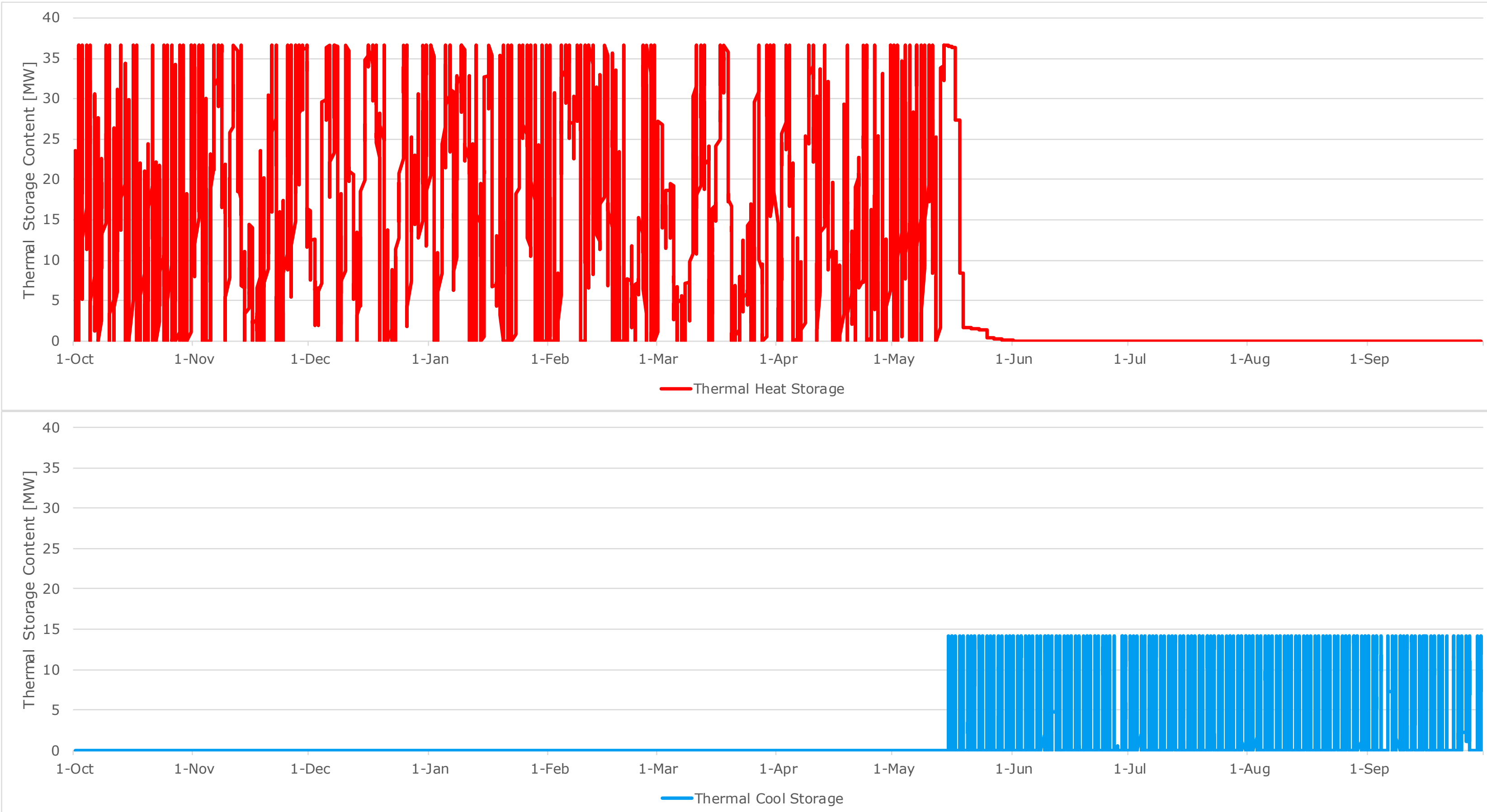



**Figure 50. State of charge of the thermal energy storage during the heating and cooling season**

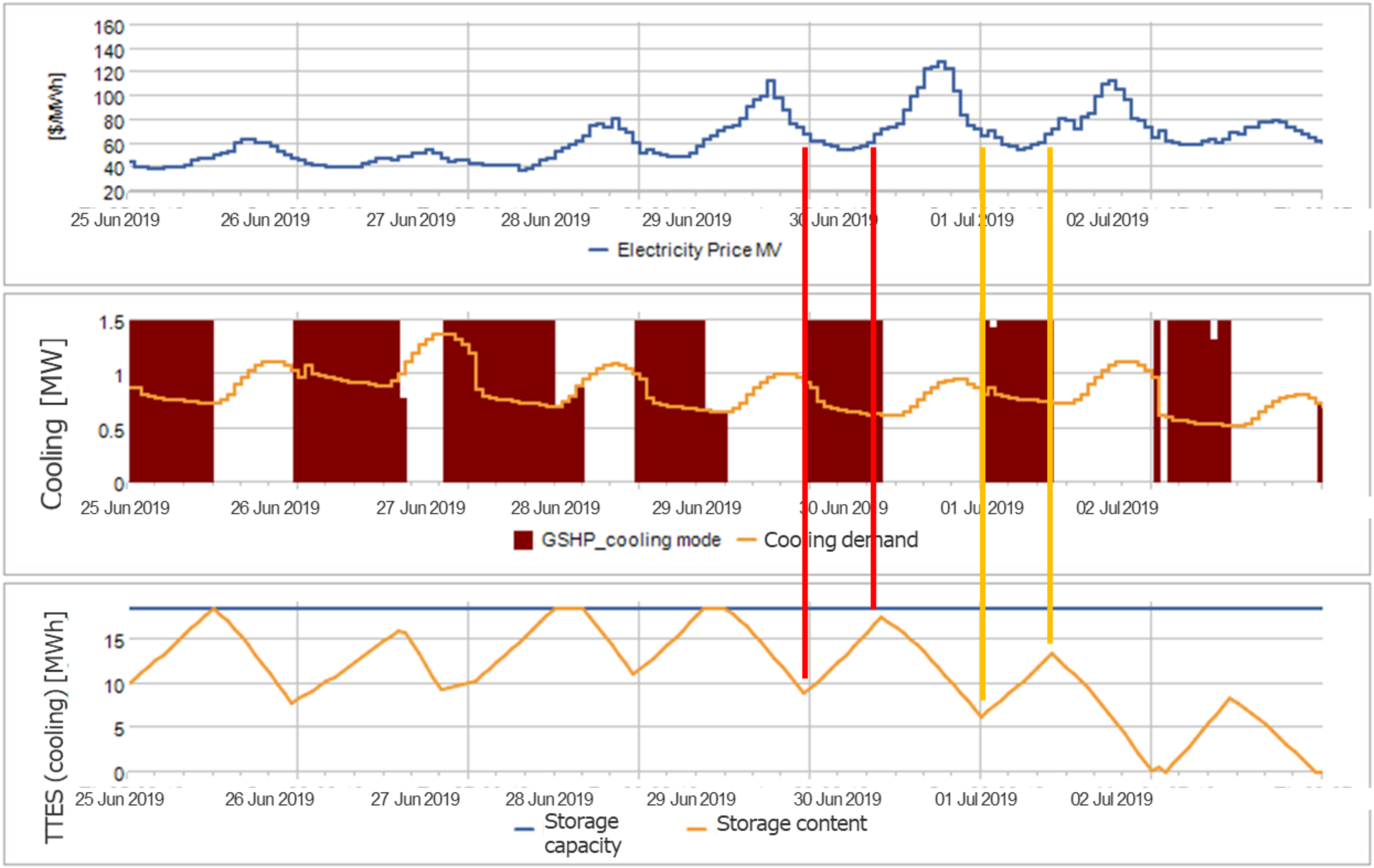



Figure 51. Operation of the central chiller in summer in connection to the available storage capacity and the electricity price

### 5.7.2.3 Modeling: technical results

Figure 52 and Figure 53 show the annual heating and cooling production (output) from the main technologies in the different scenarios. The heating and cooling demand are the same in all scenarios, but the heating and cooling generated can vary due to different distribution losses between scenarios, and the required input energy to meet the demands (Figure 54) varies due to differing conversion efficiencies of the various production units. Detailed output of the modeling results for the scenarios can be found in Appendix F.

In all scenarios, the heat pumps cover about 80% of the annual heating load. Since the campus is heating dominated, Scenarios 2a through 4b utilize dry coolers to help balance the borefield. However, Scenarios 5b through 6b rely on alternative heat sources to reduce the heat extraction from the borefield, eliminating the need for rebalancing. Establishing how much a baseload technology should cover of the total annual heat load and the associated NPV is an optimization exercise that was not part of this analysis.

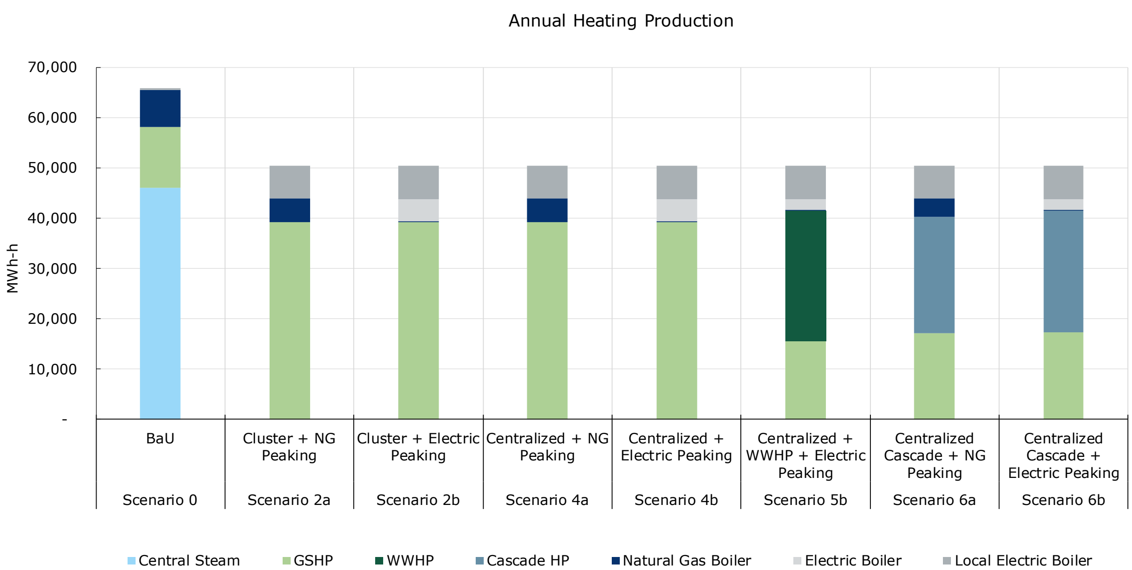



**Figure 52. Annual heating production**

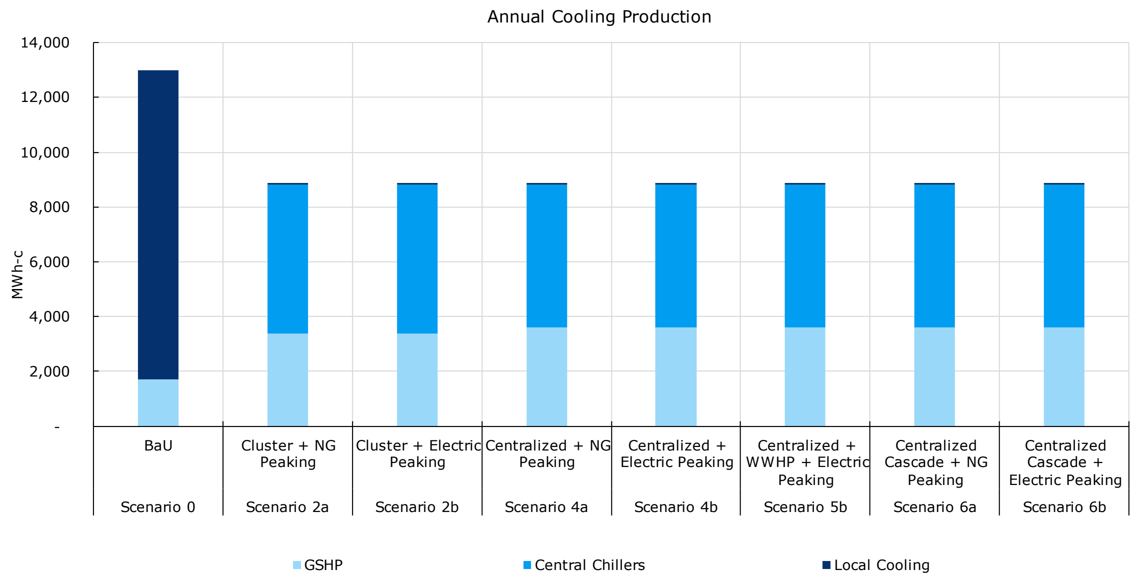



**Figure 53. Annual cooling production**

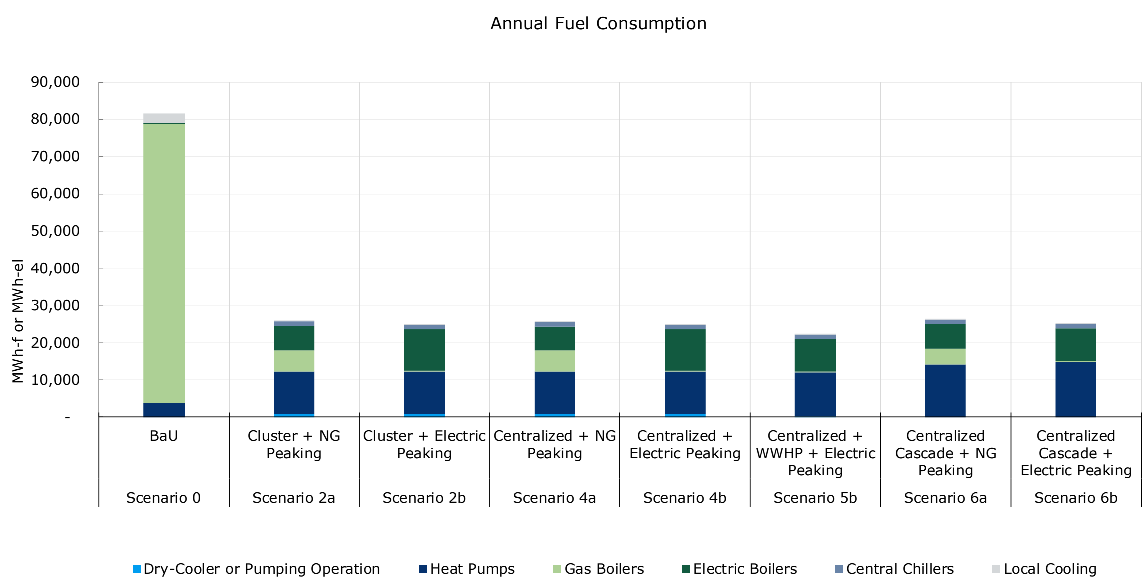



**Figure 54. Annual fuel/electricity consumption to meet heating and cooling demand**

### 5.7.2.4 Capital expenditures (CAPEX)

Cost estimating was performed by Trophy Point Construction Services & Consulting (Trophy Point) for Scenarios 2a and 2b. The remaining scenario costs were extrapolated from this cost estimate and previous studies conducted by Ramboll. The full cost estimate with associated breakdown is provided in Appendix G.

The cost estimates include raw labor and material in addition to the markups listed below:

- General Conditions – 15%
- Overhead & Profit – 10%
- Design Contingency[11] – 20%
- Bid Contingency – 5%
- Phasing – 10%

Figure 55 denotes the CAPEX for the BaU and the scenario variants divided, respectively, into CAPEX for building level installations, distribution system, centralized system and other. Additional detail is provided in Appendix G. As expected, the CAPEX in the BaU is limited ($37 million), whereas the CAPEX for Scenario 2b, which is the most CAPEX intensive, is approximately $140 million.

Comparing the natural gas peaking variants (2a, 4a, and 6a) with electric peaking variants (2b, 4b, 5b, and 6b) provides the estimated cost impact to cover 100% of the annual heating load through electrification assets. The additional cost for an electric boiler, electrical upgrade, and backup natural gas boilers is around $5.3M to $6.7M as compared to the natural gas peaking scenarios. A backup natural gas boiler in the electrical scenarios will provide resiliency in the event of extended power outage, whereas the peaking natural gas boilers already included in cost estimates can also serve as backup boilers. A natural gas variant for the wastewater heat recovery, Scenario 5b, was not completed. Scenario 5b was developed strictly to compare wastewater heat recovery with the centralized GSHP variant.

The cluster scenarios (2a and 2b) were more expensive than the fully centralized scenarios (4, 5, 6) by $3.8M to $15.6M.

[11] Design contingency is related to the progress of the project. In early stages before details have been defined the contingency is higher and typically decreases as the project progresses.

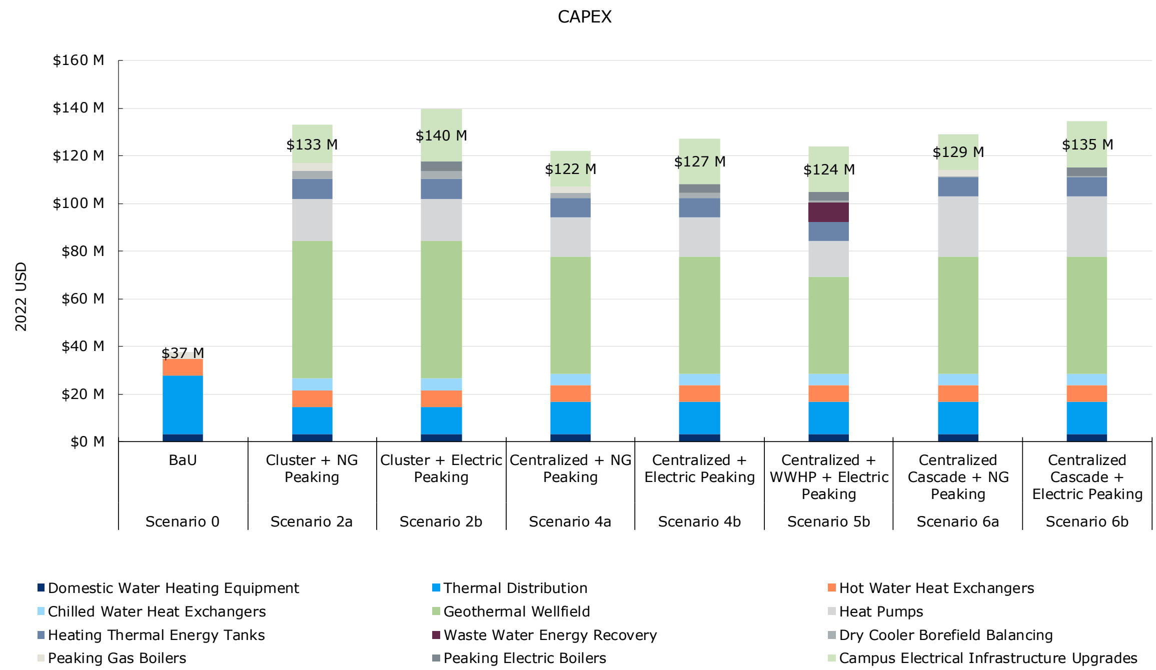



**Figure 55. CAPEX for the scenarios**

### 5.7.2.5 Modeling: economic results

Figure 56 provides an overview of the economic performance of the different scenarios in terms of project net present value of costs (NPV) over the project lifetime. CAPEX costs, together with the operational costs (OPEX), are fed into a cashflow model which considers a period of 20 years for the economic evaluation of each scenario.

Assets whose lifetime exceeds the 20-year project period are attributed a residual value at the end of the project period in order to align all costs to that point in time; this shows up in the calculation as a fictitious revenue (incoming cashflow) occurring at the end of the project period. The residual value of the asset is determined by assuming linear depreciation of the asset value (its original CAPEX) over its technical lifetime. For example, an asset with a technical lifetime of 30 years and CAPEX of 3,000,000 USD, installed in the first year of the 20-year project period will retain at the end of the project period a residual value equal to 1/3 of the original CAPEX, *i.e.*, $1,000,000. Conversely, assets whose technical lifetime ends before the end of the 20-year period will require additional investments for replacement or overhaul; these costs and the residual value of the replacements are also included in the cashflow analysis. This approach provides an equitable comparison across the scenarios despite the different technical lifetimes of the assets. The CAPEX shown in the shown in Figure 56 includes the initial CAPEX investment, any replacement costs over the 20-year project period, reduced by any residual value of assets. A year-by-year breakout of the NPV analysis is included in Appendix F that shows the initial investment, annual energy and O&M costs, when replacement costs occur, and the residual value of assets.

The WWHP scenario (5b) has the lowest NPV of the decarbonization scenarios. The centralized GSHP scenario with natural gas peaking (4a) has a similar NPV with a slightly lower CAPEX.

Based exclusively on economics, there is no clear guidance on which scenario is the most favorable. However, the scenarios using a gas boiler for peaking purposes (scenarios 2a, 4a and 6a) have less capital investment needs than scenarios using an electric boiler for peaking purposes (scenarios 2b, 4b and 6b).

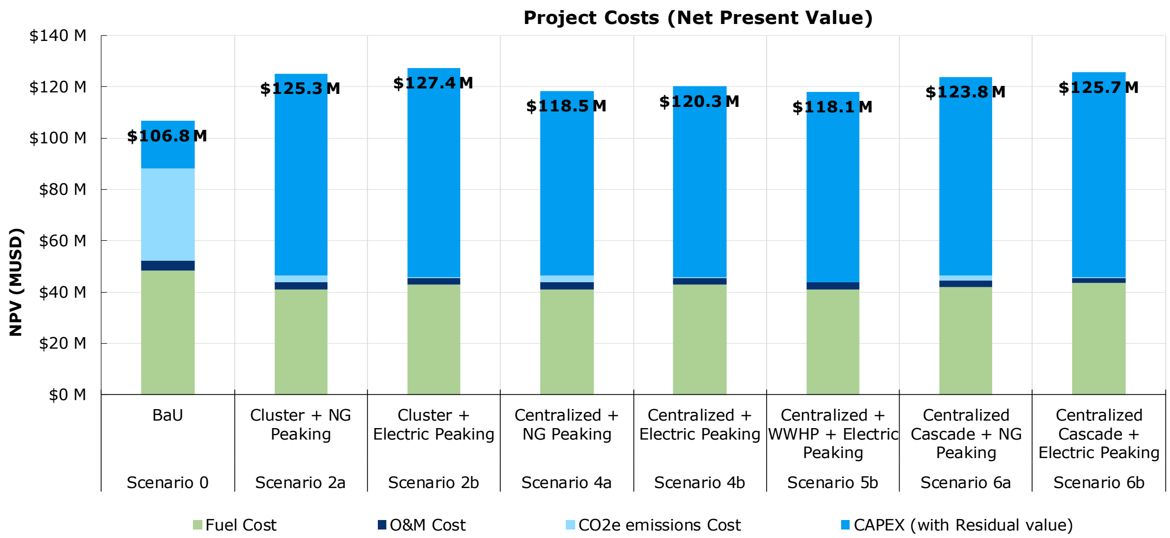



**Figure 56. Economic overview of the different scenarios: NPV of the overall system cost over the project lifetime**

#### 5.7.2.6 Modeling: environmental results

Figure 57 shows the $CO_2e$ emissions for the different scenarios together with the overall NPV (CAPEX, OPEX and residual value). The total NPV is shown with social costs of carbon (green triangle) and without social costs of carbon (yellow dot) for each scenario. The project lifetime social cost of carbon was calculated from the values listed in Table 28, with a projected starting year of 2030 and a 20-year project life. From this representation, the overall NPV of the BaU scenario (with high $CO_2e$ emissions) increases significantly when including the cost of carbon; not so much for the decarbonization scenarios.

It is seen that BaU has the lowest NPV of the overall system cost ("TOTAL OPEX+CAPEX (with Residual value))" and "TOTAL OPEX+CAPEX (with Residual value + carbon)". However, including a social cost of carbon reduces the difference between the BaU and the other scenarios significantly. In the BaU, the social cost of carbon increases the NPV of the costs from approximately $71M to $107M. All of the decarbonization scenarios show lower $CO_2e$ emissions and higher NPV of costs compared to the BaU.

All alternatives achieve at least a 90% reduction in $CO_2e$ emissions compared to BaU. This is due to:

- A significant reduction in the share of natural gas use towards the overall energy production in the alternative scenarios
- Beneficial electrification and the progressive decarbonization of the grid electricity over time, in alignment with the EO22 2030 goals (100% electricity from renewable sources under the

Clean Energy Standard (eligible systems) and CLCPA goals of at 100% carbon free electric grid by 2040

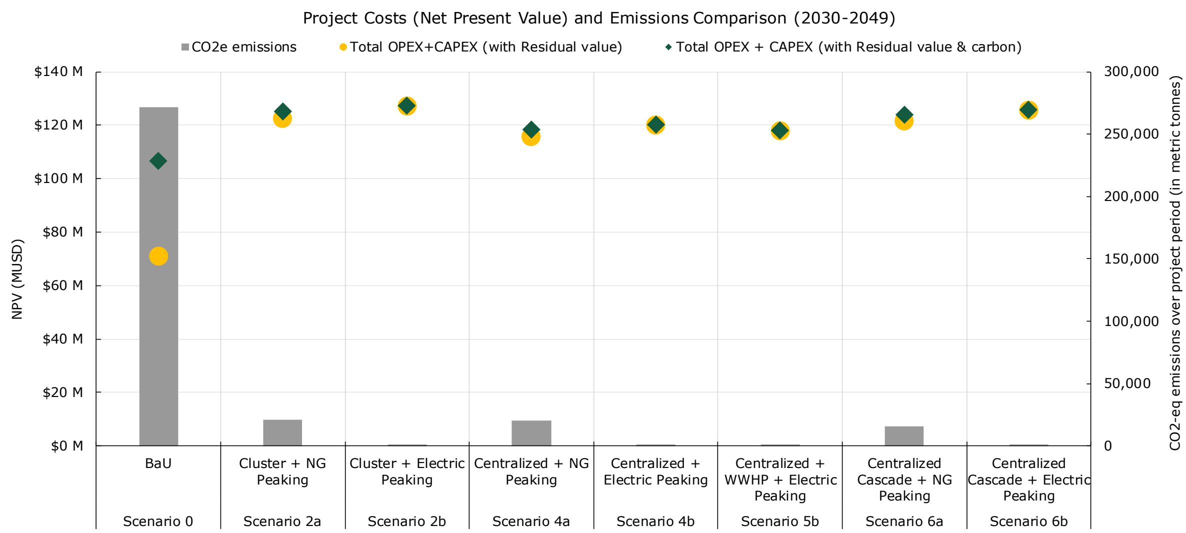



**Figure 57. $CO_2e$ emissions and project NPV for the different scenarios**

The "shadow price of carbon" represents the price of carbon which makes the NPV of each alternative scenario equal to the NPV of the BAU scenario. The shadow price is calculated as:

$$\text{Shadow price (Sc. X)} = -\frac{\text{NPV(Scenario X cost)} - \text{NPV(BaU cost)}}{\text{NPV(Sc. X CO2e emissions)} - \text{NPV(BaU CO2e emissions)}}$$

The NPV of costs in the equation above includes:

- CAPEX
- Residual Value of CAPEX
- OPEX (energy costs and O&M costs)

It does not include the social cost of carbon, as this would result in "double counting" of carbon costs. The lower the shadow price of carbon for a scenario, the more cost-efficient the scenario is in reducing carbon emissions.

Table 30 compares the shadow price of carbon for the scenarios. A shadow price of carbon between $226 and $271 per metric ton, would balance the economy between the BaU and the scenarios.

**Table 30. Shadow price of carbon compared to BaU**

| Scenario | Scenario 0 | Scenario 2a | Scenario 2b | Scenario 4a | Scenario 4b | Scenario 5b | Scenario 6a | Scenario 6b |
|---|---|---|---|---|---|---|---|---|
| | BaU | Cluster + NG Peaking | Cluster + Electric Peaking | Centralized + NG Peaking | Centralized + Electric Peaking | Centralized + WWHP + Electric Peaking | Centralized Cascade + NG Peaking | Centralized Cascade + Electric Peaking |
| Shadow Price of carbon (USD/metric ton) | 0 | 268 | 271 | 232 | 237 | 226 | 259 | 263 |

#### 5.7.2.7 Consideration for a combination of ASHP and GSHP

Scenarios 6a/b utilize a hybrid of ASHP and GSHP, which can have numerous benefits, including:

- Could mean fewer boreholes, thus reducing CAPEX
- May provide a higher resiliency level
- Would have less need for balancing

Ramboll offers the following considerations regarding a hybrid solution:

- From a pure economic standpoint, the CAPEX for a GSHP solution is higher than for a ASHP solution. On the other hand, the OPEX for a GSHP system is lower due to the increased average efficiency of the heat pump.
- A GSHP will experience more stable and higher temperatures on the evaporator. When looking at the economic evaluation of the two systems and considering all CAPEX and OPEX for the systems, the NPV of a ASHP system will be lower in a 20-year lifetime of the asset. However, the difference in NPV is minor (as for instance seen in Figure 57) and the difference is within the uncertainties of the estimates.
- A hybrid combination of GSHP and ASHP can offer the flexibility of operating the ASHP to meet heating loads when outside air temperatures are favorable, and efficiency is good. As a result, the GSHP and borefield could be reduced in size and CAPEX; the GSHP performance would also improve because the heating load carried by the ASHP did not have to be extracted from the borefield. The system still needs to be designed and operated to be able to meet the load requirements.

A GSHP system operating alone in a heating dominated system may require significant balancing of the boreholes. If the GSHP is combined with an ASHP, then the seasonal imbalance can be reduced or eliminated due to the heating load being partially met by the ASHP. This was incorporated into the scenario analysis. Challenges with larger scale ASHP systems must be considered. Larger scale systems are in operation abroad, and Ramboll has designed several systems in Denmark. Here are some of the challenges to be aware of:

- When the air temperature is close to freezing the humidity level is high. When air is cooled through the air-cooler, moisture condenses and can freeze on the ground. This can be avoided if the GSHP is prioritized at temperatures close to freezing or lower.
- Air-coolers are noisy, so sound mitigation may be needed depending on where they are located.
- Due to the low temperature on the evaporator side, the efficiency is (very) low in the winter season where the heat is needed the most. With a combination of GSHP and ASHP, it would not be necessary to operate the ASHP at conditions with low ambient temperature.
- In-service ASHP systems have experienced short circuiting at certain wind speeds. Though mitigation of these challenges has been occurring.

Until very recently, the number of vendors for high temperature heat pumps achieving 150F and higher in the US was very limited. However, the heat pump market has developed significantly through the last couple of years. Several vendors now offer heat pumps up to 170F, which is adequate in most situations.

## 5.8 Campus electrical capacity assessment

Electrification of the campus will result in increased electricity use for heating purposes, as well as an increase in peak electrical load. The existing peak electrical demands typically occur in August or September. With the shift to electrical heating sources, the electrical peak will occur in the winter months. Figure 58 summarizes the peak electrical demand impact of each scenario.

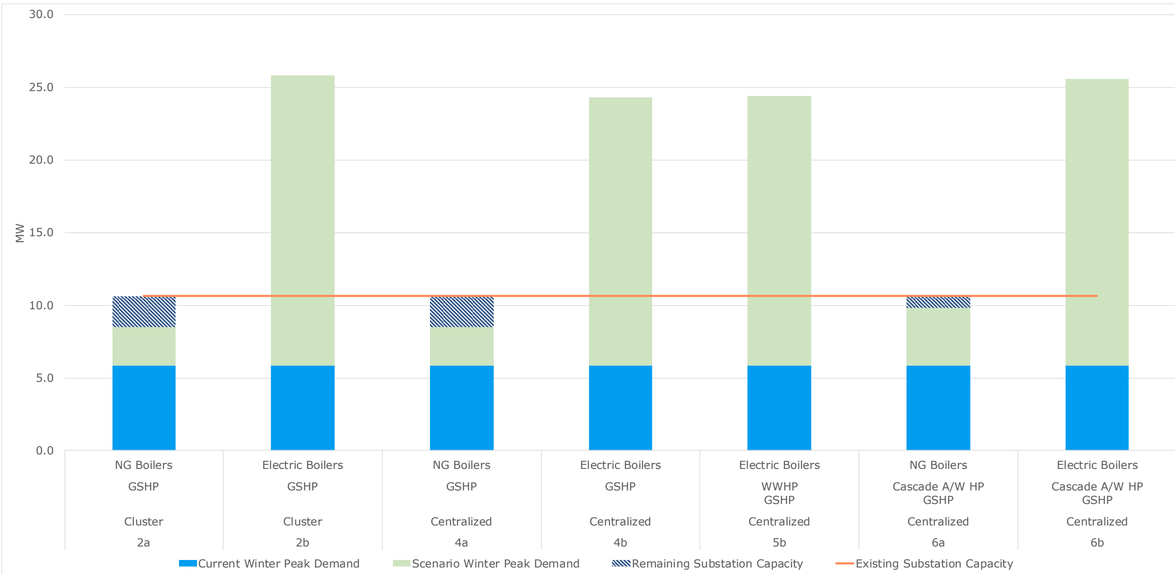



**Figure 58. Estimated electrical capacity per scenario**

The existing campus Substation #1, which serves the campus buildings north of Route 104, has two 6,250 kVA transformers. During existing peak demand periods, both transformers are required, and at about 76% loaded. There is little to no redundancy in the existing substation during peak demand periods. In all scenarios, the substation would need to be upgraded. New 34.5 kV overhead lines would be run to a new substation for the natural gas scenarios and a 115 kV overhead line would be required for the electric peaking scenarios.

The existing Substation #2, which serves the buildings south of Rout 104, has a 25 kVA and a 2,000 kVA transformer. No upgrades would be required for the natural gas peaking scenarios, but the substation would be upgraded with a 3,125 kVA transformer for electric peaking scenarios.

Building electric service upgrades would be required for all energy centers (new transformers and switchgears), regardless of peaking technology.

## 5.9 Renewable electricity generation

SUNY Oswego has two on-site solar photovoltaic (PV) arrays: a 20 $kW_{dc}$ array on the Shineman Center and a 36 $kW_{dc}$ array offsite at the Rice Creek Field Station. Ramboll discussed the potential for the campus to generate a portion of its own electricity via on-site PV or wind. Based on discussions, the area known by the campus as Hidden Fields was identified as a potential site for wind or PV. As shown in Figure 59, two 65 m hub height turbines (each rated for 850 kW) could be installed at the Hidden Fields. Due to offsets from roads, property boundaries, and buildings, and maintain a suitable spacing between turbines, it would be difficult to fit any more than two turbines.


**Figure 59. Potential location for wind turbines at the Hidden Fields**

Alternatively, the Hidden Fields is about 20 acres, which is large enough for a 6.5 $MW_{dc}$ PV array. A comparison of renewable potential at the Hidden Fields is presented in Table 31. Wind and PV annual production was estimated using EnergyPro which uses site specific wind and solar data, along with PV and wind system performance data to determine annual production. The electricity generated by the wind turbines would offset about 54% of the additional electricity required from electrifying the campus with heat pumps (based on Scenario 4a). The PV option would offset about 120% of the additional electricity from Scenario 4a.

Wind turbine installation costs were estimated based on a U.S. Department of Energy study[12]. This study showed an average installation cost of $1,370 per kW in 2022 dollars, which includes material and labor, balance of plant, and any substation and interconnection expenses. However, the study indicates that the installed costs exhibit economies of scale. There is no data available for smaller projects on the scale applicable to the Hidden Fields consideration. The study shows that the average cost for the 5-20 MW range is $2,693 per kW. Ramboll assumed a project cost of $3,000 per kW.

PV installation costs were estimated based on an NREL study[13]. The study shows that commercial ground mount systems, 500 $kW_{dc}$, have an installed cost of $\$1.94/W_{dc}$. Utility scale ground mount systems, 100 $MW_{dc}$, $\$0.99/W_{dc}$. Ramboll assumed a project cost of $\$1.88/W_{dc}$.

[12] *Land-Based Wind Market Report: 2023 Edition* https://emp.lbl.gov/sites/default/files/2023_lbwmr_final.pdf

[13] *U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2022* https://www.nrel.gov/docs/fy22osti/83586.pdf

**Table 31. Renewable potential at hidden fields**

| | Wind (65 m Hub Height) | PV |
|---|---|---|
| System Size | 2 turbines @ 850 kW ea<br>1.7 $MW_{ac}$ | ~ 20 acres<br>6.5 $MW_{dc}$<br>5.6 $MW_{ac}$ |
| Annual Production | 3,983 MWh | 8,800 MWh |
| % of additional electricity from heat pumps offset by renewables[1] | 54% | 120% |
| CAPEX | $5,100,000 | $13,300,000 |
| Cost savings[2] | $235,000 | $520,000 |
| SPB | 21.7 | 25.6 |

Notes:

1. Scenario 4a, Centralized Heat Pump Scenario with natural gas peaking
2. $0.059/kWh from Table 16

Some items that need to be considered for developing renewables at the Hidden Fields include:

- Hidden Fields is on the opposite end of the campus from the campus electric substation
- Both renewable options could potentially connect to a feeder loop at the western part of campus
- The feeder loop could handle a maximum of 4.5 MW without major changes to the distribution system
- Any renewable system more than 4.5 MW in capacity would require a feed back to the substation, over a mile from point to point
- Interconnection with the grid may be needed for systems larger than the feeder loop can accept
- Distributed energy resource interconnection requirements vary by utility
  - Application process
  - Feasibility study
  - Potentially a Coordinated Electric System Interconnection Review (CESIR) study
- Studies review the impact of the generation on the grid as well as the customer's point of common coupling (PCC)
- This could mean as little as adding special relaying and controls to the substation or an entire substation rebuild

Renewable technologies at Hidden Fields could be as a direct owned asset or through a developer power purchase agreement (PPA) where a separate entity would invest in the infrastructure and the campus would purchase the energy that is produced. Ground mount PV was analyzed, as it typically has the lowest cost per MW installed. However, rooftop and PV covered parking, whether it was direct ownership or a PPA, could be considered as well. PV covered parking should be coordinated with any parking renovation plans.

It is noted that EO 22 was issued (during the course of this project) by Governor Kathy Kochul on September 20, 2022. EO 22 stipulates three approaches for NYS agencies to reduce GHG emissions (from electricity use) 100% by 2030. Those include:

3. Count the amount of clean energy generated by Eligible Systems across the State that the Affected Entity pays for in its electricity bills or otherwise towards compliance with the Clean Energy Standard (CES), based on calculations provided by NYSERDA. Affected Entities shall provide information requested by NYSERDA to perform the applicable calculations, including load data, CES compliance payments, and any other necessary information.
4. For the remainder of its electricity usage, each Affected Entity shall next be required to demonstrate meeting this obligation, where feasible, through the use of on- or off-site Eligible Systems providing energy dedicated to the Affected Entity's operations.
5. For the portion of electricity that cannot be served by such Eligible Systems, each Affected Entity shall, in consultation and agreement with NYSERDA and Department of Public Services (DPS), procure renewable energy certificates ("RECs") qualified under a Qualifying Tier of the CES.

EO 22 further notes that NYSERDA and DPS shall establish further detailed guidelines and requirements with respect to how each Affected Entity shall comply and report compliance.

### 5.10 Conclusions

Several conclusions can be drawn from the techno-economic analysis:

1. The cluster scenarios (2a and 2b) are more expensive than the fully centralized scenarios (4, 5, 6)
2. Scenarios with electric boilers for peaking (Scenario 2b, 4b, 5b, and 6b) have higher costs due to electrical upgrades that are required compared to natural gas peaking boiler counterparts (Scenario 2a, 4a, and 6a)
3. Utilizing wastewater as a heat source (Scenario 5b) reduces borefield size by about 200 boreholes and overall CAPEX by about $3M compared to scenario 4b
4. The air-source/water-source cascade scenario (Scenario 6a/b) has the highest CAPEX, due to the addition of ASHPs
5. The BAU scenario has the lowest NPV and does not meet GHG emission goals
6. When the social cost of carbon is not included, centralized GSHP with natural gas peaking (Scenario 4a) has the lowest NPV of the beneficial electrification scenarios. This scenario has the lowest OPEX (fuel costs plus O&M) and lowest CAPEX of the beneficial electrification scenarios analyzed
7. A peaking natural gas variant was not analyzed for the wastewater heat recovery (Scenario 5b). It can be inferred from the difference of Scenario 4a and Scenario 4b that utilizing waste water as a heat source with natural gas peaking would result in the lowest CAPEX and lowest NPV of the decarbonization scenarios.
8. When the social cost of carbon is included, utilizing wastewater as a heat source (Scenario 5b) has the lowest NPV
9. By applying a social cost of carbon, the difference in NPV costs between the BaU and the scenarios is reduced significantly, but the BAU remains the lowest NPV scenario
10. A value of carbon between $226 and $271 per metric ton, would balance the economics between the BaU and the scenarios
11. All scenarios except BaU, would require electrical substation upgrades in order to meet the projected electrical peak demand. Even without an increase in electrical peak demand, the

campus has identified a need to upgrade the electrical substation for resiliency purposes (cost not included in the BaU).

12. The Hidden Fields could potentially site 1.7 $MW_{ac}$ of wind or 5.6 $MW_{ac}$ of PV. The annual production from the wind would cover about 54% of the additional electricity use of the heat pumps, while PV would cover about 120%.
13. Offsite renewable energy generation and/or renewable energy certificates (RECs) would be required to meet the EO22 mandate of 100% renewable sources for electricity by 2030.

# 6. Phasing and Implementation

This section describes initial phasing and implementation considerations to support the low carbon transition planning horizon, while also balancing the near-term campus operational needs associated with end-of-life central heating plant assets. The following guiding principles influence the decarbonization strategy:

1. Move away from producing steam (for space heating) as soon as practical
2. Focus on transitioning clusters with a central plant in mind
3. Focus on transitioning Clusters C and W, which account for 75% of the total heat demand
4. Manageable construction schedule in line with FMP
5. Enable projects to coordinate with landscaping, utilities, and borefields
6. Identify a pragmatic and cost-efficient solution that is future proof and allows for easy plug and play of low carbon technologies
7. Establish a realistic implementation horizon that is flexible, recognizes utility constraints and allows for incorporation of technology and market advancements
8. Look to enhance operational and structural resilience in anticipation of a forecasted increase in average global temperatures. Rise in average global temperatures may result in increased likelihood of extreme weather events. Building for resiliency and quick recovery from extreme weather events will be key to best serving the campus community and beyond.

## 6.1 Phasing and sequencing

Based on discussions with the campus, the clusters were viewed as phases that could be transitioned to electrification with a centralized plant in mind, as shown in Figure 60. The following timeframes were identified based on discussions between Ramboll, SUNY Oswego, and JMZ Architects (JMZ) (the authors of the current FMP study being conducted):

- Cluster C and W has extensive renovation plans over the next 10-15 years
- Cluster C and W transitioned by 2040
- Cluster E has plans for renovations in the 15-20 year timeframe
- Cluster E transitioned by 2045
- Cluster N was not discussed in JMZ's FMP, but can be considered 25 years out
- Cluster N transitioned by 2050
- Cluster S was not discussed in JMZ's FMP, but can be considered 15-25 years out
- Cluster S transitioned by 2050

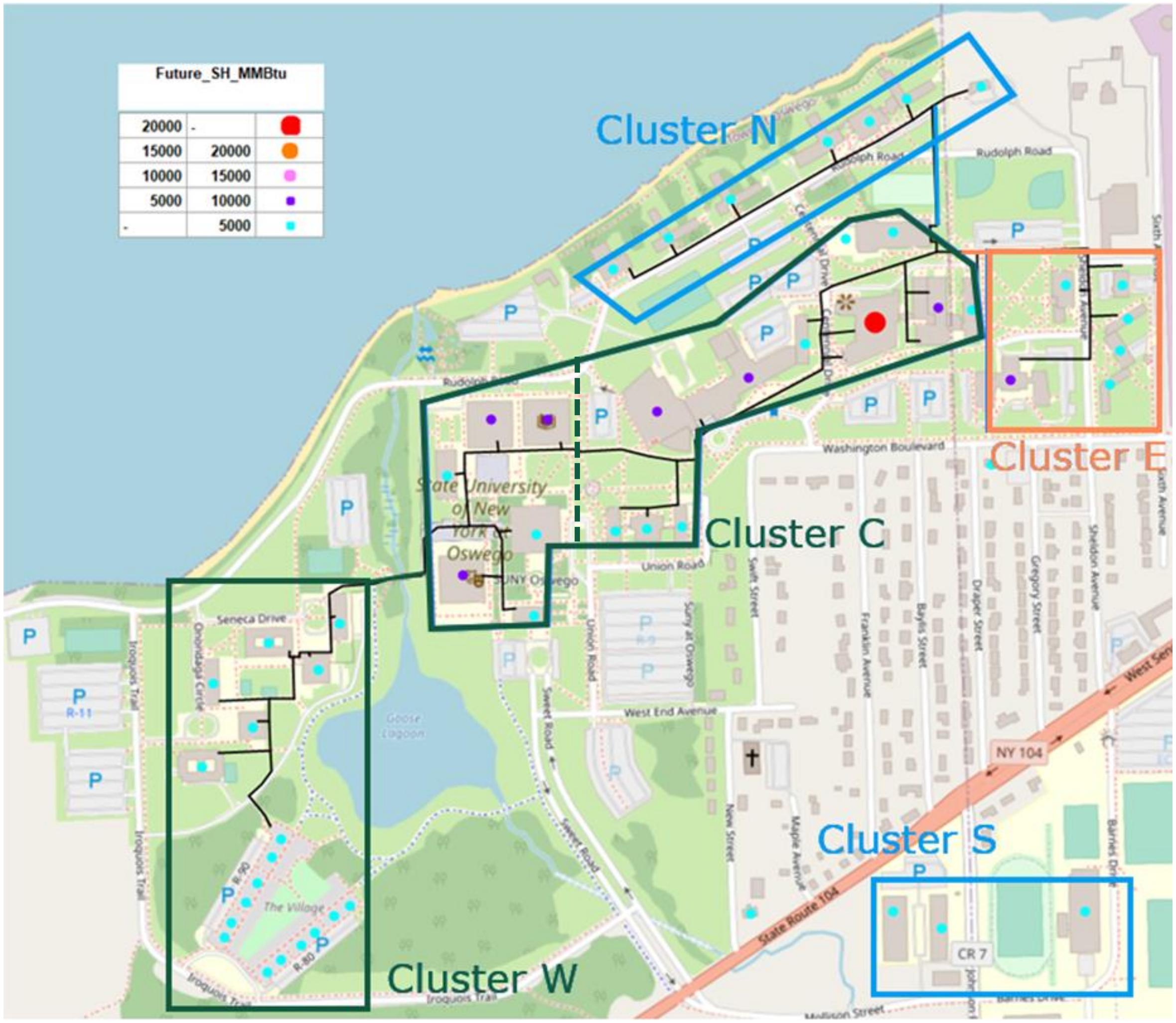



**Figure 60. Campus phasing plan**

Clusters C and W together account for 75% of the total heat load and over 80% of the heat load of buildings on campus north of Route 104 (which would be served by a centralized or cluster energy centers). Through discussions between Ramboll and SUNY Oswego, focus was placed on transitioning these two clusters. The campus would like to remove the west campus from the steam network, as it is the furthest extent of the network. This includes Cluster W and parts of Cluster C (separated from Cluster C with a dashed line in Figure 60). These areas have substantial projects planned or projects that the campus would like to develop with high priority:

- Hewitt is under construction with a geothermal plant in the plans, 90 wells have been installed at the time of this study
- Mahar will be under construction in 2 years
- Lanigan and Penfield are high priority projects
- Littlepage Dining Hall is under construction
- The courtyard in between Onondaga, Littlepage, Cayuga, and Pathfinder will be renovated as part of JMZ's FMP.

The western part of the campus could potentially be built up with its own plants then connected to distribution network from Lee Hall as equipment ages out. The courtyard renovation only covers about an acre, which is not of sufficient size to handle the Cluster W heating load; Cluster W requires about 1.5 acres. There were discussions of removing The Villages from Cluster W, but they only account for 10% of the heating load and would only reduce the borefield to about 1.3 acres. Adjacent green area to the west of Cayuga and east of Littlepage could be included to form a borefield of about 2 acres, as shown in Figure 61. Based on the cost estimates from Trophy Point, building a dedicated energy center for Cluster W would cost over $1 million more than connecting to a centralized energy center.

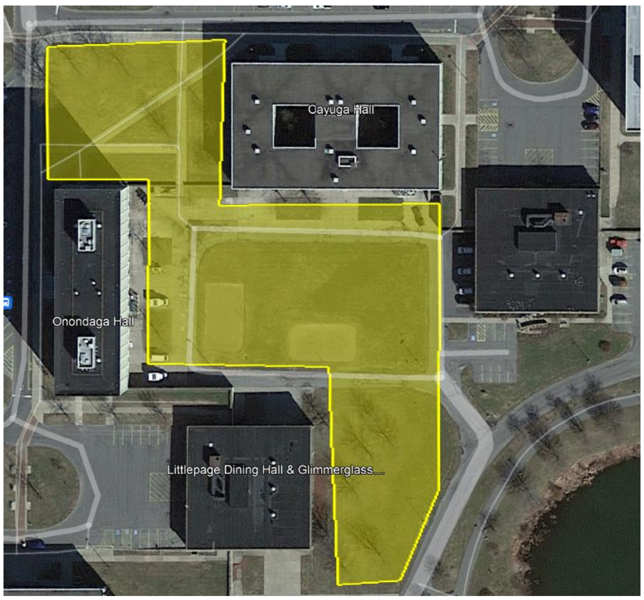



**Figure 61. Potential borefield for Cluster W**

Transitioning the rest of the buildings on Cluster C will focus on building up an energy center at the Lee Hall Central Heating Plant and extending the distribution network towards the buildings on the western part of campus. If energy centers are developed on the western part of campus, the networks could eventually be connected to the Cluster C network to form a centralized network as the original energy center equipment ages. However, the network piping should be installed with a centralized approach in mind, which means it should be sized so that it has capacity to carry heat to portions that may eventually be connected. For example, the main network piping connecting buildings on the western part of Cluster C (Hewitt, Mahar, Penfield, Lanigan, etc.) should be sized so it has capacity to serve Cluster W. Likewise, the main network piping in the remaining Cluster C should be sized so that it can serve the loads of the entire campus, not just the buildings in Cluster C.

Cluster E accounts for about 10% of the heating load of buildings on campus north of Route 104. A distribution network stemming from Cluster C could connect a network connecting buildings in Cluster E. As buildings are added to the network, the centralized energy center would need to be upgraded to handle the additional load.

Cluster N accounts for less than 10% of the heating load of buildings on campus north of Route 104. Like Cluster E, network piping could be installed; extending Cluster C to serve a network in Cluster N.

Cluster S is separated from the rest of campus by Route 104.

Table 32 below provides a summary of the phasing strategy and associated key actions towards decarbonization and electrification of campus heating and cooling. It is noted that these actions are based on a centralized scenario approach. When a final scenario has been selected for advancement, phasing and sequencing would be developed specific to the scenario.

**Table 32. Low-carbon electrification phasing strategy**

| Cluster C and W (2025-2040) | Cluster E (2035-2045) | Cluster N and S (2040-2050) |
|---|---|---|
| • Remove Clusters C and W from the steam network<br>• Develop new Energy Center at Lee Hall and potential smaller centers in the western part of campus<br>  • Establish borefields<br>  • Ground source heat pumps<br>  • Dry coolers<br>  • Utilize central heating plant natural gas steam boilers as backup<br>  • Potential ASHP<br>  • Thermal energy storage tank<br>• Develop LTW network and connect to Energy Center<br>• Substation #1 electrical improvements<br>• Potential end of life building renovations/upgrades<br>• Targeted energy efficiency measures for entire campus | • Establish LTW network and connect to main LTW network<br>• Some building renovations/upgrades/hot water coil replacement<br>• Increase centralized energy center capacity to handle additional load of Cluster E | • Establish LTW network and connect Cluster N to main LTW network<br>• Increase centralized energy center capacity to handle additional load of Cluster N<br>• Develop energy center for cluster S<br>  • Establish borefields<br>  • Ground source heat pumps<br>  • Dry coolers<br>  • Potential ASHP<br>  • Thermal energy storage tank<br>• Substation #2 electrical improvements<br>• Some building renovations/upgrades/hot water coil replacement |

### 6.1.1 Stand-alone initiatives

Stand-alone initiatives include the following:

- New Energy Center
  - Establishing first part of LTW network and connect to energy center
  - Utilize existing natural gas steam boilers for backup and/or peaking
- Potential ASHP
  - Electric feed to energy center
- Tank thermal energy storage

- Emergency generator
- New LTW network to replace steam lines
- Site electrical improvements
- Targeted energy efficiency measures (*e.g.*, building retro-commissioning)
- Ground source heat pumps
- Dry air coolers

### 6.1.2 Interdependent initiatives

Interdependent initiatives include the following:

- Building renovations/upgrades
- HVAC mechanical equipment replacements
- Borefield installation

### 6.1.3 Implementation considerations

The following implementation considerations are provided to help highlight the market and technology nuances that influence a low carbon transition:

**Heat Pumps** – The US market for heat pumps is changing rapidly with higher efficiency and/or higher potential supply temperature regularly becoming available, and additional options expected to grow pending energy code updates in 2024. Many heat pumps with higher efficiency and temperature exist today on the European market and, therefore, it is anticipated that similar units will be introduced in the US from the main vendors. The campus and SUCF will want to monitor market maturity and technology advancements to help inform design and installation decisions and timing.

**Building HVAC**

- Monitor supply and return temperature and assess measures to increase the delta T for hot water and chilled water
- Ensure building hot water and chilled water loops have outdoor temperature reset implemented

## 6.2 Funding source and incentive program potential

There are many potential funding sources and incentive programs that could support energy projects or activities at the campus. Source and programs typically have application deadlines and expirations dates, so periodic monitoring is needed to confirm eligibility. Below are some example resources for consideration.

NYSERDA

- https://www.nyserda.ny.gov/All-Programs#category=schools-colleges-universities
- Community Heat Pump Systems (PON 4614)
- NY-Sun Commercial / Industrial Incentive Program (PON 3082)
- Carbon Challenge and Carbon Neutral Community Economic Development programs

Inflation Reduction Act

- Established new credit delivery mechanisms that enables state, local, Tribal governments, non-profit organizations, U.S. territories, and other entities to take advantage of clean energy tax credits
- RMI developed a list that breaks out Inflation Reduction Act programs and incentives RMI IRA break down by incentive
- Production Tax Credit for Electricity from Renewables

Additional incentives may be found at the following websites which provide a list of available incentives:

DSIRE

- https://programs.dsireusa.org/system/program/ny

US Department of Energy (DOE)

- https://www.energy.gov/eere/funding/eere-funding-opportunities

# 7. Key Takeaways and Recommended Next Steps

## 7.1 Key takeaways from the Clean Energy Master Planning Process

Table 33 provides a summary of important topics and associated aspects that surfaced during the planning process. These inform the complexities and challenges that will need to be considered and managed as part of the campus energy transition. These aspects intersect to influence and balance carbon reduction, energy efficiency, flexibility, resiliency, and redundancy in a pragmatic and cost-effective manner.

**Table 33. Key takeaways from the clean energy master planning process**

| Electrical Demand Impact | Natural Gas Peaking Benefits | Building Improvements | Infrastructure Scenarios | Emission Reduction |
|---|---|---|---|---|
| In all scenarios, the Substation #1 would need to be upgraded<br><br>Substation #2 would need to be upgraded in full-electrification scenarios<br><br>Significant emergency/stand-by power requirements, without nonelectric-based backup<br><br>High CAPEX with relatively small carbon emissions reduction to electrify peak load in addition to baseload<br><br>Connection of renewables from Hidden Fields to campus electric feeder loop has limitations | Flexibility<br><br>Redundancy for emergency<br><br>Bridging fuel-while electric utility infrastructure catches up<br><br>Manages capital spend<br><br>Future NYS plans of NG to renewable natural gas (RNG) and hydrogen<br><br>Reuse of existing infrastructure and backup power assets | Address steam use in buildings<br><br>Can buildings operate acceptably at lower supply temperatures? (coil replacements or load reductions)<br><br>Renovation approval and timing<br><br>Add cooling to non-cooled buildings/spaces<br><br>Hazardous materials impact | Piping material decisions – temperature and pressure<br><br>Centralized vs cluster<br><br>Property space needs for geothermal | 85% reduction is achievable without 100% electrification |

Figure 62 illustrates the forecasted GHG emissions ($CO_2e$) trend for the campus. 1990 GHG data was taken from the campus' 2012 Climate Action Plan (CAP). Scenario 4a was selected for illustrative purposes. The black line represents the BAU scenario, gray shading above the black line represents emission reductions attributed to the electric grid getting cleaner over time. The red line represents the forecasted emissions after energy efficiency and beneficial electrification is implemented. This trend shows that even when natural gas is used for peaking purposes, the campus can achieve greater than 85% reduction and would meet the CLCPA reduction goal.

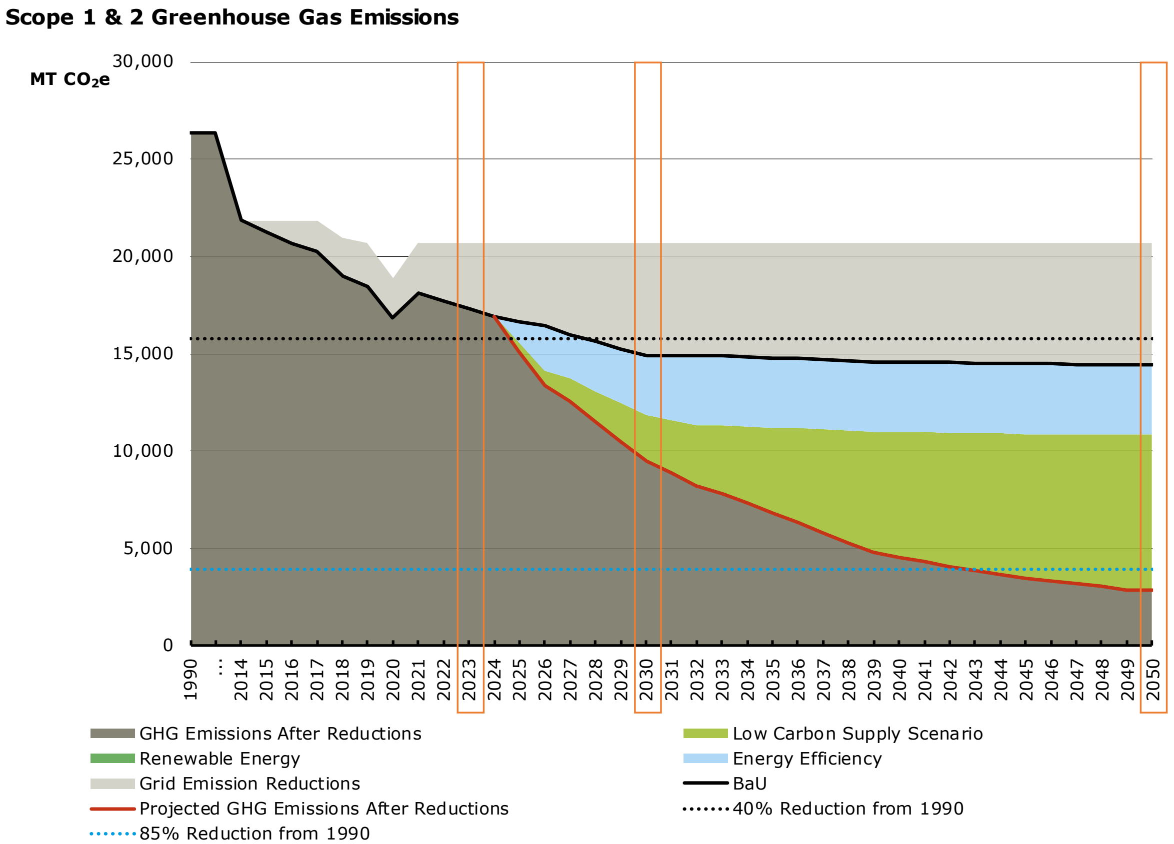



**Figure 62. Projected GHG emissions trend (Scenario 4a)**

## 7.2 Recommended next steps

Ramboll has identified the following recommend next steps to help the campus prioritize projects that can influence future systems designs and demonstrate progress towards campus goals.

1. Implement EEMs that will be cost effective within the time periods that buildings would benefit from the measure
2. Existing geothermal test bore studies previously conducted at the campus can be utilized to inform future borefield design
3. Establish detailed strategy to convert from steam to low temperature hot water, including distribution network piping and impact to specific buildings currently using steam directly
4. Establish a building strategy
    a. Install building level thermal submetering
        i. Most of the campus buildings have electric, but some may need to be calibrated or replaced
        ii. Install building-level steam meters

        iii. Submetering is required by BuildSmart 2025 for buildings greater than 25,000 GSF Buildings shall be submetered for all fuels and other energy sources including, but not limited to, electricity, natural gas, steam, chilled water, and oil
        iv. Clamp-on ultrasonic thermal submetering could be cost-efficient option to explore
    b. Monitor building level hot water data and explore lower building supply temperatures on the district loop during the heating season – refer to Section 5.3.3.2.
    c. Steam building conversion
        i. All buildings on campus are hydronic
        ii. Remaining direct uses need a transition plan (i.e. steam kitchen equipment)
5. Monitor market developments and advancements in heat pump technology and US market availability
6. Some of the preceding recommendations should be completed to help the campus select a preferred scenario, or variation thereof, prior to beginning preliminary design

# Appendix A
# Preliminary Energy-Use Analysis (PEA)

# Energy Use Analysis and Benchmarking Profile

## All Fuels Summary

## SUNY Oswego

## 000 - Campus Total

| Building Data | | | |
|---|---|---|---|
| **Gross Area (SF):** 3,498,777 | | **% Heated:** 99% | **% Cooled:** 59% |
| **Building Type(s)** | **Year(s) of Construction** | **Year(s) of Renovation** | **Operating Schedule** |
| 20% College/university<br>33% Dormitory/fraternity/sorority<br>15% Office<br>12% Recreation<br>2% Laboratory | NA | NA | NA |

| Benchmark Comparisons | | |
|---|---|---|
| **Site EUI** | **Source EUI** | |
| 100.0 | 170.8 | **Weighted CBECS Comparison** |
| 115.2 | 196.7 | **Average** |
| 116.7 | 199.3 | **Weather Normalized** |
| 115.8 | 197.8 | **Jan 2018 to Dec 2018** |
| 114.5 | 195.6 | **Jan 2019 to Dec 2019** |
| 104.2 | 178.0 | **Jan 2020 to Dec 2020** |

**Total Energy Profile**

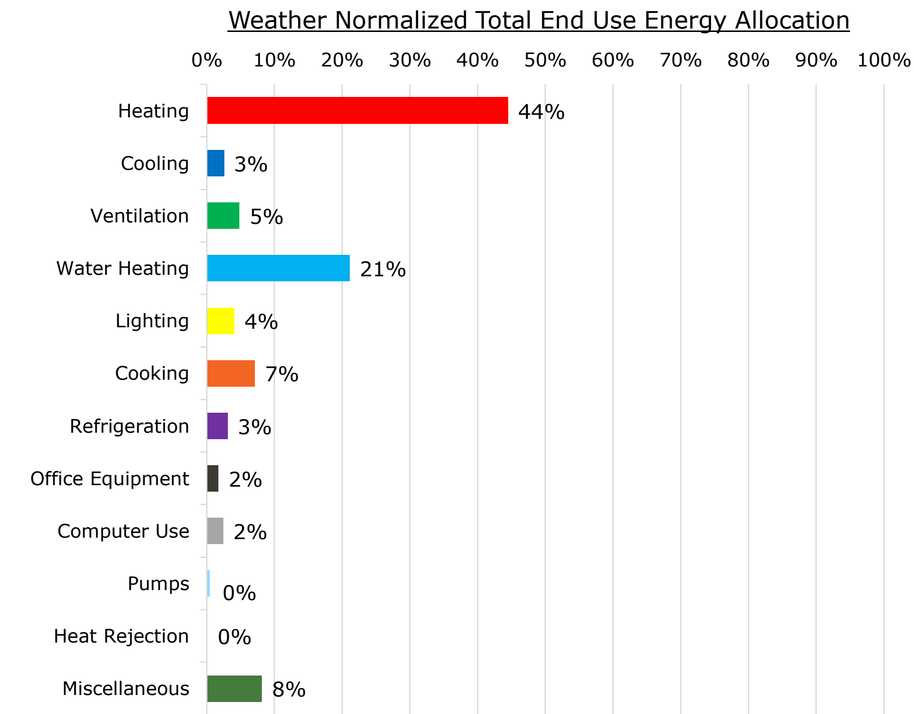
| Month | Average | | Weather Normalized | | Jan 2018 to Dec 2018 | | Jan 2019 to Dec 2019 | | Jan 2020 to Dec 2020 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | MMBtu | Cost | MMBtu | Cost | MMBtu | Cost | MMBtu | Cost | MMBtu | Cost |
| **Jan** | 52,685 | $ 347,205 | 41,389 | $ 312,783 | 56,700 | $ 438,195 | 48,670 | $ 344,934 | 44,943 | $ 225,591 |
| **Feb** | 47,069 | $ 271,234 | 41,760 | $ 254,468 | 45,465 | $ 303,085 | 48,673 | $ 292,371 | 47,122 | $ 217,647 |
| **Mar** | 45,622 | $ 248,816 | 39,932 | $ 243,980 | 46,325 | $ 263,488 | 44,919 | $ 263,654 | 38,383 | $ 188,920 |
| **Apr** | 38,920 | $ 231,913 | 38,559 | $ 245,117 | 41,563 | $ 268,079 | 36,276 | $ 235,517 | 31,604 | $ 142,398 |
| **May** | 23,303 | $ 177,850 | 30,910 | $ 212,386 | 19,632 | $ 183,971 | 26,973 | $ 169,741 | 23,327 | $ 158,175 |
| **Jun** | 17,010 | $ 176,931 | 21,817 | $ 195,354 | 15,888 | $ 191,291 | 18,132 | $ 155,018 | 13,289 | $ 147,830 |
| **Jul** | 19,345 | $ 218,592 | 15,748 | $ 209,124 | 18,762 | $ 232,372 | 19,928 | $ 211,987 | 21,845 | $ 202,360 |
| **Aug** | 20,020 | $ 210,061 | 22,199 | $ 220,407 | 20,112 | $ 235,443 | 19,928 | $ 195,328 | 19,401 | $ 194,199 |
| **Sep** | 22,979 | $ 210,040 | 32,502 | $ 245,475 | 23,029 | $ 233,528 | 22,929 | $ 187,110 | 20,081 | $ 179,751 |
| **Oct** | 29,633 | $ 220,165 | 41,176 | $ 265,287 | 30,816 | $ 255,200 | 28,450 | $ 196,160 | 27,584 | $ 179,268 |
| **Nov** | 42,105 | $ 289,115 | 40,942 | $ 258,741 | 42,697 | $ 305,185 | 41,514 | $ 313,416 | 38,235 | $ 216,721 |
| **Dec** | 44,277 | $ 311,571 | 41,297 | $ 269,256 | 44,299 | $ 363,850 | 44,255 | $ 301,412 | 38,838 | $ 226,936 |
| **Annual** | **402,967** | **$ 2,913,494** | **408,231** | **$ 2,932,377** | **405,288** | **$ 3,273,689** | **400,647** | **$ 2,866,648** | **364,651** | **$ 2,279,796** |

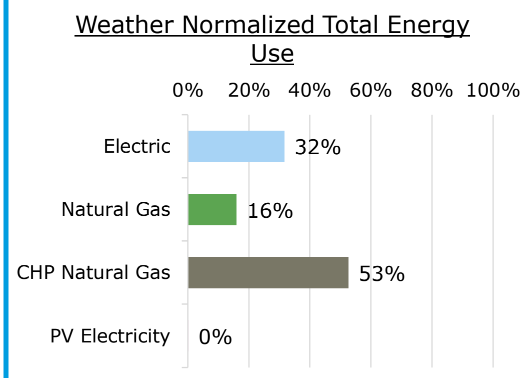
| | | Average | Weather Normalized | Jan 2018 to Dec 2018 | Jan 2019 to Dec 2019 | Jan 2020 to Dec 2020 |
|---|---|---|---|---|---|---|
| **Total** | **Site EUI** | 115.2 kBtu/SF | 116.7 kBtu/SF | 115.8 kBtu/SF | 114.5 kBtu/SF | 104.2 kBtu/SF |
| | **ECI** | 0.83 $/SF | 0.84 $/SF | 0.94 $/SF | 0.82 $/SF | 0.65 $/SF |
| | **Utility Cost** | 7.23 $/MMBtu | 7.18 $/MMBtu | 8.08 $/MMBtu | 7.16 $/MMBtu | 6.25 $/MMBtu |
| **Electric** | **Site EUI** | 36.8 kBtu/SF | 36.8 kBtu/SF | 37.4 kBtu/SF | 36.1 kBtu/SF | 32.6 kBtu/SF |
| | | 10.8 kWh/SF | 10.8 kWh/SF | 11.0 kWh/SF | 10.6 kWh/SF | 9.5 kWh/SF |
| | **Demand/SF** | 2.18 W/SF | 2.18 W/SF | 2.31 W/SF | 2.04 W/SF | 1.96 W/SF |
| | **ECI** | 0.552 $/SF | 0.552 $/SF | 0.636 $/SF | 0.511 $/SF | 0.442 $/SF |
| | **Utility Cost** | 0.051 $/kWh | 0.051 $/kWh | 0.058 $/kWh | 0.048 $/kWh | 0.046 $/kWh |
| | | 15.02 $/MMBtu | 15.02 $/MMBtu | 17.01 $/MMBtu | 14.15 $/MMBtu | 13.58 $/MMBtu |
| **Natural Gas** | **Site EUI** | 18.1 kBtu/SF | 18.5 kBtu/SF | 18.8 kBtu/SF | 17.4 kBtu/SF | 15.4 kBtu/SF |
| | | 0.181 Therms/SF | 0.185 Therms/SF | 0.188 Therms/SF | 0.174 Therms/SF | 0.154 Therms/SF |
| | **ECI** | 0.068 $/SF | 0.069 $/SF | 0.074 $/SF | 0.070 $/SF | 0.049 $/SF |
| | **Utility Cost** | 0.374 $/Therm | 0.374 $/Therm | 0.394 $/Therm | 0.404 $/Therm | 0.320 $/Therm |
| | | 3.74 $/MMBtu | 3.74 $/MMBtu | 3.94 $/MMBtu | 4.04 $/MMBtu | 3.20 $/MMBtu |
| **CHP Natural Gas** | **Site EUI** | 60.2 kBtu/SF | 61.3 kBtu/SF | 59.5 kBtu/SF | 60.9 kBtu/SF | 56.2 kBtu/SF |
| | | 0.602 Therms/SF | 0.613 Therms/SF | 0.595 Therms/SF | 0.609 Therms/SF | 0.562 Therms/SF |
| | **ECI** | 0.213 $/SF | 0.217 $/SF | 0.225 $/SF | 0.238 $/SF | 0.160 $/SF |
| | **Utility Cost** | 0.353 $/Therm | 0.353 $/Therm | 0.378 $/Therm | 0.391 $/Therm | 0.286 $/Therm |
| | | 3.53 $/MMBtu | 3.53 $/MMBtu | 3.78 $/MMBtu | 3.91 $/MMBtu | 2.86 $/MMBtu |
| **PV Electricity** | **Site EUI** | 0.1 kBtu/SF | 0.1 kBtu/SF | 0.1 kBtu/SF | 0.1 kBtu/SF | 0.1 kBtu/SF |
| | | 0.018 kWh/SF | 0.018 kWh/SF | 0.018 kWh/SF | 0.018 kWh/SF | 0.018 kWh/SF |
| | **ECI** | 0.000 $/SF | 0.000 $/SF | 0.000 $/SF | 0.000 $/SF | 0.000 $/SF |
| | **Utility Cost** | 0.000 $/kWh | 0.000 $/kWh | 0.000 $/kWh | 0.000 $/kWh | 0.000 $/kWh |
| | | 0.00 $/MMBtu | 0.00 $/MMBtu | 0.00 $/MMBtu | 0.00 $/MMBtu | 0.00 $/MMBtu |

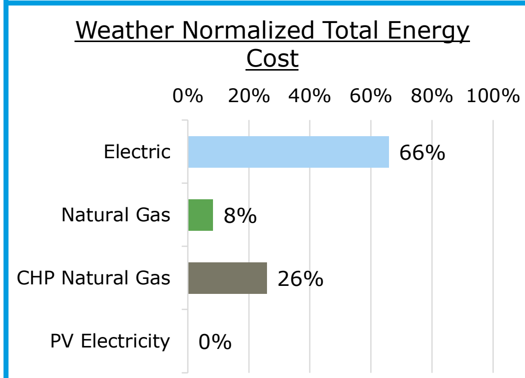
Notes:
- Energy Use Intensity (EUI) is expressed as energy per square foot per year. Energy Cost Intensity (ECI) is expressed as energy cost per square foot per year.
- Comparison site EUI, source EUI and end-use estimates are based on 2012 CBECS (Commercial Building Energy Consumption Survey).
- Site EUI indicates site energy requirement. Source EUI includes transmission losses and energy conversion efficiency.
- Key Performance Indicators (KPIs) allow comparison between buildings. Base 55°F used for Cooling Degree Days (CDD) and Heating Degree Days (HDD).
- "Average" may not match the average of billing month data when billing months don't start and end with the actual month.
- Utility data include all campus accounts covering the campus buildings.
- "Weather Normalized" Natural Gas energy uses typical weather year heating degree days in a model fit of metered natural gas use data.
- "Weather Normalized" CHP Natural Gas energy uses typical weather year heating degree days in a model fit of metered natural gas use data.
- "Monthly PV output estimated using PV Watts.

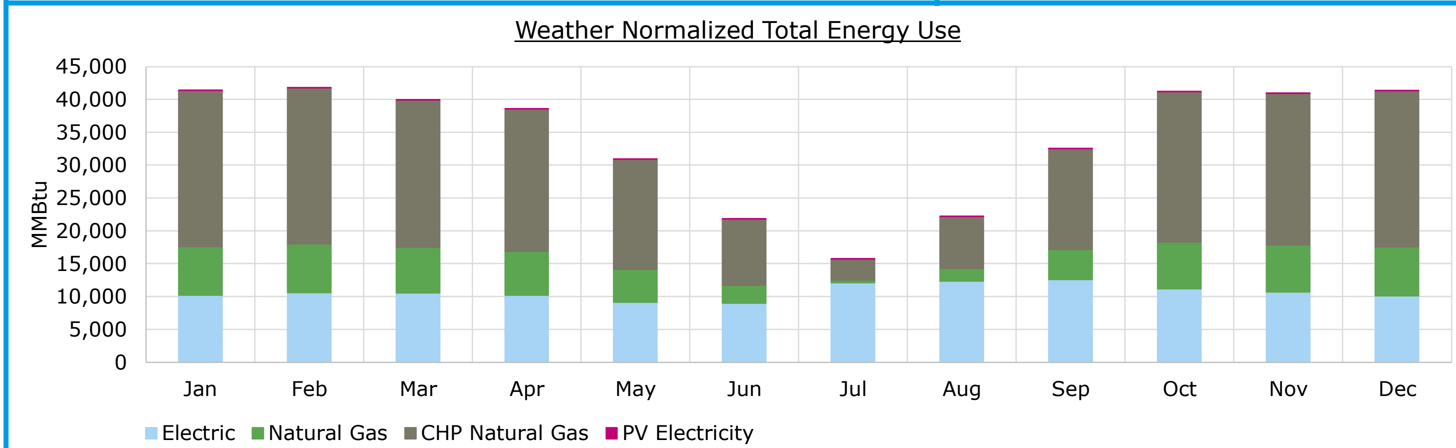
**Energy Use Analysis and Benchmarking Profile** **All Fuels Summary**

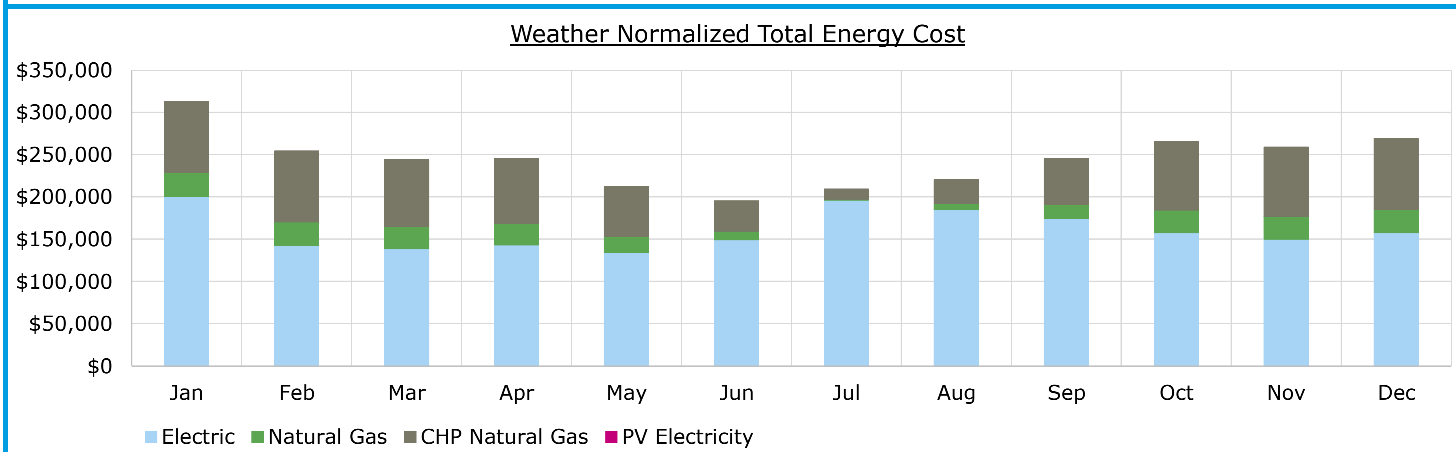
**SUNY Oswego** **000 - Campus Total**



**Utility Account Information**

| Component | Provider | Account Number | Rate Class |
|---|---|---|---|
| **Electric Delivery** | National Grid | Multiple | Multiple |
| **Electric Supply** | 0 | Multiple | |

**Electric Energy Profile**

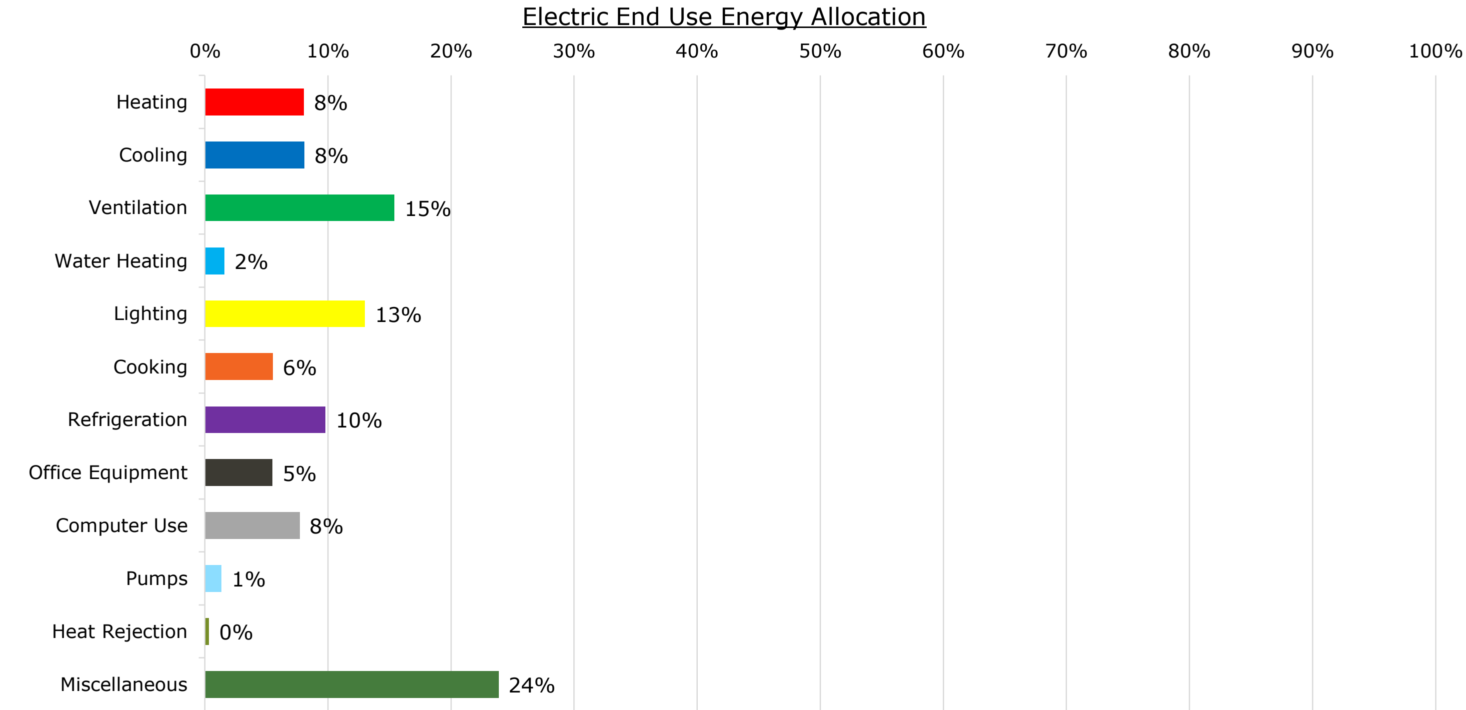
| Month | Average kWh | Average kW | Average Total Cost | Average CDD | Average HDD | Weather Normalized kWh | Weather Normalized kW | Weather Normalized Total Cost | Weather Normalized CDD | Weather Normalized HDD |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 2,991,948 | 5,566 | $ 201,077 | 0 | 919 | 2,991,948 | 5,566 | $ 201,077 | 0 | 919 |
| Feb | 3,099,489 | 5,780 | $ 142,763 | 0 | 721 | 3,099,489 | 5,780 | $ 142,763 | 0 | 721 |
| Mar | 3,085,285 | 5,570 | $ 138,690 | 1 | 606 | 3,085,285 | 5,570 | $ 138,690 | 1 | 606 |
| Apr | 2,983,602 | 5,352 | $ 143,510 | 8 | 378 | 2,983,602 | 5,352 | $ 143,510 | 8 | 378 |
| May | 2,681,436 | 5,316 | $ 134,532 | 153 | 95 | 2,681,436 | 5,316 | $ 134,532 | 153 | 95 |
| Jun | 2,634,802 | 5,807 | $ 149,548 | 320 | 3 | 2,634,802 | 5,807 | $ 149,548 | 320 | 3 |
| Jul | 3,540,338 | 6,416 | $ 196,178 | 592 | 0 | 3,540,338 | 6,416 | $ 196,178 | 592 | 0 |
| Aug | 3,610,442 | 7,313 | $ 185,169 | 511 | 0 | 3,610,442 | 7,313 | $ 185,169 | 511 | 0 |
| Sep | 3,695,102 | 7,620 | $ 174,297 | 300 | 7 | 3,695,102 | 7,620 | $ 174,297 | 300 | 7 |
| Oct | 3,281,447 | 6,703 | $ 157,907 | 62 | 143 | 3,281,447 | 6,703 | $ 157,907 | 62 | 143 |
| Nov | 3,127,849 | 5,581 | $ 150,306 | 18 | 459 | 3,127,849 | 5,581 | $ 150,306 | 18 | 459 |
| Dec | 2,965,451 | 5,535 | $ 157,550 | 0 | 700 | 2,965,451 | 5,535 | $ 157,550 | 0 | 700 |
| **Annual** | **37,697,187** | **7,620** | **$ 1,931,526** | **1,965** | **4,032** | **37,697,187** | **7,620** | **$ 1,931,526** | **1,965** | **4,032** |
| KPIs | 10.8 kWh/SF | 2.18 W/SF | 0.55 $/SF | | | 10.8 kWh/SF | 2.18 W/SF | 0.55 $/SF | | |
| Load Factor | 56% | | | | | 56% | | | | |
| Blended Rates | 0.051 $/kWh | | | | | 0.051 $/kWh | | | | |

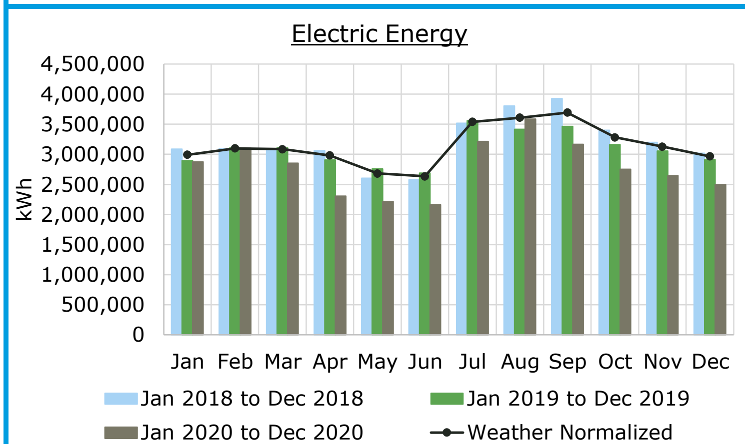
**Electric Energy Profile**

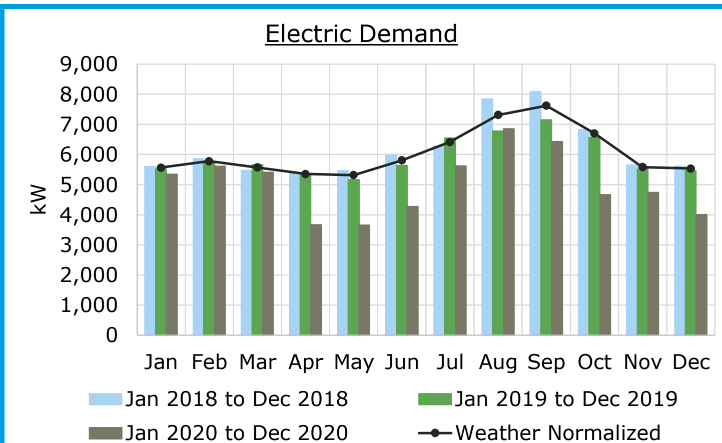
| Month | Jan 2018 to Dec 2018 kWh | kW | Total Cost | CDD | HDD | Jan 2019 to Dec 2019 kWh | kW | Total Cost | CDD | HDD | Jan 2020 to Dec 2020 kWh | kW | Total Cost | CDD | HDD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 3,086,669 | 5,605 | $ 296,585 | 0 | 972 | 2,897,226 | 5,527 | $ 178,810 | 0 | 1,014 | 2,876,875 | 5,342 | $ 120,315 | 0 | 772 |
| Feb | 3,092,534 | 5,853 | $ 148,676 | 0 | 625 | 3,106,444 | 5,707 | $ 155,600 | 0 | 777 | 3,101,540 | 5,608 | $ 123,228 | 0 | 760 |
| Mar | 3,062,734 | 5,473 | $ 148,064 | 0 | 684 | 3,107,835 | 5,668 | $ 144,141 | 0 | 683 | 2,851,289 | 5,412 | $ 113,782 | 4 | 452 |
| Apr | 3,060,795 | 5,366 | $ 165,970 | 7 | 474 | 2,906,408 | 5,338 | $ 144,592 | 8 | 308 | 2,306,692 | 3,667 | $ 85,551 | 9 | 352 |
| May | 2,603,506 | 5,468 | $ 144,308 | 230 | 16 | 2,759,365 | 5,164 | $ 111,468 | 55 | 129 | 2,214,654 | 3,661 | $ 121,281 | 173 | 142 |
| Jun | 2,579,833 | 5,977 | $ 164,542 | 317 | 0 | 2,689,770 | 5,636 | $ 123,525 | 266 | 8 | 2,162,736 | 4,274 | $ 131,129 | 379 | 1 |
| Jul | 3,518,375 | 6,281 | $ 206,059 | 575 | 0 | 3,562,300 | 6,551 | $ 187,437 | 573 | 0 | 3,216,062 | 5,619 | $ 175,057 | 628 | 0 |
| Aug | 3,806,571 | 7,845 | $ 208,870 | 564 | 0 | 3,414,313 | 6,780 | $ 170,207 | 440 | 0 | 3,589,051 | 6,854 | $ 173,538 | 531 | 0 |
| Sep | 3,925,038 | 8,086 | $ 197,682 | 351 | 8 | 3,465,166 | 7,155 | $ 152,829 | 254 | 0 | 3,166,734 | 6,430 | $ 146,688 | 294 | 14 |
| Oct | 3,401,662 | 6,838 | $ 183,324 | 83 | 209 | 3,161,231 | 6,567 | $ 136,179 | 51 | 111 | 2,750,840 | 4,666 | $ 125,262 | 53 | 110 |
| Nov | 3,198,816 | 5,651 | $ 182,019 | 0 | 558 | 3,056,882 | 5,511 | $ 142,771 | 0 | 559 | 2,645,804 | 4,742 | $ 104,573 | 54 | 261 |
| Dec | 3,020,758 | 5,610 | $ 180,680 | 0 | 719 | 2,910,143 | 5,460 | $ 140,365 | 0 | 766 | 2,497,157 | 4,011 | $ 125,669 | 0 | 616 |
| **Annual** | **38,357,291** | **8,086** | **$ 2,226,781** | **2,125** | **4,263** | **37,037,083** | **7,155** | **$ 1,787,924** | **1,645** | **4,354** | **33,379,434** | **6,854** | **$ 1,546,075** | **2,124** | **3,479** |
| KPIs | 11.0 kWh/SF | 2.31 W/SF | 0.64 $/SF | | | 10.6 kWh/SF | 2.04 W/SF | 0.51 $/SF | | | 9.5 kWh/SF | 1.96 W/SF | 0.44 $/SF | | |
| Load Factor | 54% | | | | | 59% | | | | | 56% | | | | |
| Blended Rates | 0.058 $/kWh | | | | | 0.048 $/kWh | | | | | 0.046 $/kWh | | | | |

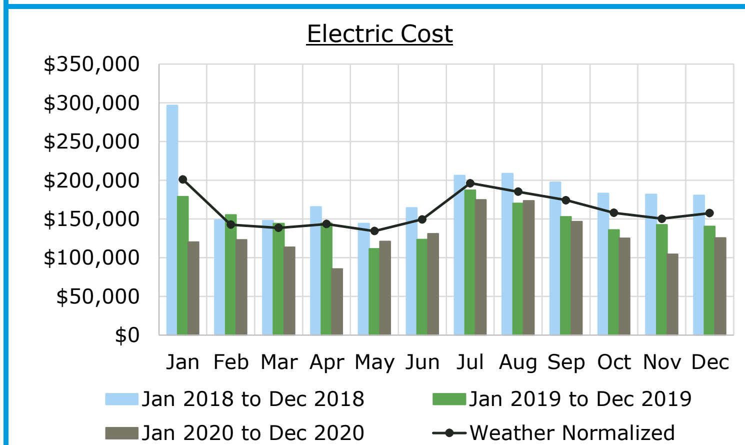
Notes:

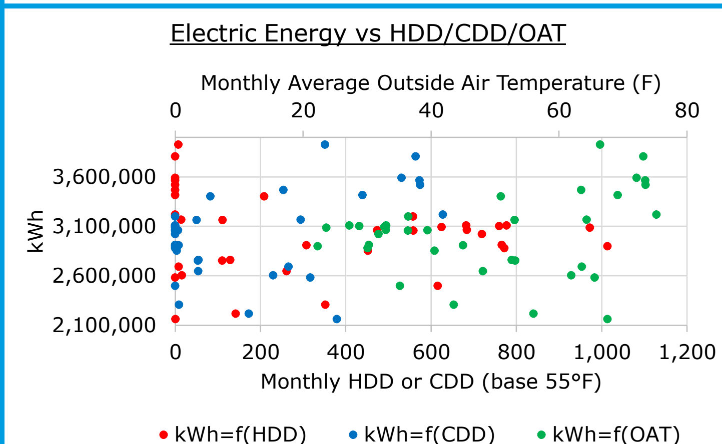
- Energy Use Intensity (EUI) is expressed as energy per square foot per year. Energy Cost Intensity (ECI) is expressed as energy cost per square foot per year.
- Comparison site EUI, source EUI and end-use estimates are based on 2012 CBECS (Commercial Building Energy Consumption Survey).
- Site EUI indicates site energy requirement. Source EUI includes transmission losses and energy conversion efficiency.
- Key Performance Indicators (KPIs) allow comparison between buildings. Base 55°F used for Cooling Degree Days (CDD) and Heating Degree Days (HDD).
- "Average" may not match the average of billing month data when billing months don't start and end with the actual month.
- Electric data from utility billing data.


Electric End Use Energy Allocation
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Heating 8%
Cooling 8%
Ventilation 15%
Water Heating 2%
Lighting 13%
Cooking 6%
Refrigeration 10%
Office Equipment 5%
Computer Use 8%
Pumps 1%
Heat Rejection 0%
Miscellaneous 24%


Electric Energy
kWh
4,500,000
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Jan 2018 to Dec 2018
Jan 2019 to Dec 2019
Jan 2020 to Dec 2020
Weather Normalized


Electric Demand
kW
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Jan 2018 to Dec 2018
Jan 2019 to Dec 2019
Jan 2020 to Dec 2020
Weather Normalized


Electric Cost
$350,000
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Jan 2018 to Dec 2018
Jan 2019 to Dec 2019
Jan 2020 to Dec 2020
Weather Normalized


Electric Energy vs HDD/CDD/OAT
Monthly Average Outside Air Temperature (F)
0
20
40
60
80
kWh
3,600,000
3,100,000
2,600,000
2,100,000
0
200
400
600
800
1,000
1,200
Monthly HDD or CDD (base 55°F)
kWh=f(HDD)
kWh=f(CDD)
kWh=f(OAT)

| Utility Account Information | | | |
|---|---|---|---|
| **Component** | **Provider** | **Account Number** | **Rate Class** |
| **Natural Gas Delivery** | National Grid | Multiple | Multiple |
| **Natural Gas Supply** | - | - | |

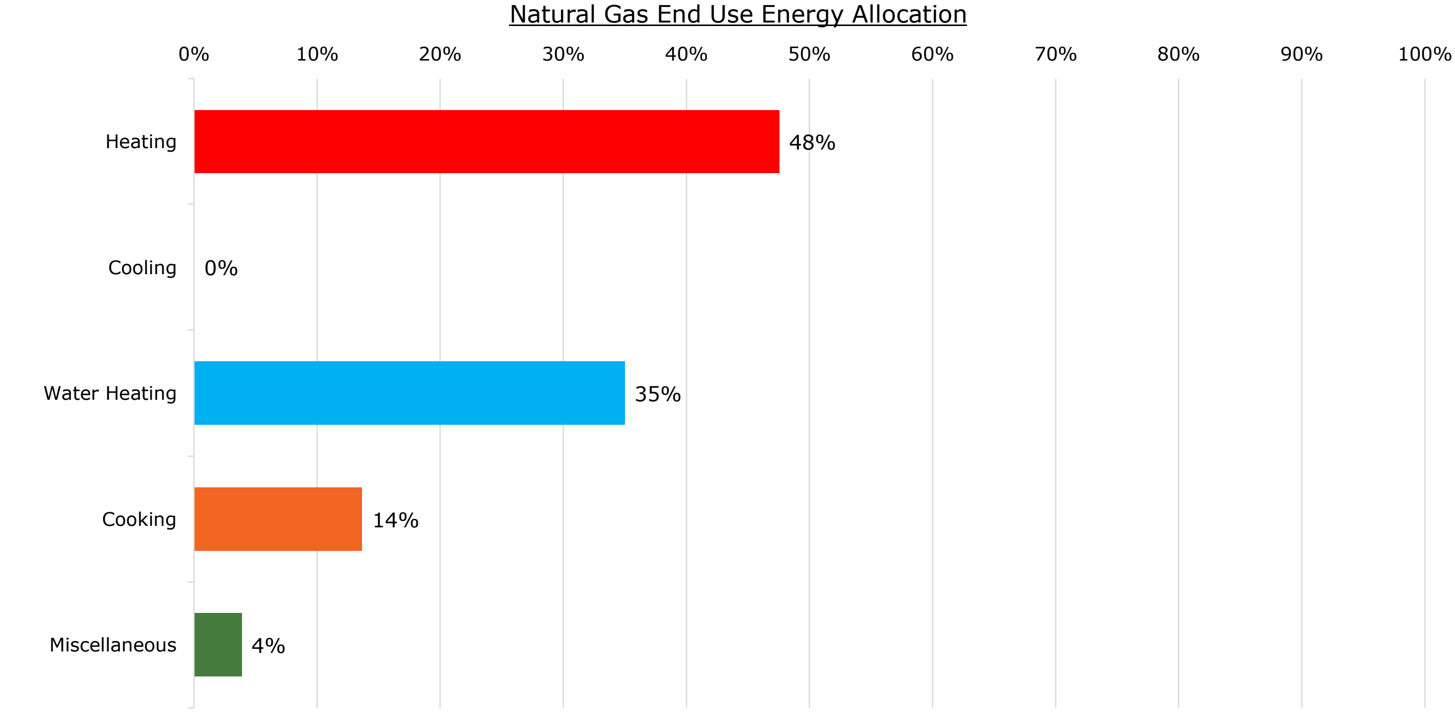
**Natural Gas Energy Profile**

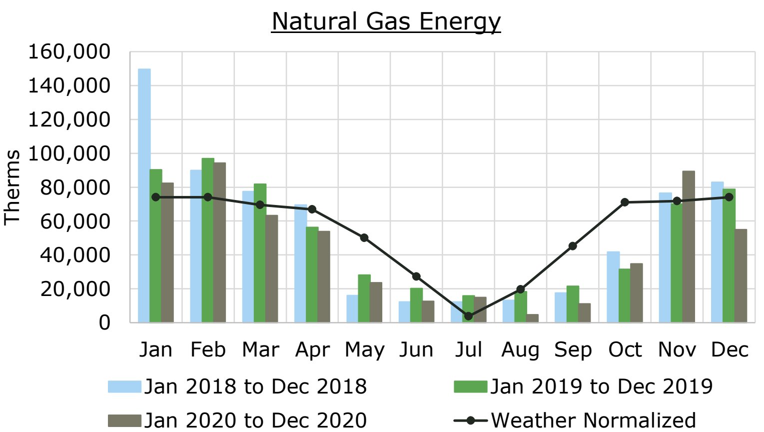
| Month | Average | | | | Weather Normalized | | | |
|---|---|---|---|---|---|---|---|---|
| | Therms | Total Cost | CDD | HDD | Therms | Total Cost | CDD | HDD |
| Jan | 119,957 | $ 41,709 | 0 | 919 | 74,152 | $ 27,765 | 0 | 899 |
| Feb | 93,399 | $ 35,355 | 0 | 721 | 74,152 | $ 27,765 | 0 | 830 |
| Mar | 79,665 | $ 27,882 | 1 | 606 | 69,586 | $ 26,056 | 34 | 578 |
| Apr | 62,943 | $ 21,444 | 8 | 378 | 66,964 | $ 25,074 | 53 | 265 |
| May | 22,115 | $ 8,163 | 153 | 95 | 50,060 | $ 18,744 | 178 | 27 |
| Jun | 16,332 | $ 6,044 | 320 | 3 | 27,252 | $ 10,204 | 347 | 4 |
| Jul | 14,153 | $ 4,833 | 592 | 0 | 3,866 | $ 1,448 | 519 | 0 |
| Aug | 15,779 | $ 5,809 | 511 | 0 | 19,730 | $ 7,388 | 402 | 0 |
| Sep | 19,571 | $ 7,412 | 300 | 7 | 45,309 | $ 16,965 | 213 | 42 |
| Oct | 36,697 | $ 14,635 | 62 | 143 | 71,073 | $ 26,612 | 23 | 194 |
| Nov | 73,246 | $ 30,660 | 18 | 459 | 71,824 | $ 26,894 | 17 | 440 |
| Dec | 80,826 | $ 33,703 | 0 | 700 | 74,152 | $ 27,765 | 0 | 845 |
| **Annual** | **634,680** | **$ 237,648** | **1,965** | **4,032** | **648,119** | **$ 242,680** | **1,786** | **4,123** |
| KPIs | 0.181 Therms/SF | 0.068 $/SF | | | 0.185 Therms/SF | 0.069 $/SF | | |
| Blended Rates | 0.374 $/Therm | 3.74 $/MMBtu | | | 0.374 $/Therm | 3.74 $/MMBtu | | |

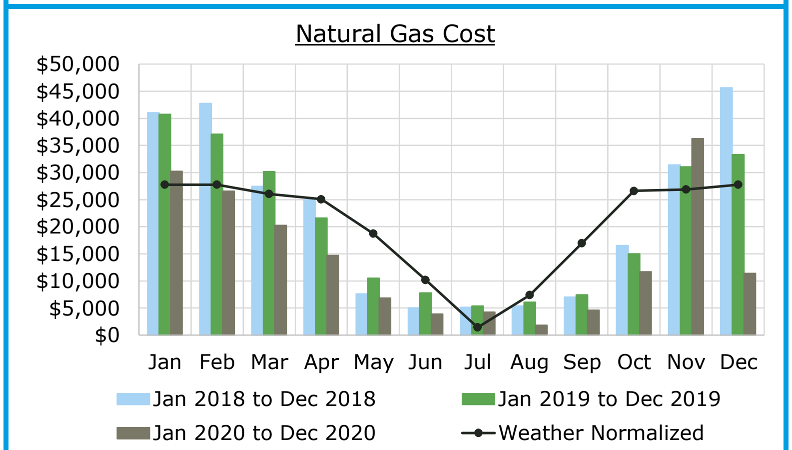
**Natural Gas Energy Profile**

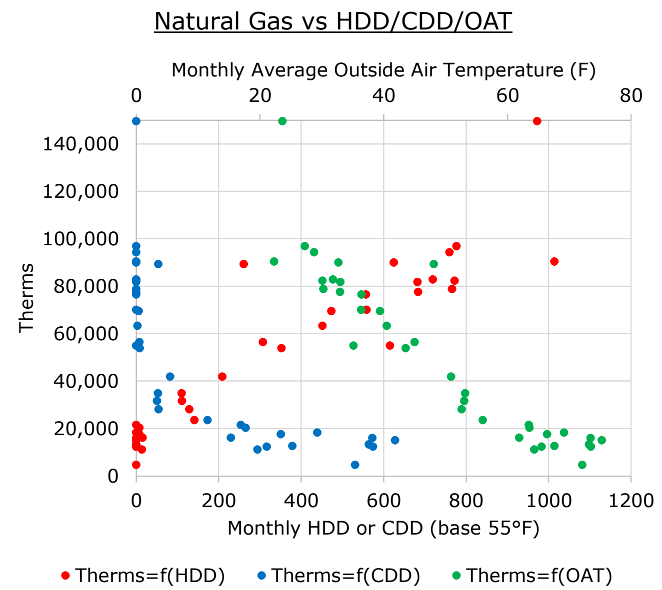
| Month | Jan 2018 to Dec 2018 | | | | Jan 2019 to Dec 2019 | | | | Jan 2020 to Dec 2020 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Therms | Total Cost | CDD | HDD | Therms | Total Cost | CDD | HDD | Therms | Total Cost | CDD | HDD |
| Jan | 149,559 | $ 41,021 | 0 | 972 | 90,355 | $ 40,765 | 0 | 1,014 | 82,300 | $ 30,247 | 0 | 772 |
| Feb | 89,921 | $ 42,729 | 0 | 625 | 96,877 | $ 37,054 | 0 | 777 | 94,216 | $ 26,590 | 0 | 760 |
| Mar | 77,567 | $ 27,475 | 0 | 684 | 81,762 | $ 30,189 | 0 | 683 | 63,295 | $ 20,253 | 4 | 452 |
| Apr | 69,518 | $ 24,983 | 7 | 474 | 56,367 | $ 21,592 | 8 | 308 | 53,904 | $ 14,678 | 9 | 352 |
| May | 16,069 | $ 7,647 | 230 | 16 | 28,160 | $ 10,521 | 55 | 129 | 23,569 | $ 6,857 | 173 | 142 |
| Jun | 12,386 | $ 5,051 | 317 | 0 | 20,277 | $ 7,778 | 266 | 8 | 12,618 | $ 3,929 | 379 | 1 |
| Jul | 12,392 | $ 5,151 | 575 | 0 | 15,913 | $ 5,405 | 573 | 0 | 15,034 | $ 4,245 | 628 | 0 |
| Aug | 13,255 | $ 5,370 | 564 | 0 | 18,303 | $ 6,112 | 440 | 0 | 4,678 | $ 1,857 | 531 | 0 |
| Sep | 17,594 | $ 7,014 | 351 | 8 | 21,548 | $ 7,438 | 254 | 0 | 11,168 | $ 4,603 | 294 | 14 |
| Oct | 41,833 | $ 16,523 | 83 | 209 | 31,560 | $ 14,974 | 51 | 111 | 34,861 | $ 11,675 | 53 | 110 |
| Nov | 76,440 | $ 31,412 | 0 | 558 | 70,051 | $ 31,045 | 0 | 559 | 89,330 | $ 36,257 | 54 | 261 |
| Dec | 82,885 | $ 45,653 | 0 | 719 | 78,768 | $ 33,292 | 0 | 766 | 54,978 | $ 11,385 | 0 | 616 |
| **Annual** | **659,419** | **$ 260,029** | **2,125** | **4,263** | **609,941** | **$ 246,165** | **1,645** | **4,354** | **539,951** | **$ 172,575** | **2,124** | **3,479** |
| KPIs | 0.188 Therms/SF | 0.074 $/SF | | | 0.174 Therms/SF | 0.070 $/SF | | | 0.154 Therms/SF | 0.049 $/SF | | |
| Blended Rates | 0.394 $/Therm | 3.94 $/MMBtu | | | 0.404 $/Therm | 4.04 $/MMBtu | | | 0.320 $/Therm | 3.20 $/MMBtu | | |

Notes:
- Energy Use Intensity (EUI) is expressed as energy per square foot per year. Energy Cost Intensity (ECI) is expressed as energy cost per square foot per year.
- Comparison site EUI, source EUI and end-use estimates are based on 2012 CBECS (Commercial Building Energy Consumption Survey).
- Site EUI indicates site energy requirement. Source EUI includes transmission losses and energy conversion efficiency.
- Key Performance Indicators (KPIs) allow comparison between buildings. Base 55°F used for Cooling Degree Days (CDD) and Heating Degree Days (HDD).
- "Average" may not match the average of billing month data when billing months don't start and end with the actual month.
- Natural Gas data includes all utility accounts.
- "Weather Normalized" Natural Gas energy uses typical weather year heating degree days in a model fit of metered natural gas use data.


Natural Gas End Use Energy Allocation
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Heating
48%
Cooling
0%
Water Heating
35%
Cooking
14%
Miscellaneous
4%


Natural Gas Energy
Therms
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Jan 2018 to Dec 2018
Jan 2019 to Dec 2019
Jan 2020 to Dec 2020
Weather Normalized


Natural Gas Cost
$50,000
$45,000
$40,000
$35,000
$30,000
$25,000
$20,000
$15,000
$10,000
$5,000
$0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Jan 2018 to Dec 2018
Jan 2019 to Dec 2019
Jan 2020 to Dec 2020
Weather Normalized


Natural Gas vs HDD/CDD/OAT
Monthly Average Outside Air Temperature (F)
0 20 40 60 80
Therms
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
0 200 400 600 800 1000 1200
Monthly HDD or CDD (base 55°F)
Therms=f(HDD)
Therms=f(CDD)
Therms=f(OAT)

## Utility Account Information

| Component | Provider | Account Number | Rate Class |
|---|---|---|---|
| CHP Natural Gas | National Grid | Multiple | Multiple |
| Natural Gas Supply | - | - | |

## CHP Natural Gas Energy Profile

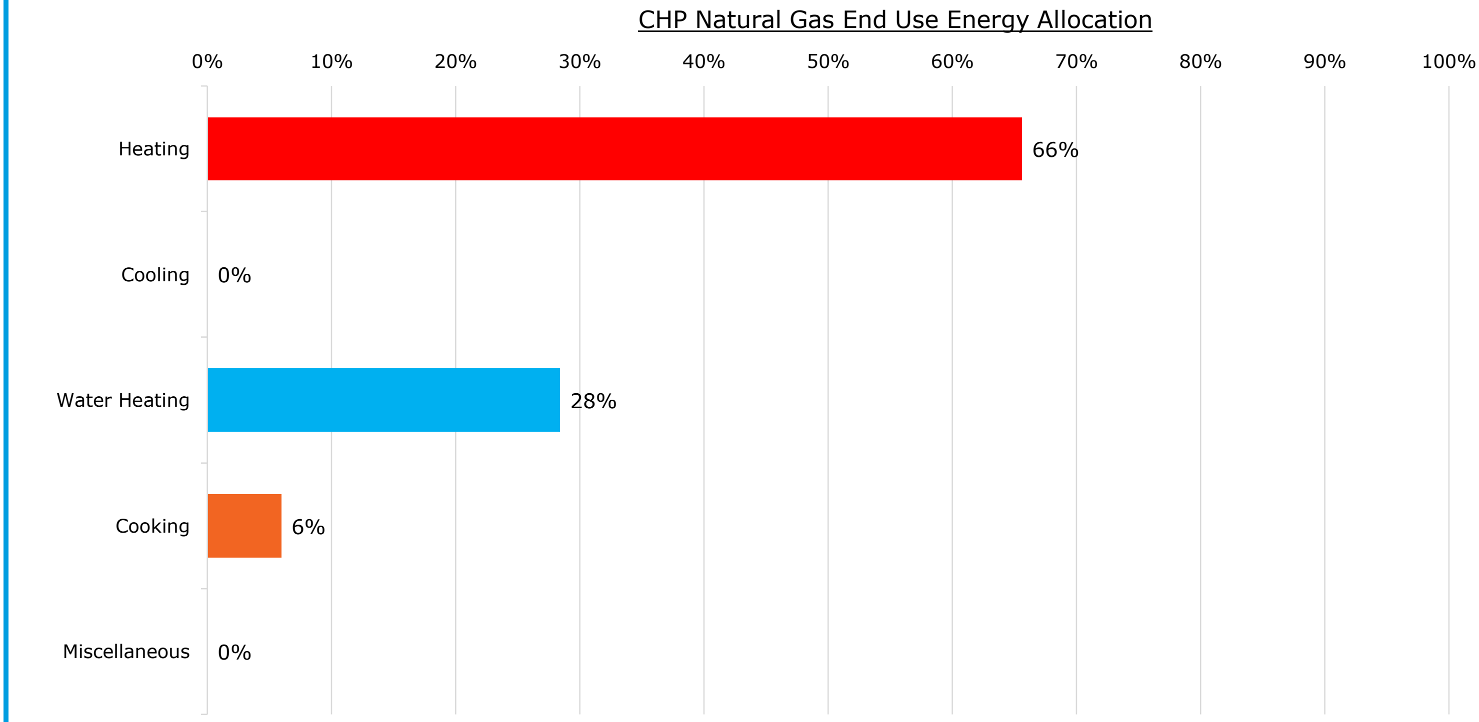
| Month | Average | | | | | Weather Normalized | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Therms | Total Cost | | CDD | HDD | Therms | Total Cost | | CDD | HDD |
| Jan | 304,717 | $ | 104,419 | 0 | 919 | 237,569 | $ | 83,940 | 0 | 899 |
| Feb | 271,410 | $ | 93,116 | 0 | 721 | 237,569 | $ | 83,940 | 0 | 830 |
| Mar | 271,078 | $ | 82,245 | 1 | 606 | 224,251 | $ | 79,235 | 34 | 578 |
| Apr | 224,230 | $ | 66,959 | 8 | 378 | 216,603 | $ | 76,533 | 53 | 265 |
| May | 119,159 | $ | 35,155 | 153 | 95 | 167,292 | $ | 59,109 | 178 | 27 |
| Jun | 63,614 | $ | 21,339 | 320 | 3 | 100,761 | $ | 35,602 | 347 | 4 |
| Jul | 58,231 | $ | 17,581 | 592 | 0 | 32,544 | $ | 11,499 | 519 | 0 |
| Aug | 60,986 | $ | 19,083 | 511 | 0 | 78,822 | $ | 27,850 | 402 | 0 |
| Sep | 83,944 | $ | 28,331 | 300 | 7 | 153,434 | $ | 54,213 | 213 | 42 |
| Oct | 147,531 | $ | 47,623 | 62 | 143 | 228,588 | $ | 80,767 | 23 | 194 |
| Nov | 240,986 | $ | 108,149 | 18 | 459 | 230,779 | $ | 81,541 | 17 | 440 |
| Dec | 260,694 | $ | 120,318 | 0 | 700 | 237,569 | $ | 83,940 | 0 | 845 |
| **Annual** | **2,106,579** | **$** | **744,319** | **1,965** | **4,032** | **2,145,780** | **$** | **758,170** | **1,786** | **4,123** |
| KPIs | 0.602 Therms/SF | 0.213 $/SF | | | | 0.613 Therms/SF | 0.217 $/SF | | | |
| Blended Rates | 0.353 $/Therm | 3.53 $/MMBtu | | | | 0.353 $/Therm | 3.53 $/MMBtu | | | |

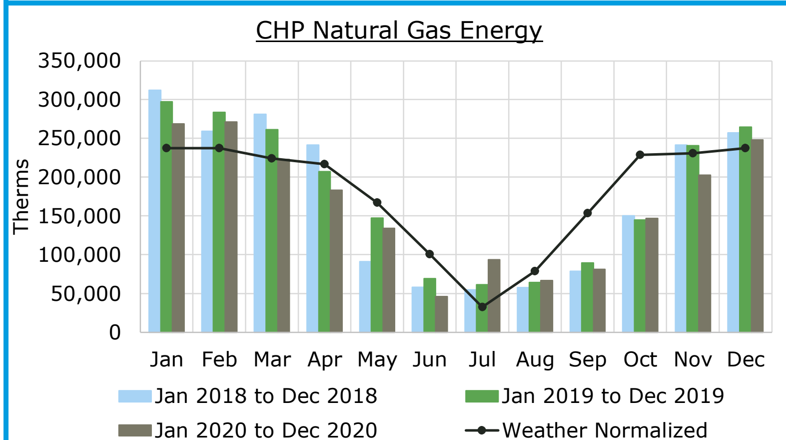
## CHP Natural Gas Energy Profile

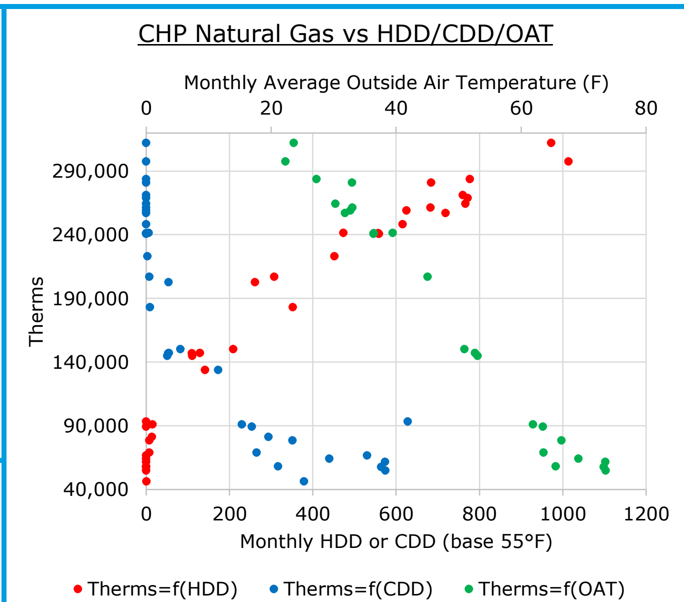
| Month | Jan 2018 to Dec 2018 | | | | | Jan 2019 to Dec 2019 | | | | | Jan 2020 to Dec 2020 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Therms | Total Cost | | CDD | HDD | Therms | Total Cost | | CDD | HDD | Therms | Total Cost | | CDD | HDD |
| Jan | 312,033 | $ | 100,589 | 0 | 972 | 297,401 | $ | 125,359 | 0 | 1,014 | 268,878 | $ | 75,029 | 0 | 772 |
| Feb | 259,081 | $ | 111,680 | 0 | 625 | 283,739 | $ | 99,717 | 0 | 777 | 271,056 | $ | 67,829 | 0 | 760 |
| Mar | 280,976 | $ | 87,949 | 0 | 684 | 261,179 | $ | 89,324 | 0 | 683 | 223,035 | $ | 54,885 | 4 | 452 |
| Apr | 241,456 | $ | 77,125 | 7 | 474 | 207,004 | $ | 69,334 | 8 | 308 | 183,208 | $ | 42,169 | 9 | 352 |
| May | 91,162 | $ | 32,015 | 230 | 16 | 147,156 | $ | 47,753 | 55 | 129 | 133,874 | $ | 30,037 | 173 | 142 |
| Jun | 58,214 | $ | 21,698 | 317 | 0 | 69,014 | $ | 23,715 | 266 | 8 | 46,224 | $ | 12,772 | 379 | 1 |
| Jul | 54,909 | $ | 21,163 | 575 | 0 | 61,553 | $ | 19,145 | 573 | 0 | 93,417 | $ | 23,059 | 628 | 0 |
| Aug | 57,742 | $ | 21,203 | 564 | 0 | 64,230 | $ | 19,008 | 440 | 0 | 66,624 | $ | 18,803 | 531 | 0 |
| Sep | 78,574 | $ | 28,832 | 351 | 8 | 89,314 | $ | 26,843 | 254 | 0 | 81,397 | $ | 28,459 | 294 | 14 |
| Oct | 150,122 | $ | 55,353 | 83 | 209 | 144,941 | $ | 45,007 | 51 | 111 | 146,978 | $ | 42,332 | 53 | 110 |
| Nov | 241,284 | $ | 91,753 | 0 | 558 | 240,687 | $ | 139,600 | 0 | 559 | 202,651 | $ | 75,891 | 54 | 261 |
| Dec | 256,969 | $ | 137,517 | 0 | 719 | 264,419 | $ | 127,755 | 0 | 766 | 248,127 | $ | 89,883 | 0 | 616 |
| **Annual** | **2,082,522** | **$** | **786,878** | **2,125** | **4,263** | **2,130,637** | **$** | **832,559** | **1,645** | **4,354** | **1,965,469** | **$** | **561,146** | **2,124** | **3,479** |
| KPIs | 0.595 Therms/SF | 0.225 $/SF | | | | 0.609 Therms/SF | 0.238 $/SF | | | | 0.562 Therms/SF | 0.160 $/SF | | | |
| Blended Rates | 0.378 $/Therm | 3.78 $/MMBtu | | | | 0.391 $/Therm | 3.91 $/MMBtu | | | | 0.286 $/Therm | 2.86 $/MMBtu | | | |

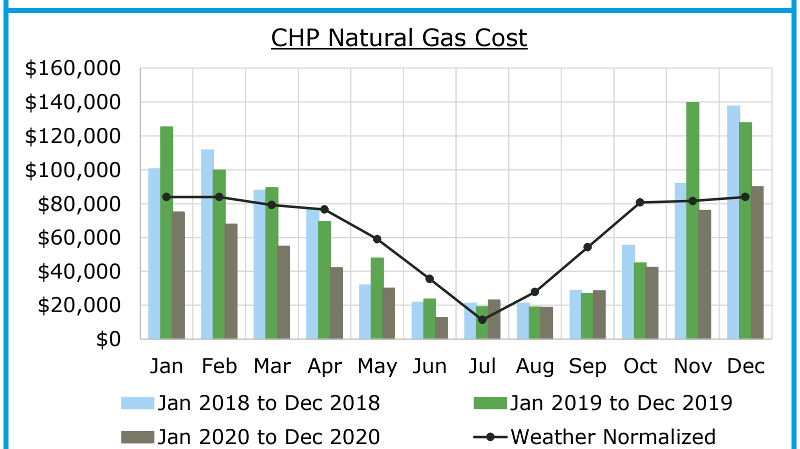
Notes:

- Energy Use Intensity (EUI) is expressed as energy per square foot per year. Energy Cost Intensity (ECI) is expressed as energy cost per square foot per year.
- Comparison site EUI, source EUI and end-use estimates are based on 2012 CBECS (Commercial Building Energy Consumption Survey).
- Site EUI indicates site energy requirement. Source EUI includes transmission losses and energy conversion efficiency.
- Key Performance Indicators (KPIs) allow comparison between buildings. Base 55°F used for Cooling Degree Days (CDD) and Heating Degree Days (HDD).
- "Average" may not match the average of billing month data when billing months don't start and end with the actual month.
- Natural gas data from CHP daily steam logs.
- "Weather Normalized" CHP Natural Gas energy uses typical weather year heating degree days in a model fit of metered natural gas use data.


CHP Natural Gas End Use Energy Allocation
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Heating
66%
Cooling
0%
Water Heating
28%
Cooking
6%
Miscellaneous
0%


CHP Natural Gas Energy
Therms
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Jan 2018 to Dec 2018
Jan 2019 to Dec 2019
Jan 2020 to Dec 2020
Weather Normalized


CHP Natural Gas vs HDD/CDD/OAT
Monthly Average Outside Air Temperature (F)
0
20
40
60
80
Therms
290,000
240,000
190,000
140,000
90,000
40,000
0
200
400
600
800
1000
1200
Monthly HDD or CDD (base 55°F)
Therms=f(HDD)
Therms=f(CDD)
Therms=f(OAT)


CHP Natural Gas Cost
$160,000
$140,000
$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Jan 2018 to Dec 2018
Jan 2019 to Dec 2019
Jan 2020 to Dec 2020
Weather Normalized

Utility Account Information

| Component | Account Number | Provider | Rate Class |
|---|---|---|---|
| PV Electricity | - | SASP | - |

PV Electricity Energy Profile

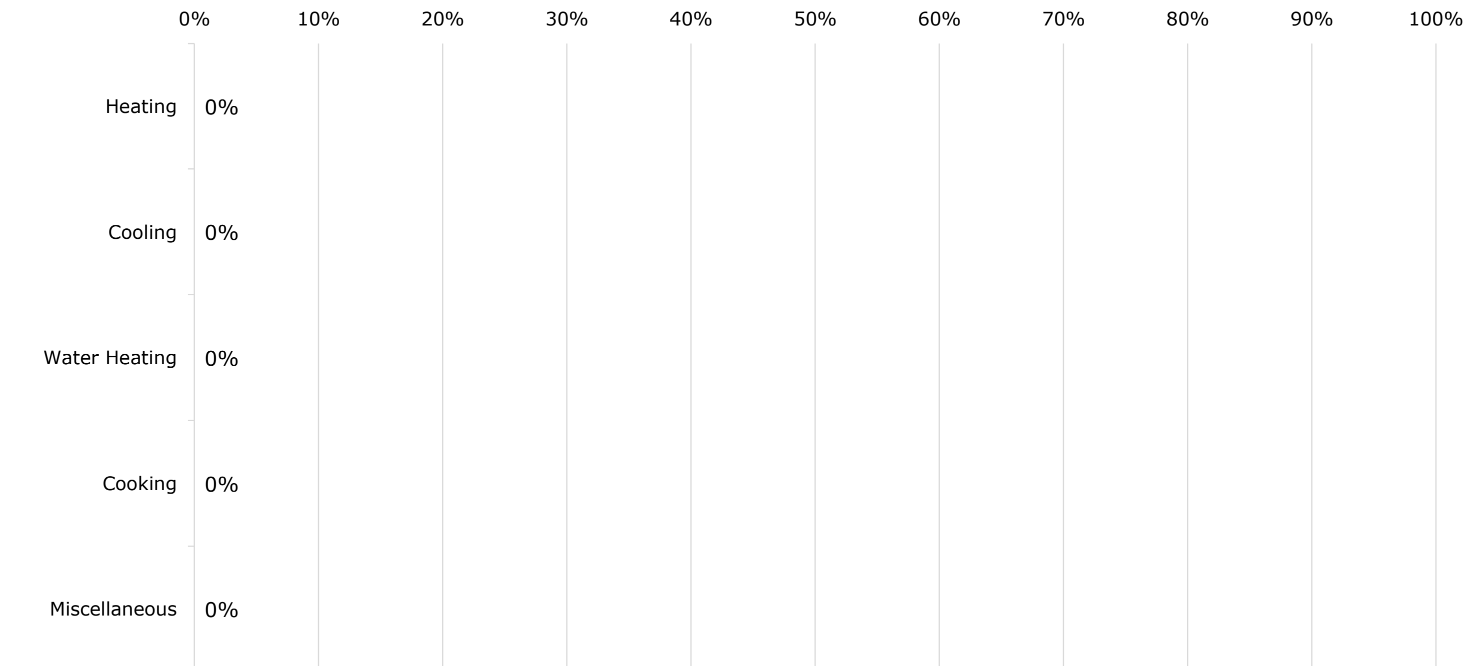
| Month | Average | | | | Weather Normalized | | | |
|---|---|---|---|---|---|---|---|---|
| | kWh | Total Cost | CDD | HDD | kWh | Total Cost | CDD | HDD |
| Jan | 2,602 | $ - | 0 | 919 | 2,602 | $ - | 0 | 919 |
| Feb | 3,710 | $ - | 0 | 721 | 3,710 | $ - | 0 | 721 |
| Mar | 6,128 | $ - | 1 | 606 | 6,128 | $ - | 1 | 606 |
| Apr | 6,590 | $ - | 8 | 378 | 6,590 | $ - | 8 | 378 |
| May | 7,660 | $ - | 153 | 95 | 7,660 | $ - | 153 | 95 |
| Jun | 7,530 | $ - | 320 | 3 | 7,530 | $ - | 320 | 3 |
| Jul | 7,882 | $ - | 592 | 0 | 7,882 | $ - | 592 | 0 |
| Aug | 7,210 | $ - | 511 | 0 | 7,210 | $ - | 511 | 0 |
| Sep | 5,863 | $ - | 300 | 7 | 5,863 | $ - | 300 | 7 |
| Oct | 4,079 | $ - | 62 | 143 | 4,079 | $ - | 62 | 143 |
| Nov | 2,868 | $ - | 18 | 459 | 2,868 | $ - | 18 | 459 |
| Dec | 1,964 | $ - | 0 | 700 | 1,964 | $ - | 0 | 700 |
| **Annual** | **64,087** | **$ -** | **1,965** | **4,032** | **64,087** | **$ -** | **1,965** | **4,032** |
| KPIs | 0.018 kWh/SF | 0.000 $/SF | | | 0.018 kWh/SF | 0.000 $/SF | | |
| Blended Rates | 0.000 $/kWh | 0.00 $/MMBtu | | | 0.000 $/kWh | 0.00 $/MMBtu | | |

PV Electricity Energy Profile

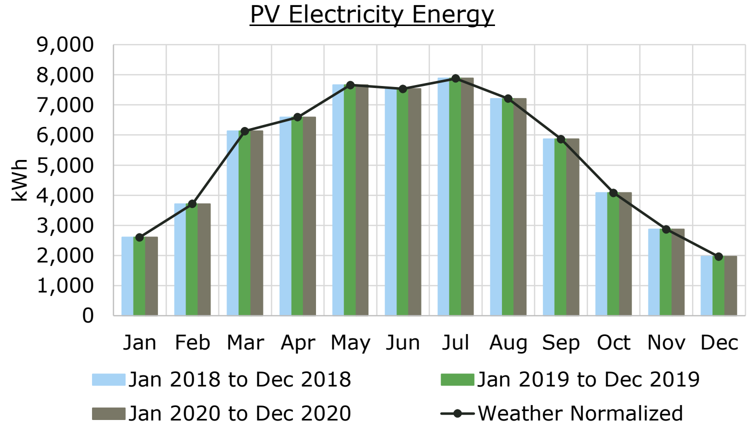
| Month | Jan 2018 to Dec 2018 | | | | Jan 2019 to Dec 2019 | | | | Jan 2020 to Dec 2020 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | kWh | Total Cost | CDD | HDD | kWh | Total Cost | CDD | HDD | kWh | Total Cost | CDD | HDD |
| Jan | 2,602 | $ - | 0 | 972 | 2,602 | $ - | 0 | 1,014 | 2,602 | $ - | 0 | 772 |
| Feb | 3,710 | $ - | 0 | 625 | 3,710 | $ - | 0 | 777 | 3,710 | $ - | 0 | 760 |
| Mar | 6,128 | $ - | 0 | 684 | 6,128 | $ - | 0 | 683 | 6,128 | $ - | 4 | 452 |
| Apr | 6,590 | $ - | 7 | 474 | 6,590 | $ - | 8 | 308 | 6,590 | $ - | 9 | 352 |
| May | 7,660 | $ - | 230 | 16 | 7,660 | $ - | 55 | 129 | 7,660 | $ - | 173 | 142 |
| Jun | 7,530 | $ - | 317 | 0 | 7,530 | $ - | 266 | 8 | 7,530 | $ - | 379 | 1 |
| Jul | 7,882 | $ - | 575 | 0 | 7,882 | $ - | 573 | 0 | 7,882 | $ - | 628 | 0 |
| Aug | 7,210 | $ - | 564 | 0 | 7,210 | $ - | 440 | 0 | 7,210 | $ - | 531 | 0 |
| Sep | 5,863 | $ - | 351 | 8 | 5,863 | $ - | 254 | 0 | 5,863 | $ - | 294 | 14 |
| Oct | 4,079 | $ - | 83 | 209 | 4,079 | $ - | 51 | 111 | 4,079 | $ - | 53 | 110 |
| Nov | 2,868 | $ - | 0 | 558 | 2,868 | $ - | 0 | 559 | 2,868 | $ - | 54 | 261 |
| Dec | 1,964 | $ - | 0 | 719 | 1,964 | $ - | 0 | 766 | 1,964 | $ - | 0 | 616 |
| **Annual** | **64,087** | **$ -** | **2,125** | **4,263** | **64,087** | **$ -** | **1,645** | **4,354** | **64,087** | **$ -** | **2,124** | **3,479** |
| KPIs | 0.018 kWh/SF | 0.000 $/SF | | | 0.018 kWh/SF | 0.000 $/SF | | | 0.018 kWh/SF | 0.000 $/SF | | |
| Blended Rates | 0.000 $/kWh | 0.00 $/MMBtu | | | 0.000 $/kWh | 0.00 $/MMBtu | | | 0.000 $/kWh | 0.00 $/MMBtu | | |

Notes:
- Energy Use Intensity (EUI) is expressed as energy per square foot per year. Energy Cost Intensity (ECI) is expressed as energy cost per square foot per year.
- Comparison site EUI, source EUI and end-use estimates are based on 2012 CBECS (Commercial Building Energy Consumption Survey).
- Site EUI indicates site energy requirement. Source EUI includes transmission losses and energy conversion efficiency.
- Key Performance Indicators (KPIs) allow comparison between buildings. Base 55°F used for Cooling Degree Days (CDD) and Heating Degree Days (HDD).
- "Average" may not match the average of billing month data when billing months don't start and end with the actual month.
- "Monthly PV output estimated using PV Watts.

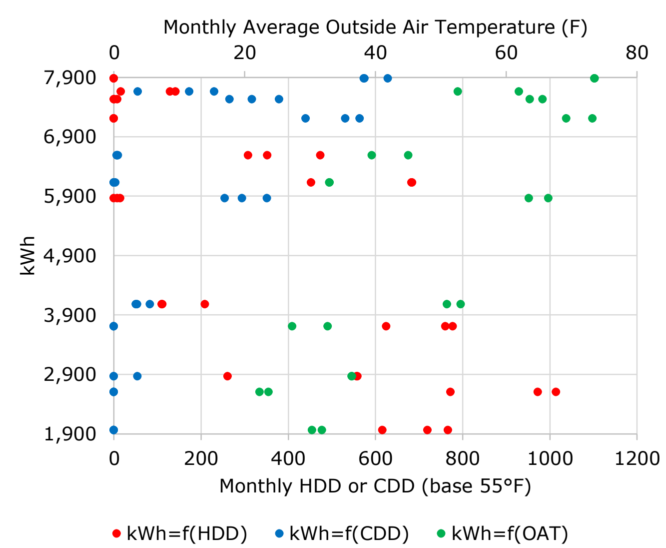
## PV Electricity End Use Energy Allocation



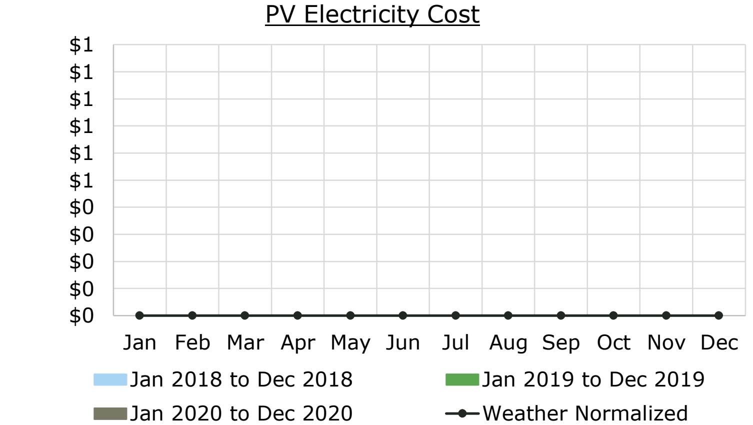

## PV Electricity Energy




## PV Electricity vs HDD/CDD/OAT




## PV Electricity Cost



| Building | Gross Area (SF) | Weather Normalized EUI: Electricity (kBtu/SF) | Natural Gas (kBtu/GSF) | CHP Natural Gas (kBtu/GSF) | PV Electricity (kBtu/GSF) | Total (kBtu/SF) | CBECS Building Type | Weighted CBECS Comparison (kBtu/SF) | Notes |
|---|---|---|---|---|---|---|---|---|---|
| 0001 - SHELDON HALL | 119,211 | 30.5 | 5.8 | 55.8 | 0.0 | 92.1 | 30% College/university<br>50% Office<br>20% Recreation | 96.4 | 2, 4, 5 |
| 0002 - J C PARK HALL | 66,979 | 35.2 | 6.8 | 90.8 | 0.0 | 132.9 | 60% College/university<br>40% Office | 112.0 | 1, 5 |
| 0003 - CAMPUS CENTER | 185,524 | 50.9 | 32.9 | 100.6 | 0.0 | 184.4 | 30% College/university<br>30% Office<br>15% Recreation<br>25% Restaurant/cafeteria | 150.3 | 1, 5 |
| 003A - I POUCHER HALL | 40,080 | 35.3 | 18.8 | 93.8 | 0.0 | 147.9 | 75% College/university<br>25% Office | 118.5 | 1, 5 |
| 003B - REC & CONVOCATION CTR | 115,421 | 31.7 | 45.0 | 97.2 | 0.0 | 173.9 | 100% College/university | 127.5 | 1, 5 |
| 003C - CC STORAGE BLDG | 310 | 2.8 | 0.0 | 0.0 | 0.0 | 2.8 | 100% Self-storage | 3.8 | 1 |
| 0004 - M V LEE HALL | 65,000 | 15.9 | 0.0 | 67.3 | 0.0 | 83.2 | 10% Office<br>90% Recreation | 67.5 | 1, 5 |
| 004A - CENTRAL HEATING PLANT | 21,980 | 7.8 | 0.0 | 47.5 | 0.0 | 55.3 | 5% Office<br>95% Other service | 47.1 | 1, 3 |
| 0005 - SHADY SHORE | 8,754 | 9.1 | 51.7 | 0.0 | 0.0 | 60.9 | 100% Single-Family Detached | 42.9 | 1, 4 |
| 0005A - PRESIDENT GARAGE | 576 | 2.8 | 0.0 | 0.0 | 0.0 | 2.8 | 100% Self-storage | 3.8 | 1 |
| 0006 - J LANIGAN HALL | 88,200 | 36.9 | 25.7 | 101.5 | 0.0 | 164.1 | 80% College/university<br>10% Office<br>5% Restaurant/cafeteria<br>5% Other service | 129.4 | 1, 5 |
| 0007 - J TYLER HALL | 115,430 | 26.5 | 17.9 | 76.7 | 0.0 | 121.0 | 50% College/university<br>10% Office<br>10% Recreation<br>30% Other service | 94.6 | 1, 5 |
| 0008 - RICHARD S SHINEMAN CENTER | 235,860 | 94.3 | 17.4 | 0.0 | 0.3 | 112.1 | 30% College/university<br>20% Office<br>5% Restaurant/cafeteria<br>30% Laboratory<br>15% Other service | 146.8 | 1, 5 |
| 0009 - WILBER HALL | 108,933 | 30.5 | 0.0 | 80.0 | 0.0 | 110.5 | 40% College/university<br>40% Office<br>20% Other service | 95.5 | 1, 5 |
| 0010 - MARY WALKER HEALTH CENTER | 33,260 | 22.5 | 0.0 | 43.0 | 0.0 | 65.5 | 5% College/university<br>40% Office<br>15% Self-storage<br>40% Other service | 60.9 | 1, 5 |
| 0011 - COMMISSARY BLDG | 30,836 | 58.1 | 114.7 | 0.0 | 0.0 | 172.8 | 10% Office<br>40% Self-storage<br>50% Restaurant/cafeteria | 157.8 | 1, 4 |
| 0012 - MAINTENANCE BLDG | 20,664 | 18.2 | 22.2 | 0.0 | 0.0 | 40.4 | 30% Office<br>10% Self-storage<br>60% Other service | 52.3 | 1, 4, 6 |
| 0013 - M E MAHAR HALL | 91,530 | 32.9 | 0.0 | 87.5 | 0.0 | 120.4 | 50% College/university<br>40% Office<br>10% Other service | 103.8 | 1, 5 |
| 0014 - RICH HALL | 53,742 | 38.9 | 6.7 | 96.3 | 0.0 | 141.9 | 55% College/university<br>40% Office<br>5% Restaurant/cafeteria | 120.5 | 1, 5 |
| 0015 - MACKIN HALL | 41,984 | 41.2 | 37.6 | 92.4 | 0.0 | 171.2 | 30% College/university<br>5% Dormitory/fraternity/sorority<br>15% Office<br>25% Self-storage<br>25% Restaurant/cafeteria | 129.1 | 1, 5 |
| 015A - MORELAND HALL | 29,400 | 25.4 | 11.5 | 66.5 | 0.0 | 103.3 | 90% Dormitory/fraternity/sorority<br>10% Self-storage | 80.9 | 1, 5 |
| 015B - LONIS HALL | 32,285 | 26.6 | 12.0 | 69.8 | 0.0 | 108.4 | 95% Dormitory/fraternity/sorority<br>5% Self-storage | 85.0 | 1, 5 |
| 0016 - OBSERVATORY | 460 | 40.7 | 0.0 | 0.0 | 0.0 | 40.7 | 100% College/university | 56.6 | 1 |
| 0017 - J PENFIELD LIB | 192,298 | 28.8 | 0.0 | 65.7 | 0.0 | 94.5 | 10% College/university<br>10% Office<br>15% Self-storage<br>5% Restaurant/cafeteria<br>60% Library | 87.0 | 1, 5 |
| 0019 - LAKER HALL | 196,608 | 16.7 | 71.1 | 0.0 | 0.0 | 87.8 | 5% Office<br>90% Recreation<br>5% Self-storage | 63.9 | 1, 4 |

| Building | Gross Area (SF) | Weather Normalized EUI Electricity (kBtu/SF) | Natural Gas (kBtu/GSF) | CHP Natural Gas (kBtu/GSF) | PV Electricity (kBtu/GSF) | Total (kBtu/SF) | CBECS Building Type | Weighted CBECS Comparison (kBtu/SF) | Notes |
|---|---|---|---|---|---|---|---|---|---|
| 0020 - GAR-20 | 14,850 | 12.7 | 63.4 | 0.0 | 0.0 | 76.1 | 20% Office<br>50% Self-storage<br>30% Other service | 35.6 | 1, 4 |
| 0021 - ROMNEY FIELD HOUSE | 55,000 | 136.2 | 93.7 | 0.0 | 0.0 | 229.9 | 95% Recreation<br>5% Self-storage | 63.2 | 2, 4 |
| 0022 - KING HALL | 7,200 | 11.0 | 56.6 | 0.0 | 0.0 | 67.6 | 90% Office<br>10% Self-storage | 73.7 | 2, 4 |
| 0023A - RICE CREEK FIELD STATION | 7,500 | 114.3 | 0.0 | 0.0 | 18.6 | 132.8 | 60% College/university<br>15% Office<br>20% Laboratory<br>5% Self-storage | 136.9 | 2, 7 |
| 0024A - BIO FIELD GARAGE | 960 | 3.4 | 0.0 | 0.0 | 0.0 | 3.4 | 100% Self-storage | 3.8 | 2, 7 |
| 0026 - CULKIN HALL | 63,591 | 33.5 | 0.0 | 0.0 | 0.0 | 33.5 | 95% Office<br>5% Self-storage | 82.2 | 1, 5 |
| 0028 - SEWAGE PUMP STATION | 1,881 | 20.0 | 0.0 | 0.0 | 0.0 | 20.0 | 100% Other service | 27.8 | 1 |
| 0028A - SEWAGE PUMP STATION - SENECA | 211 | 20.0 | 0.0 | 0.0 | 0.0 | 20.0 | 100% Other service | 27.8 | 1 |
| 0028B - SEWAGE PUMP STATION - BLG 12 | 224 | 20.0 | 0.0 | 0.0 | 0.0 | 20.0 | 100% Other service | 27.8 | 1 |
| 0029 - HEWITT HALL | 135,010 | 29.7 | 0.0 | 77.3 | 0.0 | 106.9 | 35% College/university<br>40% Office<br>5% Recreation<br>20% Other service | 92.7 | 1, 5 |
| 0031 - PATHFINDER DH | 33,827 | 59.0 | 46.7 | 118.3 | 0.0 | 223.9 | 30% Office<br>20% Self-storage<br>50% Restaurant/cafeteria | 177.1 | 1, 3 |
| 0032 - SENECA HALL | 152,548 | 28.9 | 0.0 | 72.2 | 0.0 | 101.1 | 95% Dormitory/fraternity/sorority<br>5% Self-storage | 85.0 | 1, 12 |
| 0033 - CAYUGA HALL | 105,072 | 27.8 | 0.0 | 74.6 | 0.0 | 102.4 | 95% Dormitory/fraternity/sorority<br>5% Self-storage | 85.0 | 1, 12 |
| 0034 - ONONDAGA HALL | 152,548 | 26.6 | 0.0 | 77.2 | 0.0 | 103.9 | 95% Dormitory/fraternity/sorority<br>5% Self-storage | 85.0 | 1, 5 |
| 0035 - LITTLEPAGE DH | 33,827 | 55.9 | 12.8 | 129.9 | 0.0 | 198.6 | 5% Other service<br>5% Office<br>35% Recreation<br>10% Self-storage<br>45% Restaurant/cafeteria | 167.6 | 1, 5 |
| 0036 - ONEIDA HALL | 105,000 | 25.4 | 0.0 | 73.6 | 0.0 | 99.0 | 90% Dormitory/fraternity/sorority<br>10% Self-storage | 80.9 | 1, 5 |
| 0037A - TOWNHOUSE A | 10,260 | 28.3 | 36.8 | 0.0 | 0.0 | 65.1 | 100% Dormitory/fraternity/sorority | 90.7 | 1, 4, 8 |
| 0037B - TOWNHOUSE B | 8,082 | 27.0 | 36.8 | 0.0 | 0.0 | 63.8 | 95% Dormitory/fraternity/sorority<br>5% Self-storage | 86.6 | 1, 4, 8 |
| 0037C - TOWNHOUSE C | 12,599 | 28.3 | 36.8 | 0.0 | 0.0 | 65.1 | 100% Dormitory/fraternity/sorority | 90.7 | 1, 4, 8 |
| 0037D - TOWNHOUSE D | 12,599 | 28.3 | 36.8 | 0.0 | 0.0 | 65.1 | 100% Dormitory/fraternity/sorority | 90.7 | 1, 4, 8 |
| 0037E - TOWNHOUSE E | 15,880 | 28.3 | 36.8 | 0.0 | 0.0 | 65.1 | 100% Dormitory/fraternity/sorority | 90.7 | 1, 4, 8 |
| 0037F - TOWNHOUSE F | 18,295 | 28.4 | 36.5 | 0.0 | 0.0 | 64.9 | 75% Dormitory/fraternity/sorority<br>5% Office<br>20% Library | 88.7 | 1, 4, 8 |
| 0037G - TOWNHOUSE G | 8,082 | 27.0 | 44.3 | 0.0 | 0.0 | 71.3 | 95% Dormitory/fraternity/sorority<br>5% Self-storage | 86.6 | 1, 4, 9 |
| 0037H - TOWNHOUSE H | 10,260 | 28.3 | 44.3 | 0.0 | 0.0 | 72.6 | 100% Dormitory/fraternity/sorority | 90.7 | 1, 4, 9 |
| 0037I - TOWNHOUSE I | 12,599 | 28.3 | 44.1 | 0.0 | 0.0 | 72.4 | 100% Dormitory/fraternity/sorority | 90.7 | 1, 4, 9 |
| 0037J - TOWNHOUSE J | 12,599 | 28.3 | 44.3 | 0.0 | 0.0 | 72.6 | 100% Dormitory/fraternity/sorority | 90.7 | 1, 4, 9 |
| 0037K - TOWNHOUSE K | 16,729 | 28.3 | 44.1 | 0.0 | 0.0 | 72.4 | 100% Dormitory/fraternity/sorority | 90.7 | 1, 4, 9 |
| 0037L - TOWNHOUSE L | 12,567 | 28.3 | 44.3 | 0.0 | 0.0 | 72.6 | 100% Dormitory/fraternity/sorority | 90.7 | 1, 4, 9 |
| 0041 - JOHNSON HALL | 79,097 | 28.0 | 0.8 | 74.3 | 0.0 | 103.1 | 95% Dormitory/fraternity/sorority<br>5% Self-storage | 86.6 | 1, 5 |
| 0042 - LAKESIDE DH | 27,870 | 55.8 | 46.7 | 113.7 | 0.0 | 216.1 | 20% Office<br>30% Self-storage<br>50% Restaurant/cafeteria | 169.3 | 1, 5 |
| 0043 - RIGGS HALL | 58,201 | 28.2 | 0.9 | 80.3 | 0.0 | 109.4 | 100% Dormitory/fraternity/sorority | 90.7 | 1, 5 |

| Building | Gross Area (SF) | Weather Normalized EUI: Electricity (kBtu/SF) | Natural Gas (kBtu/GSF) | CHP Natural Gas (kBtu/GSF) | PV Electricity (kBtu/GSF) | Total (kBtu/SF) | CBECS Building Type | Weighted CBECS Comparison (kBtu/SF) | Notes |
|---|---|---|---|---|---|---|---|---|---|
| 0044 - WATERBURY HALL | 57,464 | 29.1 | 0.0 | 78.3 | 0.0 | 107.4 | 100% Dormitory/fraternity/sorority | 89.0 | 1, 5 |
| 0045 - SCALES HALL | 57,464 | 29.1 | 0.0 | 78.3 | 0.0 | 107.4 | 100% Dormitory/fraternity/sorority | 89.0 | 1, 5 |
| 0046 - HART HALL | 114,365 | 27.9 | 31.5 | 61.3 | 0.0 | 120.8 | 100% Dormitory/fraternity/sorority | 89.0 | 1, 5 |
| 0047 - COOPER DH | 33,546 | 52.8 | 46.7 | 119.8 | 0.0 | 219.3 | 25% Recreation<br>25% Self-storage<br>50% Restaurant/cafeteria | 168.4 | 1, 5 |
| 0048 - FUNNELLE HALL | 114,365 | 28.2 | 31.0 | 60.3 | 0.0 | 119.5 | 95% Dormitory/fraternity/sorority<br>5% Office | 88.6 | 1, 5 |
| 0049 - PUBLIC RESTROOM | 160 | 20.0 | 0.0 | 0.0 | 0.0 | 20.0 | 100% Other service | 27.8 | 1 |
| 0051 - FM RADIO TRANSMISSION FAC | 440 | 2167.8 | 0.0 | 0.0 | 0.0 | 2167.8 | 100% Other service | 27.8 | 2, 5 |
| 0061 - MAINTENANCE STORAGE | 100 | 2.8 | 0.0 | 0.0 | 0.0 | 2.8 | 100% Self-storage | 3.8 | 1 |
| 0071 - POLE BARN (FALLBROOK) | 17,369 | 18.0 | 0.0 | 0.0 | 0.0 | 18.0 | 100% Recreation | 25.0 | 1 |
| 0080 - FT DRM ED SVC CONSORTIUM | 290 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 100% Office | 49.1 | |
| 0081 - RICE CREEK OBSERVATORY | 550 | 49.5 | 0.0 | 0.0 | 0.0 | 49.5 | 100% College/university | 56.6 | 2, 7 |
| 0082 - PRESS BOX | 495 | 20.0 | 0.0 | 0.0 | 0.0 | 20.0 | 100% Other service | 27.8 | 1, 5 |
| 0083 - RICE CREEK PAVILION | 893 | 49.5 | 0.0 | 0.0 | 0.0 | 49.5 | 100% College/university | 56.6 | 2, 7 |
| 0104 - SECURITY PARKING OFFICE | 2,297 | 100.7 | 64.4 | 0.0 | 0.0 | 165.1 | 100% Office | 86.0 | 2, 4, 10 |
| 0106 - VOLATILE STO | 400 | 2.8 | 0.0 | 0.0 | 0.0 | 2.8 | 100% Self-storage | 3.8 | 1 |
| 0107 - 1 ROOM SCHOOL HSE | 550 | 40.3 | 0.0 | 0.0 | 0.0 | 40.3 | 100% College/university | 62.0 | 2, 3 |
| 0108 - POWER STATION 1 | 216 | 20.0 | 0.0 | 0.0 | 0.0 | 20.0 | 100% Other service | 27.8 | 1 |
| 0109 - POWER STATION 1A | 175 | 20.0 | 0.0 | 0.0 | 0.0 | 20.0 | 100% Other service | 27.8 | 1 |
| 0110 - POWER STATION 2 | 177 | 20.0 | 0.0 | 0.0 | 0.0 | 20.0 | 100% Other service | 27.8 | 1 |
| FALLBROOK REC CENTER | 17,167 | 0.0 | 28.5 | 0.0 | 0.0 | 28.5 | 15% College/university<br>10% Office<br>50% Recreation<br>25% Library | 45.2 | 4, 11 |
| **Campus Total** | **3,498,777** | **36.7** | **18.5** | **61.3** | **0.1** | **116.6** | **Weighted CBECS Comparison** | **100.0** | - |

Overall Notes:

- Weather Normalized electric energy and demand are represented by the "Average" year data due to limited correlation to monthly cooling degree days.
- Weather Normalized natural gas energy uses typical weather year heating degree days in a model fit of metered natural gas use data.
- EUI calculated based on building submeter data.
- PV Electric output estimated using PV Watts.

Building Specific Notes:

1 Electric service from main campus electric service. Electric EUI estimated.
2 Electric service provided by National Grid utility meter
3 Natural gas supplied to the building from main campus natural gas service. Natural gas EUI estimated.
4 Natural gas supplied to the building by National Grid utility meter
5 Steam provided from Central Heating Plant. CHP Natural Gas EUI estimated.
6 Maintenance building served by 'POLE BARN/SALT STORAGE' natural gas meter
7 Buildings served by 'RICE CREEK FIELD STATION-ALL BLDGS' electric meter
8 Buildings served by '90 IROQOUIS TOWNHOUSES' natural gas meter
9 Buildings served by '80 IROQOUIS TOWNHOUSES' natural gas meter
10 Building served by 'CHS104' and 'PARKING OFFICE' natural gas meters
11 Building served by 'AUXILLARY SVS/CULKIN HALL' natural gas meter
12 Steam provided from Pathfinder Dining Hall boiler. Natural Gas EUI estimated.

# Appendix B
# Building Assessment Reports

# SUNY Oswego | EEM Opportunity Matrix (DRAFT)

Potential Energy Efficiency Measure[1]→

| Category | Buildings | Year Built | GSF | Level 1 Audit | Renovations Scheduled | Envelope: Upgrade Roof Insulation[2] | Envelope: Upgrade Exterior Wall Insulation[2] | Envelope: Replace Single Glazed Windows with High Performance Windows | Envelope: Install Window Film | Envelope: Repair or replace doors, windows, and weather seals to prevent air infiltration | Submeters: Install Building-Level Gas Submeter | Submeters: Install Building-Level Steam Submeter | Lighting: Replace Interior Fluorescent Light Fixtures with LED Fixtures | Lighting: Install Occupancy/Vacancy Sensor Controls | Lighting: Install Daylight Sensor Controls | Lighting: Replace Exterior Light Fixtures with LED Fixtures |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Academic | 0001 - SHELDON HALL | 1912 | 119,211 | ● | | | | | ● | ● | | ● | 🟢 | ◑ (green) | 🟢 | ● |
| Academic | 0002 - J C PARK HALL | 1933 | 66,979 | ● | | | | | ● | | ● | ● | 🟢 | 🟢 | 🟢 | ● |
| Academic | 0003 - CAMPUS CENTER | 1963 | 185,524 | ● | | | | | ● | | ● | ● | ◑ (green) | ◑ (green) | 🟢 | ● |
| Academic | 003A - I POUCHER HALL | 1963 | 40,080 | ● | | | | | ● | | ● | ● | ◑ | ◑ | 🟢 | ● |
| Academic | 003B - REC & CONVOCATION CTR | 2006 | 115,421 | ● | | | | | ● | | ● | ● | ◑ (green) | ◑ (green) | 🟢 | ● |
| Academic | 003C - CC STORAGE BLDG | 2007 | 310 | | | | | | | | | | | | | ● |
| Academic | 0004 - M V LEE HALL | 1958 | 65,000 | ● | | | | | ● | | ● | ● | ● | ● | ● | ● |
| Academic | 0006 - J LANIGAN HALL | 1967 | 88,200 | ● | | | | ● | | | ● | ● | 🟢 | 🟢 | ● | ● |
| Academic | 0007 - J TYLER HALL | 1968 | 115,430 | ● | | | | | ● | | | ● | | ◑ | ● | |
| Academic | 0008 - RICHARD S SHINEMAN CENTER | 2013 | 235,860 | ● | | | | | ● | | | ● | ◑ | ● | ◑ | ● |
| Academic | 0009 - WILBER HALL | 1964 | 108,933 | ● | | | | | ● | | | ● | ● | ● | ● | ● |
| Academic | 0013 - M E MAHAR HALL | 1966 | 91,530 | ● | ● | ● | ● | | ● | | | ● | ● | ● | ● | ● |
| Academic | 0014 - RICH HALL | 1961 | 53,742 | ● | | | | | ● | ● | | | ● | ● | ● | ● |
| Academic | 0016 - OBSERVATORY | 2013 | 460 | | | | | | | | | | | | | ● |
| Academic | 0017 - J PENFIELD LIB | 1968 | 192,298 | ● | ● | ● | ● | ● | | | | | ◑ | ● | ● | ● |
| Academic | 0019 - LAKER HALL | 1968 | 196,608 | ● | ◔ | ● | | ● | | ● | | | ◑ | ● | ● | |
| Academic | 0021 - ROMNEY FIELD HOUSE | 1962 | 55,000 | ● | | | | ● | | ● | ● | | ● | ● | ● | |
| Academic | 0023A - RICE CREEK FIELD STATION | 2013 | 7,500 | ● | | | | | | | | | ● | ◑ | ◑ | |
| Academic | 0024A - BIO FIELD GARAGE | 2013 | 960 | | | | | | | | | | | | | |
| Academic | 0029 - HEWITT HALL | 1967 | 135,010 | ○ | ● | ● | ● | | | | | | | | | |
| Academic | 0053 - METRO CENTER | 2008 | 14,526 | | | | | | | | | | | | | |
| Academic | 0080 - FT DRM ED SVC CONSORTIUM | | 290 | | | | | | | | | | | | | |
| Academic | 0081 - RICE CREEK OBSERVATORY | 2013 | 550 | | | | | | | | | | | | | |
| Academic | 0082 - PRESS BOX | 2015 | 495 | | | | | | | | | | | | | ● |
| Academic | 0083 - RICE CREEK PAVILION | 2013 | 893 | | | | | | | | | | | | | |
| Support | 004A - LEE HALL (HEATING PLANT) | 1958 | 21,980 | ● | | | | | | | | | ● | ● | ● | ● |
| Support | 0005 - SHADY SHORE | 1909 | 8,754 | ● | | | | ◔ | ● | | | | | | | ◑ |
| Support | 0005A - PRESIDENT GARAGE | 1984 | 576 | | | | | | | | | | | | | |
| Support | 0010 - MARY WALKER HEALTH CENTER | 1965 | 33,260 | ● | | | | | | | | ● | ◔ | | ● | |
| Support | 0011 - COMMISSARY BLDG | 1966 | 30,836 | ● | | | | ● | | | | | ◑ | ● | ● | ● |
| Support | 0012 - MAINTENANCE BLDG | 1965 | 20,664 | ● | | | | ● | | | | | ◑ | ● | ● | ● |
| Support | 0020 - GAR-20 | 1971 | 14,850 | ● | | | | | ● | | | | ● | ● | ● | ● |
| Support | 0022 - KING HALL | 1935 | 7,200 | ● | | | | | ● | | | | ● | ● | ● | ● |
| Support | 0026 - CULKIN HALL | 1967 | 63,591 | ● | | | | | ● | | ● | ● | ◑ | ● | ● | ● |
| Support | 0028 - SEWAGE PUMP STATION | 1964 | 1,881 | | | | | | | | | | | | | |
| Support | 0028A - SEWAGE PUMP STATION - SENECA | 1998 | 211 | | | | | | | | | | | | | |
| Support | 0028B - SEWAGE PUMP STATION - BLG 12 | 1988 | 224 | | | | | | | | | | | | | |
| Support | 0031 - PATHFINDER DH | 1967 | 33,827 | ● | | | | ● | | | ● | ● | ● | ◑ | ● | ● |
| Support | 0035 - LITTLEPAGE DH | 1968 | 33,827 | ● | ● | ● | ● | ● | | | | ● | ● | ● | ● | ● |
| Support | 0042 - LAKESIDE DH | 1959 | 27,870 | ● | | | | | ● | | ● | ● | ● | ● | ● | ◑ |
| Support | 0047 - COOPER DH | 1967 | 33,546 | ● | | | | ● | | | ● | ● | ◑ | ● | ● | ● |
| Support | 0049 - PUBLIC RESTROOM | | 160 | | | | | | | | | | | | | ● |
| Support | 0051 - FM RADIO TRANSMISSION FAC | | 440 | | | | | | | | | | | | | ● |
| Support | 0061 - MAINTENANCE STORAGE | | 100 | | | | | | | | | | | | | ● |
| Support | 0071 - POLE BARN | 1984 | 6,925 | | | | | | | | | | | | | |
| Support | 0084 - BUSINESS AND COMMUNITY RELATIONS | | 1,917 | | | | | | | | | | | | | |
| Support | 0085 - BUSINESS RESOURCE CENTER | | 2,739 | | | | | | | | | | | | | |
| Support | 0104 - SECURITY PARKING OFFICE | 1980 | 2,297 | | | | | | | | | | | | | ● |
| Support | 0106 - VOLATILE STO | | 400 | | | | | | | | | | | | | ● |
| Support | 0107 - 1 ROOM SCHOOL HSE | 1905 | 550 | | | | | | | | | | | | | ● |
| Support | 0108 - POWER STATION 1 | | 216 | | | | | | | | | | | | | |
| Support | 0109 - POWER STATION 1A | | 175 | | | | | | | | | | | | | |
| Support | 0110 - POWER STATION 2 | | 177 | | | | | | | | | | | | | |

| Buildings | HVAC Controls: Retro-Commissioning of HVAC Systems and Controls | Implement Duct Static Pressure Reset Controls | Implement Pump Differential Pressure Reset Controls | Implement Demand Control Ventilation | Implement Laboratory Demand Control Ventilation | Implement Kitchen Demand Control Ventilation | Install Occupancy-Based HVAC Controls | Implement HW Supply Temperature Reset | Implement CHW Supply Temperature Reset | Connect Building Systems to BAS | Setback Equipment During Academic Breaks | Replace Pneumatic Actuators with Electric Actuators |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0001 - SHELDON HALL | ● | 🟢 | 🟢 | 🟢 | | | 🟢 | ● | ● | ◑ | ● | ● |
| 0002 - J C PARK HALL | ● | 🟢 | 🟢 | 🟢 | | | 🟢 | ● | ● | ◑ | ● | ◑ |
| 0003 - CAMPUS CENTER | 🟢 | 🟢 | 🟢 | 🟢 | | 🟢 | 🟢 | | ● | ◑ | ● | ◑ |
| 003A - I POUCHER HALL | 🟢 | 🟢 | 🟢 | ● | | | 🟢 | | | ◑ | ● | ◑ |
| 003B - REC & CONVOCATION CTR | 🟢 | 🟢 | 🟢 | ● | | 🟢 | 🟢 | | ● | ◑ | ● | ◑ |
| 003C - CC STORAGE BLDG | | | | | | | | | | | | |
| 0004 - M V LEE HALL | ● | | | 🟢 | | | 🟢 | ● | | ◔ | ● | ● |
| 0006 - J LANIGAN HALL | ● | | | 🟢 | | | 🟢 | | ● | ◑ | ● | ● |
| 0007 - J TYLER HALL | 🟢 | 🟢 | 🟢 | 🟢 | | | 🟢 | | | | ● | ◑ |
| 0008 - RICHARD S SHINEMAN CENTER | ● | | 🟢 | 🟢 | 🟢 | | 🟢 | ● | | | ● | ● |
| 0009 - WILBER HALL | ● | 🟢 | 🟢 | 🟢 | | | 🟢 | | ● | ◑ | ● | ● |
| 0013 - M E MAHAR HALL | ● | 🟢 | 🟢 | ● | | | 🟢 | | | | ● | ● |
| 0014 - RICH HALL | 🟢 | 🟢 | 🟢 | | | | 🟢 | | ● | | ● | |
| 0016 - OBSERVATORY | | | | | | | | | | | | |
| 0017 - J PENFIELD LIB | ● | | | ● | | | 🟢 | | ● | ● | ● | ● |
| 0019 - LAKER HALL | ● | | | 🟢 | | | 🟢 | | | ◑ | ● | ● |
| 0021 - ROMNEY FIELD HOUSE | ● | | | 🟢 | | | | ● | | ◑ | ● | |
| 0023A - RICE CREEK FIELD STATION | ● | | | | ● | | | | | | | |
| 0024A - BIO FIELD GARAGE | | | | | | | | | | | | |
| 0029 - HEWITT HALL | | | | | | | | | | | | |
| 0053 - METRO CENTER | | | | | | | | | | | | |
| 0080 - FT DRM ED SVC CONSORTIUM | | | | | | | | | | | | |
| 0081 - RICE CREEK OBSERVATORY | | | | | | | | | | | | |
| 0082 - PRESS BOX | | | | | | | | | | | | |
| 0083 - RICE CREEK PAVILION | | | | | | | | | | | | |
| 004A - LEE HALL (HEATING PLANT) | | | | | | | | | | | | ◑ |
| 0005 - SHADY SHORE | | | | | | | | ● | | ● | | |
| 0005A - PRESIDENT GARAGE | | | | | | | | | | | | |
| 0010 - MARY WALKER HEALTH CENTER | ● | | 🟢 | | | | 🟢 | | | | ● | ● |
| 0011 - COMMISSARY BLDG | ● | | | | | 🟢 | | ● | | ◑ | | |
| 0012 - MAINTENANCE BLDG | ● | | | | | | | | | ● | | |
| 0020 - GAR-20 | ● | | | | | | | ● | | ● | ● | ● |
| 0022 - KING HALL | ● | | | | | | | ● | | ● | | |
| 0026 - CULKIN HALL | ● | | | | | | 🟢 | ● | ● | | ● | ● |
| 0028 - SEWAGE PUMP STATION | | | | | | | | | | | | |
| 0028A - SEWAGE PUMP STATION - SENECA | | | | | | | | | | | | |
| 0028B - SEWAGE PUMP STATION - BLG 12 | | | | | | | | | | | | |
| 0031 - PATHFINDER DH | ● | | | 🟢 | | 🟢 | 🟢 | | ● | ◑ | ● | ● |
| 0035 - LITTLEPAGE DH | ● | | | 🟢 | | 🟢 | 🟢 | ● | ● | ◑ | ● | ● |
| 0042 - LAKESIDE DH | ● | 🟢 | 🟢 | 🟢 | | 🟢 | 🟢 | | ● | ◑ | ● | ● |
| 0047 - COOPER DH | ● | | | 🟢 | | 🟢 | 🟢 | | ● | ◑ | ● | ● |
| 0049 - PUBLIC RESTROOM | | | | | | | | | | | | |
| 0051 - FM RADIO TRANSMISSION FAC | | | | | | | | | | | | |
| 0061 - MAINTENANCE STORAGE | | | | | | | | | | | | |
| 0071 - POLE BARN | | | | | | | | | | | | |
| 0084 - BUSINESS AND COMMUNITY RELATIONS | | | | | | | | | | | | |
| 0085 - BUSINESS RESOURCE CENTER | | | | | | | | | | | | |
| 0104 - SECURITY PARKING OFFICE | | | | | | | | | | | | |
| 0106 - VOLATILE STO | | | | | | | | | | | | |
| 0107 - 1 ROOM SCHOOL HSE | | | | | | | | | | | | |
| 0108 - POWER STATION 1 | | | | | | | | | | | | |
| 0109 - POWER STATION 1A | | | | | | | | | | | | |
| 0110 - POWER STATION 2 | | | | | | | | | | | | |

| Buildings | HVAC Equipment: Install VFD on Hot Water Pump Motor | Install VFD on Chilled Water Pump Motor | Convert Constant Volume Single Zone System to Single Zone VAV System | Add Mechanical Cooling for Pool Dehumidification | Install Electronically Commutated Motors | Replace Chiller with High-Efficiency Chiller | Install VFD on Cooling Tower Fan Motor | Add Hot Water Zone Valves for Controlling Individual Spaces Served by FTR | Replace and Upgrade HVAC System[4] | Install an Exhaust Air Energy Recovery System | Install Destratification Fans | Replace Domestic Water Heaters with Semi-Instantaneous Domestic Water Heaters |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0001 - SHELDON HALL | 🟢 | 🟢 | | | | ● | | | | | | ● |
| 0002 - J C PARK HALL | | | | | | ● | | | | | | |
| 0003 - CAMPUS CENTER | | | | | ● | ● | | | | ● | ● | ● |
| 003A - I POUCHER HALL | | | | | ● | | | | | | | |
| 003B - REC & CONVOCATION CTR | | | | | ● | ● | | | | | ● | ● |
| 003C - CC STORAGE BLDG | | | | | | | | | | | | |
| 0004 - M V LEE HALL | | | 🟢 | 🟢 | | | | ● | | ● | | |
| 0006 - J LANIGAN HALL | 🟢 | 🟢 | 🟢 | | ● | | | ● | ● | | ● | ● |
| 0007 - J TYLER HALL | | | | | | | ● | ● | | | | |
| 0008 - RICHARD S SHINEMAN CENTER | | | | | | | | ● | | | | |
| 0009 - WILBER HALL | | | | | | | | ● | | | | |
| 0013 - M E MAHAR HALL | 🟢 | | | | ● | ● | | ● | ● | ● | | ● |
| 0014 - RICH HALL | | | | | ● | ● | | | | | ● | ● |
| 0016 - OBSERVATORY | | | | | | | | | | | | |
| 0017 - J PENFIELD LIB | 🟢 | 🟢 | | | | ● | | ● | ● | ● | | |
| 0019 - LAKER HALL | 🟢 | | 🟢 | 🟢 | | | | ● | | ● | ● | ● |
| 0021 - ROMNEY FIELD HOUSE | | | 🟢 | | ● | | | | | ● | ● | ● |
| 0023A - RICE CREEK FIELD STATION | | | | | | | | | | | ● | |
| 0024A - BIO FIELD GARAGE | | | | | | | | | | | | |
| 0029 - HEWITT HALL | | | | | | | | | ● | | | |
| 0053 - METRO CENTER | | | | | | | | | | | | |
| 0080 - FT DRM ED SVC CONSORTIUM | | | | | | | | | | | | |
| 0081 - RICE CREEK OBSERVATORY | | | | | | | | | | | | |
| 0082 - PRESS BOX | | | | | | | | | | | | |
| 0083 - RICE CREEK PAVILION | | | | | | | | | | | | |
| 004A - LEE HALL (HEATING PLANT) | | | | | | | | | | | | |
| 0005 - SHADY SHORE | | | | | ● | | | | | | | |
| 0005A - PRESIDENT GARAGE | | | | | | | | | | | | |
| 0010 - MARY WALKER HEALTH CENTER | | | ● | | | | | | | | | |
| 0011 - COMMISSARY BLDG | | | | | ● | | | | | | | ● |
| 0012 - MAINTENANCE BLDG | | | | | | | | | | | | |
| 0020 - GAR-20 | | | | | ● | | | ● | | | | |
| 0022 - KING HALL | | | | | ● | | | | | | | |
| 0026 - CULKIN HALL | 🟢 | | | | | ● | | ● | ● | | | |
| 0028 - SEWAGE PUMP STATION | | | | | | | | | | | | |
| 0028A - SEWAGE PUMP STATION - SENECA | | | | | | | | | | | | |
| 0028B - SEWAGE PUMP STATION - BLG 12 | | | | | | | | | | | | |
| 0031 - PATHFINDER DH | 🟢 | 🟢 | | | | ● | ● | ● | | ● | | ● |
| 0035 - LITTLEPAGE DH | 🟢 | 🟢 | | | ● | ● | ● | ● | ● | ● | | ● |
| 0042 - LAKESIDE DH | | | | | ● | ● | | | | | | ● |
| 0047 - COOPER DH | 🟢 | 🟢 | | | ● | ● | | ● | ● | | | ● |
| 0049 - PUBLIC RESTROOM | | | | | | | | | | | | |
| 0051 - FM RADIO TRANSMISSION FAC | | | | | | | | | | | | |
| 0061 - MAINTENANCE STORAGE | | | | | | | | | | | | |
| 0071 - POLE BARN | | | | | | | | | | | | |
| 0084 - BUSINESS AND COMMUNITY RELATIONS | | | | | | | | | | | | |
| 0085 - BUSINESS RESOURCE CENTER | | | | | | | | | | | | |
| 0104 - SECURITY PARKING OFFICE | | | | | | | | | | | | |
| 0106 - VOLATILE STO | | | | | | | | | | | | |
| 0107 - 1 ROOM SCHOOL HSE | | | | | | | | | | | | |
| 0108 - POWER STATION 1 | | | | | | | | | | | | |
| 0109 - POWER STATION 1A | | | | | | | | | | | | |
| 0110 - POWER STATION 2 | | | | | | | | | | | | |

| Buildings | O&M: Repair Duct and Piping Leaks | O&M: Repair Duct and Piping Insulation | O&M: Change V-belt Fan Drives to Cogged Belt Fan Drives | Water: Install Low-Flow or Ultra Low-Flow Showerheads | Special Systems Presence: Building Automation System | Laboratory Fume Hoods | Cafeterias and Service Kitchens | Data Centers | Refrigeration | Utility Meter Presence: Electricity | Natural Gas |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0001 - SHELDON HALL | | ● | ● | | C | | | | | ● | ● |
| 0002 - J C PARK HALL | | | ● | | T | | | | | | |
| 0003 - CAMPUS CENTER | | | ● | | C & T | | ◑ | | | | |
| 003A - I POUCHER HALL | ● | | ● | | T | | | | | | |
| 003B - REC & CONVOCATION CTR | ● | ● | ● | ◑ | T | | ● | | | | |
| 003C - CC STORAGE BLDG | | | | | | | | | | | |
| 0004 - M V LEE HALL | ● | | ● | ● | C | | | | | | |
| 0006 - J LANIGAN HALL | | ● | ● | | C | | ◔ | | | | |
| 0007 - J TYLER HALL | | | ● | ● | T | | | | | | |
| 0008 - RICHARD S SHINEMAN CENTER | | | ● | | C & T | ● | ◑ | | | | |
| 0009 - WILBER HALL | | ● | ● | ● | T | | | | | | |
| 0013 - M E MAHAR HALL | | | ● | | C | | | | | | |
| 0014 - RICH HALL | | ● | ● | | T | | ◑ | | | | |
| 0016 - OBSERVATORY | | | | | | | | | | | |
| 0017 - J PENFIELD LIB | ● | ● | ● | | C & T | | ◑ | | | | |
| 0019 - LAKER HALL | | ● | ● | ● | C & T | | | | | | ● |
| 0021 - ROMNEY FIELD HOUSE | | | ● | ● | C | | | | | ● | ● |
| 0023A - RICE CREEK FIELD STATION | | | ● | ● | T | ● | | | | ● | |
| 0024A - BIO FIELD GARAGE | | | | | | | | | | | |
| 0029 - HEWITT HALL | | | | | | | | | | | |
| 0053 - METRO CENTER | | | | | | | | | | | |
| 0080 - FT DRM ED SVC CONSORTIUM | | | | | | | | | | | |
| 0081 - RICE CREEK OBSERVATORY | | | | | | | | | | | |
| 0082 - PRESS BOX | | | | | | | | | | | |
| 0083 - RICE CREEK PAVILION | | | | | | | | | | | |
| 004A - LEE HALL (HEATING PLANT) | | | ● | ● | T | | | | | | ● |
| 0005 - SHADY SHORE | | | | ● | | | | | | | ● |
| 0005A - PRESIDENT GARAGE | | | | | | | | | | | |
| 0010 - MARY WALKER HEALTH CENTER | | ◑ | ● | | T | | | | | | |
| 0011 - COMMISSARY BLDG | | | ● | | T | | ● | | ● | | ● |
| 0012 - MAINTENANCE BLDG | | | | ● | | | | | | | ● |
| 0020 - GAR-20 | | ● | ● | | | | | | | | ● |
| 0022 - KING HALL | | ● | | | | | | | | ● | ● |
| 0026 - CULKIN HALL | | | ● | | C & T | | | ● | | | |
| 0028 - SEWAGE PUMP STATION | | | | | | | | | | | |
| 0028A - SEWAGE PUMP STATION - SENECA | | | | | | | | | | | |
| 0028B - SEWAGE PUMP STATION - BLG 12 | | | | | | | | | | | |
| 0031 - PATHFINDER DH | | | ● | | | | | | ● | | |
| 0035 - LITTLEPAGE DH | | ● | ● | | C | | ● | | ● | | |
| 0042 - LAKESIDE DH | | | ● | | C | | ● | | ● | | |
| 0047 - COOPER DH | | | ● | | C | | | | ● | | |
| 0049 - PUBLIC RESTROOM | | | | | | | | | | | |
| 0051 - FM RADIO TRANSMISSION FAC | | | | | | | | | | ● | |
| 0061 - MAINTENANCE STORAGE | | | | | | | | | | | |
| 0071 - POLE BARN | | | | | | | | | | | |
| 0084 - BUSINESS AND COMMUNITY RELATIONS | | | | | | | | | | | |
| 0085 - BUSINESS RESOURCE CENTER | | | | | | | | | | | |
| 0104 - SECURITY PARKING OFFICE | | | | | | | | | | ● | ● |
| 0106 - VOLATILE STO | | | | | | | | | | | |
| 0107 - 1 ROOM SCHOOL HSE | | | | | | | | | | ● | |
| 0108 - POWER STATION 1 | | | | | | | | | | | |
| 0109 - POWER STATION 1A | | | | | | | | | | | |
| 0110 - POWER STATION 2 | | | | | | | | | | | |

# SUNY Oswego | EEM Opportunity Matrix (DRAFT)

| | | | | | Potential Energy Efficiency Measure[1]→ | Upgrade Roof Insulation[2] | Upgrade Exterior Wall Insulation[3] | Replace Single Glazed Windows with High Performance Windows | Install Window Film | Repair or replace doors, windows, and weather seals to prevent air infiltration | Install Building-Level Gas Submeter | Install Building-Level Steam Submeter | Replace Interior Fluorescent Light Fixtures with LED Fixtures | Install Occupancy/Vacancy Sensor Controls | Install Daylight Senor Controls | Replace Exterior Light Fixtures with LED Fixtures | Retro-Commissioning of HVAC Systems and Controls | Implement Duct Static Pressure Reset Controls | Implement Pump Differential Pressure Reset Controls | Implement Demand Control Ventilation | Implement Laboratory Demand Control Ventilation | Implement Kitchen Demand Control Ventilation | Install Occupancy-Based HVAC Controls | Implement HW Supply Temperature Reset | Implement CHW Supply Temperature Reset | Connect Building Systems to BAS | Setback Equipment During Academic Breaks | Replace Pneumatic Actuators with Electric Actuators | Install VFD on Hot Water Pump Motor | Install VFD on Chilled Water Pump Motor | Convert Constant Volume Single Zone System to Single Zone VAV System | Add Mechanical Cooling for Pool Dehumidification | Install Electronically Commutated Motors | Replace Chiller with High-Efficiency Chiller | Install VFD on Cooling Tower Fan Motor | Add Hot Water Zone Valves for Controlling Individual Spaces Served by FTR | Replace and Upgrade HVAC System[4] | Install an Exhaust Air Energy Recovery System | Install Destratification Fans | Replace Domestic Water Heaters with Semi-Instantaneous Domestic Water Heaters | Repair Duct and Piping Leaks | Repair Duct and Piping Insulation | Change V-belt Fan Drives to Cogged Belt Fan Drives | Install Low-Flow or Ultra Low-Flow Showerheads | Building Automation System | Laboratory Fume Hoods | Cafeterias and Service Kitchens | Data Centers | Refrigeration | Electricity | Natural Gas |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Buildings | Year Built | GSF | Level 1 Audit | Renovations Scheduled | Envelope | | | | | Submeters | | Lighting | | | | HVAC Controls | | | | | | | | | | | | HVAC Equipment | | | | | | | | | | | | O&M | | | Water | Special Systems Presence | | | | | Utility Meter Presence | |
| Residential | 0015 - MACKIN DINING HALL | 1951 | 41,984 | ● | ● | ● | ● | ◔ | | | ● | ● | ● | ● | ● | ● | ● | | | | | ● | | ● | | ◑ | ● | ◑ | | | | | ● | | | ● | ● | | | ● | | | ● | ● | C | | ● | | ◑ | | |
| | 015A - MORELAND HALL | 1951 | 29,400 | ● | ● | ● | ● | ◔ | | | ● | ● | ● | ● | ● | ● | | | | | | | | | | ◑ | ● | | | | | | | | | ● | | | | | | | | ● | C | | | | | | |
| | 015B - LONIS HALL | 1951 | 32,285 | ● | ● | ● | ● | ◔ | | | ● | ● | ● | ● | ● | ● | | | | | | | | | | ◑ | ● | | | | | | | | | ● | | | | | | | | ● | C | | | | | | |
| | 0032 - SENECA HALL | 1967 | 152,548 | ● | ● | ● | ● | | | | | ● | ● | ● | ● | ● | ● | | | | | | ● | ● | | ◑ | ● | ● | ● | | | | ● | | | ● | ● | ● | | ● | ● | | ● | ● | C | | | | | | |
| | 0033 - CAYUGA HALL | 1967 | 105,072 | ● | ● | ● | ● | | | | | ● | ● | ● | ● | ● | ● | | | | | | ● | ● | | | ● | ● | ● | | | | ● | | | ● | ● | ● | | ● | | | ● | ● | T | | | | | | |
| | 0034 - ONONDAGA HALL | 1968 | 152,548 | ● | ● | ● | ● | | | | | ● | ◑ | ◑ | ● | ● | ● | | | | | | | | | ◑ | ● | ◑ | ● | | | | | | | ● | ● | ● | | ● | | | ● | ● | C | | | | | | |
| | 0036 - ONEIDA HALL | 1970 | 105,000 | ● | ● | ● | ● | | | | | ● | ● | ● | ● | ● | ● | | | | | | | | | ◑ | ● | ◑ | ● | | | | ● | | | ● | ● | ● | | ● | | | ● | ● | C | | | | | | |
| | 0037 - THE VILLAGE TOWNHOUSES | 2010 | 150,551 | ● | | | | | ● | | | | ● | ● | ● | ◑ | ● | | ● | | | | ● | | | | ● | | | | | | | | | | | | | ● | | | | ● | C | | | | | | ●● |
| | 0041 - JOHNSON HALL | 1958 | 79,097 | ● | | | | | ● | | ● | | ● | ◑ | ● | ● | ● | | ● | ● | | | ● | | ● | | ● | ● | | | ● | | ● | | | ● | | ● | | ● | | | ● | ● | C | | | | | | |
| | 0043 - RIGGS HALL | 1960 | 58,201 | ● | | | | | ● | | | ● | ● | ● | ● | ● | ● | ● | ● | | | | ● | ● | ● | | ● | ● | | | | | ● | | | ● | | | | ● | | | ● | ● | C | | | | | | |
| | 0044 - WATERBURY HALL | 1960 | 57,464 | ● | | | | | ● | | | | | ● | ● | | ● | ● | ● | | | | ● | | | | ● | | | | | | ● | | | ● | | ● | | ● | | | ● | ● | T | | | | | | |
| | 0045 - SCALES HALL | 1961 | 57,464 | ● | | | | | ● | | | | | ◑ | ● | | ● | | ● | | | | ● | | | | ● | | | | | | ● | | | ● | | ● | | ● | | | ● | ● | C | | | | | | |
| | 0046 - HART HALL | 1963 | 114,365 | ● | | | | | ● | | ● | | ◑ | ● | ● | ● | ● | | | ● | | | | | | ◑ | ● | ◑ | | | | | ● | | | ● | | | | ● | | | ● | ● | T | | | | | | |
| | 0048 - FUNNELLE HALL | 1965 | 114,365 | ● | | | | | ● | | ● | | ◑ | ● | ● | ● | ● | | ● | | | | | | | ◑ | ● | | | | | | | | | ● | | | | ● | | | ● | ● | T | | | | | | |
| | Total | 1905 - 2015 | - | 43 | 12 | 12 | 11 | 13 | 23 | 4 | 17 | 25 | 38 | 40 | 41 | 44 | 38 | 12 | 18 | 20 | 2 | 8 | 27 | 15 | 15 | 28 | 36 | 29 | 13 | 6 | 6 | 2 | 23 | 12 | 3 | 26 | 12 | 15 | 7 | 25 | 5 | 11 | 36 | 24 | 37 | 2 | 10 | 1 | 6 | 7 | 11 |
| | Energy and Greenhouse Gas Savings Potential (L, M, H) | | | | | L | L | L | L | L | L | L | M | M | L | H | H | L | L | M | H | H | M | L | L | M | M | M | M | M | M | - | L | M | M | L | H | M | L | M | L | L | L | L | - | - | - | - | - | - | - |
| | Estimated Capital Cost (L, M, H) | | | | | H | H | H | M | L | M | M | H | L | M | M | M | L | L | L | H | M | H | L | L | H | L | M | M | M | M | H | L | H | M | M | H | M | L | H | L | L | L | L | - | - | - | - | - | - | - |
| | Estimated Simple Payback Period (L, M, H) | | | | | H | H | H | M | L | H | H | H | L | M | M | L | L | L | M | M | M | M | L | L | M | L | L | M | M | M | - | M | H | M | M | H | M | H | M | L | L | L | L | - | - | - | - | - | - | - |

**Legend:**

Measures in green shading denote targeted measures that will be further analyzed to assess technical and economic potential

● EEM to consider

◑ EEM already partially implemented, additional opportunity for savings

T Trane Tracer Ensemble controls system

C Carrier i-Vu controls system

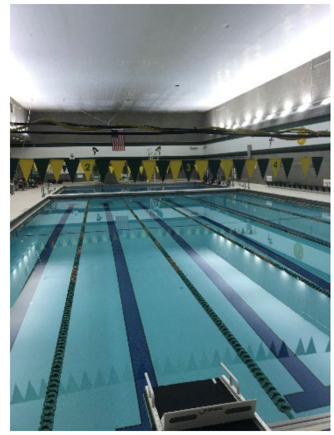
○ Under construction at time of walk-through, unable to audit

| Energy and Greenhouse Gas Savings Potent | Estimated Capital Cost | Estimated Simple Payback Period |
|---|---|---|
| L = Low | L = Low | L = 0-5 years |
| M = Medium | M = Medium | M = 5-10 years |
| H = High | H = High | H = 10+ years |

**Notes:**

1 Refer to Building Assessment Reports for details on EEM implementation.
2 Upgrade roof insulation to at least code levels during gut rehab projects.
3 Upgrade exterior wall insulation to at least code levels during gut rehab projects.
4 Replace and upgrade HVAC system during gut rehab projects.

# SUNY OSWEGO | LAKER HALL BUILDING ASSESSMENT



## Building Description

**Building Name:** Laker Hall

**Year Constructed:** 1968

**No. of Floors:** 2 + Basement

**Est. GSF:** 196,608

### Recent Building Upgrades
- Boiler replacement – 2010
- Pool mechanical system upgrades, pool gutter and piping replacement – 2011
- LED lighting upgrade in swimming pool – 2015
- LED lighting upgrade in gymnasiums – 2016

### Functional Description
Laker Hall is an athletic facility located on the southern side of Route 104. It houses two gymnasiums, a pool, locker rooms, laundry room, weight room, racquet ball courts, classrooms, and coaches' offices.

### Occupancy Patterns
The building has varying occupancy patterns dependent on season and athletic schedules. The gymnasium has a capacity of 3,500. During the fall, winter, and spring seasons, Laker Hall is open from 6 a.m. to 11 p.m. on weekdays and from 7 a.m. to 11 p.m. on weekends. During the summer season, Laker Hall is open from 6 a.m. to 8 p.m. on weekdays and from 10 a.m. to 5 p.m. on weekends.

## Building Envelope

### Roof
- Roof is insulated and in good condition according to 2010 Facilities Master Plan
- Courtyard roof is an insulated membrane roof and in good condition

### Exterior Walls
- Original walls are constructed of precast concrete panels, 1-1/2-inch or 2-inch rigid insulation, and interior concrete blocks

### Windows
- Single glazed, fixed windows in gymnasiums and pools areas
- Single glazed, operable windows on second floor

### Doors
- Building entryway doors are metal framed, glass doors

### Air Infiltration/Leakage
- Single set of entryway doors may allow air infiltration

- No noticeable signs of excessive infiltration

## Utilities

### Electricity
- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas
- The building has a National Grid gas service separate from the rest of the campus
  - Used for steam production

### District Steam
- This building does not receive steam from the Central Heating Plant

### Submeters
- None observed during walk-through

## Lighting

### Interior Fixture Types
- Predominant lighting types as follows:
  - Pool: Indirect LED wall sconces on each side of pool with light directed upward toward white ceilings and LED canned lights above bleachers
  - Large gymnasium: LED lighting
  - Small (auxiliary) gymnasium: LED lighting
  - Racquetball courts: Recessed 2F32 T8 fixtures
  - Mechanical room: 2F32 T8 fixtures
  - Basement: F17 linear T8 fixtures
  - Stairway: Tri-tube fluorescent fixtures
  - Hallways: Compact fluorescent lamps (CFL)

### Interior Lighting Controls
- Manually switched lighting
- LEDs in gymnasium are sectioned in different lighting circuits so lights can be turned on when specific basketball/volleyball courts are used. These circuits are controlled via local panels.
- Bi-level lighting in natatorium

### Exterior Lighting and Controls
- LED wall pack fixtures above entryway doors (including service entrances)
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System
- Two (2) boilers generate steam for building heating
  - One (1) Cleaver Brooks packaged Scotch Marine natural gas-fired, fire tube boiler

    - One (1) Hurst cast-iron sectional forced draft boiler
    - Steam supplied to heating coils in heating and ventilating units, unit heaters, and steam-to-hot-water converters
- One (1) steam-to-hot-water converter CV-1 generates heating hot water (HW) for finned tube radiation and cabinet unit heaters
    - Two (2) base-mounted hot water pumps circulate HW to building heating terminals
        - Pumps observed to be corroded and missing nameplates
    - Finned tube radiation loop supply temperature is reset based on outside air (OA) temperature

**Condensate and Feedwater System**
- One (1) condensate tank collects and stores condensate return
    - Three (3) condensate pumps
- One (1) deaerator tank removes dissolved gases from the feedwater loop and stores the treated feedwater

**Central Cooling System**
- No space cooling in this building

**Air Handling Units**
- Air handling unit AHU-1 serves the weight room
    - 100% OA unit
    - Steam heating coils and direct expansion (DX) coils for future cooling use
- 11 heating and ventilating units HV-1 through HV-11 serve the remainder of the building
    - HV-1 provides combustion air to the boiler mechanical room
        - 100% OA unit
        - Steam heating coils
    - HV-2, HV-4 through HV-7 serve locker rooms and gymnasiums
        - Each unit has one (1) HW heating coil
        - Constant speed supply fan motors
    - HV-3
        - Steam heating coils
    - HV-8 serves the natatorium
        - Supply fan motor controlled by variable frequency drive (VFD) with a temperature-based control scheme
        - Return fan motor controlled by VFD to track supply fan VFD
        - Glycol preheat coil and steam heating coil
        - Newer unit
    - HV-9 through HV-11
        - Each unit has one (1) steam heating coil with a pneumatic control valve
        - Two-way valves
        - Older units
- HRC-1
    - Heat recovery glycol coil
    - Unclear what this unit serves and source of glycol heat recovery

**Exhaust Systems**
- Four (4) exhaust fans serve the building
  - EF-2 controls integrated with HV-2
  - EF-3 has VFD control of fan motor speed, controls integrated with HV-8
  - EF-5 and EF-6 controls integrated with HV-9

**Zone Heating/Cooling**
- HW finned tube radiation provides perimeter heating
- HW cabinet unit heaters
- Steam unit heaters

## HVAC Controls

**Building Automation System**
- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of the majority of building HVAC systems
  - Includes CV-1 and the heating and ventilating units
- Trane Tracer® Ensemble™ BAS used for monitoring, DDC, and energy management of AHU-1
- Domestic hot water (DHW) system is not on either BAS

**Operating Schedules**
- HVAC equipment is scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**
- Two (2) steam bundle storage tanks
  - 1/3 & 2/3 pneumatic control valves with receiver-controllers
  - Pneumatic thermostats in tanks
  - Condensate return unit
  - Only one (1) tank operates at a time, tank in use alternates every year

**DHW Load**
- Bathroom hand sinks
- Locker room showers

## Piping and Ductwork

**Piping Systems/Insulation**
- Some piping to the heating and ventilating units is missing insulation
- Substantial corrosion observed on some older heating and ventilating units
- Spot observations of DHW piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**
- The deaerator and some of the older heating and ventilating units are missing insulation

**Piping and Ductwork Leaks**
- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug loads**
- Offices: computers or laptops, desk phones, desk lamps, etc.
- Gyms and pool: athletic equipment (i.e., speakers, ball machine, etc.)
- Corridors: vending machines

**Elevators**
- One (1) elevator serves the building

## Specialty Systems

**Air Compressors**
- One (1) air compressor generates compressed air for pneumatic controls

**Swimming Pool**
- One (1) steam-to-hot-water converter generates hot water for pool heating
  - One (1) pneumatic control valve

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**
- Install automatic interior lighting controls on existing LED fixtures
- Implement automatic lighting schedules through BAS
- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control
  - Scheduling of HVAC equipment and space temperature setbacks
- If not already implemented, install interlock controls on HV-1 to turn on when boilers are operating
- Setback equipment during academic breaks
- Install low-flow or ultra low-flow showerheads

**Capital Measures**
- Upgrade roof insulation to at least code levels during roof replacement project
- Replace single glazed windows with high performance windows
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces, especially for larger spaces such as the gymnasium
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Install VFDs on the HW pump motors and implement pump differential pressure reset controls
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life

- Convert AHU-1, HV-1 through HV-7, and HV-9 through HV-11 to single-zone variable air volume (VAV) systems by installing VFDs on systems and implementing temperature-based control schemes to modulate airflow
- Install occupancy-based HVAC controls
- Install mechanical cooling on HV-8 (serving natatorium) to provide dehumidification to the space
- Consider installing an exhaust air energy recovery system on AHU-1
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Install destratification fans in gymnasium
- Replace pneumatic actuators with electric actuators
- Consider implementing demand control ventilation in Zeil gymnasium and the auxiliary gymnasium
- Connect remaining building systems to BAS
- Replace DHW heater with semi-instantaneous water heater

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives
- Repair missing piping and equipment insulation

# SUNY OSWEGO | LANIGAN HALL BUILDING ASSESSMENT

## Building Description


| | |
|---|---|
| **Building Name:** | Lanigan Hall |
| **Year Constructed:** | 1967 |
| **No. of Floors:** | 2 + Projector Room |
| **Est. GSF:** | 88,200 |

### Recent Building Upgrades

- None

### Functional Description

Lanigan Hall is an academic building in the center of campus housing the departments of communications, art, campus technology services, and auxiliary services. The upper floor consists of seven lecture halls, three classrooms, and a café, arranged in a circle around a central staircase. The basement is comprised of offices, workrooms, classrooms, and main electrical and mechanical rooms. A small projector room serving the lecture halls is located on an upper level in the center of the building.

### Occupancy Patterns

Lanigan Hall is occupied 24/7 during the academic year.

## Building Envelope

### Roof

- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Concrete masonry with a stone façade
- Insulation type and levels not accessible during walk-through

### Windows

- Tinted, single glazed, fixed, aluminum frame floor-to-ceiling windows

### Doors

- Building entryway doors are clear, double glazed, aluminum frame doors

### Air Infiltration/Leakage

- No excessive infiltration was observed

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for domestic water heating

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

### Submeters

- This building has a campus-managed Electro Industries revenue grade electricity submeter

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Basement corridors: Recessed fixtures with LED bulbs
  - Upper floor corridors: Recessed fixtures with linear T8 fluorescent lamps
  - Lecture halls: Prismatic fixtures with linear T8 fluorescent lamps

### Interior Lighting Controls

- Manually switched lighting in offices, classrooms, and lecture halls
- Occupancy sensors in basement corridors

### Exterior Lighting and Controls

- Predominant exterior lighting type is high-intensity discharge (HID)
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- One (1) shell & tube steam-to-hot-water converter CV-1 generates heating hot water (HW) for radiation heaters and air handler reheat coils
  - Two (2) pneumatic steam valves modulate HW supply temperature at the outlet of the converter
  - Hot water pumps P-7 and P-8 serve the radiation loop. P-9 and P-10 serve the reheat coils. All four (4) pump motors are constant speed.
    - P-7 and P-8 are Worthington base-mounted centrifugal pumps with 7.5 horsepower (hp) motors, rated for 135 gallons per minute (gpm) at 110 feet of head
    - P-9 and P-10 are Worthington base-mounted centrifugal pumps with 3 hp motors, rated for 73 gpm at 60 feet of head
  - Supply temperature of 128°F observed during walk-through
- A second shell & tube steam-to-hot-water converter CV-2 generates HW for air handler heating coils
  - One (1) pneumatic steam valve modulates HW supply temperature at the outlet of the converter
  - Hot water pumps P-5 and P-6 serve the heating coils. Both pump motors are constant speed.
    - P-5 is a newer Goulds vertical multi-stage pump with a 15 hp motor
    - P-6 is an original Worthington base-mounted centrifugal pump with a 10 hp motor, rated for 411 gpm at 60 feet of head
- Appear to utilize reset of HW supply temperature based on outside air temperature

**Central Cooling System**

- Steam absorption chiller located in Lanigan Hall abandoned in place
  - Last used in the 1980s
- 535-ton water-cooled chiller located in Penfield Library generates chilled water (CHW) for building cooling in both Penfield Library and Lanigan Hall
  - Chilled water pumps P-1 and P-2 serve the Lanigan air handler cooling coils. Both pump motors are constant speed.
    - Worthington base-mounted centrifugal pumps with 40 hp motors, rated for 848 gpm at 100 feet of head

**Air Handling Units**

- Air handling unit AC-1 serves the basement and prep. area
  - Constant volume dual-duct multi-zone unit
  - Pneumatic damper actuators
  - 20 hp supply air fan motor; 5 hp return air fan motor
  - HW heating and terminal reheat coils; CHW cooling coil
- Air handling unit AC-2 serves the television control and projection spaces
  - Constant volume multi-zone unit
  - 20 hp supply air fan motor; 7.5 hp return air fan motor
  - No heating or cooling coils in the unit; HW and CHW coils at each zone terminal
- Air handling unit AC-3 serves lecture room 101
  - Constant volume single-zone unit
  - 10 hp supply air fan motor; 3 hp return air fan motor
  - HW and CHW coils
- Air handling unit AC-4 serves the northeastern section of the upper floor
  - Constant volume dual-duct multi-zone unit
  - 15 hp supply air fan motor; 3 hp return air fan motor
  - HW and CHW coils
- Air handling unit AC-5 serves the northwestern section of the upper floor
  - Constant volume dual-duct multi-zone unit
  - 15 hp supply air fan motor; 3 hp return air fan motor
  - HW and CHW coils
- Air handling unit AC-6 serves the southeastern section of the upper floor
  - Constant volume dual-duct multi-zone unit
  - 15 hp supply air fan motor; 5 hp return air fan motor
  - HW and CHW coils
- Air handling unit AC-7 serves the southwestern section of the upper floor
  - Constant volume dual-duct multi-zone unit
  - 20 hp supply air fan motor; 5 hp return air fan motor
  - HW and CHW coils
- Heating and ventilating unit HV-1 serves the basement
  - Constant volume unit
  - 10 hp supply air fan motor; 5 hp return air fan motor
  - HW coil
- One (1) split system air conditioner serves the radio station

#### Exhaust Systems
- Five (5) general exhaust fans with constant speed motors serve the building

#### Zone Heating/Cooling
- Finned tube radiation provides perimeter heating in corridors, offices, classrooms, and studios; temperature control is limited to HW supply temperature reset control
- HW cabinet unit heaters serve the main entryways

### HVAC Controls

#### Building Automation System
- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems
  - Only air handling units and exhaust fans are on the BAS

#### Operating Schedules
- HVAC systems are scheduled to operate in occupied mode 24/7

### Domestic/Service Water Heating

#### Domestic Water Heaters
- One (1) natural draft, gas-fired tank water heater with an additional external storage tank
  - Small in-line circulating pumps

#### Domestic Hot Water (DHW) Load
- Bathroom hand sinks

### Piping and Ductwork

#### Piping Systems/Insulation
- Some steam piping is missing insulation in several areas
- Spot observations of ductwork insulation revealed no remarkable deficiencies

#### Equipment Insulation
- Spot observations of equipment insulation revealed no remarkable deficiencies

#### Piping and Ductwork Leaks
- Spot observations revealed no leakage issues

### Miscellaneous Loads

#### Plug Loads
- Offices: computers or laptops, desk phones, desk lamps, etc.
- Workrooms and classrooms: computers, monitors, projectors, printers, etc.
- Café: one (1) beverage vending machine, cold food holding cabinet, coffee makers, etc.

**Elevators**

- One (1) elevator serves the building

## Specialty Systems

**Air Compressors**

- Two (2) air compressors generate compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control
  - Scheduling of HVAC equipment and space temperature setbacks
- Implement CHW supply temperature reset
- Setback equipment during academic breaks

**Capital Measures**

- Replace single glazed windows with high performance windows
- Install building-level gas and steam submeters
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Install variable frequency drives (VFD) on the motors of HW pumps P-5, P-6, P-7, and P-8 and Lanigan CHW pumps P-1 and P-2
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Replace constant volume dual duct AHUs with VAV systems during gut rehab project
- Convert AC-3 to single-zone variable air volume (VAV) system by installing VFD on fan motors and implementing a temperature-based control scheme to modulate airflow
- Install occupancy-based HVAC controls
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Install destratification fans in lecture halls
- Replace pneumatic actuators with electric actuators
- Consider implementing demand control ventilation in lecture halls and workrooms
- Connect remaining building systems to BAS
- Replace DHW heater with semi-instantaneous water heater
- Replace DHW circulating pumps and motors with electronically commutated motors

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives
- Repair missing and damaged piping insulation

# SUNY OSWEGO | LEE HALL BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | Lee Hall |
| **Year Constructed:** | 1958 |
| **No. of Floors:** | 3 + Basement |
| **Est. GSF:** | 65,000 |

### Recent Building Upgrades
- Exterior renovation – 2017

### Functional Description
Lee Hall is a recreation center located in the center of campus which houses athletic offices, racquetball courts, a gymnasium, a pool, locker rooms, storage spaces, and mechanical spaces. Lee Hall also houses the campus central heating plant, which is addressed in a separate building assessment.

### Occupancy Patterns
Lee Hall is open from 6 a.m. to 9 p.m. daily during the academic year. The gymnasiums are open from 11:30 a.m. to 10 p.m. daily. The pool is open from 11:30 a.m. to 9 p.m. on weekdays and from 12 p.m. to 5 p.m. on weekends.

## Building Envelope

### Roof
- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls
- Concrete masonry with a brick façade
- Insulation type and levels not accessible during walk-through

### Windows
- Double glazed, hopper, aluminum frame windows with aluminum spacers

### Doors
- Building entryway doors are metal framed, glass doors

### Air Infiltration/Leakage
- No excessive infiltration was observed

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the Central Heating Plant from the main campus gas service

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

### Submeters

- None observed during walk-through

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Pool: Compact fluorescent lamp (CFL) fixtures
  - Gymnasium: LED bulbs have been installed in old fixtures
  - Racquetball/Squash courts: Canned CFL fixtures
  - Mechanical rooms: 2F32 T8 fixtures

### Interior Lighting Controls

- Manually switched lighting

### Exterior Lighting and Controls

- High intensity discharge (HID) wall pack fixtures above entryway doors
- Exterior lights are controlled by photosensors

## HVAC

### Central Heating System

- Heating hot water (HW) system is the steam-to-hot-water converter CV-1 located in the Central Heating Plant

### Central Cooling System

- No space cooling in this building

### Air Handling Units

- Eight (8) heating and ventilating units HV-1 through HV-8 serve the building
  - Single-zone units
  - HV-3 through HV-8 are 100% outside air (OA) units
  - Constant speed supply fan motors
  - Steam preheat and reheat coils with pneumatic control valves
  - HV-1 serves the natatorium

- HV-2 serves the gymnasiums
- HV-4 serves the women's locker room
- HV-5 and HV-6 serve squash and handball courts
- HV-7 serves the men's locker room
- HV-8 serves the basement

**Exhaust Systems**

- One (1) large exhaust fan EF-1 serves the main gym
  - Inlet observed to be in need of repair – tears in connection
- Six (6) smaller exhaust fans serve the remainder of the building
  - EF-3 controls integrated with HV-3
  - EF-4 serves the auxiliary gym
  - EF-6 serves the natatorium
  - EF-7 controls integrated with HV-7
  - EF-8 controls integrated with HV-8
  - EF-10 controls integrated with HV-4, HV-5, and HV-6

**Zone Heating/Cooling**

- HW finned tube radiators located under windows provide heating in corridors
- Ceiling diffusers and return air vents serve natatorium and gym

## HVAC Controls

**Building Automation System**

- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems
  - Heating and ventilating unit steam coil setpoints, CV-1, and exhaust fans EF-3 and EF-10 are on the BAS

**Operating Schedules**

- Operating schedules could not be verified during walk-through

## Domestic/Service Water Heating

**Domestic Water Heaters**

- Domestic hot water (DHW) system is the steam bundle storage tank located in the Central Heating Plant

**DHW Load**

- Bathroom hand sinks
- Locker room showers

## Piping and Ductwork

**Piping Systems/Insulation**

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

### Equipment Insulation

- Spot observations of equipment insulation revealed no remarkable deficiencies

### Piping and Ductwork Leaks

- Some steam piping leaks observed near HV-2 and HV-3
- Spot observations revealed no ductwork leakage issues

## Miscellaneous Loads

### Plug loads

- Offices: computers or laptops, desk phones, desk lamps, etc.
- Break room: microwaves, mini fridges, etc.
- Gyms and pool: athletic equipment (i.e., speakers, ball machine, etc.)
- Corridors: vending machines

## Specialty Systems

### Air Compressors

- Air compressors located in the Central Heating Plant generate compressed air for pneumatic controls

### Swimming Pool

- One (1) steam-to-hot-water converter generates hot water for pool heating
  - One (1) pneumatic control valve
  - Pool filter with one (1) filter pump cleans and circulates water to the pool. Pump has variable frequency drive (VFD) control of pump motor speed.
    - Base-mounted pump with a 10 horsepower (hp) motor

## Potential Energy Efficiency Measures (EEMs)

### No Cost/Low Cost Measures

- Retro-commissioning of HVAC systems and controls
  - Schedule HVAC equipment and space temperature setbacks
- Setback equipment during academic breaks
- Install low-flow or ultra low-flow showerheads
- If not already implemented, implement HW supply temperature reset control

### Capital Measures

- Install window film for solar heat gain reduction
- Replace interior fluorescent light fixtures and old fixtures retrofit with LED bulbs with new LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life

- Convert heating and ventilating units to single-zone variable air volume (VAV) systems by installing VFDs on systems and implementing temperature-based control schemes to modulate airflow, or consider replacing existing units with new VAV systems, as most equipment is original and past end-of-life
- Install mechanical cooling on HV-1 (serving natatorium) to provide dehumidification to the space
- Consider installing an exhaust air energy recovery system on HV-3 through HV-8
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace pneumatic actuators with electric actuators
- Consider implementing demand control ventilation in the gymnasiums
- Consider implementing occupancy-based HVAC controls on HV-3 through HV-7
- Connect remaining exhaust fans to BAS

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives
- Repair piping to stop steam leakage

# SUNY OSWEGO | MAHAR HALL BUILDING ASSESSMENT

## Building Description

**Building Name:** Mahar Hall

**Year Constructed:** 1966

**No. of Floors:** 5 + Penthouse

**Est. GSF:** 91,530

### Recent Building Upgrades

- None

### Functional Description

Mahar Hall is an academic building in the center of campus housing the department of social sciences. The upper floor consists of faculty offices and a lounge. The first, second, and third floors are comprised of classrooms, offices, workrooms, and storage spaces. Additional classrooms, offices, storage spaces, and main electrical and mechanical rooms are located in the basement.

### Occupancy Patterns

During the academic year, Mahar Hall is occupied from 8 a.m. to 9 p.m. Monday through Thursday, 8 a.m. to 4 p.m. on Fridays, and closed on weekends.

## Building Envelope

### Roof

- Built-up flat roof with concrete deck
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Concrete masonry with a concrete façade
- Insulation type and levels not accessible during walk-through

### Windows

- Double glazed, fixed and awning, aluminum frame windows

### Doors

- Building entryway doors are clear, double glazed, aluminum frame doors

### Air Infiltration/Leakage

- No excessive infiltration was observed

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

**Natural Gas**
- This building does not receive natural gas

**District Steam**
- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

**Submeters**
- No submeters observed during walk-through

## Lighting

**Interior Fixture Types**
- Predominant lighting types as follows:
  - Classrooms, labs, and offices: Surface mount fixtures with linear T8 fluorescent lamps
  - Corridors and common spaces: Surface mount fixtures with linear T8 fluorescent lamps

**Interior Lighting Controls**
- Manually switched lighting in classrooms, labs, and offices
- Some lighting is controlled with occupancy sensors

**Exterior Lighting and Controls**
- Predominant exterior lighting type is high-intensity discharge (HID)
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

**Central Heating System**
- One (1) shell & tube steam-to-hot-water converter generates heating hot water (HW) for building heating
  - One (1) direct digital control (DDC), pneumatically actuated steam valve modulates HW supply temperature at the outlet of the converter. Mixing valves control supply temperatures to each of two (2) HW distribution zones.
  - Hot water pumps P-5 and P-6 operate as lead/standby. Both HW pump motors are constant speed.
    - Worthington base-mounted centrifugal pumps with 15 horsepower (hp) motors, rated for 450 gallons per minute (gpm) at 85 feet of head
- Appears to utilize reset of HW supply temperature based on outside air (OA) temperature

**Central Cooling System**
- Trane 120-ton chiller generates chilled water (CHW) for building cooling
  - Air-cooled chiller with remote condensing unit
  - Chilled water pumps P-1 and P-2 operate as lead/standby. Both CHW pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure.
    - Bell & Gossett base-mounted centrifugal pumps with 10 hp motors, rated for 322 gpm at 76 feet of head
- Appears to utilize reset of CHW supply temperature based on OA temperature

**Air Handling Units**

- Air handling unit AC-1 serves classrooms
  - Multi-zone variable air volume (VAV) unit
  - 15 hp supply air fan motor controlled by VFD to maintain duct static pressure
  - Steam heating coil; CHW cooling coil with 3-way pneumatic control valve
- Air handling unit AC-2 serves three classrooms that were formerly animal labs
  - 100% OA dual-duct multi-zone VAV unit
  - 3 hp supply air fan motor controlled by VFD
    - Control of the VFD is unknown. 100% speed observed during walk-through.
  - Steam preheat and heating coils; CHW cooling coil with two-way pneumatic control valve
- Heating and ventilating unit HV-1 provides ventilation air to classrooms
  - Constant volume unit
  - 25 hp constant speed supply air fan motor
  - Steam heating coil with two-way pneumatic control valve

**Exhaust Systems**

- Four (4) exhaust fans with constant speed motors serve the building
  - EF-2 is a dedicated "lab" exhaust fan
  - EF-4 is a dedicated mechanical room exhaust fan and can operate on a timer

**Zone Heating/Cooling**

- Finned tube radiation provides perimeter heating; temperature control is limited to HW supply temperature control of two (2) building zones
- Steam and hot water unit heaters serve the entryways, basement storage spaces, and electrical and mechanical rooms
- Two-pipe and 4-pipe fan coil units (FCU) provide heating and cooling to all rooms on the fourth floor and some rooms on the second floor
  - Heating coil capacities range from 13.3 to 58 thousand Btus per hour (MBH)
  - Cooling coil capacities range from 4.6 to 45.6 MBH

## HVAC Controls

**Building Automation System**

- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, DDC, and energy management of HVAC systems

**Operating Schedules**

- HVAC systems are assumed to operate in occupied mode from 7 a.m. to 10 p.m. on weekdays, based on building occupancy schedule

## Domestic/Service Water Heating

**Domestic Water Heaters**

- One (1) steam bundle storage tank
  - Manufactured 1960

**Domestic Hot Water (DHW) Load**
- Bathroom hand sinks
- Common area kitchenette sink
- Lab sinks

## Piping and Ductwork

**Piping Systems/Insulation**
- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**
- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**
- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug Loads**
- Offices: computers or laptops, desk phones, desk lamps, printers, etc.
- Classrooms: computers, projectors, etc.
- Corridors: two (2) snack and beverage vending machines on the fourth floor

**Elevators**
- One (1) elevator serves the building

## Specialty Systems

**Air Compressors**
- One (1) air compressor generates compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**
- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control
  - Optimize CHW supply temperature reset control
  - Scheduling of HVAC equipment and space temperature setbacks
- Implement pump differential pressure reset controls on the CHW pumps
- Implement duct static pressure reset controls on AC-1
- Setback equipment during academic breaks

**Capital Measures**
- Upgrade roof insulation to at least code levels during gut rehab project
- Upgrade exterior wall insulation to at least code levels during gut rehab project
- Install window film for solar heat gain reduction

- Install building-level steam submeter
- Replace interior fluorescent light fixtures with LED fixtures
    - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
    - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Install VFDs on the HW pump motors
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Replace existing chiller with high-efficiency air-cooled variable speed magnetic bearing chiller
- Replace AC-2 and HV-1 with new VAV systems during gut rehab project
- Install occupancy-based HVAC controls
- Consider installing an exhaust air energy recovery system
- Replace FCUs and include electronically commutated motors
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace pneumatic actuators with electric actuators
- Consider implementing demand control ventilation in classrooms and workrooms
- Replace DHW heater with new semi-instantaneous water heater

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | MARANO CAMPUS CENTER BUILDING ASSESSMENT

## Building Description

**Building Name:** Marano Campus Center

**Year Constructed:** 1963

**No. of Floors:** 3 + 2 Penthouses

**Est. GSF:** 225,604

**Recent Building Upgrades**

- Student activity center construction – 2019
- Arena concourse-level flooring replacement – Ongoing
- Arena ice compressor replacement – Ongoing

**Functional Description**

Marano Campus Center is an "E"-shaped building in the center of campus. The west wing is known as the Deborah F. Stanley Arena & Convocation Hall and the east wing is referred to as Poucher Hall. The building houses administrative and athletic offices, and the departments of philosophy, modern languages and literatures, and English and creative writing. A complete summary of space functions is given in the table below.

**Table 1. Space Function Summary**

| | Arena & Convocation Hall | Marano Campus Center | Poucher Hall |
|---|---|---|---|
| Location in Building | West Wing | Central Wing | East Wing |
| Lower Level | N/A | Main Electrical & Mechanical Rooms, Student Activity Center | N/A |
| First Floor | Food Court, Hockey Arena, Locker Rooms, Main Electrical & Mechanical Rooms | Auditorium, Classrooms, Compass Credit Union, Meeting Rooms, Offices, Radio Station, Storage Spaces, Swetman Gym, Work Rooms | Computer Labs, Lounges, Main Mechanical Room, Meeting Rooms, Offices, Work Rooms |
| Second Floor | Box Office, Café, College Store, Hockey Arena, Lounge, Meeting Room, Welcome Center | Café, Classrooms, Computer Labs, Lounges, Meeting Rooms, Offices | Classrooms, Lounges, Offices |
| Third Floor | N/A | N/A | Classrooms, Meeting Rooms, Offices |

**Occupancy Patterns**
The building is occupied from 6:30 a.m. to 1:30 a.m. daily during the academic year and from 6:30 a.m. to 9 p.m. on weekdays only during the summer break.

## Building Envelope

**Roof**
- Flat roof; no roof access during February 2022 walk-through
- Insulation type and levels not accessible during February 2022 walk-through

**Exterior Walls**
- Concrete masonry with brick and stone façades
- Insulation type and levels not accessible during February 2022 walk-through

**Windows**
- Arena & Convocation Hall
  - Clear, double glazed, fixed, aluminum frame windows with interior shades
    - Large, nearly floor-to-ceiling
- Campus Center
  - Clear, double glazed, fixed, aluminum frame windows
- Poucher Hall
  - Clear, double glazed, fixed and single-hung, aluminum frame windows

**Doors**
- Building entryway doors are clear, double glazed, aluminum frame doors

**Air Infiltration/Leakage**
- No excessive infiltration was observed

## Utilities

**Electricity**
- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

**Natural Gas**
- Natural gas is delivered to the building from the main campus gas service
  - Used for desiccant dehumidification in the Arena & Convocation Hall, domestic hot water (DHW) heating, ice making, and backup generator

**District Steam**
- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building
  - One (1) condensate receiver with two (2) condensate pumps returns condensate from the Campus Center to the Central Heating Plant

**Submeters**
- This building has a campus-managed Electro Industries revenue grade electricity submeter

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Arena & Convocation Hall
    - Corridors: Recessed fixtures with compact fluorescent lamps (CFL) and surface mount fixtures with linear T8 fluorescent lamps
    - Kitchen: Surface mount fixtures with LED lamps
    - First-floor food court: High bay surface mount fixtures with high-intensity discharge (HID) lamps
    - Second-floor café: Surface mount fixtures with linear T5 fluorescent lamps
    - Hockey arena: Surface mount fixtures with LED lamps
  - Campus Center
    - Corridors: Pendant fixtures with linear T8 fluorescent lamps
  - Poucher Hall
    - Corridors: Surface mount and recessed fixtures with LED lamps

### Interior Lighting Controls

- Primarily manually switched lighting; some occupancy sensors located across building
- Arena & Convocation Hall lighting can be scheduled off and on at set times of day
  - Scheduling not enabled during February 2022 walk-through
- Poucher Hall lighting is scheduled on at 6:30 a.m. and off at 12 a.m. daily

### Exterior Lighting and Controls

- Predominant exterior lighting type is HID
- Exterior lights on campus are controlled by photosensors and astronomical time clocks
  - Some exterior lighting on the northern side of the building was observed to be on during February 2022 walk-through, despite ample daylight

## HVAC

### Central Heating System

- One (1) shell & tube steam-to-hot-water converter HX-1, located in MCC Rm. 42, generates heating hot water (HW) for building heating in the Arena & Convocation Hall
  - Armstrong Type WS heat exchanger, manufactured 2005
  - 1/3 & 2/3 direct digital control (DDC), pneumatically actuated steam valves modulate HW supply temperature at the outlet of the converter. A mixing valve controls supply temperature to the primary HW pumps.
  - Hot water pumps P-1 and P-2 operate as lead/standby for the HW return. Hot water pumps P-3 and P-4 operate as lead/standby for the HW supply. All four (4) HW pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure.
    - P-1 and P-2 are Armstrong in-line centrifugal pumps with 15 horsepower (hp) motors, rated for 384 gallons per minute (gpm) at 75 feet of head
    - P-3 and P-4 are Armstrong in-line centrifugal pumps with 20 hp motors, rated for 384 gpm at 110 feet of head
  - System is enabled when outside air (OA) temperature is below 70°F, or when more than two (2) heating calls are active

    - HW supply temperature is reset based on OA temperature
        - 180°F supply temperature at OA temperature below 45°F
        - 140°F supply temperature at OA temperature above 45°F
- One (1) shell & tube steam-to-hot-glycol converter, located in MCC Rm. 42, generates hot glycol for building heating in the Arena & Convocation Hall
    - Armstrong Type WS heat exchanger, manufactured 2005
    - 1/3 & 2/3 DDC controlled, pneumatically actuated steam valves modulate glycol supply temperature at the outlet of the converter
    - Hot glycol pumps P-5 and P-6 operate as lead/standby for the glycol loop. Both glycol pumps have VFD control of pump motor speed based on differential pressure.
        - Armstrong in-line centrifugal pumps with 15 hp motors, rated for 500 gpm at 69 feet of head
    - System is disabled when outside air (OA) temperature is above 65°F
    - System is enabled when the glycol valve on AHU-1 or AHU-2, both located in MCC Rm. PH1, is open greater than 5% for five minutes
    - Glycol supply temperature is reset based on OA temperature
        - 180°F supply temperature at 10°F OA temperature
        - 110°F supply temperature at 60°F OA temperature
- One (1) plate & frame steam-to-hot-glycol converter HX-1, located in the MCC basement, generates hot glycol for building heating in the Campus Center and Poucher Hall
    - Bell & Gossett heat exchanger, manufactured 2006
    - 1/3 & 2/3 DDC controlled, pneumatically actuated steam valves modulate glycol supply temperature at the outlet of the converter
    - Hot glycol pumps P-2A and P-2B, located in the MCC basement, operate as lead/standby for the glycol loop. Both glycol pumps have VFD control of pump motor speed based on differential pressure.
        - Bell & Gossett base-mounted centrifugal pumps with 10 hp motors, rated for 238 gpm at 65 feet of head
    - Hot glycol pumps P-3 and P-4, located in Poucher Rm. 163, circulate hot glycol to Poucher Hall. Both Poucher glycol pumps have VFD control of pump motor speed based on differential pressure.
        - Bell & Gossett in-line pumps with 1.5 hp motors, rated for 90 gpm at 30 feet of head
- One (1) plate & frame steam-to-hot-water converter HX-2, located in the MCC basement, generates heating HW for variable air volume (VAV) terminal reheat coils and the finned tube radiation loop in the Campus Center and building heating in Poucher Hall
    - Bell & Gossett heat exchanger, manufactured 2006
    - 1/3 & 2/3 DDC controlled, pneumatically actuated steam valves modulate HW supply temperature at the outlet of the converter
    - Hot water pumps P-3A and P-3B operate as lead/standby for the HW loop. Both HW pumps have VFD control of pump motor speed based on differential pressure.
        - Bell & Gossett base-mounted centrifugal pumps with 15 hp motors, rated for 280 gpm at 65 feet of head
    - Hot water pumps P-1 and P-2, located in Poucher Rm. 163, circulate HW to Poucher Hall. Both Poucher HW pumps have VFD control of pump motor speed based on differential pressure.
        - Bell & Gossett in-line pumps with 5 hp motors, rated for 100 gpm at 60 feet of head

**Central Cooling System**

- Trane nominal 300-ton chiller CH-1, located in MCC Rm. 42, generates chilled water (CHW) for building cooling in the Arena & Convocation Hall
  - Trane Model RTHD water-cooled rotary screw chiller
  - R-134A refrigerant
  - Chilled water pumping arrangement is constant flow primary/variable flow secondary. Chilled water pump P-8 serves the primary CHW loop. Chilled water pumps P-7 and P-9 operate as lead/standby for the secondary CHW loop. Both secondary pumps have VFD control of pump motor speed based on differential pressure.
    - P-8 is an Armstrong centrifugal pump with a 10 hp motor
    - P-7 and P-9 are Armstrong centrifugal pumps with 25 hp motors
  - Condenser water pumps P-10 and P-11 operate as lead/standby and circulate condenser water between the chiller condenser and the cooling tower. Both condenser water pumps have VFD control of pump motor speed.
    - Armstrong centrifugal pumps with 40 hp motors, rated for 900 gpm at 99 feet of head
  - Cooling tower fan has VFD control of fan motor speed to maintain leaving water temperature
  - One (1) CHW-glycol converter HX-3 provides free cooling in the winter
    - One (1) CHW valve modulates supply temperature at the outlet of the converter
    - Chilled glycol pump P-12 and CHW pump P-13 serve the free cooling loop
      - Armstrong pumps with 2 hp motors, rated for 150 gpm at 20 feet of head
  - System is enabled when OA temperature is above 50°F
- Two (2) Carrier 146-ton chillers CH-1A and CH-1B, located in the MCC basement, generate CHW for building cooling in the Campus Center and Poucher Hall
  - Carrier Model 30HX rotary screw chillers with remote air-cooled condensers
  - R-134A refrigerant
  - Chilled water pump P-4 serves CH-1A and chilled water pump P-5 serves CH-1B. Both pump motors are constant speed.
    - Bell & Gossett base-mounted centrifugal pumps with 3 hp motors, rated for 250 gpm at 30 feet of head
  - Chilled water pumps P-1A and P-1B, located in the MCC basement, circulate CHW to the Campus Center air handlers and cooling terminal equipment and to the Poucher CHW system. Both CHW pumps have VFD control of pump motor speed based on differential pressure.
    - Bell & Gossett base-mounted centrifugal pumps with 25 hp motors, rated for 647 gpm at 75 feet of head
  - Chilled water pumps P-5 and P-6, located in Poucher Rm. 163, operate as lead/standby and circulate CHW to Poucher Hall air handlers and cooling terminal equipment. A CHW valve modulates supply temperature from the CHW system in the MCC basement to maintain the Poucher Hall CHW supply temperature setpoint. Both Poucher CHW pumps have VFD control of pump motor speed based on differential pressure.
    - Bell & Gossett base-mounted centrifugal pumps with 7.5 hp motors, rated for 275 gpm at 60 feet of head

**Air Handling Units**

- Air handling unit AHU-1, located in MCC Rm. PH1, serves the food court and smaller spaces around the hockey arena in the Arena & Convocation Hall
  - Multi-zone VAV unit with economizer control

  - Supply fan motor controlled by VFD to maintain duct static pressure
  - Return fan motor controlled by VFD to track supply fan VFD
  - Hot glycol preheat coil; CHW cooling coil; terminal reheat coils
  - Discharge air temperature is reset based on OA temperature and voting system
    - 55°F discharge air temperature at 80°F OA temperature
    - 65°F discharge air temperature at 40°F OA temperature
    - "If cooling votes are greater than one (1), discharge air will subtract down to 55°F, if heating votes are greater than three and cooling votes are less than two (2), discharge air will add up to 80°F due to reheat system"
  - OA flow is reset based on the number of exhaust fans running
- Air handling unit AHU-2, located in MCC Rm. PH1, serves the hockey arena in the Arena & Convocation Hall
  - Single-zone VAV unit with economizer control
  - Supply fan motor controlled by VFD with a temperature-based control scheme
  - Return fan motor controlled by VFD to track supply fan VFD
  - Hot glycol preheat coil; CHW cooling coil; HW heating coil
  - OA flow is varied based on the amount of carbon dioxide sensed in the hockey arena
  - Return airflow is varied based on event type
    - 60,000 cubic feet per minute (cfm) for ice event
    - 40,000 cfm for non-ice event
- Two (2) air handling units AHU-3 and AHU-4, located in MCC Rm. PH1, provide humidity control in the hockey arena in the Arena & Convocation Hall, either directly or in conjunction with AHU-2, also located in MCC Rm. PH1
  - Single-zone units with desiccant dehumidification
  - Constant speed supply and exhaust fan motors
  - CHW cooling coils; natural gas reactivation
  - Units are enabled when ice event is occurring and space humidity is above the setpoint
  - Units can operate as lead/standby based on percent relative humidity and amount of carbon dioxide sensed in the hockey arena
  - Discharge air dampers open to the hockey arena and close to AHU-2 when AHU-2 is not running; dampers close to the hockey arena and open to AHU-2 when AHU-2 is running
  - Discharge air is reset
- Five (5) air handling units AHU-1 through AHU-5, located in Poucher Rm. 163, serve Poucher Hall
  - AHU-1 and AHU-5 are multi-zone VAV units; AHU-2 through AHU-4 are single zone units
  - AHU-1 and AHU-5 supply fan motors controlled by VFDs to maintain duct static pressure; AHU-2 through AHU-4 have constant speed supply fan motors
    - AHU-1 supply fan motor was operating at 93% speed and AHU-5 supply fan motor was operating at 100% speed during October 2022 walk-through
  - AHU-1 has a CHW cooling coil with a 3-way electronic control valve and a hot glycol heating coil with a 3-way electronic control valve
  - AHU-2, AHU-3, and AHU-4 have CHW cooling coils and HW heating coils
  - AHU-5 has hot glycol preheat and heating coils with 3-way electronic control valves and a CHW cooling coil with a 3-way electronic control valve
  - One (1) rooftop heat recovery unit HRU-1 provides 100% of the process air for AHU-1
    - Constant speed supply and exhaust fan motors
    - Heat wheel with VFD recovers heat from the exhaust airstream

    - AHU-1 and HRU-1 discharge air temperature is reset based on OA temperature
        - 55°F discharge air temperature at 62°F OA temperature
        - 72°F discharge air temperature at 20°F OA temperature
- One (1) split-system air conditioner serves the telecommunications room in Poucher Hall
- Two (2) heating and ventilating (HV) units S-3 and S-4 serve Swetman Gym
    - Constant volume single-zone units
    - Constant speed supply and return fan motors
        - Supply fan belt on S-4 not connected during February 2022 walk-through
    - Steam heating coils with two-way pneumatic control valves
- One (1) air handling unit AHU-1 serves "The Space", a newly renovated student organization event venue in the MCC basement, and some spaces on the first floor of the Campus Center
    - Multi-zone VAV unit
    - Supply fan motor controlled by VFD to maintain duct static pressure
    - Return fan motor controlled by VFD to track supply fan VFD
    - Hot glycol preheat coil with a 3-way electronic control valve; CHW cooling coil with a 3-way electronic control valve; terminal reheat coil at each of three VAV boxes
    - Two (2) high-efficiency electronically commutated motors circulate hot glycol to the preheat coil. Two (2) additional high-efficiency electronically commutated motors circulate CHW to the cooling coil.
    - Heat wheel with OA and exhaust bypass dampers recovers heat from the exhaust airstream
- Seven air handling units AHU-1A, AHU-1B, AHU-1C, AHU-2, AHU-3, AHU-5, and AHU-6 serve the remaining spaces on the first and second floors of the Campus Center, as well as a few spaces in the Arena & Convocation Hall and Poucher Hall
    - Multi-zone VAV units
    - Supply fan motors controlled by VFDs to maintain duct static pressure
        - AHU-1B supply fan motor VFD was operating at 60 Hertz (Hz) during October 2022 walk-through
    - Return fan motors controlled by VFDs to track supply fan VFDs
    - Hot glycol preheat coils; CHW cooling coils; HW terminal reheat coils at the VAV boxes
        - AHU-6 does not have a cooling coil

**Exhaust Systems**

- Arena & Convocation Hall
    - Seven (7) exhaust fans serve locker rooms, bathrooms, an electric room, and the concourse
        - Time-of-day scheduling controls
    - Four (4) exhaust fans serve elevator rooms and janitorial closets
        - Space temperature controls
    - Four (4) exhaust fans serve the kitchen and hockey arena
        - Manual and time-of-day scheduling controls
    - One (1) exhaust fan serves the garbage room
        - Manual control
    - Three (3) exhaust fans serve the main electrical room, the Zamboni room, and the penthouse
        - Space temperature and carbon monoxide controls
- Campus Center and Poucher Hall
    - Two (2) exhaust fans serve the mechanical space in the MCC basement
    - Two (2) exhaust fans serve the bathrooms
    - One (1) exhaust fan serves a janitorial closet

  - Two (2) exhaust fans serve the crawlspace
  - Five (5) general exhaust fans serve the building

**Zone Heating/Cooling**

- Arena & Convocation Hall
  - VAV boxes with HW reheat coils provide airflow to nearly all rooms and common spaces
  - Finned tube radiation provides heating in the food court, locker rooms, and bathrooms; HW zone control valves modulate to maintain space temperature setpoints
  - One (1) unit heater serves the Zamboni room
  - Cabinet unit heaters serve the entryways, stairwells, and mechanical rooms
  - Two-pipe fan coil units (FCU) provide heating and cooling to the kitchen and café, locker rooms, coaching offices, telecommunications room, and sports medicine room
- Campus Center
  - VAV boxes with HW reheat coils provide airflow to nearly all rooms and common spaces
  - Finned tube radiation provides heating in the eastern part of the second floor; HW zone control valves modulate to maintain space temperature setpoints
  - Unit heaters serve basement storage spaces and the penthouse
  - Cabinet unit heaters serve the entryways
  - Two-pipe and 4-pipe FCUs provide heating and cooling to mechanical spaces, the Al Roker TV Studio, and second-floor classrooms, offices, and meeting rooms
- Poucher Hall
  - VAV boxes with HW reheat coils provide airflow to some rooms and common spaces on the southern side of the building
  - Finned tube radiation provides heating in the basement, lobby, stairwells, and bathrooms
  - Cabinet unit heaters serve the entryways
  - 4-pipe FCUs provide heating and cooling on the first, second, and third floors
    - Cooling availability based on Poucher CHW supply temperature
      - FCU cooling is available when CHW temperature is less than 60°F
  - Poucher Hall receives HW from the Campus Center for radiant floor heating system
    - One (1) DDC controlled HW valve modulates to maintain return temperature setpoint
    - One (1) in-line hot water pump P-7 circulates HW to the radiant floor heating loop
    - Supply setpoint of 90°F observed

## HVAC Controls

**Building Automation System**

- Trane Tracer® Ensemble™ building automation system (BAS) used for monitoring, DDC, and energy management of HVAC systems located in the Arena & Convocation Hall and Poucher Hall, and a few systems located in the Campus Center
- Carrier i-Vu® 8.0 BAS used for monitoring, DDC, and energy management of the majority of HVAC systems located in the Campus Center

**Operating Schedules**

- Arena & Convocation Hall
  - AHU-1 is scheduled to operate in occupied mode from 7 a.m. to 11 p.m. daily

- Locker room exhaust systems are scheduled to operate in occupied mode from 5 a.m. to 12 a.m. daily
  - Café kitchen exhaust hoods are on 24/7; main kitchen exhaust hoods are on from 8 a.m. to 9 p.m. daily
  - Other HVAC systems are scheduled to operate in occupied mode 24/7
- Campus Center
  - HVAC systems are scheduled to operate in occupied mode 24/7
- Poucher Hall
  - HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**

- Two (2) direct-vent, natural gas-fired tank water heaters with a shared additional external storage tank serve the Arena & Convocation Hall
  - 1,000 thousand Btus per hour (MBH) input each
  - Storage setpoint of 120°F observed
  - Two (2) small in-line pumps circulate DHW through the water heaters
  - Storage tank has a 900-gallon capacity
- Two (2) direct-vent, natural gas-fired condensing water heaters with a shared additional external storage tank serve the Campus Center and Poucher Hall
  - 400 MBH input each
  - 470 gal/hour recovery rates
  - Storage setpoint of 120°F observed
  - Three (3) small in-line pumps circulate DHW through the water heaters and storage tank
  - Storage tank has a 400-gallon capacity
    - Manufactured 1986

**DHW Load**

- Bathroom and locker room hand sinks and showers
- Kitchen and café sinks
- Faculty/staff break room kitchenette sinks

## Piping and Ductwork

**Piping Systems/Insulation**

- Some DHW piping is missing insulation in the Arena & Convocation Hall second-floor mechanical room
- Spot observations of HW piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**

- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Some piping leaks observed near HX-1 in the Arena & Convocation Hall first-floor mechanical room
- Some HW piping leaks observed in the Poucher Hall first-floor mechanical room
- Spot observations revealed no ductwork leakage issues

## Miscellaneous Loads

### Plug Loads

- Offices: computers or laptops, desk phones, desk lamps, printers, etc.
- Classrooms: computers, monitors, projectors, etc.
- Kitchen and café: freezers, coolers, dishwashers, blenders, food processors, fountain drink machines, griddles, holding cabinets, coffee makers, etc.
- Corridors: ATMs, monitors, vending machines, etc.
- Arena: four-sided scoreboard, speakers, microphones, etc.

### Elevators

- Two (2) elevators serve the Arena & Convocation Hall
- Two (2) elevators serve the Campus Center
- One (1) elevator serves Poucher Hall

## Specialty Systems

### Air Compressors

- Two (2) air compressors generate compressed air for pneumatic controls

### Ice Rink

- One (1) CIMCO 158-ton chiller generates chilled brine for the ice rink
  - Outside skid packaged chiller
  - R-717A (ammonia) refrigerant
  - Three (3) compressors
  - Two (2) glycol pumps have VFD control of pump motor speed based on differential pressure
  - Ice temperature of 17.1°F observed during February 2022 walk-though
- One (1) direct-vent, gas-fired tank water heater
  - 800 MBH input
  - 800 gal/hour recovery rate
  - 150-gallon capacity
  - 83% thermal efficiency
  - 1/3 hp blower motor
  - Storage setpoint of 156°F observed
  - Manufactured 2019

### Snow Melt Systems

- One (1) shell & tube HW-to-hot-glycol converter generates hot glycol for Zamboni room snow melt pit in the Arena & Convocation Hall
  - 1/3 DDC controlled HW valve modulates glycol supply temperature at the outlet of the converter
  - One (1) in-line glycol pump circulates hot glycol between the converter and the snow melt pit
  - Pit setpoint of 70°F observed
- Poucher Hall receives hot glycol from the Campus Center for east entryway snow melt system
  - System is disabled; 2005 project never completed
  - One (1) DDC controlled glycol valve modulates to maintain return temperature setpoint
  - One (1) in-line glycol pump P-8 circulates hot glycol to the snow melt system

  - Supply setpoint of 45°F observed

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Install automatic interior lighting controls on existing LED fixtures where not already installed
- Turn off exterior light fixtures during the day
- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control
  - Optimize hot glycol supply temperature reset control
  - Optimize cooling tower water temperature control
  - Optimize VFD control of supply and return fan motors
  - Scheduling of HVAC equipment and space temperature setbacks
  - Scheduling of kitchen exhaust fan operation
- Implement pump differential pressure reset controls on the HW pumps, glycol pumps, Arena & Convocation Hall CHW pumps P-7 and P-9, Campus Center CHW pumps P-1A and P-1B, and Poucher Hall CHW pumps P-5 and P-6
- Implement CHW supply temperature reset control
- Implement duct static pressure reset controls on the multi-zone VAV systems
- Setback equipment during academic breaks
- Install low-flow or ultra low-flow showerheads

**Capital Measures**

- Install window film for solar heat gain reduction
- Install building-level gas and steam submeters
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity, such as the corridor connecting the Campus Center and Poucher Hall
- Replace exterior light fixtures with LED fixtures
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Replace existing space cooling chillers with high-efficiency variable speed magnetic bearing chillers at end of useful life
  - R-134A refrigerant is being phased out starting January 1, 2024
  - Once manufacturing of R-134A is eliminated, the price of R-134A stock is expected to rise substantially
- Install occupancy-based HVAC controls
- Consider installing an exhaust air energy recovery system in Swetman Gym
- Replace FCUs and include electronically commutated motors
- Replace pneumatic actuators with electric actuators
- Consider installing destratification fans in the Arena & Convocation Hall hockey arena and food court, and in Swetman Gym
- Consider implementing demand control ventilation in the kitchens, the food court, Swetman Gym, “The Space”, the auditorium, conference rooms, meeting rooms, and workrooms

- Connect remaining building systems to BAS
- Replace storage tank DHW heaters with semi-instantaneous water heaters
- Replace DHW and snow melt system circulating pumps and motors with electronically commutated motors

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives
- Repair piping to stop water leakage
- Repair missing insulation
- Calibrate/replace/reposition temperature sensor for DHW storage tank in the MCC basement mechanical room
  - During February 2022 walk-through, the setpoint was 120°F and the water heater was reading 127°F, but thermometers were reading 176°F

# SUNY OSWEGO | PARK HALL BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | Park Hall |
| **Year Constructed:** | 1933 |
| **No. of Floors:** | 4 + Basement |
| **Est. GSF:** | 66,979 |

**Recent Building Upgrades**
- Full building renovation – 2014

**Functional Description**
Park Hall is an academic building connected to Shineman Center and Wilber Hall as part of the campus' science and engineering complex. Park Hall houses classrooms, study spaces, offices, a welding room, and a transportation lab.

**Occupancy Patterns**
Park Hall has fluctuating levels of occupancy throughout the day. The building has higher occupancy on weekdays during the day when classes are taking place.

## Building Envelope

**Roof**
- Built-up flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

**Exterior Walls**
- Concrete and brick façades
- Insulation type and levels not accessible during walk-through

**Windows**
- Double glazed, operable, metal frame windows with aluminum thermal breaks

**Doors**
- Building entryway doors are two (2) sets of glass double doors

**Air Infiltration/Leakage**
- No excessive infiltration was observed

## Utilities

**Electricity**
- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for makeup air unit with gas-fired furnace section

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

### Submeters

- This building has a campus-managed Electro Industries revenue grade electricity submeter

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Corridors: Linear T5 fluorescent lighting
  - Classrooms and lecture halls: Linear T5 fluorescent lighting

### Interior Lighting Controls

- Daylighting controls in main lobby
- Lobby lights are turned off when building is not in use

### Exterior Lighting and Controls

- Predominant exterior lighting type is high-intensity discharge (HID)
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- Two (2) steam-to-hot-water converters HX-3 and HX-4, located in the Wilber Hall basement, generate heating hot water (HW) for building heating
  - Hot water pumps HWP-1 and HWP-2 circulate HW to the building. HW pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure.
- Two (2) steam-to-hot-water converters HX-1 and HX-2 generate hot glycol for building heating in Wilber Hall and Park Hall. Only one (1) converter operates at a time, while the other serves as backup.
  - 1/3 & 2/3 pneumatically actuated steam valves modulate hot glycol supply temperature at the outlet of the converter
  - Hot glycol pumps P-7 and P-8 circulate hot glycol to Park Hall air handler heating coils. Both glycol pumps have VFD control of pump motor speed based on differential pressure.
    - Bell & Gossett pumps with 3 horsepower (hp) motors and suction diffusers
  - System is enabled when the glycol valve on any air handler is open greater than 5%
  - Hot glycol supply temperature is reset based on outside air (OA) temperature
    - 180°F supply temperature at OA temperature of 0°F and below
    - 160°F supply temperature at OA temperature of 20°F and above

**Central Cooling System**

- Two (2) Trane chillers CH-1 and CH-2 generate chilled water (CHW) for building cooling in Wilber Hall and Park Hall
  - Water-cooled screw chillers
  - R-134A refrigerant
  - Two (2) compressors each
  - Chilled water pumping arrangement is variable flow primary. Two (2) chilled water pumps circulate CHW to Park Hall. Both CHW pumps have VFD control of pump motor speed based on differential pressure.
    - Bell & Gossett pumps with 30 hp motors
  - Condenser water pumps CTP-1 and CTP-2, located in the Wilber Hall basement, circulate condenser water between the chiller condenser and the cooling tower. Both condenser water pumps have VFD control of pump motor speed.
    - Bell & Gossett pumps with 15 hp motors
  - Cooling tower fan has VFD control of fan motor speed to maintain leaving water temperature

**Air Handling Units**

- Nine (9) air handling units AHU-1 through AHU-9 serve the building
  - Multi-zone variable air volume (VAV) units with economizer controls
    - Economizer enable setpoints are maintained through the building automation system (BAS)
  - Supply fan motors controlled by VFDs to maintain duct static pressure
  - Return fan motors controlled by VFDs to track supply fan VFDs
  - Hot glycol heating coils; CHW cooling coils
  - Discharge air temperature is reset based on average space temperature
  - Duct static pressure is reset
- One (1) air handling unit MAU-1 provides make-up air to the transportation lab
  - Gas-fired furnace section
  - Controls integrated with exhaust fans EF-1, EF-3, and EF-4
  - Unit runs when any of the above exhaust fans are on
- One (1) energy recovery unit ERU-1 serves fan coil units (FCU)
  - Enthalpy wheel recovers energy from general building exhaust airstreams to condition outdoor air supplied to the FCUs
  - Supply and return fan motors have VFDs for balancing, and run at a fixed speed

**Exhaust Systems**

- Multiple exhaust fans serve the building
  - EF-1 serves the transportation lab
  - EF-2 serves electrical and mechanical rooms
  - EF-3 serves emergency exhaust for the transportation lab
  - EF-4 serves the welding room in the transportation lab
  - EF-5 serves the laser printer

**Zone Heating/Cooling**

- FCUs provide additional heating in labs, studios, and common spaces
- Hydronic baseboard heaters serve the connector hallway, Lecture Hall 315, and some first-floor classrooms

- Unit heaters serve the transportation lab and attic
- Cabinet unit heaters serve stairwells and entry vestibules

## HVAC Controls

**Building Automation System**

- Trane Tracer® Ensemble™ BAS used for monitoring, DDC, and energy management of HVAC systems
  - Includes HW system, glycol system, and air handling units
  - Chillers are not on the BAS

**Operating Schedules**

- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**

- Domestic hot water (DHW) system was not observed during walk-through

**DHW Load**

- Bathroom hand sinks

## Piping and Ductwork

**Piping Systems/Insulation**

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**

- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug loads**

- Classrooms: Laptops, charger, desktop computers, printers, projectors, etc.
- Data closet: computer equipment, servers, etc.
- Computer room: computers, etc.

**Elevators**

- One (1) elevator serves the building

## Specialty Systems

**Air Compressors**

- Two (2) Ingersol-Rand air compressors generate compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Retro-commissioning of HVAC systems and controls
  - Optimize HW, glycol, and CHW supply temperature reset controls
  - Optimize cooling tower water temperature control
  - Scheduling of HVAC equipment and space temperature setbacks
  - Scheduling of lab exhaust fan operation
- Implement pump differential pressure reset controls on the HW pumps, hot glycol pumps P-5 and P-6, CHW pumps, and chilled glycol pumps
- Implement duct static pressure reset controls on multi-zone VAV systems
- Implement HW and CHW supply temperature reset
- Setback equipment during academic breaks

**Capital Measures**

- Install window film for solar heat gain reduction
- Install building-level gas and steam submeters
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces, especially for Lecture Hall 315
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity, such as the corridors
- Replace exterior light fixtures with LED fixtures
- Replace existing chillers with high-efficiency water-cooled variable speed magnetic bearing chillers at end of useful life
  - R-134A refrigerant is being phased out starting January 1, 2024
  - Once manufacturing of R-134A is eliminated, the price of R-134A stock is expected to rise substantially
- If not already implemented, install a VFD on MAU-1 supply fan motor and vary speed based on number of transportation lab exhaust fans running
- Install occupancy-based HVAC controls
- Implement individual zone control on hydronic baseboard heaters
- Replace any remaining pneumatic actuators with electric actuators
- Consider implementing demand control ventilation in Lecture Hall 315
- Connect remaining building systems to BAS

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | PENFIELD LIBRARY BUILDING ASSESSMENT


## Building Description

**Building Name:** Penfield Library

**Year Constructed:** 1968

**No. of Floors:** 4

**Est. GSF:** 192,298

### Recent Building Upgrades

- Basement and first floor renovations – 2016-18
- Chiller replacement – Ongoing

### Functional Description

Penfield Library is an academic building in the center of campus. The upper two floors consist of bookstacks, offices, and study spaces arranged around a central staircase. The first floor is comprised of classrooms, offices, workrooms, conference rooms, a 24-hour study room, a broadcast studio, and a café. Staff lounges, offices, an archive, storage spaces, and main electrical and mechanical rooms are located in the basement.

### Occupancy Patterns

The building is occupied 24/7 during the academic year. Typical hours of operation for the library and café are listed in the table below. This schedule is extended during exam periods and reduced on holidays.

**Table 1. Penfield Library Hours of Operation**

| Area | Monday-Thursday | Friday | Saturday | Sunday |
|---|---|---|---|---|
| Main Library | 8:00 a.m. to 11:00 p.m. | 8:00 a.m. to 7:00 p.m. | 11:00 a.m. to 7:00 p.m. | 11:00 a.m. to 11:00 p.m. |
| Lake Effect Café | 7:30 a.m. to 6:00 p.m. | 7:30 a.m. to 5:00 p.m. | Closed | 11:00 a.m. to 6:00 p.m. |

## Building Envelope

### Roof

- Flat roof with concrete deck; no roof access during walk-through
- One (1) layer of 4” rigid insulation; insulation type and levels not accessible during walk-through

### Exterior Walls

- Concrete masonry with a concrete façade
- Insulation type and levels not accessible during walk-through

### Windows
- Tinted, single glazed, fixed, aluminum frame floor-to-ceiling windows with sheer curtains

### Doors
- Building entryway doors are clear, double glazed, aluminum frame doors

### Air Infiltration/Leakage
- No excessive infiltration was observed

## Utilities

### Electricity
- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas
- Natural gas is delivered to the building from the main campus gas service
  - Used for backup generator

### District Steam
- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building
  - One (1) condensate receiver returns condensate from Penfield Library to the Central Heating Plant

### Submeters
- This building has a campus-managed Electro Industries revenue grade electricity submeter
- This building has a campus-managed steam submeter to measure pressure, flow, and temperature of medium pressure steam entering building

## Lighting

### Interior Fixture Types
- Predominant lighting types as follows:
  - Corridors, bookstacks, and common spaces: Recessed prismatic fixtures with linear and U-tube T8 fluorescent lamps
  - Central stairwell: LED lamps
  - First floor circulation area: Square recessed fixtures with LED lamps
  - First floor café: Recessed parabolic fixtures with linear T8 fluorescent lamps and round recessed fixtures with compact fluorescent lamps (CFL)
  - First floor corridor: Pendant fixtures with linear T8 fluorescent lamps
  - Basement: Industrial fixtures with linear T8 fluorescent lamps

### Interior Lighting Controls
- No automatic controls observed during walk-through

### Exterior Lighting and Controls
- Predominant exterior lighting type is high-intensity discharge (HID)
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- One (1) shell & tube steam-to-hot-water converter HC-1 generates heating hot water (HW) for zone heating equipment
  - One (1) direct digital control (DDC), pneumatically actuated steam valve modulates HW supply temperature at the outlet of the converter
  - Hot water pumps P-5 and P-6 serve the zone heating equipment loop. Both pump motors are constant speed.
    - One (1) original Weinman double suction base-mounted centrifugal pump with a 7.5 horsepower (hp) motor, rated for 225 gallons per minute (gpm) at 75 feet of head
    - One (1) newer Bell & Gossett vertical in-line centrifugal pump with a 7.5 hp motor, rated for 225 gpm at 75 feet of head
- One (1) shell & tube steam-to-hot-water converter HC-2 generates heating HW for air handler coils
  - One (1) DDC controlled, pneumatically actuated steam valve modulates HW supply temperature at the outlet of the converter
  - Hot water pumps P-3 and P-4 operate as lead/standby for the air handler coils loop. Both pump motors are constant speed.
    - Weinman double suction base-mounted centrifugal pumps with 5 hp motors, rated for 280 gpm at 35 feet of head
- Appear to utilize reset of HW supply temperature based on outside air temperature

### Central Cooling System

- Trane 535-ton chiller generates chilled water (CHW) for building cooling in both Penfield Library and Lanigan Hall
  - Trane Model CVHE water-cooled centrifugal chiller
  - R-123 refrigerant
  - Vane guides modulate chiller capacity
  - Chilled water pumps P-1 and P-2 serve the Penfield CHW loop. Both pump motors are constant speed.
    - Weinman double suction base-mounted centrifugal pumps with 40 hp motors, rated for 1,510 gpm at 80 feet of head
  - Cooling tower fan has variable frequency drive (VFD) control of fan motor speed to maintain leaving water temperature
    - Condenser water pump with 75 hp motor, rated for 1,600 gpm at 120 feet of head

### Air Handling Units

- One (1) heating and ventilating unit HV-1
  - Constant volume multi-zone unit
  - Constant speed 15 hp supply fan motor
  - Return fan RF-4 with a constant speed 10 hp motor
  - HW preheat and heating coils with pneumatic control valves
- One (1) air handling unit AHU-1 serves the radio station
  - Constant volume multi-zone unit
  - Constant speed 1 hp supply fan motor
  - HW preheat coil; direct expansion (DX) cooling coil

    - Remote air-cooled condensing unit with 26.5 thousand Btus per hour (MBH) capacity
  - Humidifier not in service
  - Added in the late 1980's
- Seven (7) air handling units AC-1 through AC-7 serve the remainder of the building
  - Constant volume dual-duct multi-zone units with economizer controls
    - AC-1 through AC-6 each serve 6-8 zones; AC-7 serves 3 zones
  - AC-1 through AC-6 have constant speed 30 hp supply fan motors; AC-7 has a constant speed 10 hp supply fan motor
  - Return fan RF-1 with a constant speed 40 hp motor serves AC-1 through AC-3; return fan RF-2 with a constant speed 40 hp motor serves AC-4 through AC-6; return fan RF-3 with a constant speed 5 hp motor serves AC-7
  - HW preheat and heating coils with pneumatic control valves; CHW cooling coils with pneumatic control valves; electric terminal reheat coils
  - Electric duct heaters utilize discharge air temperature reset based on OA temperature
    - Minimum discharge air temperature setpoint at 55°F OA temperature
    - Maximum discharge air temperature setpoint at 85°F OA temperature

**Exhaust Systems**
- Five (5) rooftop exhaust fans with constant speed ⅛ to 1.5 hp motors serve the bathrooms
- One (1) exhaust fan with a constant speed 1.5 hp motor serves the main mechanical room

**Zone Heating/Cooling**
- Finned tube radiation provides perimeter heating; temperature control is limited to HW supply temperature reset control
- HW unit heaters serve the main mechanical room
- HW cabinet unit heaters serve the entryways and stairwells

## HVAC Controls

**Building Automation System**
- Carrier i-Vu® 8.0 and Trane Tracer® Ensemble™ building automation systems (BAS) used for monitoring, DDC, and energy management of HVAC systems
  - Only HC-1, HC-2, AHU-1, AC-1, electric reheat coils, and exhaust fans are on the BAS

**Operating Schedules**
- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**
- One (1) electric storage tank water heater
  - 47 gal/hour recovery rate
  - 80-gallon capacity

**Domestic Hot Water (DHW) Load**
- Bathroom hand sinks

- Staff lounge and café kitchenette sinks

## Piping and Ductwork

**Piping Systems/Insulation**
- Some steam piping is missing insulation in several areas
- Some condensate piping is missing insulation in several areas
- Spot observations of ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**
- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**
- Some piping leaks observed in basement mechanical room
  - Steam leak at pressure reducing valve (PRV)
  - Water leak in AC-7 HW return line
- Spot observations revealed no ductwork leakage issues

## Miscellaneous Loads

**Plug Loads**
- Offices: computers or laptops, desk phones, desk lamps, etc.
- Library and classrooms: computers, monitors, projectors, printers, etc.
- Café: one (1) beverage vending machine, cold food holding cabinet, coffee makers, etc.
- 24-hour room: two (2) beverage and snack vending machines

**Elevators**
- One (1) elevator serves the building

## Specialty Systems

**Air Compressors**
- One (1) air compressor generates compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**
- Install automatic interior lighting controls on existing LED fixtures
- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control
  - Optimize cooling tower water temperature control
  - Scheduling of HVAC equipment and space temperature setbacks
- Implement CHW supply temperature reset
- Setback equipment during academic breaks

**Capital Measures**

- Upgrade roof insulation to at least code levels during gut rehab project
- Upgrade exterior wall insulation to at least code levels during gut rehab project
- Replace single glazed windows with high performance windows
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Install VFDs on the motors of HW pumps P-5 and P-6 and CHW pumps P-1 and P-2
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Replace existing Penfield/Lanigan chiller with high-efficiency water-cooled variable speed magnetic bearing chiller
  - R-123 refrigerant is being phased out starting January 1, 2020
  - Once manufacturing of R-123 is eliminated, the price of R-123 stock is expected to rise substantially
- Replace constant volume dual duct AHUs with VAV systems during gut rehab project
- Install occupancy-based HVAC controls
- Consider installing an exhaust air energy recovery system on AC-1 through AC-6
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace pneumatic actuators with electric actuators
- Consider implementing demand control ventilation
- Connect remaining building systems to BAS

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives
- Repair piping to stop steam and water leakage
- Repair missing insulation

# SUNY OSWEGO | RICE CREEK FIELD STATION BUILDING ASSESSMENT

## Building Description

**Building Name:** Rice Creek Field Station

**Year Constructed:** 2013

**No. of Floors:** 1

**Est. GSF:** 7,500

**Recent Building Upgrades**
- None

**Functional Description**
Rice Creek Field Station is a research facility located about 1.5 miles south of the college's main campus. The one-story building, housing research and instructional spaces for the study of natural sciences and the environment, consists of a main hallway joining offices, classrooms, and labs.

**Occupancy Patterns**
The building is occupied from 8 a.m. to 4:30 p.m. on weekdays, 9 a.m. to 3 p.m. on Saturdays, and closed on Sundays.

## Building Envelope

**Roof**
- Pitched roof with photovoltaic (PV) system; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

**Exterior Walls**
- Wood paneling with lap siding and brick façade
- High-rated foam insulation

**Windows**
- Tinted, double and triple glazed, fixed, aluminum frame windows with exterior louvers
  - Large, nearly floor-to-ceiling

**Doors**
- Building entryway doors are clear, double glazed, aluminum frame doors

**Air Infiltration/Leakage**
- No excessive infiltration was observed

## Utilities

### Electricity

- This building and the adjacent pavilion have a National Grid electric service separate from the rest of the campus

### Natural Gas

- This building does not receive natural gas

### Submeters

- This building has campus-managed PV electricity submeters

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Corridor: Surface mount fixtures with linear T8 fluorescent lamps and ringed pendant fixtures
  - Classrooms, labs, and mechanical room: Surface mount and recessed prismatic fixtures with linear T5 fluorescent lamps

### Interior Lighting Controls

- Manually switched lighting in offices
- Photosensors and occupancy sensors in corridor, classrooms, and bathrooms

### Exterior Lighting and Controls

- Streetlights with LED lamps
- Exterior lights are controlled by astronomical time clocks

## HVAC

### Central Heating, Cooling, and Air Handling System

- A variable refrigerant flow (VRF) system serves the building
  - Two-pipe simultaneous heating and cooling system
  - Two (2) 12-ton outside air-cooled condensing units
    - R-410A refrigerant
    - 144 thousand Btus per hour (MBH) cooling capacities
    - 160 MBH heating capacities
    - One (1) inverter-driven scroll hermetic compressor per unit
  - Twelve indoor units
    - Ceiling cassette, wall-mounted, and ceiling concealed types
    - Rated for 200 to 2,100 cubic feet per minute (cfm)
    - 6 to 72 MBH coil capacities
  - Four (4) energy recovery ventilators (ERV) pre-condition the supply air
    - Supply fans rated for 300 to 1,200 cfm
    - Bypass and auto capabilities
    - ERV-1, ERV-2, and ERV-3 have carbon dioxide controls

    - ERV-4 is turned off when outside air (OA) humidity is greater than lockout setpoint
  - Six (6) electric heating coils maintain 40°F air temperature entering ERVs

**Exhaust Systems**
- Two small (350 cfm) in-line exhaust fans with variable speed motors serve the bathrooms
- One small (400 cfm) centrifugal exhaust fan with a constant speed motor serves the research lab
- One larger (1,350 cfm) centrifugal exhaust fan with a constant speed motor serves the wet lab

**Zone Heating/Cooling**
- Electric baseboard heaters provide perimeter heating
  - System enabled when OA temperature is below 55°F
- Electric unit heaters serve the entryway, corridor, bathrooms, and mechanical room
- Temperature control through electric wall thermostats

## HVAC Controls

**Building Automation System**
- Trane Tracer® Ensemble™ building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems

**Operating Schedules**
- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**
- One (1) electric storage tank water heater
  - Storage setpoint of 120°F observed
  - 50-gallon capacity

**Domestic Hot Water (DHW) Load**
- Bathroom hand sinks and showers
- Lab sinks, emergency showers, and eyewash stations

## Piping and Ductwork

**Piping Systems/Insulation**
- Spot observations of piping insulation revealed no remarkable deficiencies

**Equipment Insulation**
- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**
- Spot observations revealed no leakage issues

## Miscellaneous Loads

### Plug Loads

- Offices: computers or laptops, desk phones, desk lamps, etc.
- Labs and classrooms: computers, projectors, printers, desk phones, space heaters, portable fans, fume hoods, etc.
- Break room and storage room: fridges, microwaves, coffee makers, etc.

## Specialty Systems

### PV Array

- 36-kW rooftop array

## Potential Energy Efficiency Measures (EEMs)

### No Cost/Low Cost Measures

- Retro-commissioning of HVAC systems and controls
  - Scheduling of HVAC equipment and space temperature setbacks
  - Scheduling of lab exhaust fan operation
- Install low-flow or ultra low-flow showerheads

### Capital Measures

- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Consider implementing laboratory demand control ventilation
- Install a destratification fan in the welcome area

### O&M Measures

- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | RICH HALL BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | Rich Hall |
| **Year Constructed:** | 1961 |
| **No. of Floors:** | 3 |
| **Est. GSF:** | 53,742 |

**Recent Building Upgrades**
- Roof replacement – 2016

**Functional Description**
Rich Hall is an academic building on the east side of campus housing the school of business and the departments of accounting, finance, & law and marketing & management. The top floor consists of classrooms, a computer lab, faculty suites, and a mechanical room. The second floor is comprised of classrooms, seminar rooms, faculty suites, a café, and a lounge. Additional faculty suites and the main electrical and mechanical rooms are located on the first floor.

**Occupancy Patterns**
During the academic year, Rich Hall is occupied from 8 a.m. to 9 p.m. Monday through Thursday, 8 a.m. to 4 p.m. on Fridays, and closed on weekends.

## Building Envelope

**Roof**
- Flat roof with SBS modified bituminous membrane
- Insulation type and levels not accessible during walk-through

**Exterior Walls**
- Concrete masonry with a brick façade
- Insulation type and levels not accessible during walk-through

**Windows**
- Tinted, double glazed, fixed, aluminum frame windows
  - Interior window shades in most offices and classrooms
  - Eastern side of the building and main vestibule have some large, floor-to-ceiling windows

**Doors**
- Building entryway doors are tinted, double glazed, aluminum frame doors

**Air Infiltration/Leakage**
- Signs of excessive infiltration observed in main vestibule

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for backup generator and makeup air unit with gas-fired furnace section

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building
  - Two (2) condensate receivers, each with two (2) pumps, return condensate from Rich Hall to the Central Heating Plant

### Submeters

- This building has a campus-managed Electro Industries revenue grade electricity submeter

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Faculty suites: Parabolic troffer fixtures with linear fluorescent lamps
  - Classrooms: Classrooms not accessible during walk-through
  - Café: Recessed and track fixtures with compact fluorescent lamps (CFL)
  - Corridors: Volumetric fixtures with linear T8 fluorescent lamps
  - Main entryway: Pendant fixtures with linear fluorescent lamps and surface mount fixtures with CFLs
  - Mechanical rooms: Surface mount fixtures with linear fluorescent lamps

### Interior Lighting Controls

- No automatic controls observed during walk-through

### Exterior Lighting and Controls

- Predominant exterior lighting type is high-intensity discharge (HID)
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- One (1) shell & tube steam-to-hot-water converter generates heating hot water (HW) for building heating
  - One (1) two-way direct digital control (DDC), electronically actuated steam valve modulates HW supply temperature at the outlet of the converter. One (1) mixing valve controls supply temperature to the primary HW pumps.
    - Primary hot water pumps P-1 and P-2 circulate HW to AHU-1 and to the secondary HW pumps. Both primary HW pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure.

        - Bell & Gossett base-mounted centrifugal pumps with 3 horsepower (hp) motors, rated for 300 gallons per minute (gpm) at 27 feet of head
    - Secondary hot water pumps P-3 and P-4 circulate HW through the secondary HW loop. Both secondary HW pump motors are constant speed.
        - Bell & Gossett in-line centrifugal pumps with 7.5 hp motors, rated for 240 gpm at 60 feet of head
- System is enabled when outside air (OA) temperature is below 90°F
- HW supply temperature is reset based on OA temperature
    - 180°F supply temperature at 0°F OA temperature
    - 100°F supply temperature at 60°F OA temperature

**Central Cooling System**

- Trane 130-ton chiller generates chilled water (CHW) for building cooling
    - Trane Model RTAA air-cooled rotary screw chiller
    - R-22 refrigerant
    - Two (2) compressors; remote condenser
    - Two (2) chilled water pumps circulate CHW through the CHW loop. CHW pump motors are constant speed.
        - Bell & Gossett base-mounted centrifugal pumps with 5 hp motors, rated for 305 gpm at 35 feet of head
    - System is enabled when OA temperature is above 55°F

**Air Handling Units**

- One (1) rooftop heating and ventilating unit MU-1 provides make-up air to the third-floor mechanical room
    - Trane 100% OA unit
    - Blower with constant speed 1 hp motor
    - Power vented, gas-fired furnace section
    - 150 thousand Btus per hour (MBH) input
    - Time-of-day scheduling controls, integrated with exhaust fan EF-13
- Two (2) ventilating units AHU-3 and AHU-4 provide make-up air to the two (2) electrical rooms
    - Constant volume single-zone units
    - Constant speed supply fan motors
    - Controls integrated with exhaust fans and unit heaters serving the two (2) spaces
- Two (2) air handling units AHU-1 and AHU-2 serve the remainder of the building
    - Multi-zone variable air volume (VAV) units with economizer controls
    - Supply fan motors controlled by VFDs to maintain duct static pressure
    - Return fan motors controlled by VFDs to track supply fan VFDs
    - HW heating coils with 3-way electronic control valves; CHW cooling coils with 3-way electronic control valves
        - Two (2) parallel in-line circulating pumps with fractional hp motors operate as lead/standby for the HW coil on each unit and protect the coil from freezing
        - CHW valve position setpoints overridden to 50% open during walk-through
    - Economizers are enabled when OA temperature is below 70°F
    - Discharge air temperature is reset based on OA temperature
        - 65°F discharge air temperature at 40°F OA temperature

- 55°F discharge air temperature at 65°F OA temperature

**Exhaust Systems**

- Two (2) exhaust fans with constant speed motors serve the electrical rooms
  - Controls integrated with AHU-3, AHU-4, and electrical room unit heaters
- Four (4) exhaust fans with constant speed motors serve the mechanical rooms
  - EF-13 has time-of-day scheduling controls, integrated with MU-1
- Eight (8) general exhaust fans with constant speed motors serve the building

**Zone Heating/Cooling**

- VAV boxes provide airflow to nearly all rooms and common spaces
- Unit heaters serve the electrical and mechanical rooms; HW zone control valves modulate to maintain space temperature setpoints
- Cabinet unit heaters serve the entryways and stairwells; HW zone control valves modulate to maintain space temperature setpoints

## HVAC Controls

**Building Automation System**

- Trane Tracer® Ensemble™ building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems

**Operating Schedules**

- Air handling units and unit heaters are scheduled to operate in occupied mode 24/7. Exhaust fans are scheduled to operate in occupied mode from 6 a.m. to 11 p.m. daily.

## Domestic/Service Water Heating

**Domestic Water Heaters**

- Primary domestic hot water (DHW) system is one (1) steam bundle storage tank
  - One (1) two-way electric control valve
  - One (1) small in-line pump circulates DHW
  - Manufactured 2002
  - Storage setpoint of 120°F observed
- Alternate DHW system is one (1) electric storage tank water heater
  - 80-gallon capacity
  - One (1) small in-line pump circulates DHW

**DHW Load**

- Bathroom hand sinks
- Café sink

## Piping and Ductwork

**Piping Systems/Insulation**

- Condensate piping is missing insulation in the first-floor mechanical room

- Steam piping is missing insulation in the first-floor mechanical room
- Spot observations of ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**
- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**
- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug Loads**
- Offices: computers or laptops, desk phones, desk lamps, etc.
- Classrooms: computers, monitors, projectors, etc.
- Café: cooler, holding cabinets, coffee makers, etc.

**Elevators**
- One (1) elevator serves the building

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**
- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control
  - Revert overridden CHW valve setpoints on AHU-1 and AHU-2 to default values
  - Scheduling of HVAC equipment and space temperature setbacks
- Implement pump differential pressure reset controls on the primary HW pumps
- Implement CHW supply temperature reset
- Implement duct static pressure reset controls on AHU-1 and AHU-2
- Setback equipment during academic breaks

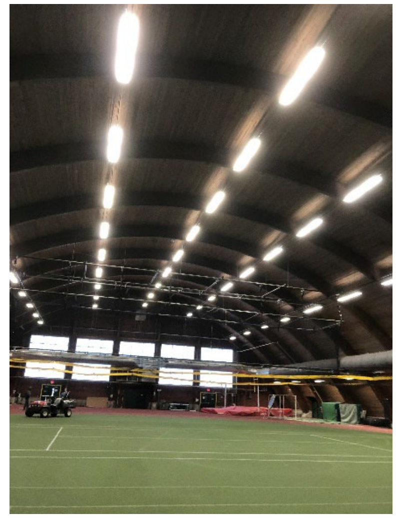
**Capital Measures**
- Install window film for solar heat gain reduction
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Replace existing chiller with high-efficiency air-cooled variable speed magnetic bearing chiller
  - R-22 refrigerant was phased out in 2020
- Replace AHU-1 and AHU-2 coil pumps and motors with electronically commutated motors
- Install occupancy-based HVAC controls
- Install a destratification fan in entrance landing/vestibule
- Replace steam bundle DHW heater with semi-instantaneous water heater

- Replace DHW circulating pumps and motors with electronically commutated motors

**O&M Measures**

- Repair or replace doors, windows, and weather seals in main vestibule to prevent air infiltration
- Change v-belt fan drives to cogged belt fan drives
- Repair missing insulation

# SUNY OSWEGO | ROMNEY FIELD HOUSE BUILDING ASSESSMENT



## Building Description

**Building Name:** Romney Field House

**Year Constructed:** 1962

**No. of Floors:** 1

**Est. GSF:** 55,000

### Recent Building Upgrades

- Full building renovation – 2013

### Functional Description

Romney Field House is located next to the Laker Hall athletic facility on the southern side of Route 104 and serves SUNY Oswego athletics. Romney houses an indoor turf and track, offices, mechanical spaces, storage spaces, and bathrooms.

### Occupancy Patterns

Romney Field House is open to the public from 11 a.m. to 12:30 p.m. Tuesday through Thursday. At other weekday times and on the weekends, the field house is used regularly for various sport practices.

## Building Envelope

### Roof

- Curved roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Metal exterior skin
- Insulation type and levels not accessible during walk-through

### Windows

- Large, single glazed windows at both ends of field house

### Doors

- Building entryway doors are two (2) sets of metal framed, glass doors

### Air Infiltration/Leakage

- Signs of excessive infiltration observed at the entryway
  - Result of a broken door latch

## Utilities

### Electricity
- The building has a National Grid electric service separate from the rest of the campus

### Natural Gas
- The building has a National Grid gas service separate from the rest of the campus
  - Used for space heating and domestic hot water heating

### District Steam
- This building does not receive steam from the Central Heating Plant

### Submeters
- None observed during walk-through

## Lighting

### Interior Fixture Types
- Predominant lighting types as follows:
  - Main field house: High bay pendant fixtures and linear T8 fluorescent lighting
  - Entry vestibule: Fluorescent tri-tube lighting
  - Bathrooms: Linear T8 fluorescent lighting and T8 fluorescent vanity lights
  - Corridors: F32 T8 fluorescent lighting and compact fluorescent lamps (CFL)

### Interior Lighting Controls
- Bi-level lighting in field house
- No other automatic controls observed during walk-through

### Exterior Lighting and Controls
- LED wall pack fixtures
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System
- One (1) natural gas-fired boiler generates heating hot water (HW) used for building space heating
  - HW supplied to air handler heating coil
- One (1) cast-iron sectional boiler
  - Abandoned in place; natural gas line is disconnected

### Central Cooling System
- No space cooling in this building

### Air Handling Units
- One (1) air handling unit AHU-1, located outside, serves the building
  - Constant speed supply fan motor

- HW heating coil
- Heating is enabled when the lowest space temperature falls below the minimum space temperature setpoint
- Long, perforated supply air ductwork runs along the interior sides of the building

**Exhaust Systems**
- None observed during walk-through

**Zone Heating/Cooling**
- HW unit heaters serve storage rooms, bathrooms, and the entry vestibule
  - Winter/summer zone control for heating terminal equipment HW loop

## HVAC Controls

**Building Automation System**
- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems
  - Domestic hot water (DHW) system is not on the BAS

**Operating Schedules**
- Operating schedules could not be verified during walk-through

## Domestic/Service Water Heating

**Domestic Water Heaters**
- One (1) boiler generates DHW and HW for the heating terminal equipment
  - Weil-McLain natural gas-fired hot water boiler
  - External DHW storage tank
  - Two (2) circulating pumps
- One (1) indirect, steam-fired tank water heater and one (1) electric water heater
  - Abandoned in place

**DHW Load**
- Bathroom hand sinks and showers

## Piping and Ductwork

**Piping Systems/Insulation**
- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**
- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**
- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug loads**
- Offices: computers or laptops, desk phones, desk lamps, etc.
- Main field house: athletic equipment (i.e., speakers, ball machine, etc.)

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**
- Retro-commissioning of HVAC systems and controls
  - Scheduling of HVAC equipment and space temperature setbacks
- Implement HW supply temperature reset
- Setback equipment during academic breaks
- Install low-flow or ultra low-flow showerheads

**Capital Measures**
- Replace single glazed windows with high performance windows
- Install building-level gas submeter
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Convert AHU-1 to single zone variable air volume (VAV) system by installing VFD on system and implementing a temperature-based control scheme to modulate airflow
- Consider installing an energy recovery system
- Consider implementing demand controlled ventilation of the field house
- Consider installing destratification fans in the main field house
- Connect remaining building systems to BAS
- Replace DHW heater with semi-instantaneous water heater
- Replace DHW circulating pumps and motors with electronically commutated motors

**O&M Measures**
- Repair door latch at main entryway to prevent air infiltration
- Remove equipment no longer in use (i.e., DHW heaters, gas-fired steam boiler)
- Change any v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | SHELDON HALL BUILDING ASSESSMENT

## Building Description

**Building Name:** Sheldon Hall

**Year Constructed:** 1912

**No. of Floors:** 3 + Basement + Attic

**Est. GSF:** 119,211

### Recent Building Upgrades

- Exterior renovation – 2012

### Functional Description

Sheldon Hall is a mixed-use academic building on the east side of campus that houses classrooms, offices (including the Admissions Office), guest rooms, a ballroom, a lecture hall, and a children's center. The ballroom is used as a meeting/event space and has a capacity of 350 people.

### Occupancy Patterns

The building is occupied from 6 a.m. to 9 p.m. daily during the academic year.

## Building Envelope

### Roof

- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Brick façade
- Insulation type and levels not accessible during walk-through

### Windows

- Double glazed, metal frame windows with a thermal break
  - Most windows are operable

### Doors

- Building entryway doors are wooden doors with single glazed windows

### Air Infiltration/Leakage

- No excessive infiltration was observed

## Utilities

### Electricity

- The building has a National Grid electric service separate from the rest of the campus

### Natural Gas

- The building has a National Grid gas service separate from the rest of the campus
  - Used for domestic hot water (DHW) heating

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building
  - One (1) duplex condensate unit returns condensate from Sheldon Hall to the Central Heating Plant

### Submeters

- None observed during walk-through

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Ballroom: Recessed fluorescent lighting with dimming switch
  - Corridors: Pendant T8 fluorescent fixtures with electronic ballasts, recessed ceiling T8 fluorescent fixtures with electronic ballasts, and surface mount T8 fluorescent fixtures with electronic ballasts
  - Classrooms and offices: Recessed ceiling T8 fluorescent fixtures with electronic ballasts
  - Mechanical rooms: 2F32 T8 industrial fixtures with electronic ballasts

### Interior Lighting Controls

- Primarily manually switched lighting, dimming switches and occupancy sensors in limited spaces

### Exterior Lighting and Controls

- Clock tower lights and high-intensity discharge (HID) wall pack fixtures
  - Exterior lights on campus are controlled by photosensors and astronomical time clocks
- Sheldon Hall canopy lighting is scheduled on at 11 p.m. and off at 6 a.m. daily

## HVAC

### Central Heating System and Heat Pump Loop

- One (1) shell & tube steam-to-hot-glycol converter HX-1 generates hot glycol for building heating in Sheldon Hall’s west wing
  - Bell & Gossett heat exchanger
  - 1/3 & 2/3 pneumatic steam valves modulate glycol supply temperature at the outlet of the converter
  - Hot glycol pumps P-7 and P-8 circulate hot glycol to air handler heating coils
    - In-line centrifugal pumps with 3 horsepower (hp) motors
  - 5 psi float and thermostatic steam trap
  - 35% propylene glycol storage tank
- One (1) shell & tube steam-to-hot-water converter HX-2 generates heating hot water (HW) for building heating in Sheldon Hall’s west wing
  - Bell & Gossett heat exchanger
  - 1/3 & 2/3 pneumatic steam valves modulate HW supply temperature at the outlet of the converter
  - Hot water pumps P-9 and P-10 circulate HW to variable air volume (VAV) box reheat coils

    - In-line centrifugal pumps with 1.5 hp motors
  - 5 psi float and thermostatic steam trap
- One (1) steam-to-hot-water converter generates HW for building heating in Sheldon Hall's east and central wings
  - Pumps P-1 and P-2 serve the heat pump loop
    - Base-mounted pumps with 15 hp motors, rated for 465 gallons per minute (gpm) at 80 feet of head
  - The low limit setpoint to add heat to the heat pump loop could not be determined during the walk-through
  - Heat is rejected to a cooling tower; the high limit setpoint to reject heat from the heat pump loop could not be determined during the walk-through

**Central Cooling System**
- Carrier 93.6-ton chiller generates chilled water (CHW) for building cooling in Sheldon Hall's west wing
  - Carrier water-cooled screw chiller
  - R-134A refrigerant
  - Chilled water pumping arrangement is constant flow primary/variable flow secondary. Chilled water pumps P-3 and P-4 serve the primary CHW loop. Chilled water pumps P-5 and P-6 serve the secondary CHW loop.
    - P-3 and P-4 have 3 hp motors
    - P-5 and P-6 have 5 hp motors. Secondary pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure.
  - One (1) condenser water pump circulates condenser water between the chiller condenser and the cooling tower
    - 7.5 hp pump motor
  - Baltimore Air Cooler cooling tower fan has VFD control of fan motor speed to maintain leaving water temperature
    - 10 hp fan motor

**Air Handling Units**
- Four (4) air handling units AHU-1 through AHU-4, located in the west attic, serve Sheldon Hall's west wing
  - Multi-zone VAV units
    - Each unit serves 8-11 VAV boxes
  - 7.5 hp supply fan motors controlled by VFDs to maintain duct static pressure
  - 3 hp return fan motors controlled by VFDs to track supply fan VFDs
  - Hot glycol heating coils; CHW cooling coils; HW terminal reheat coils at the VAV boxes

**Exhaust Systems**
- Four (4) exhaust fans serve bathrooms
  - Two (2) fans rated for 75 cubic feet per minute (cfm)
  - Two (2) attic belt-drive fans with 3 hp motors, rated for 700-950 cfm
- One (1) exhaust fan serves the chiller
  - Roof exhauster with a 3 hp motor, rated for 1,280 cfm

**Zone Heating/Cooling**

- VAV boxes with HW reheat coils provide airflow to rooms in Sheldon Hall's west wing
- Three (3) cabinet unit heaters serve vestibules and a staircase
- One (1) hydronic unit heater serves a mechanical room

## HVAC Controls

**Building Automation System**

- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems

**Operating Schedules**

- HVAC systems are scheduled to operate in occupied mode from 5 a.m. to 10 p.m. daily

## Domestic/Service Water Heating

**Domestic Water Heaters**

- Two (2) natural draft, natural gas-fired water heaters with four (4) external storage tanks
  - Glass-lined commercial storage tanks, each with a 140-gallon capacity

**DHW Load**

- Bathroom hand sinks

## Piping and Ductwork

**Piping Systems/Insulation**

- Some HW piping was missing insulation
- Spot observations of DHW piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**

- A steam-to-hot-water converter was missing insulation

**Piping and Ductwork Leaks**

- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug loads**

- Offices: computers or laptops, desk phones, desk lamps, etc.
- Common spaces: vending machines

**Elevators**

- One (1) elevator serves the building

## Specialty Systems

**Air Compressors**

- One (1) air compressor generates compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Retro-commissioning of HVAC systems and controls
  - Optimize heat pump loop setpoints
  - Optimize cooling tower water temperature control
  - Scheduling of HVAC equipment and space temperature setbacks
- Implement pump differential pressure reset controls on the secondary CHW pumps
- Implement HW and CHW supply temperature reset
- Implement duct static pressure reset controls on AHU-1 through AHU-4
- Setback equipment during academic breaks

**Capital Measures**

- Install window film for solar heat gain reduction
- Install building-level steam submeter
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces, especially for the ballroom
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Replace existing chiller with high-efficiency water-cooled variable speed magnetic bearing chiller
  - R-134A refrigerant is being phased out starting January 1, 2024
  - Once manufacturing of R-134A is eliminated, the price of R-134A stock is expected to rise substantially
- Install VFDs on HW pumps and Glycol pumps and control based on differential pressure
- If not already implemented, consider implementing economizer controls on AHU-1 through AHU-4
- Where not already implemented, install occupancy-based HVAC controls
- Replace pneumatic actuators with electric actuators
- Consider implementing demand control ventilation in the classrooms, ballroom, and lecture hall
- Replace DHW heaters with semi-instantaneous water heaters

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives
- Repair missing insulation

# SUNY OSWEGO | RICHARD S. SHINEMAN CENTER BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | Richard S. Shineman Center |
| **Year Constructed:** | 2013 |
| **No. of Floors:** | 4 + Basement |
| **Est. GSF:** | 235,860 |

**Recent Building Upgrades**

- LEED Gold certified

**Functional Description**

The Richard S. Shineman Center is a science and engineering academic building in the center of campus which houses classrooms, lecture halls, common spaces, a café, laboratories, offices, a planetarium, and a greenhouse. The building has multiple sustainable energy features including rooftop solar panels, wind turbines, and a geothermal energy system. There are electric vehicle charging stations in the Shineman Center parking lot.

**Occupancy Patterns**

Shineman has fluctuating levels of occupancy throughout the day. The building has higher occupancy on weekdays from 8 a.m. to 9 p.m. during the academic year.

## Building Envelope

**Roof**

- Built-up flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

**Exterior Walls**

- Concrete and brick façades
- Insulation type and levels not accessible during walk-through

**Windows**

- Double glazed, metal frame windows
- Skylights in main lobby

**Doors**

- Building entryway doors are clear, double glazed, aluminum frame doors

**Air Infiltration/Leakage**

- No excessive infiltration was observed

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for chemistry lab equipment and backup generator

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

### Submeters

- This building has a campus-managed steam submeter to measure pressure, flow, and temperature of medium pressure steam entering building
- This building has campus-managed Btu submeters on the building geothermal loop

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Café: F26 TT compact fluorescent fixtures with electronic ballasts
  - First-floor lobby: Recessed F26 TT compact fluorescent fixtures with electronic ballasts, recessed and pendant LED fixtures, wall mount T5 fluorescent fixtures with electronic ballasts, and track mount metal halide fixtures with electronic ballasts
  - Lab classrooms: Recessed troffer fixtures with T8 fluorescent lamps and electronic ballasts
  - Non-lab classrooms: Recessed troffer and pendant fixtures with T8 fluorescent lamps and electronic ballasts and recessed wall mount fixtures with T5 fluorescent lamps
  - Corridors: Ceiling surface mount fixtures with T8 fluorescent lamps and electronic ballasts and recessed troffer fixtures with T8 fluorescent lamps and electronic ballasts
  - Offices: Recessed troffer fixtures with T8 fluorescent lamps and electronic ballasts
  - Lecture Hall (Room 1022): Pendant TT compact fluorescent fixtures with electronic ballasts and pendant fixtures with T5 fluorescent lamps and dimming switches
  - Conference room (Room 1024): Recessed TT compact fluorescent fixtures with dimming switches
  - Stairwells: Wall mount and recessed troffer fixtures with T5 fluorescent lamps and electronic ballasts
  - Elevator lobby: Recessed troffer fixtures with T5 fluorescent lamps and electronic ballasts
  - Bathrooms: Surface mount and pendant fixtures with T8 fluorescent lamps and electronic ballasts
  - Mechanical room: Industrial fixtures with T8 fluorescent lamps and electronic ballasts
  - Wilber connector (enclosed walkway): Recessed troffer fixtures with T5 fluorescent lamps and electronic ballasts
  - Entry vestibules: Recessed fixtures with T5 fluorescent lamps and compact fluorescent lamps (CFLs) and electronic ballasts

### Interior Lighting Controls

- Lecture Hall 1022 has dimming controls and bi-level lighting

- Some classrooms and conference room 1024 have dimming controls
- Daylighting controls in stairwell
- Lighting in most areas is scheduled on at 6 a.m. and off at 12 a.m. daily

**Exterior Lighting and Controls**
- T5 fluorescent wall pack and wall sconce fixtures with electronic ballasts
- Entryway lighting and exterior HDs are controlled by photosensors

## HVAC

**Geothermal Loop**
- 240 boreholes at 499 feet deep
- Primary pumps P-13 and P-14 circulate 18% glycol through the borefield. Both pumps have variable frequency drive (VFD) control of pump motor speed.
  - 100 horsepower (hp) motors

**Dual Temperature Loop**
- Two (2) Multistack 560-ton chillers CH-1 and CH-2 serve as modular heat pumps
  - Eight (8) modules each
  - Units produce either heating hot water (HW) at 120°F or chilled water (CHW) at 45°F on the *load* side, and use *source* water for heat extraction or heat rejection
  - Primary pumps P-11 and P-12 serve the primary dual temperature loop and secondary pumps P-7 and P-8 circulate water from the dual temperature loop to air handler coils. All four (4) dual temperature pumps have VFD control of pump motor speed based on differential pressure.
    - P-11 and P-12 have 50 hp motors and are rated for 2,300 gallons per minute (gpm) at 56 feet of head
    - P-7 and P-8 have 100 hp motors and are rated for 2,300 gpm at 99 feet of head
  - Pumps P-9 and P-10 circulate *source* water for either heat rejection or heat extraction, depending on the dual temperature loop mode of operation. Both *source* water pumps have VFD control of pump motor speed based on differential pressure.
    - P-9 and P-10 have 75 hp motors and are rated for 3,225 gpm at 50 feet of head
  - Heating mode is enabled whenever the outside air (OA) temperature is below 60°F for 12 hours or longer
  - The dual temperature loop transitions to cooling mode whenever the OA temperature is above 60°F for 12 hours or longer
- Geothermal field pumps P-13 and P-14 (described in the Geothermal Loop section)
- Flow is modulated by the geothermal field pump (P-13 and P-14, described in the Geothermal Loop section) VFDs to maintain the *source* water at 47°F when the system is in heating mode, or at 87°F when the system is in cooling mode

**Central Heating System**
- Two (2) shell & tube steam-to-hot-water converters HX-1 and HX-2 generate HW for building heating. One (1) converter generates HW while the other is for redundancy.
  - 1/3 & 2/3 direct digital control (DDC), pneumatically actuated steam valves modulate to supply HW at 120°F

- Primary pumps P-1 and P-2 serve the primary HW loop and secondary pumps P-5 and P-6 circulate HW to the finned tube radiation loop, cabinet unit heaters, and air handler reheat coils. All four (4) HW pumps have VFD control of pump motor speed based on differential pressure.
  - P-1 and P-2 have 20 hp motors and are rated for 708 gpm at 60 feet of head
  - P-5 and P-6 have 30 hp motors and are rated for 708 gpm at 83 feet of head
- Drawings show there is a changeover valve that can provide HW from the dual temperature loop to supplement HX-1 and HX-2. However, the sequence of operations is not clear under what conditions this can be done.
- Two (2) shell & tube steam-to-hot-glycol converters HX-3 and HX-4 generate hot glycol for building heating. One (1) converter generates hot glycol while the other is for redundancy.
  - 1/3 & 2/3 DDC, pneumatically actuated steam valves modulate glycol supply temperature at the outlet of the converter
  - Hot glycol pumps P-3 and P-4 circulate hot glycol to air handler preheat coils. Both glycol pumps have VFD control of pump motor speed based on differential pressure.
    - P-3 and P-4 have 20 hp motors and are rated for 600 gpm at 71 feet of head
  - Glycol supply temperature is reset based on OA temperature
    - 180°F supply temperature at 0°F OA temperature
    - 140°F supply temperature at 60°F OA temperature

**Central Cooling System**

- One (1) rooftop dry cooler serves air handling units AC-1 and AC-2 which provide cooling to the chemistry NMR room

**Air Handling Units**

- Two (2) air handling units AHU-1 and AHU-2 serve non-lab spaces throughout the building
  - Multi-zone variable air volume (VAV) units with enthalpy economizers
  - Supply fan motor controlled by VFD to maintain duct static pressure
    - Static pressure is reset
  - Return fan motor controlled by VFD to track supply fan VFD
  - Hot glycol preheat coil; two-pipe dual temperature heating/cooling coil
    - Units operate in heating or cooling mode based on the dual temperature loop mode of operation. The units discharge 70°F air in heating mode and 55°F air in cooling mode.
  - OA flow is varied based on the difference between the amount of carbon dioxide sensed in the OA air and return air
- Two (2) air handling units AHU-3 and AHU-4 serve lab spaces throughout the building
  - 100% OA multi-zone variable air volume (VAV) units
  - Supply fan motor controlled by VFD to maintain duct static pressure
    - Static pressure is reset
  - Return fan motor controlled by VFD to track supply fan VFD
  - Hot glycol preheat coil; two-pipe dual temperature heating/cooling coil
    - Units operate in heating or cooling mode based on the dual temperature loop mode of operation. The units discharge 70°F air in heating mode and 55°F air in cooling mode.
  - Units operate in conjunction with exhaust fans LEF-1, LEF-2, LEF-3, and LEF-4
  - Heat recovery units served by a glycol runaround loop recover heat from lab exhaust to precondition the OA provided to AHU-3 and AHU-4
    - Heat recovery units modulate to maintain AHU-3 and AHU-4 discharge air temperatures

    - Glycol runaround loop pumps P-15 and P-16 circulate glycol between a heat recovery coil in the lab exhaust air stream and heat transfer coils in AHU-3 and AHU-4. Both glycol pumps have VFD control of pump motor speed based on differential pressure.
        - P-15 and P-16 have 15 hp motors and are rated for 275 gpm at 96 feet of head
    - Glycol runaround loop is enabled when the OA temperature is below 55°F and above 80°F
- Penthouse air handling units; AHU-5 and AHU-6 operate in parallel and serve Trane TU VAV boxes
    - 100% OA units
    - Supply fan motor controlled by VFD
    - Duct static pressure setpoint is set by critical zone reset
    - Hot glycol preheat coil; two-pipe dual temperature heating/cooling coil
        - Units operate in heating or cooling mode based on the dual temperature loop supply temperature. The units operate in heating mode when the supply temperature is above 110°F and operate in cooling mode when the supply temperature is less than 55°F.
    - One (1) heat recovery unit serves AHU-5 and AHU-6

**Exhaust Systems**

- Three (3) exhaust fans EF-3, EF-4, and EF-5 serve the atrium
- Eight (8) exhaust fans serve the labs
    - Constant volume fans connected to common exhaust plenum. Plenum bypass dampers are modulated to maintain system static pressure and to maintain discharge velocity from each fan at a minimum of 4,000 FPM.
    - LEF-1, LEF-2, LEF-3, and LEF-4 controls integrated with AHU-3 and AHU-4
    - LEF-7, LEF-8, LEF-9, and LEF-10 controls integrated with AHU-5 and AHU-6
    - All lab hoods exhaust to common exhaust plenum
        - Occupancy sensor in hoods to setback face velocity when no occupancy is detected

**Zone Heating/Cooling**

- VAV boxes provide airflow to individual rooms
- Finned tube radiation provides perimeter heating
- Radiant floor heating in vestibule is enabled when the OA temperature is less than 60°F. One (1) 100% return air unit ventilator with a dual temperature coil provides additional heating and cooling.
- Unit ventilators serve common spaces and corridors
- Fan coil units (FCU) provide heating and cooling in corridors

## HVAC Controls

**Building Automation System**

- Carrier i-Vu® 8.0 and Trane Tracer® Ensemble™ building automation systems (BAS) used for monitoring, DDC, and energy management of HVAC systems

**Operating Schedules**

- Room 175 HVAC equipment is scheduled to operate in occupied mode from 6 a.m. to 11 p.m. daily
- Other HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**

- Domestic hot water (DHW) system was not observed during walk-through

**DHW Load**

- Bathroom hand sinks
- Café sink
- Lab sinks, showers, and eye wash stations

## Piping and Ductwork

**Piping Systems/Insulation**

- Connection for the dual temperature supply and return piping on AHU-4 was observed to be missing
- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**

- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug Loads**

- Offices: computers or laptops, desk phones, desk lamps, etc.
- Library and classrooms: computers, monitors, projectors, printers, etc.
- Café: cold food holding cabinet, coffee makers, etc.
- Specialty rooms: greenhouse equipment, planetarium equipment, etc.
- Labs: autoclave, lab hoods, sinks, emergency showers, eye wash stations, etc.
- Common spaces: vending machines

**Elevators**

- Three (3) elevators serve the building

## Specialty Systems

**Lab Equipment**

- One (1) cold room with independent refrigeration system
- Approximately 44 refrigerators and freezers in lab rooms throughout the building
- Autoclaves

**Air Compressors**

- One (1) air compressor located in the basement mechanical room generates compressed air for labs
- One (1) air compressor located in the greenhouse mechanical room generates compressed air for pneumatic controls on steam converters

**Photovoltaic (PV) Array**

- Approximately 20 kilowatt (kW) rooftop array
- Five (5) inverters in the fourth-floor electrical room

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Install automatic interior lighting controls on existing LED fixtures
- Retro-commissioning of HVAC systems and controls
  - Optimize hot glycol supply temperature reset control
  - Scheduling of HVAC equipment and space temperature setbacks
- Implement pump differential pressure reset controls on the geothermal field, dual temperature loop, HW, and hot glycol pumps
- Implement HW supply temperature reset
- Setback equipment during academic breaks
- If not already implemented, install low-flow or ultra low-flow showerheads

**Capital Measures**

- Consider installing window film for solar heat gain reduction
- Install building-level steam submeter
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity, such as the main lobby, which has skylights
- Replace exterior light fixtures with LED fixtures
- If not already implemented, install occupancy-based HVAC controls
- Replace pneumatic actuators with electric actuators
- If not already implemented, consider implementing demand control ventilation in lecture hall and planetarium spaces
- Consider implementing laboratory demand control ventilation

**O&M Measures**

- Change any v-belt fan drives to cogged belt fan drives
- Replace missing coil connection for dual temperature supply and return on AHU-4

# SUNY OSWEGO | TYLER HALL BUILDING ASSESSMENT

## Building Description

**Building Name:** Tyler Hall

**Year Constructed:** 1968

**No. of Floors:** 2 + Basement

**Est. GSF:** 115,430

**Recent Building Upgrades**
- Full building renovation – 2020
- Exterior renovation – 2007
- LEED Gold certified – May 2017

**Functional Description**
Tyler Hall is a fine arts academic building in the center of campus housing classrooms, studio spaces, lobby areas, galleries, and an auditorium.

**Occupancy Patterns**
Tyler Hall has fluctuating levels of occupancy throughout the day. The building has higher occupancy on weekdays during the academic year when classes/studios are in session.

## Building Envelope

**Roof**
- Flat roof
  - Broken panel observed during walk-through
- Insulation type and levels not accessible during walk-through

**Exterior Walls**
- Walls renovated during exterior renovation in 2007
- Insulation type and levels not accessible during walk-through

**Windows**
- Double glazed, aluminum frame windows

**Doors**
- Building entryway doors are two (2) sets of glass double doors

**Air Infiltration/Leakage**
- No excessive infiltration was observed

## Utilities

### Electricity
- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas
- Natural gas is delivered to the building from the main campus gas service
  - Two (2) pressure reducing valves on the building natural gas line
  - No natural gas equipment observed during walk-through

### District Steam
- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building by two (2) pressure reducing valves (PRV) operating in parallel with a bypass

### Submeters
- This building has a campus-managed Honeywell submeter on the building natural gas line

## Lighting

### Interior Fixture Types
- Predominant lighting types as follows:
  - Lobby: Recessed ceiling fixtures with compact fluorescent lamps (CFL) and pendant LED fixtures
  - Stage level
    - Corridors: 2x2 recessed low-profile LED fixtures with dimming switches
    - Auditorium: Linear pendant LED fixtures
    - Changing room: Linear pendant LED fixtures with dimming switches and 2x4 recessed LED fixtures with dimming switches
    - Bathrooms: LED vanity fixtures
  - Commons level
    - Classrooms and studios: Linear pendant LED fixtures
    - Offices: 2x2 recessed low-profile LED fixtures with dimming switches
    - Corridors: Recessed LEDs with aluminum housing
    - Bathrooms: Recessed downlight LEDs
    - Costume shop: Linear pendant LED fixtures with dimming switches
  - Second floor
    - Classrooms: Linear pendant LED fixtures
    - Offices: Linear pendant LED fixtures
    - Corridors: 2x2 recessed low-profile LED fixtures with dimming switches
    - Bathrooms: Recessed downlight LEDs
  - Stairwells: Pendant LED fixtures

### Interior Lighting Controls
- Occupancy sensors in most common spaces
- Interior lighting is scheduled on at 6 a.m. and off at 11 p.m. daily

**Exterior Lighting and Controls**

- LEDs on pathway along building perimeter
- Exterior lighting is scheduled on at 7 p.m. and off at 7 a.m. daily
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

**Central Heating System**

- One (1) steam-to-hot-water converter generates heating hot water (HW) for building heating
  - 1/3 & 2/3 direct digital control (DDC), electronically actuated Belimo steam valves modulate HW supply temperature at the outlet of the converter
  - Hot water pumps HWP-1 and HWP-2 operate as lead/standby for the air handler heating coils loop. HW pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure.
    - Bell & Gossett base-mounted centrifugal pumps with 15 horsepower (hp) motors
  - Hot water pumps HWP-3 and HWP-4 circulate HW to the northeast and southwest finned tube radiation loops, respectively. HW pumps have VFD control of pump motor speed based on differential pressure.
    - Both HWP-3 and HWP-4 were observed to be operating at 100% speed during walk-through and later building automation system (BAS) observations
  - HW supply temperature is reset based on outside air (OA) temperature
    - 185°F HW supply temperature at 0°F OA temperature
    - 120°F HW supply temperature at 60°F OA temperature

**Central Cooling System**

- One (1) chiller generates chilled water (CHW) for building cooling
  - Water-cooled chiller with cooling tower
  - Two (2) CHW pumps circulate CHW to air handler cooling coils
  - Two (2) condenser water pumps circulate condenser water between the chiller condenser and the cooling tower. Both condenser water pumps have VFD control of pump motor speed.
  - A CHW supply temperature reset schedule based on OA temperature is established in the BAS. During the walk-through, CHW supply temperature was set to 45°F at all OA temperatures.

**Air Handling Units**

- Air handling unit AHU-3 serves the auditorium
  - Single-zone variable air volume (VAV) unit
  - Supply fan motor controlled by VFD with a temperature-based control scheme
  - Duct-mount humidity and temperature sensors, pressure and flow sensors, and DDC controls
- Three (3) air handling units AHU-1, AHU-2, and AHU-4 serve the remainder of the building
  - Multi-zone VAV units with economizer controls
    - Economizer and airflow monitor on OA intake to each unit
  - Supply fan motors controlled by VFDs to maintain duct static pressure
  - Return fan motors controlled by VFDs to track supply fan VFDs
  - HW heating coils with two-way electronic control valves; CHW cooling coils with two-way electronic control valves
  - Duct-mount humidity and temperature sensors, pressure and flow sensors, and DDC controls

- One (1) make-up air unit serves the spray booth
- One (1) split-system direct-expansion (DX) cooling unit serves the data closet

**Exhaust Systems**

- Exhaust fans serve the studios, first floor, bathrooms, penthouse, laundry room, and electrical rooms
- Three (3) larger exhaust fans serve studio spaces
  - EF-SB serves the spray booth
    - EF-SB has a 5 hp motor and is rated for 12,800 cfm
  - EF-128 and EF-128E serve the dust collection system
    - EF-128 and EF-128E have 5 hp motors and are rated for 1,000 cfm

**Zone Heating/Cooling**

- VAV boxes provide airflow to nearly all rooms and common spaces
- Finned tube radiation provides perimeter heating
- Radiant heating with OA reset schedule
  - 180°F supply temperature at 0°F OA temperature
  - 150°F supply temperature at 60°F OA temperature
- Eight (8) HW unit heaters
  - 120°F HW supply temperature setpoint observed during walk-through
  - 60°F space temperature setpoint observed during walk-through
- Cabinet unit heaters serve an entry vestibule and a staircase
- A steam unit heater serves the spray booth

## HVAC Controls

**Building Automation System**

- Trane Tracer® Ensemble™ BAS used for monitoring, DDC, and energy management of HVAC systems

**Operating Schedules**

- AHU-4 is scheduled to operate in occupied mode from 12 a.m. to 11 p.m. daily
- EF-10 and an exhaust fan serving room 237 are scheduled to operate in occupied mode from 6 a.m. to 12 a.m. daily
- Other HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**

- One (1) semi-instantaneous water heater
  - Setpoint of 132°F and supply temperature of 126°F observed

**Domestic Hot Water (DHW) Load**

- Bathroom hand sinks and showers
- Kitchenette sinks
- Art studio sinks

## Piping and Ductwork

**Piping Systems/Insulation**

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**

- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug loads**

- Laundry room: two (2) washers and two (2) dryers served by exhaust fan
- Kitchenettes: microwaves, coffee makers, etc.
- Auditorium/stage: theatre lighting and equipment
- Computer lab and printing lab: computers, printers, etc.
- Data closet: computer equipment, servers, etc.

**Elevators**

- Two (2) elevators serve the building

## Specialty Systems

**Air Compressors**

- Two (2) air compressor pumps generate compressed air for pneumatic controls
  - One (1) compressor in the penthouse was observed to be excessively loud

**Ceramics Studio**

- Three (3) large electric kilns and two (2) small electric kilns
- Coal room
- Dust collection system with independent exhaust
- Spray booth with independent exhaust and steam unit heater

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Retro-commissioning of HVAC systems and controls
  - Optimize VFD control of HWP-3 and HWP-4 pump motors
  - Optimize HW and CHW supply temperature reset control
    - CHW reset schedule could be adjusted to raise CHW supply temperature at lower OA temperatures
  - Optimize cooling tower water temperature control
  - Optimize radiant heating reset control
  - Scheduling of HVAC equipment and space temperature setbacks

    - Scheduling of studio exhaust fan operation
- Implement pump differential pressure reset controls on the HW pumps
- Implement duct static pressure reset controls on AHU-1, AHU-2, and AHU-4
- Setback equipment during academic breaks
- If not already implemented, install low-flow or ultra low-flow showerheads

**Capital Measures**

- Consider installing window film for solar heat gain reduction
- Install building-level steam submeter
- Consider additional occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
- Consider daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- If not already implemented, install VFD on cooling tower fan motor to maintain condenser water temperature at setpoint
- Replace any remaining pneumatic actuators with electric actuators
- If not already implemented, consider implementing demand control ventilation on AHU-3 serving the auditorium
- If not already implemented, consider installing occupancy-based HVAC controls in classrooms, studio spaces, and auditorium
- If not already installed, consider adding hot water zone valves for controlling individual spaces served by finned tube radiation

**O&M Measures**

- Change any v-belt fan drives to cogged belt fan drives
- Repair or replace the loud compressor in the penthouse

# SUNY OSWEGO | WILBER HALL BUILDING ASSESSMENT

## Building Description

**Building Name:** Wilber Hall

**Year Constructed:** 1964

**No. of Floors:** 4 + Basement

**Est. GSF:** 108,933

### Recent Building Upgrades

- Full building renovation – 2014
- Wilber Wireless Lab constructed in 2016
- New exhaust fans installed in Room 166 by J&A - 2022

### Functional Description

Wilber Hall is an academic building in the center of campus connected to Shineman Center and Park Hall as part of the campus' science and engineering complex. Wilber Hall houses classrooms, common spaces, technical labs, a wood shop studio, and manufacturing lab. The Wilber Wireless lab is also located in the building and includes a polymer lab.

### Occupancy Patterns

Wilber Hall has fluctuating levels of occupancy throughout the day. During the academic year, the building has higher occupancy on weekdays while classes are in session.

## Building Envelope

### Roof

- Built-up flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Concrete and brick façades
- Insulation type and levels not accessible during walk-through

### Windows

- Double glazed, aluminum frame windows
  - Operable windows in classrooms, fixed windows elsewhere

### Doors

- Building entryway doors are two (2) sets of metal frame, glass double doors

### Air Infiltration/Leakage

- No excessive infiltration was observed

## Utilities

### Electricity
- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas
- Natural gas is delivered to the building from the main campus gas service
  - Used for space heating in the Wilber Wireless lab

### District Steam
- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building by two (2) pressure reducing valves (PRV)

### Submeters
- None observed during walk-through

## Lighting

### Interior Fixture Types
- Predominant lighting types as follows:
  - Classrooms: Ceiling recessed T8 fluorescent fixtures with electronic ballasts
  - Wood lab: 1x4 high bay pendant T5 fluorescent fixtures with electronic ballasts
  - Mezzanine: 1x4 industrial pendant T5 fluorescent fixtures with electronic ballasts
  - Paint room: Recessed T5 fluorescent fixtures with electronic ballasts
  - Metal shop: Sodium halide fixtures
  - Corridors: 4x4 recessed troffer T5 fluorescent fixtures with electronic ballasts and recessed T8 fluorescent fixtures with electronic ballasts
  - Offices: Compact fluorescent fixtures with electronic ballasts, recessed T5 fluorescent fixtures with electronic ballasts, and ceiling recessed T8 fluorescent fixtures with electronic ballasts
  - Conference room: Ceiling recessed T8 fluorescent fixtures with electronic ballasts
  - Bathrooms: Wall mount T8 fluorescent fixtures with electronic ballasts
  - Mechanical room: 1x2 twin industrial T5 fluorescent fixtures with electronic ballasts

### Interior Lighting Controls
- Bi-level lighting in classrooms
- Classroom lighting is scheduled off and on at set times of day
- Interior lighting is scheduled through local panels

### Exterior Lighting and Controls
- Recessed T5 fluorescent wall pack fixtures with electronic ballasts and T5 fluorescent wall sconce fixtures with electronic ballasts
- Entryway lighting and exterior HDs are controlled by photosensors

## HVAC

**Central Heating System**

- One (1) steam-to-hot water converter generates heating hot water (HW) for building heating
  - 1/3 & 2/3 pneumatically actuated steam valves modulate HW supply temperature at the outlet of the converter
  - Hot water pumps HWP-1 and HWP-2 circulate HW to the finned tube radiation loop and fan coil units. Hot water pumps HWP-9 and HWP-10 circulate HW to the first-floor labs.
  - HW supply temperature is reset based on outside air (OA) temperature
    - 180°F supply temperature at OA temperature of 0°F and below
    - 85°F supply temperature at OA temperature of 60°F and above
- Two (2) steam-to-hot-glycol converters HX-1 and HX-2 generate hot glycol for building heating in Wilber Hall and Park Hall. Only one (1) converter operates at a time, while the other serves as backup.
  - 1/3 & 2/3 pneumatically actuated steam valves modulate hot glycol supply temperature at the outlet of the converter
  - Hot glycol pumps P-1 and P-2 circulate hot glycol to Wilber Hall air handler heating coils. Both glycol pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure.
  - System is enabled when the glycol valve on any air handler is open greater than 5%
- One (1) shell & tube steam-to-hot-glycol converter, located in the Wilber Hall penthouse, generates hot glycol for Wilber Hall energy recovery ventilation (ERV) units
  - 1/3 & 2/3 direct digital control (DDC), electronically actuated steam valves modulate hot glycol supply temperature at the outlet of the converter
  - Hot glycol pumps P-5 and P-6 circulate hot glycol to ERV-1 and ERV-2 heating coils. Both glycol pumps have VFD control of pump motor speed based on differential pressure.
    - Bell & Gossett pumps with 5 horsepower (hp) motors and suction diffusers
- One (1) natural gas-fired boiler generates HW for the Wilber Wireless lab
  - Lochinvar boiler generates HW for unit heaters, finned tube radiators, and AHU-1 heating coils in the Wireless lab

**Central Cooling System**

- Two (2) Trane chillers CH-1 and CH-2, located in Park Hall, generate chilled water (CHW) for building cooling in Wilber Hall and Park Hall
  - Water-cooled screw chillers
  - R-134A refrigerant
  - Two (2) compressors each
  - Chilled water pumps CWP-3 and CWP-4 circulate CHW to air handler cooling coils in Wilber Hall. Both CHW pumps have VFD control of pump motor speed based on differential pressure.
  - Condenser water pumps CTP-1 and CTP-2, located in the Wilber Hall basement, circulate condenser water between the chiller condenser and the cooling tower. Both condenser water pumps have VFD control of pump motor speed.
    - Bell & Gossett pumps with 15 hp motors
  - Cooling tower fan has VFD control of fan motor speed to maintain leaving water temperature
- One (1) plate & frame CHW-glycol converter generates chilled glycol for Wilber Hall ERV units
  - Chilled glycol pumps P-7 and P-8 circulate chilled glycol to ERV-1 and ERV-2 cooling coils. Both glycol pumps have VFD control of pump motor speed based on differential pressure.

    - Bell & Gossett pumps with 3 hp motors
- One (1) Motivair chiller generates CHW for the Wilber Wireless lab
  - Chiller generates CHW for air handler cooling coils

**Air Handling Units**

- Four (4) air handling units serve the building
  - Air handling unit AHU-1 serves eight (8) variable air volume (VAV) boxes that provide airflow to first-floor office spaces
    - Multi-zone VAV unit
    - 3 hp supply fan motor controlled by VFD to maintain duct static pressure
    - 2 hp return fan motor controlled by VFD to track supply fan VFD
    - Hot glycol heating coil with two-way electronic control valve; CHW cooling coil with two-way electronic control valve
    - Energy recovery wheel recovers heat from the exhaust airstream
      - Rated for 3,000 cfm
    - Heating and cooling coil valves are enabled based on OA temperature
      - Cooling coil valves are enabled when the OA temperature is greater than 75°F
      - Heating coil valves are enabled when the OA temperature is less than 65°F
  - Air handling unit AHU-2 serves three (3) VAV boxes that provide airflow to the wood shop and manufacturing lab
    - Multi-zone VAV unit
    - Receives return air from the wood lab
    - 15 hp supply fan motor controlled by VFD to maintain duct static pressure
    - 7.5 hp return fan motor controlled by VFD to track supply fan VFD
    - Hot glycol heating coil with two-way electronic control valve; CHW cooling coil with two-way electronic control valve
    - Heating and cooling coil valves are enabled based on OA temperature
      - Cooling coil valves are enabled when the OA temperature is greater than 75°F
      - Heating coil valves are enabled when the OA temperature is less than 65°F
  - Air handling unit AHU-3 serves the wood shop
    - 100% OA single-zone VAV unit
    - 7.5 hp supply fan motor controlled by VFD to track dust collector system VFD
    - Hot glycol heating coils; CHW cooling coils
    - System is enabled when the dust collector system is enabled
    - Heating mode is enabled when the OA temperature is below 60°F. Cooling mode is enabled when the OA temperature is above 74°F.
  - Air handling unit AHU-4 serves the paint room
    - 100% OA single-zone VAV unit
    - 7.5 hp supply fan motor controlled by VFD
      - Runs at 25% speed when the paint room exhaust fan is off and at 100% speed when the paint room exhaust fan is on
    - Hot glycol heating coils; CHW cooling coils
    - Cooling mode is enabled based on space temperature. Cooling valve position is determined based on OA temperature.
- Two (2) energy recovery ventilators ERV-1 and ERV-2
  - Enthalpy wheels recover heat from tech shop (Rooms 166 and 163) exhaust airstreams

  - Heating and cooling coils with DDC controls
- A separate air handling unit serves spaces in the Wilber Wireless Lab

**Exhaust Systems**

- Nine (9) exhaust fans serve mechanical rooms, electrical rooms, paint booth, finishing room, dust collector, laser room, fume hoods, and storage rooms
  - EF-1, EF-2, and EF-3 serve the wood lab
    - EF-1 controls are integrated with the dust collection system; fan is enabled when the dust collection system is enabled
  - EF-4 and EF-5 serve the paint booth and finishing room
  - EF-6 serves storage room 159
  - EF-7 and EF-8 serve basement mechanical spaces
  - EF-9 serves the first-floor lab
  - EF-2, EF-3, and EF-9 are controlled by a manual switch and do not have automated controls
- A separate exhaust fan serves the Wilber Wireless lab

**Zone Heating/Cooling**

- Ceiling diffusers provide airflow to nearly all rooms and common spaces
- VAV boxes provide airflow to a limited number of rooms
- Finned tube radiation provides perimeter heating along the walkway connecting Shineman and Wilber

## HVAC Controls

**Building Automation System**

- Trane Tracer® Ensemble™ building automation system (BAS) used for monitoring, DDC, and energy management of HVAC systems
  - CWP-3 and CWP-4 are not on the BAS

**Operating Schedules**

- Hot water heating system is enabled 24/7
- Air handling units are scheduled to operate 24/7
  - Occupied, unoccupied, and night-time temperature setpoints are determined in the BAS
- General exhaust fans are scheduled to operate in occupied mode from 6 a.m. to 12 a.m. daily
- EF-1 is scheduled to operate in occupied mode from 6 a.m. to 11 p.m. daily
- Finned tube radiation in the Wilber-Shineman connector is scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**

- One (1) instantaneous water heater IWH-1
  - Uses direct steam
- One (1) electric water heater EWH-1

**Domestic Hot Water (DHW) Load**

- Bathroom hand sinks
- Lab sinks

- Lab eye wash stations and showers

## Piping and Ductwork

### Piping Systems/Insulation

- Some piping is missing insulation on the HW supply and return lines to the converter
- Spot observations of DHW piping and ductwork insulation revealed no remarkable deficiencies

### Equipment Insulation

- Spot observations of equipment insulation revealed no remarkable deficiencies

### Piping and Ductwork Leaks

- Spot observations revealed no leakage issues

## Miscellaneous Loads

### Plug loads

- Classrooms: laptops, chargers, desktop computers, printers, projectors, etc.
- Data closet: computer equipment, servers, etc.

### Elevators

- One (1) elevator serves the building

## Specialty Systems

### Air Compressors

- Three (3) air compressors generate compressed air at 125 psig for lab equipment and pneumatic controls
  - Comairco compressed air system
  - Ingerson-Rand air compressor C-1 with one (1) compressed air storage tank
  - Succair 1500 ell air compressor with one (1) compressed air storage tank

### Dust Collection System

- Dust collection system serves the wood shop
  - Controls integrated with AHU-3 and EF-3
    - Make-up air unit AHU-3 and exhaust fan EF-1 are only enabled when the dust collection system is enabled

## Potential Energy Efficiency Measures (EEMs)

### No Cost/Low Cost Measures

- Retro-commissioning of HVAC systems and controls
  - Optimize HW and glycol supply temperature reset control
  - Scheduling of HVAC equipment and space temperature setbacks
  - Scheduling of lab exhaust fan operation
- If not already implemented, implement CHW supply temperature reset control

- Implement pump differential pressure reset controls on HW pumps HWP-1 and HWP-2 and hot glycol pumps
- Implement duct static pressure reset controls on AHU-1 and AHU-2
- Setback equipment during academic breaks
- Install low-flow or ultra low-flow showerheads

**Capital Measures**

- Consider installing window film for solar heat gain reduction
- Install building-level steam submeter
- Replace interior fluorescent light fixtures with LED fixtures
    - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
    - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity, such as the corridors
- Replace exterior light fixtures with LED fixtures
- Install occupancy-based HVAC controls on AHU-1 and AHU-2
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace pneumatic actuators with electric actuators
- Consider implementing demand control ventilation in classrooms
- Connect remaining building systems to BAS

**O&M Measures**

- Change any v-belt fan drives to cogged belt fan drives
- Repair missing HW piping insulation

# SUNY OSWEGO | CAYUGA HALL BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | Cayuga Hall |
| **Year Constructed:** | 1967 |
| **No. of Floors:** | 4 + Basement |
| **Est. GSF:** | 105,072 |

### Recent Building Upgrades

- Exterior renovation – 2006
- Roof replacement - 2022

### Functional Description

Cayuga Hall is a residence hall on West campus. The building encloses two courtyards and consists of dorm rooms, a director's apartment, and lounge areas. The basement houses a laundry room, larger lounge area, and kitchenette. This residence hall was used as a COVID-19 isolation dorm for the 2021-2022 academic year.

### Occupancy Patterns

The dorm is occupied 24/7 during the academic year and can house approximately 500 students. As an isolation dorm, the building is temporarily occupied by fewer people on a more consistent daily schedule.

## Building Envelope

### Roof

- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Concrete panel walls
- Insulation type and levels not accessible during walk-through

### Windows

- Double glazed, double hung windows with fixed sidelights
  - Windows replaced in 2006 renovation

### Doors

- Building entryway doors are clear, double glazed, metal frame doors

### Air Infiltration/Leakage

- No excessive infiltration was observed

## Utilities

### Electricity
- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas
- This building does not receive natural gas

### District Steam
- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

### Submeters
- This building has a campus-managed Electro Industries revenue grade electricity submeter

## Lighting

### Interior Fixture Types
- Predominant lighting types as follows:
  - Dorms: Student rooms not accessible during walk-through
  - Bathrooms: Bathrooms not accessible during walk-through
  - Corridors and common spaces: Linear T8 fluorescent lamps

### Interior Lighting Controls
- Occupancy sensors in some bathrooms
- No other automatic controls observed during walk-through
- Interior lighting is scheduled on at 7 a.m. and off at 8 p.m. daily

### Exterior Lighting and Controls
- High-intensity discharge (HID) wall packs
- Exterior lights are controlled by photosensors

## HVAC

### Central Heating System
- One (1) steam-to-hot-water converter CV-1 generates heating hot water (HW) for the building
  - Direct digital control (DDC), pneumatically actuated steam valve modulates HW supply temperature at the outlet of the converter
  - Hot water pumps CIR-P1 and CIR-P2 operate as lead/standby for the HW loop serving air handler coils and finned tube radiation
    - CIR-P1 and CIR-P2 have 10 horsepower (hp) motors
  - Appears to utilize reset of HW supply temperature based on outside air (OA) temperature
- One (1) steam-to-hot-water converter CV-2 generates HW for Resident Director apartment suite
  - DDC controlled, pneumatically actuated steam valve modulates HW supply temperature at the outlet of the converter
  - In-line circulating pump circulates HW to the apartment

**Central Cooling System**

- One (1) small outside air-cooled chiller generates chilled glycol for cooling data closets
  - Chilled glycol is circulated to indoor ductless fan coil units (FCU)
  - Operates in free cooling mode (compressor off) during the winter
- No other space cooling in this building

**Air Handling Units**

- Five (5) heating and ventilating units HV-1 through HV-5 serve corridors and common spaces
  - Constant volume single-zone units
  - HV-1 serves the laundry room
    - 100% OA unit
    - Steam heating coils with 3-way valves
    - Constant speed 1 hp supply fan motor
  - HV-2 through HV-5 serve lounges
    - HV-2 and HV-3 have constant speed ¼ hp supply fan motors
    - HV-4 and HV-5 have constant speed ¾ hp supply fan motors
    - HW heating coils with 3-way valves

**Exhaust Systems**

- Several exhaust fans serve the bathrooms, laundry room, mechanical room, and electrical room
  - EF-1 serves the laundry room
    - EF-1 has a 1.5 hp motor and is rated for 42,000 cubic feet per minute (cfm)
    - HV-1 provides make-up air

**Zone Heating/Cooling**

- Ceiling diffusers provide airflow to corridors and common spaces
- Finned tube radiation provides perimeter heating in dorm rooms and lounges; temperature control is limited to HW supply temperature reset control based on OA temperature
- No sensors or room-level temperature control in dorm rooms
- Temperature sensors in lounges control associated heating and ventilating units

## HVAC Controls

**Building Automation System**

- Trane Tracer® Ensemble™ building automation system (BAS) used for monitoring, DDC, and energy management of HVAC systems
  - HW and domestic hot water (DHW) equipment has pneumatic controls, but temperature is monitored by the BAS; the plan is to transition to full BAS control in the future

**Operating Schedules**

- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**

- One (1) steam bundle storage tank serves most of the building

  - Estimated 400-gallon capacity
  - Storage temperature is set manually and maintained through pneumatic controls
    - Storage temperature of 152°F observed
  - One (1) recirculating pump and tempering valve
- One (1) electric water heater serves the Resident Director apartment suite

**DHW Load**
- Bathroom hand sinks and showers
- Kitchenette sinks

## Piping and Ductwork

**Piping Systems/Insulation**
- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**
- Spot observations of equipment insulation revealed no remarkable deficiencies
- Removable insulation observed on steam traps

**Piping and Ductwork Leaks**
- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug loads**
- Laundry room: washing machines and dryers
- Kitchenettes: microwaves, stoves, hoods, and refrigerators
- Four (4) data closets: computer equipment, etc.
- Dorm rooms: laptops, chargers, microwaves, mini fridges, coffee makers, televisions, and portable fans

**Elevators**
- One (1) traction elevator serves the building

## Specialty Systems

**Air Compressors**
- One (1) pair of reciprocating air compressors generate compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**
- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control. Current reset schedule could not be viewed through the BAS.
  - Scheduling of HVAC equipment and space temperature setbacks

- Setback equipment during academic breaks
- Install low-flow or ultra low-flow showerheads

**Capital Measures**

- Upgrade roof insulation to at least code levels during gut rehab project
- Upgrade exterior wall insulation to at least code levels during gut rehab project
- Install building-level steam submeter
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Install variable frequency drives (VFD) on the HW pump motors
- Replace HW circulating pump and motor serving Resident Director apartment suite with electronically commutated motor
- Consider installing VFDs on laundry exhaust fan and HV-1 supply fan
- Replace constant volume heating and ventilating units with VAV systems during gut rehab project
- Install occupancy-based HVAC controls on HV-2 through HV-5
- Consider implementing exhaust heat recovery on stacked bathroom exhaust
- Consider replacing data closet FCUs and include electronically commutated motors
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace pneumatic actuators with electric actuators
- Replace DHW heater with semi-instantaneous water heater
- Replace DHW circulating pumps and motors with electronically commutated motors

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | COOPER DINING HALL BUILDING ASSESSMENT

## Building Description


| | |
|---|---|
| **Building Name:** | Cooper Dining Hall |
| **Year Constructed:** | 1967 |
| **No. of Floors:** | 2 |
| **Est. GSF:** | 33,546 |

**Recent Building Upgrades**
- Chiller – 1994, 2013
- Renovated CHP – 2003
- Lighting - 2018

**Functional Description**
Cooper Dining Hall is a building in the center of campus that houses both a dining hall and a fitness center. The upper floor consists of a commercial kitchen, a serving line, and a large dining area. The lower floor is comprised of the fitness center, storage space, and mechanical and electrical rooms.

**Occupancy Patterns**
The dining hall is occupied from 8 a.m. to 8:30 p.m. on weekdays and from 10 a.m. to 8:30 p.m. on weekends, with short closures from 3 p.m. to 4:30 p.m. daily.

## Building Envelope

**Roof**
- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

**Exterior Walls**
- Concrete façade
- Insulation type and levels not accessible during walk-through

**Windows**
- Dining room windows are floor-to-ceiling, single glazed, single hung, metal frame windows

**Doors**
- Building entryway doors are metal frame, glass double doors

**Air Infiltration/Leakage**
- No excessive infiltration was observed

## Utilities

**Electricity**

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

**Natural Gas**

- Natural gas is delivered to the building from the main campus gas service
  - Used for cooking

**District Steam**

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building
  - Condensate is collected and returned from Cooper Dining Hall to the Central Heating Plant

**Submeters**

- This building has campus-managed Electro Industries revenue grade electricity submeters

## Lighting

**Interior Fixture Types**

- Predominant lighting types as follows:
  - Dining area: Recessed ceiling fixtures with T8 fluorescent lamps
  - Kitchen: Pendant fixtures with fluorescent lamps
  - Fitness center: LED lighting (upgraded in 2018 renovation)

**Interior Lighting Controls**

- No automatic controls observed during walk-through
- Interior lighting is controlled through local panels
- Lighting is scheduled on at 7 a.m. and off at 8 p.m. daily

**Exterior Lighting and Controls**

- High-intensity discharge (HID) fixtures above entryway
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

**Central Heating System**

- One (1) natural gas-fired boiler
  - Not in use
- One (1) steam-to-hot-water converter generates heating hot water (HW) for building heating
  - Hot water pumps P-1 and P-2 operate in parallel and circulate HW to air handler heating coils and heating terminal equipment
  - Pneumatic controls
  - Appears to utilize reset of HW supply temperature based on outside air (OA) temperature

**Central Cooling System**

- Trane chiller generates chilled water (CHW) for building cooling

- Trane water-cooled chiller, manufactured 2013
- Two (2) constant speed screw compressors
- R-134A refrigerant
- Chilled water pump P-3 circulates CHW to air handler cooling coils and cooling terminal equipment
- Condenser water pump P-5 circulates condenser water between the chiller condenser and the cooling tower
- Pump P-4 can serve as standby for either P-3 or P-5
- Forced-draft cooling tower with mist eliminator
  - Cooling tower fan has variable frequency drive (VFD) control of fan motor speed to maintain leaving water temperature

**Air Handling Units**

- Air handling unit AC-1 serves the lounge and men's workout room
  - HW heating coil; CHW cooling coil
- Air handling unit AC-2 serves five (5) zones in the dining area
  - Terminal reheat coils
- Heating and ventilating unit HV-1 provides makeup air to the kitchen
  - 100% OA units
  - HW heating coils with two-way pneumatic control valves

**Exhaust Systems**

- Commercial kitchen cooking exhaust system
  - Kitchen hoods are scheduled off at night, with the exception of one hood that cannot be turned off
- Exhaust fans serve bathrooms, mechanical rooms, and the kitchen
- Transfer vent between corridor and fitness center

**Zone Heating/Cooling**

- Ceiling diffusers provide airflow to the dining area
- Finned tube radiation provides perimeter heating in the dining area
- Two-to-three fan coil units (FCU) provide additional heating and cooling throughout the building, including in the fitness center
- Unit ventilators serve stairwells and the kitchen entryway
  - Manually controlled

## HVAC Controls

**Building Automation System**

- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems
  - HV-2, make-up air unit, some exhaust fans, and the domestic hot water (DHW) heater are not on the BAS

**Operating Schedules**

- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**

- One (1) steam bundle storage tank
  - Self-contained pneumatic control valve
  - Storage setpoint of 140°F observed
- Two (2) Burkay natural draft water heaters
  - Exhaust fan
  - Disconnected; not in use

**DHW Load**

- Bathroom hand sinks
- Commercial kitchen equipment and dishwasher

## Piping and Ductwork

**Piping Systems/Insulation**

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies
- Some corrosion observed on DHW tank piping

**Equipment Insulation**

- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug loads**

- Fitness center: 17 plug-in exercise machines

**Kitchen Equipment**

- Exhaust system
- One (1) pilot standby stove with six (6) burners
- Ice maker
- Coolers and freezers (reach-in and walk-in types)

**Elevators**

- One (1) hydraulic elevator serves the building

## Specialty Systems

**Commercial Kitchen Equipment**

- Direct steam used for kitchen dishwashers, three (3) steam kettles, and two (2) steam-heated convection ovens

**Air Compressors**

- Air compressors generate compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Install automatic interior lighting controls on existing LED fixtures
- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control. Current reset schedule could not be viewed through the BAS.
  - Optimize cooling tower water temperature control
  - Scheduling of HVAC equipment and space temperature setbacks
  - Scheduling of kitchen exhaust fan operation
- Implement CHW supply temperature reset
- Setback equipment during academic breaks

**Capital Measures**

- Replace single glazed windows with high performance windows
- Install building-level gas and steam submeters
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Install VFDs on P-1, P-2, and P-3 pump motors and control based on differential pressure
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Replace existing chiller with high-efficiency water-cooled variable speed magnetic bearing chiller at end of useful life
  - R-134A refrigerant is being phased out starting January 1, 2024
  - Once manufacturing of R-134A is eliminated, the price of R-134A stock is expected to rise substantially
- Install occupancy-based HVAC controls
- Consider replacing FCUs and including electronically commutated motors
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace pneumatic actuators with electric actuators
- Convert AC-2 to a variable air volume (VAV) system by installing VAV boxes and a VFD controlled to maintain duct static pressure
- Consider implementing demand control ventilation in the dining area
- Consider implementing kitchen demand control ventilation on exhaust and makeup air systems
- Connect remaining building systems to BAS
- Replace DHW heater with semi-instantaneous water heater
- Replace refrigeration evaporator fan motors with electronically commutated motors
- Install desuperheater on refrigeration loop to recovery energy for domestic hot water heating

### O&M Measures

- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | FUNNELLE HALL BUILDING ASSESSMENT

## Building Description


| | |
|---|---|
| **Building Name:** | Funnelle Hall |
| **Year Constructed:** | 1965 |
| **No. of Floors:** | 10 + Penthouse |
| **Est. GSF:** | 114,365 |

**Recent Building Upgrades**

- Roof replacement – 2015
- Bathroom renovations – Ongoing

**Functional Description**

Funnelle Hall is a high-rise residence hall in the center of campus connected to Cooper Dining Hall on its west side. The upper eight floors each consist of two main hallways joining single-person student rooms, bathrooms, and common spaces. The first floor includes a large lounge, offices, and residential staff apartments. A laundry room, kitchenette, additional lounges, storage spaces, and main electrical and mechanical rooms are located in the basement.

**Occupancy Patterns**

The dorm is occupied 24/7 during the academic year and can house approximately 200 students.

## Building Envelope

**Roof**

- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

**Exterior Walls**

- Concrete masonry with a brick façade
- Insulation type and levels not accessible during walk-through

**Windows**

- Clear, double glazed, sliding, aluminum frame windows

**Doors**

- Building entryway doors are clear, double glazed, aluminum frame doors

**Air Infiltration/Leakage**

- No excessive infiltration was observed

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for heat recovery units with gas-fired furnace sections and alternate domestic hot water (DHW) system

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

### Submeters

- This building has a campus-managed Electro Industries revenue grade electricity submeter
- This building has a campus-managed steam submeter to measure pressure, flow, and temperature of medium pressure steam entering building

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Dorms: Student rooms not accessible during walk-through
  - Bathrooms: Flush mount fixtures with linear LED lamps
  - Corridors and lounges: Surface mount fixtures with two-lamp compact fluorescent lamps (CFL) and linear T8 fluorescent lamps
  - Basement: Surface mount fixtures with mix of LED and linear T8 fluorescent lamps

### Interior Lighting Controls

- No automatic controls observed during walk-through

### Exterior Lighting and Controls

- Wall pack fixtures appear to be low-pressure sodium type
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- One (1) shell & tube steam-to-hot-water converter generates heating hot water (HW) for most of the building
  - 1/3 & 2/3 direct digital control (DDC), electronically actuated steam valves modulate HW supply temperature at the outlet of the converter. Mixing valves control supply temperatures to each of three (3) HW distribution zones.
  - Hot water pump P-1 serves Zone 2, P-3 serves Zone 1, and P-2 can serve as standby for either P-1 or P-3. Pumps P-4 and P-5 operate as lead/standby for Zone 3. All of the HW pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure.

    - Bell & Gossett in-line centrifugal pumps
  - System is enabled when outside air (OA) temperature is below 60°F
  - HW supply temperature is reset based on OA temperature
    - 180°F supply temperature at 20°F OA temperature
    - 110°F supply temperature at 50°F OA temperature
- One (1) shell & tube steam-to-hot-water converter generates heating HW for Resident Director apartment suite
  - Steam valve modulates HW supply temperature at the outlet of the converter
  - Hot water pump P-6 with a constant speed motor circulates HW to the apartment
  - System is enabled when OA temperature is below 60°F
  - HW supply temperature is reset based on OA temperature
    - 180°F supply temperature at 0°F OA temperature
    - 110°F supply temperature at 60°F OA temperature

**Central Cooling System**
- One (1) small outdoor air-cooled chiller generates chilled water (CHW), which is circulated to indoor ductless fan coil units to provide cooling for data closets
- No other space cooling in this building

**Air Handling Units**
- One (1) heating and ventilating unit provides make-up air for laundry room exhaust
  - 100% OA unit
  - Supply fan motor controlled by VFD to track exhaust fan VFD
  - HW heating coil with two-way electronic control valve
- Two (2) rooftop heating-only heat recovery units supply ventilation air to corridors and common spaces
  - Fixed plate cross-flow heat exchanger with bypass damper; gas-fired furnace section to maintain supply temperature
  - Supply fan motors controlled by VFDs to maintain supply flow
  - Return fan motors controlled by VFDs to track supply fan VFDs

**Exhaust Systems**
- Five (5) small exhaust fans with constant speed motors serve the building
- Dedicated exhaust fan for laundry room
  - Motor controlled by VFD to maintain duct pressure setpoint

**Zone Heating/Cooling**
- Finned tube radiation provides perimeter heating in dorm rooms and common spaces; temperature control is limited to HW supply temperature reset control of three (3) building zones
- No sensors or room-level temperature control in dorm rooms
- Temperature control through electric wall thermostats in data closets

## HVAC Controls

### Building Automation System

- Trane Tracer® Ensemble™ building automation system (BAS) used for monitoring, DDC, and energy management of HVAC systems
  - HV unit and chiller are not on the BAS

### Operating Schedules

- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

### Domestic Water Heaters

- Primary DHW system is two (2) steam bundle storage tanks
  - 600-gallon capacities
  - One (1) electric control valve on each tank
  - Manufactured 2020
  - Supply setpoint of 120°F observed
- Alternate DHW system is two (2) natural draft, natural gas-fired tank water heaters with a shared additional external storage tank
  - Approximately 200-gallon tank integral to each water heater
  - External 350-gallon storage tank
  - Water heaters manufactured 1986
  - External tank manufactured 1988
  - Used only when the central plant is down

### DHW Load

- Bathroom hand sinks and showers
- Common room kitchenette sink

## Piping and Ductwork

### Piping Systems/Insulation

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

### Equipment Insulation

- Spot observations of equipment insulation revealed no remarkable deficiencies

### Piping and Ductwork Leaks

- Spot observations revealed no leakage issues

## Miscellaneous Loads

### Plug Loads

- Offices: computers or laptops, desk phones, desk lamps, etc.

- Dorm rooms: laptops, chargers, microwaves, mini fridges, coffee makers, televisions, and portable fans
- Laundry room: washing machines and dryers
- Data closet
- Basement lounge: three (3) beverage and snack vending machines

**Elevators**
- Three (3) elevators serve the building

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**
- Install automatic interior lighting controls on existing LED fixtures
- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control
- Implement pump differential pressure reset controls on HW pumps P-1 through P-5
- Setback equipment during academic breaks
- Install low-flow or ultra low-flow showerheads

**Capital Measures**
- Install window film for solar heat gain reduction
- Install building-level gas submeter
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Connect remaining building systems to BAS
- Replace domestic hot water heaters with semi-instantaneous water heaters

**O&M Measures**
- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | HART HALL BUILDING ASSESSMENT

## Building Description


| | |
|---|---|
| **Building Name:** | Hart Hall |
| **Year Constructed:** | 1963 |
| **No. of Floors:** | 10 + Penthouse |
| **Est. GSF:** | 114,365 |

**Recent Building Upgrades**

- Elevator upgrades – Ongoing

**Functional Description**

Hart Hall is a high-rise "global living" residence hall in the center of campus connected to Cooper Dining Hall on its east side. The upper eight floors each consist of two main hallways joining two-person student rooms, bathrooms, kitchenettes, and common spaces. The first floor includes a large lounge, a seminar room, offices, and residential staff apartments. A laundry room, computer lab, another large lounge, storage spaces, and main electrical and mechanical rooms are located in the basement.

**Occupancy Patterns**

The dorm is occupied 24/7 during the academic year and can house approximately 340 students.

## Building Envelope

**Roof**

- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

**Exterior Walls**

- Concrete masonry with a brick façade
- Insulation type and levels not accessible during walk-through

**Windows**

- Clear, double glazed, sliding, aluminum frame windows

**Doors**

- Building entryway doors are clear, double glazed, aluminum frame doors

**Air Infiltration/Leakage**

- No excessive infiltration was observed

## Utilities

**Electricity**

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for heat recovery units with gas-fired furnace sections and alternate domestic hot water (DHW) system

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

### Submeters

- This building has a campus-managed Electro Industries revenue grade electricity submeter
- This building has a campus-managed steam submeter to measure pressure, flow, and temperature of medium pressure steam entering building

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Dorms: Student rooms not accessible during walk-through
  - Bathrooms: Flush mount fixtures with linear LED lamps
  - Corridors and lounges: Surface mount fixtures with two-lamp compact fluorescent lamps (CFL) and linear T8 fluorescent lamps
  - Basement: Surface mount fixtures with two-lamp CFLs and linear T8 fluorescent lamps

### Interior Lighting Controls

- No automatic controls observed during walk-through

### Exterior Lighting and Controls

- Predominant exterior lighting type is high-intensity discharge (HID)
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- One (1) shell & tube steam-to-hot-water converter generates heating hot water (HW) for most of the building
  - Manufactured 1973
  - One (1) direct digital control (DDC), pneumatically actuated steam valve modulates HW supply temperature at the outlet of the converter. Mixing valves control supply temperatures to each of three (3) HW distribution zones.
  - Five (5) hot water pumps with constant speed 3 and 5 horsepower (hp) motors circulate HW to building heating terminals
  - System is enabled when outside air (OA) temperature is below 60°F
  - HW supply temperature is reset based on OA temperature
    - 170°F supply temperature at 0°F OA temperature
    - 110°F supply temperature at 60°F OA temperature

- One (1) shell & tube steam-to-hot-water converter generates heating HW for Resident Director apartment suite
  - One (1) DDC controlled, pneumatically actuated steam valve modulates HW supply temperature at the outlet of the converter
  - In-line pump with constant speed fractional hp motor circulates HW to the apartment
  - System is enabled when OA temperature is below 60°F
  - HW supply temperature is reset based on OA temperature
    - 150°F supply temperature at 0°F OA temperature
    - 100°F supply temperature at 60°F OA temperature

**Central Cooling System**
- No space cooling in this building

**Air Handling Units**
- One (1) heating and ventilating unit provides make-up air for laundry room exhaust
  - 100% OA unit
  - Supply fan motor controlled by variable frequency drive (VFD) to track exhaust fan VFD
  - HW heating coil with two-way electronic control valve
- Two (2) rooftop heating-only heat recovery units supply ventilation air to corridors and common spaces
  - Heat wheels to recover energy from exhaust streams
  - Natural gas-fired furnace sections to maintain supply temperatures

**Exhaust Systems**
- Four (4) small exhaust fans with constant speed motors serve the building
- Dedicated exhaust fan for laundry room
  - Motor controlled by VFD to maintain duct pressure setpoint

**Zone Heating/Cooling**
- Finned tube radiation provides perimeter heating in dorm rooms and common spaces; temperature control is limited to HW supply temperature control of three (3) building zones
- No sensors or room-level temperature control in dorm rooms
- HW cabinet unit heaters serve the main entryways

## HVAC Controls

**Building Automation System**
- Trane Tracer® Ensemble™ building automation system (BAS) used for monitoring, DDC, and energy management of HVAC systems
  - HW pumps are not on the BAS

**Operating Schedules**
- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

### Domestic Water Heaters

- Primary DHW system is one (1) steam bundle storage tank
  - One (1) pneumatic control valve
  - Supply setpoint of 120°F observed
- Alternate DHW system is two (2) natural draft, natural gas-fired tank water heaters with two (2) additional external storage tanks
  - External tanks each have 350-gallon capacity
  - Water heaters manufactured 1986
  - External tanks manufactured 1989
  - Used only when the central plant is down

### DHW Load

- Bathroom hand sinks and showers
- Common room kitchenette sink

## Piping and Ductwork

### Piping Systems/Insulation

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

### Equipment Insulation

- Spot observations of equipment insulation revealed no remarkable deficiencies

### Piping and Ductwork Leaks

- Spot observations revealed no leakage issues

## Miscellaneous Loads

### Plug Loads

- Offices: computers or laptops, desk phones, desk lamps, etc.
- Dorm rooms: laptops, chargers, microwaves, mini fridges, coffee makers, televisions, and portable fans
- Laundry room: two (2) beverage and snack vending machines, washing machines, and dryers
- Seminar room and computer lab: projector, printer, and computers

### Elevators

- Three (3) elevators serve the building

## Specialty Systems

### Air Compressors

- Two (2) air compressors generate compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Install automatic interior lighting controls on existing LED fixtures
- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control
- Setback equipment during academic breaks
- Install low-flow or ultra low-flow showerheads

**Capital Measures**

- Install window film for solar heat gain reduction
- Install building-level gas submeter
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Replace HW circulating pump and motor serving Resident Director apartment suite with electronically commutated motor
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace pneumatic actuators with electric actuators
- Consider implementing demand control ventilation in the seminar room and the conference room
- Connect remaining building systems to BAS
- Replace DHW heaters with semi-instantaneous water heaters

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | JOHNSON HALL BUILDING ASSESSMENT

## Building Description

**Building Name:** Johnson Hall

**Year Constructed:** 1958

**No. of Floors:** 4 + Basement

**Est. GSF:** 79,097

### Recent Building Upgrades

- Full building renovation – 2003

### Functional Description

Johnson Hall is a first-year residence hall located next to Lake Ontario on SUNY Oswego's main campus. The building consists of dorm rooms, a director's apartment, corridors, mechanical rooms, and storage spaces, with lounge areas and kitchenettes on each floor. The basement houses a laundry room and kitchen.

### Occupancy Patterns

The dorm is occupied 24/7 during the academic year and can house approximately 250 students.

## Building Envelope

### Roof

- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Concrete masonry with a brick façade
- Insulation type and levels not accessible during walk-through

### Windows

- Clear, double glazed, single-hung, wooden frame windows with aluminum thermal spacers

### Doors

- Building entryway doors are metal frame, glass doors

### Air Infiltration/Leakage

- No excessive infiltration was observed

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

**Natural Gas**

- Natural gas is delivered to the building from the main campus gas service
  - Used for backup generator and first-floor lounge gas fireplace

**District Steam**

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building by two (2) pressure reducing valves (PRV) operating in parallel with a bypass

**Submeters**

- This building has a campus-managed Electro Industries revenue grade electricity submeter
- This building has a campus-managed steam submeter to measure pressure, flow, and temperature of medium pressure steam entering building

## Lighting

**Interior Fixture Types**

- Predominant lighting types as follows:
  - Dorms: Round recessed 100-150 watt incandescent light fixtures
  - Bathrooms: 2x4 recessed prismatic T8 fluorescent fixtures with electronic ballasts and 40 watt incandescent vanity fixtures
  - Showers: Ceiling mount T8 fluorescent fixtures with electronic ballasts
  - Corridors: Surface mount compact fluorescent fixtures with electronic ballasts and 2x2 recessed, round recessed, and ceiling mount T8 fluorescent fixtures with electronic ballasts
  - Lounges: Round recessed T8 fluorescent fixtures with electronic ballasts
  - First-floor offices: 2x2 recessed T8 fluorescent fixtures with electronic ballasts
  - Laundry room: Ceiling mount T8 fluorescent fixtures with electronic ballasts
  - Vestibule: Wall mount T8 fluorescent sconce fixtures with electronic ballasts

**Interior Lighting Controls**

- Occupancy sensors in most common spaces
- Lighting is scheduled on at 7 a.m. and off at 8 p.m. daily

**Exterior Lighting and Controls**

- High-pressure sodium wall pack fixtures
- Exterior lights on campus are controlled by photosensors and astronomical time clocks
- The campus is installing LEDs in place of the existing compact fluorescent exterior lighting; this is an ongoing project at Johnson Hall

## HVAC

**Central Heating System**

- One (1) steam-to-hot-water converter HX-1 generates heating hot water (HW) for most of the building
  - Two (2) hot water pumps operate as lead/standby. HW pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure.
  - Supply temperature of 140°F observed

- One (1) steam-to-hot-water converter HX-2 generates HW for Resident Director and Assistant Resident Director apartment suites
  - Two (2) hot water pumps operate as lead/standby for the staff apartments HW loop
- Appear to utilize reset of HW supply temperature based on outside air (OA) temperature

**Central Cooling System**
- Two (2) 355-ton chillers located in Lakeside Dining Hall generate chilled water (CHW) for building cooling in Lakeside Dining Hall, Johnson Hall common spaces, and Riggs Hall
  - Chilled water pumps CWP-1 and CWP-2, located in the Johnson Hall mechanical room, operate as lead/standby for the Johnson Hall air handler cooling coils loop. CHW pumps have VFD control of pump motor speed based on differential pressure.
- No other space cooling in this building

**Air Handling Units**
- Air handling unit AHU-1 serves the lobby
  - HW heating coils and CHW cooling coils with direct digital controls (DDC)
- Two (2) make-up air units MUA-1 and MUA-2 serve the north and east wing corridors, respectively
  - 100% OA units with face and bypass dampers
  - Steam heating coils and CHW cooling coils with DDCs

**Exhaust Systems**
- Fourteen (14) exhaust fans serve the bathrooms, mechanical rooms, storage closets, attic, and elevators

**Zone Heating/Cooling**
- Ceiling diffusers provide airflow to the corridors
- Finned tube radiation provides perimeter heating in the first-floor lounge
- Unit ventilators with heating and cooling coils serve some lounges and offices
- Convection units serve the stairwells
- Fan coil units (FCU) provide heating to the dorm rooms
  - Four (4) FCUs serve each dorm
  - FCUs are controlled by occupied/unoccupied schedules set in the building automation system (BAS)
- All rooms have temperature sensors and room-level thermostats

## HVAC Controls

**Building Automation System**
- Carrier i-Vu® 8.0 BAS used for monitoring, DDC, and energy management of HVAC systems

**Operating Schedules**
- HVAC systems are scheduled to operate in occupied mode 24/7 during the academic year

## Domestic/Service Water Heating

**Domestic Water Heaters**
- One (1) steam bundle storage tank serves most of the building

- Self-contained pneumatic control valve
- Receiving pump and tempering valve
- Supply temperature of 124°F observed
- One (1) electric water heater serves the director's apartment
  - 20-gallon capacity

**Domestic Hot Water (DHW) Load**
- Bathroom hand sinks and showers
- Kitchenette sinks

## Piping and Ductwork

**Piping Systems/Insulation**
- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**
- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**
- Spot observations revealed no ductwork leakage issues

## Miscellaneous Loads

**Plug loads**
- Laundry room: washing machines and dryers
- Five (5) kitchenettes: microwaves, stoves, kitchen hoods, and refrigerators
- Data closets: computer equipment, etc.
- Dorms: laptops, chargers, microwaves, mini fridges, coffee makers, televisions, and portable fans

**Elevators**
- One (1) elevator serves the building

**Natural Gas Equipment**
- One (1) gas fireplace in the first-floor lounge

## Specialty Systems

**Air Compressors**
- Two (2) air compressor pumps generate compressed air for pneumatic controls
  - Self-contained control system

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**
- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control

  - Scheduling of HVAC equipment and space temperature setbacks
- Implement pump differential pressure reset controls on the HW and CHW pumps
- Implement CHW supply temperature reset control
- Setback equipment during academic breaks
- Install low-flow or ultra low-flow showerheads

**Capital Measures**

- Install window film for solar heat gain reduction
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Continue replacing exterior light fixtures with LED fixtures as part of ongoing campus project
- Convert AHU-1 to single-zone variable air volume (VAV) system by installing VFD on system and implementing a temperature-based control scheme to modulate airflow
- Install occupancy-based HVAC controls on AHU-1
- Install occupancy based thermostatic control of fan coil units to allow for automatic setback of space temperature setpoints when dorm rooms are unoccupied.
  - Thermostats with integrated passive infrared (PIR) occupancy sensors specifically manufactured for hotel guest room and dorm room systems are readily available in the market.
  - Alternatively, remote PIR occupancy sensors can be installed connected directly or wirelessly with the thermostat.
  - Window sensors can be installed and connected to the thermostat to turn the fan coils off when the windows are opened
- Consider installing an exhaust air energy recovery system for bathroom stacked exhaust system
- Replace pneumatic actuators with electric actuators
- Consider implementing demand control ventilation for AHU-1 serving the lobby
- Replace DHW heater with semi-instantaneous water heater
- Replace DHW circulating pumps and motors with electronically commutated motors

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | LAKESIDE DINING HALL BUILDING ASSESSMENT

## Building Description

**Building Name:** Lakeside Dining Hall

**Year Constructed:** 1959

**No. of Floors:** 1 + Basement

**Est. GSF:** 27,870

### Recent Building Upgrades

- Building renovation – 2006

### Functional Description

Lakeside Dining Hall is located next to Lake Ontario on SUNY Oswego's main campus. The building is comprised of a dining area, commercial kitchen, mechanical rooms, and bathrooms.

### Occupancy Patterns

The dining hall is open from 7 a.m. to 11 p.m. on weekdays and from 9 a.m. to 11 p.m. on weekends, with short closures between meals.

## Building Envelope

### Roof

- Flat roof over most of building; pitched metal roof over main entryway; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Concrete masonry with a brick façade
- Insulation type and levels not accessible during walk-through

### Windows

- Double glazed, single-hung windows with wood interior and aluminum thermal break

### Doors

- Building entryway doors are clear, double glazed, metal frame doors

### Air Infiltration/Leakage

- No excessive infiltration was observed

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for cooking

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building by two (2) pressure reducing valves (PRV) operating in parallel with a bypass

### Submeters

- This building has a campus-managed Electro Industries revenue grade electricity submeter

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Dining area: High bay fixtures with T5 fluorescent lamps
  - Mechanical rooms: T8 fluorescent lighting

### Interior Lighting Controls

- No automatic controls observed during walk-through

### Exterior Lighting and Controls

- The campus is installing LEDs in place of the existing compact fluorescent exterior lighting; this is an ongoing project at Lakeside Dining Hall
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- One (1) steam-to-hot-water converter HX-1 generates hot glycol for building heating
  - Hot water pumps HWP-1 and HWP-2 operate as lead/standby for the HW loop. HW pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure.
    - HWP-1 and HWP-2 have 7.5 horsepower (hp) motors
    - Triple duty valves set to 75% open during January 2022 walk-through
  - Supply temperature of 131°F and return temperature of 105°F observed
  - One (1) 35% propylene glycol tank supplies hot glycol
  - Appears to utilize reset of HW supply temperature based on outside air (OA) temperature

### Central Cooling System

- Two (2) 355-ton chillers generate chilled water (CHW) for building cooling in Lakeside Dining Hall, Johnson Hall common spaces, and Riggs Hall
  - Water-cooled chillers, each with three (3) screw compressors
  - R-134A refrigerant
  - Chilled water pumping arrangement is constant flow primary/variable flow secondary. Primary chilled water pumps PCWP-1 and PCWP-2 circulate CHW through the chillers. Secondary chilled

water pumps CHW-1 and CHW-2 circulate CHW to the building. Secondary CHW pumps have VFD control of pump motor speed based on differential pressure.
    - PCWP-1 and PCWP-2 triple duty valves set to 85% and 100% open, respectively, during January 2022 walk-through
    - CHW-1 and CHW-2 triple duty valves set to 40% and 60% open, respectively, during January 2022 walk-through
  - Three (3) condenser water pumps operate as lead/standby and circulate condenser water between the chiller condenser and the cooling tower. Both condenser water pump motors are constant speed.
  - Cooling tower fan has VFD control of fan motor speed to maintain leaving water temperature

**Air Handling Units**
- Air handling unit AHU-1, located in the penthouse mechanical room, serves the dining area and serving line
  - Supply fan motor controlled by VFD
  - HW heating coils; CHW cooling coils
- Air handling unit MAU-1 proves make-up air to the kitchen
  - 100% OA unit
  - HW heating coils

**Exhaust Systems**
- Axial exhaust fans serve the bathrooms, mechanical rooms, and elevators
- Four (4) exhaust fans serve the kitchen and dining area
  - EF-1 serves the kitchen hoods
  - EF-2, EF-3, and EF-4 serve the dining area and serving line

**Zone Heating/Cooling**
- Ceiling diffusers provide airflow throughout the building
- Radiant floor heating serves the dining area
  - Occupied/unoccupied schedules set in the building automation system (BAS)
- Cabinet unit heaters serve the stairwells
- Five (5) fan coil units (FCU) provide additional heating and cooling throughout the building
  - FCU-1 has HW heating coils and supplies air to other FCUs
  - FCU-2, FCU-3, FCU-4, and FCU-5 have heating and cooling coils

## HVAC Controls

**Building Automation System**
- Carrier i-Vu® 8.0 BAS used for monitoring, direct digital control (DDC), and energy management of HVAC systems
  - Kitchen exhaust systems are not on the BAS

**Operating Schedules**
- Kitchen exhaust hoods are manually turned on in the morning and off at night
- Other HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**

- One (1) steam bundle storage tank
  - Self-contained pneumatic control valve
  - Receiving pump and tempering valve
  - Supply temperature of 122°F observed

**Domestic Hot Water (DHW) Load**

- Bathroom hand sinks
- Commercial kitchen equipment and dishwasher

## Piping and Ductwork

**Piping Systems/Insulation**

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**

- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Kitchen Equipment**

- Kettles, fryers, ovens, etc.
- One (1) pilot standby stove with six (6) burners
- Walk-in coolers and freezers with air-cooled condensers

**Elevators**

- One (1) hydraulic elevator serves the building

## Specialty Systems

**Air Compressors**

- Air compressors generate compressed air for pneumatic controls

**Commercial Kitchen Equipment**

- Direct steam used for kitchen dishwashers, steam kettles, and steam-heated convection ovens
- Air-cooled condensing units for refrigeration

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Retro-commissioning of HVAC systems and controls

  - Optimize HW supply temperature reset control
  - Optimize cooling tower water temperature control
  - Optimize temperature setpoints and schedule of radiant heating loop
  - Scheduling of HVAC equipment and space temperature setbacks
  - Scheduling of kitchen exhaust fan operation
- Implement pump differential pressure reset controls on the HW pumps and secondary CHW pumps
- Implement CHW supply temperature reset
- Implement duct static pressure reset controls on AHU-1
- Setback equipment during academic breaks

**Capital Measures**

- Install window film for solar heat gain reduction
- Install building-level gas and steam submeters
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Continue replacing exterior light fixtures with LED fixtures as part of ongoing campus project
- Open triple duty valves to 100% and utilize HW and CHW pump VFDs to balance the flow
- Replace existing space cooling chillers with high-efficiency variable speed magnetic bearing chillers at end of useful life
  - R-134A refrigerant is being phased out starting January 1, 2024
  - Once manufacturing of R-134A is eliminated, the price of R-134A stock is expected to rise substantially
- Install occupancy-based HVAC controls
- Replace pneumatic actuators with electric actuators
- Consider implementing demand control ventilation in the dining area
- Consider implementing kitchen demand control ventilation on exhaust and makeup air systems
- Connect remaining building systems to BAS
- Replace DHW heater with semi-instantaneous water heater
- Replace DHW circulating pumps and motors with electronically commutated motors
- Replace refrigeration evaporator fan motors with electronically commutated motors
- Install desuperheater on refrigeration loop to recovery energy for domestic hot water heating

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | LITTLEPAGE DINING HALL BUILDING ASSESSMENT

## Building Description

**Building Name:** Littlepage Dining Hall

**Year Constructed:** 1968

**No. of Floors:** 2 + Penthouse

**Est. GSF:** 33,827

### Recent Building Upgrades

- Full building renovation – Ongoing
- Building envelope renovation – 2017

### Functional Description

Littlepage Dining Hall is a building on West Campus that houses both a dining hall and the Glimmerglass Fitness Center. The upper floor consists of a commercial kitchen, two serving lines, a large dining area, storage space and offices. The lower floor is comprised of the fitness center, mechanical and electrical rooms, and a maintenance shop.

### Occupancy Patterns

Typically, the dining hall is occupied from 7 a.m. to 8 p.m. on weekdays and from 9 a.m. to 12 a.m. on weekends. The fitness center is open from 7 a.m. to 10 p.m. Monday through Thursday, from 7 a.m. to 8 p.m. on Fridays, and from 10 a.m. to 8 p.m. on weekends.

## Building Envelope

### Roof

- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Concrete masonry with a concrete façade
- Insulation type and levels not accessible during walk-through

### Windows

- Clear, single glazed, fixed, aluminum frame windows
  - Large, nearly floor-to-ceiling

### Doors

- Building entryway doors are clear, single glazed, aluminum frame doors
- Loading dock doors are hollow metal doors

### Air Infiltration/Leakage

- No excessive infiltration was observed

## Utilities

### Electricity
- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas
- This building does not receive natural gas

### District Steam
- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

### Submeters
- This building has a campus-managed Electro Industries revenue grade electricity submeter

## Lighting

### Interior Fixture Types
- Predominant lighting types as follows:
  - Kitchen: Recessed fixtures with linear fluorescent lamps
  - Dining room: Recessed troffer fixtures with fluorescent lamps
  - Loading dock: Strip light fixtures with linear T8 fluorescent lamps
  - Lower level: Strip light fixtures with linear T8 fluorescent lamps

### Interior Lighting Controls
- No automatic controls observed during walk-through

### Exterior Lighting and Controls
- Predominant exterior lighting type is high-intensity discharge (HID)
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System
- One (1) shell & tube steam-to-hot-water converter generates heating hot water (HW) for building heating
  - 1/3 & 2/3 direct digital control (DDC), pneumatically actuated steam valves modulate HW supply temperature at the outlet of the converter. One (1) mixing valve controls supply temperature to the perimeter radiation loop.
  - HW pumps P-5 and P-6 operate as lead/standby for the perimeter radiation loop and HW pumps P-7 and P-8 operate as lead/standby for the air handler coils loop. All HW pump motors are constant speed.
    - P-5 and P-6 are base-mounted centrifugal pumps with 2 horsepower (hp) motors
    - P-7 and P-8 are base-mounted centrifugal pumps with 10 hp motors

### Central Cooling System
- Carrier 116-ton water-cooled chiller generates chilled water (CHW) for building cooling

- Two (2) constant speed screw compressors
- R-134A refrigerant
- Forced-draft cooling tower with constant speed fan motor
- Condenser water (CW) pumps P-1 and P-2 operate as lead/standby for the CW loop and CHW pumps P-3 and P-4 operate as lead/standby for the CHW loop. All four (4) pump motors are constant speed.
  - P-1 and P-2 are vertical in-line and horizontal split-case pumps with 20 hp motors
  - P-3 and P-4 are motor-mounted pumps with 15 hp motors

**Air Handling Units**

- Two (2) air handling units serve the building
  - Constant volume multi-zone units
  - HW heating and reheat coils and CHW cooling coils
- One (1) heating and ventilating unit provides make-up air for kitchen exhaust
  - 100% outside air (OA) unit
  - Constant speed supply fan motor
  - HW heating coil
- "Fan room" was not accessible during walk-through

**Exhaust Systems**

- Commercial kitchen cooking exhaust system
  - Four (4) approximately 6 ft. long Gaylord kitchen exhaust hoods above kitchen stoves, ovens, kettles, etc.
  - Two (2) approximately 3 ft. long kitchen exhaust hoods above serving line griddles
    - Fans observed to be on during walk-through, despite kitchen not being in use
- Commercial kitchen dishwasher exhaust system
- Four (4) small general exhaust fans with constant speed motors serve the building

**Zone Heating/Cooling**

- Finned tube radiation provides perimeter heating; temperature control appears to be limited to HW supply temperature reset control

## HVAC Controls

**Building Automation System**

- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, DDC, and energy management of HVAC systems
  - Chiller and CHW system are not on the BAS

**Operating Schedules**

- HVAC systems are assumed to operate from 6 a.m. to 11 p.m. on weekdays and from 8 a.m. to 1 a.m. on weekends

## Domestic/Service Water Heating

**Domestic Water Heaters**

- One (1) steam bundle storage tank
  - Estimated 1,000 to 2,000-gallon capacity
  - 1/3 & 2/3 pneumatically actuated steam valves
  - In-line circulating pump with fractional hp motor
    - Motor installed 2021

**Domestic Hot Water (DHW) Load**

- Bathroom hand sinks
- Commercial kitchen equipment and dishwasher

## Piping and Ductwork

**Piping Systems/Insulation**

- Condensate piping insulation was observed to be missing in several areas
- Spot observations of ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**

- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug Loads**

- Offices: computers or laptops, desk phones, desk lamps, etc.

**Kitchen Equipment**

- Main kitchen: three (3) reach-in freezers, 10 to 15 reach-in coolers, one (1) walk-in freezer, two (2) walk-in coolers, two (2) hot boxes, a dishwasher, blenders, food processors, etc.
- Serving lines: two (2) hot boxes, four (4) reach-in coolers, hot food buffet tables, cold food buffet tables, fountain drink machines, griddles, holding cabinets, etc.
- Dining area: hot food buffet tables, cold food buffet tables, etc.

## Specialty Systems

**Commercial Kitchen Equipment**

- Direct steam used for kitchen dishwasher booster heater, steam kettles, and steam-heated convection ovens

**Air Compressors**

- One (1) duplex air compressor generates compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Retro-commissioning of HVAC systems and controls
  - Optimize cooling tower water temperature control
  - Scheduling of HVAC equipment and space temperature setbacks
  - Scheduling of kitchen exhaust fan operation, if the building is used as a dining hall in the future
- Setback equipment during academic breaks

**Capital Measures**

- Upgrade roof insulation to at least code levels during gut rehab project
- Upgrade exterior wall insulation to at least code levels during gut rehab project
- Replace single glazed windows with high performance windows
- Install building-level steam submeter
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity, such as the main dining area and the fitness center
- Replace exterior light fixtures with LED fixtures
- Install variable frequency drives (VFD) on the motors of HW pumps P-7 and P-8 and CHW pumps P-3 and P-4
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Replace existing chiller with high-efficiency water-cooled variable speed magnetic bearing chiller
  - R-134A refrigerant is being phased out starting January 1, 2024
  - Once manufacturing of R-134A is eliminated, the price of R-134A stock is expected to rise substantially
- Install VFD on cooling tower fan motor to maintain condenser water temperature at setpoint
- Replace air handling units with variable air volume (VAV) systems during gut rehab project
- Install occupancy-based HVAC controls
- Consider installing an exhaust air energy recovery system on the two (2) multi-zone air handling units
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace pneumatic actuators with electric actuators
- Implement HW and CHW supply temperature reset
- Consider implementing demand control ventilation in the dining area
- Consider implementing kitchen demand control ventilation on exhaust and makeup air systems if the building is used as a dining hall in the future
- Connect remaining building systems to BAS
- Replace DHW heater with semi-instantaneous water heater
- Replace DHW circulating pump and motor with electronically commutated motor
- Replace refrigeration evaporator fan motors with electronically commutated motors if the building is used as a dining hall in the future
- Install desuperheater on refrigeration loop to recovery energy for domestic hot water heating if the building is used as a dining hall in the future

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives
- Repair missing insulation on condensate piping

# SUNY OSWEGO | LONIS HALL BUILDING ASSESSMENT

## Building Description

**Building Name:** Lonis Hall

**Year Constructed:** 1951

**No. of Floors:** 4

**Est. GSF:** 32,285

### Recent Building Upgrades

- Steam line replaced – 2021

### Functional Description

Lonis Hall is a residence hall on the east side of campus connected to Mackin Dining Hall on its south side. The upper three floors each consist of laundry rooms, kitchenettes, bathrooms, and 25 to 30 student rooms. The ground floor is comprised of additional student rooms, bathrooms, storage space, and a lounge.

### Occupancy Patterns

The Mackin Complex was used as a COVID-19 isolation residence at the onset of the pandemic, but all three buildings have now been unoccupied for approximately two years. They may be repurposed for the department of Auxiliary Services in the near future. Previously, Lonis Hall was occupied 24/7 during the academic year and housed around 75 students.

## Building Envelope

### Roof

- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Concrete masonry with a brick façade
- Insulation type and levels not accessible during walk-through

### Windows

- Clear, sliding, aluminum frame windows
  - Primarily double glazed, although some are single glazed

### Doors

- Building entryway doors are clear, double glazed, aluminum frame doors

### Air Infiltration/Leakage

- No excessive infiltration was observed

## Utilities

### Electricity
- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas
- This building does not receive natural gas

### District Steam
- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the Mackin Complex

### Submeters
- None observed during walk-through

## Lighting

### Interior Fixture Types
- Predominant lighting types as follows:
  - Student rooms: Recessed fixtures with compact fluorescent lamps (CFL)
  - Basement: Surface mount fixtures with linear fluorescent lamps

### Interior Lighting Controls
- No automatic controls observed during walk-through

### Exterior Lighting and Controls
- Predominant exterior lighting type is high-intensity discharge (HID)
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System
- Primary heating hot water (HW) system is the steam-to-hot-water converter located in Mackin Dining Hall
- Alternate HW system is the natural gas-fired hydronic boiler located in Mackin Dining Hall

### Central Cooling System
- No space cooling in this building

### Air Handling Units
- None observed during walk-through

### Exhaust Systems
- Several small general exhaust fans with constant speed motors serve the building
- Kitchenette cooking exhaust system
  - Three (3) kitchen exhaust hoods above small stoves in communal kitchenettes

**Zone Heating/Cooling**

- Finned tube radiation provides perimeter heating to student rooms and common spaces; two (2) HW zone control valves modulate to maintain space temperature setpoints
- Cast-iron radiators serve offices and storage spaces
  - Self-contained control valves
- Several spaces were markedly overheated, despite building being unoccupied

## HVAC Controls

**Building Automation System**

- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems in the Mackin Complex
  - Only one (1) heating and ventilating unit, exhaust fans, control valves for the perimeter radiation loop, and the domestic hot water (DHW) system are on the BAS

**Operating Schedules**

- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**

- Primary DHW system is the steam bundle storage tank located in Mackin Dining Hall
- Alternate DHW system is the natural gas-fired hydronic boiler located in Mackin Dining Hall

**DHW Load**

- Bathroom hand sinks and showers
- Kitchenette sinks
- Recycling room utility sinks

## Piping and Ductwork

**Piping Systems/Insulation**

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**

- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug Loads**

- Dorm rooms: laptops, chargers, microwaves, mini fridges, coffee makers, televisions, and portable fans
- Laundry room: washing machines and dryers

## Specialty Systems

### Air Compressors

- Two (2) air compressors located in Mackin Dining Hall generate compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

### No Cost/Low Cost Measures

- Setback equipment during academic breaks and when buildings are not in use
- Install low-flow or ultra low-flow showerheads

### Capital Measures

- Upgrade roof insulation to at least code levels during gut rehab project
- Upgrade exterior wall insulation to at least code levels during gut rehab project
- Replace single glazed windows with high performance windows
- Install building-level gas and steam submeters
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Connect remaining building systems to BAS

### O&M Measures

- No O&M opportunities identified during walk-through

# SUNY OSWEGO | MACKIN DINING HALL BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | Mackin Dining Hall |
| **Year Constructed:** | 1951 |
| **No. of Floors:** | 4 + Penthouse |
| **Est. GSF:** | 41,984 |

**Recent Building Upgrades**
- Steam line replaced – 2021

**Functional Description**
Mackin Dining Hall is a dining hall on the east side of campus connected to Lonis Hall on its north side and Moreland Hall on its south side. The upper two floors consist of offices, classrooms, lounges, and a director's apartment. The ground floor is comprised of a commercial kitchen and dining hall. Additional offices, storage spaces, and main electrical and mechanical rooms are located in the basement.

**Occupancy Patterns**
The Mackin Complex was used as a COVID-19 isolation residence at the onset of the pandemic, but all three buildings have now been unoccupied for approximately two years. They may be repurposed for the department of Auxiliary Services in the near future. Previously, the dining hall was open Monday through Thursday, from 3 p.m. to 7 p.m.

## Building Envelope

**Roof**
- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

**Exterior Walls**
- Concrete masonry with a brick façade
- Insulation type and levels not accessible during walk-through

**Windows**
- Clear, sliding, aluminum frame windows
  - Primarily double glazed, although some are single glazed

**Doors**
- Building entryway doors are clear, double glazed, aluminum frame doors

**Air Infiltration/Leakage**
- No excessive infiltration was observed

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for space heating and domestic hot water heating when the central plant is down

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

### Submeters

- None observed during walk-through

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Basement: Surface mount fixtures with linear fluorescent lamps
  - Other spaces were not accessible during walk-through

### Interior Lighting Controls

- No automatic controls observed during walk-through

### Exterior Lighting and Controls

- Predominant exterior lighting type is high-intensity discharge (HID)
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- One (1) shell & tube steam-to-hot-water converter generates heating hot water (HW) for the complex
  - Pneumatically actuated steam valve modulates HW supply temperature at the outlet of the converter
  - One (1) hot water pump circulates HW to building heating terminals
- One (1) cast-iron sectional boiler serves as alternate HW system when the central plant is down
  - Weil-McLain Model 1888 natural gas-fired hot water boiler
  - 2,452 thousand Btus per hour (MBH) output

### Central Cooling System

- No space cooling in this building

### Air Handling Units

- One (1) heating and ventilating unit serves the dining room
  - 100% outside air (OA) unit

  - Constant speed supply fan motor
  - HW heating coil with electronic control valve

**Exhaust Systems**
- Several small general exhaust fans with constant speed motors serve the building
- Commercial kitchen cooking exhaust system

**Zone Heating/Cooling**
- Finned tube radiation provides perimeter heating; one (1) steam valve modulates to maintain space temperature setpoint
- Cast-iron radiators serve kitchen and other spaces
  - Self-contained control valves
- Several spaces were markedly overheated, despite building being unoccupied

## HVAC Controls

**Building Automation System**
- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems in the Mackin Complex
  - Only the heating and ventilating unit, exhaust fans, control valves for the perimeter radiation loop, and the domestic hot water (DHW) system are on the BAS

**Operating Schedules**
- Operating schedules could not be verified during walk-through

## Domestic/Service Water Heating

**Domestic Water Heaters**
- Primary DHW system is one (1) steam bundle storage tank
  - Serves all three (3) buildings in the complex
- Alternate DHW system is the natural gas-fired hydronic boiler
  - Serves all three (3) buildings in the complex when the central plant is down
- One (1) shell & tube steam-to-hot-water converter generates DHW for commercial dishwasher

**DHW Load**
- Bathroom hand sinks and showers
- Kitchenette sinks
- Commercial kitchen equipment and dishwasher

## Piping and Ductwork

**Piping Systems/Insulation**
- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**
- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**
- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug Loads**
- Apartments: laptops, chargers, microwaves, fridges, kitchen ranges, coffee makers, televisions, and portable fans
- Offices: computers or laptops, desk phones, desk lamps, etc.
- Classrooms: computers, projectors, etc.
- Corridors: vending machines

**Kitchen Equipment**
- Kitchen and dining hall not accessible during walk-through

**Elevators**
- One (1) service elevator serves the basement and ground floor
- One (1) dumbwaiter serves the kitchen

## Specialty Systems

**Air Compressors**
- Two (2) air compressors generate compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**
- Retro-commissioning of HVAC systems and controls
  - Scheduling of HVAC equipment and space temperature setbacks
  - Scheduling of kitchen exhaust fan operation, if the building is used as a dining hall in the future
- Setback equipment during academic breaks and when buildings are not in use
- Install low-flow or ultra low-flow showerheads

**Capital Measures**
- Upgrade roof insulation to at least code levels during gut rehab project
- Upgrade exterior wall insulation to at least code levels during gut rehab project
- Replace single glazed windows with high performance windows
- Install building-level gas and steam submeters
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Replace hot water pump and motor with electronically commutated motor
- Replace heating and ventilating unit with variable air volume (VAV) system during gut rehab project

- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace pneumatic actuators with electric actuators
- Implement HW supply temperature reset
- Consider implementing kitchen demand control ventilation on exhaust and makeup air systems if the building is used as a dining hall in the future
- Connect remaining building systems to BAS
- Replace DHW heater with semi-instantaneous water heater
- Replace refrigeration evaporator fan motors with electronically commutated motors if the building is used as a dining hall in the future
- Install desuperheater on refrigeration loop to recovery energy for domestic hot water heating if the building is used as a dining hall in the future

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | MORELAND HALL BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | Moreland Hall |
| **Year Constructed:** | 1951 |
| **No. of Floors:** | 4 |
| **Est. GSF:** | 29,400 |

### Recent Building Upgrades

- Steam line replaced – 2021

### Functional Description

Moreland Hall is a residence hall on the east side of campus connected to Mackin Dining Hall on its north side. The upper three floors each consist of laundry rooms, kitchenettes, bathrooms, and 25 to 30 student rooms. The ground floor is comprised of a residential staff apartment, office, storage space, and a lounge.

### Occupancy Patterns

The Mackin Complex was used as a COVID-19 isolation residence at the onset of the pandemic, but all three buildings have now been unoccupied for approximately two years. They may be repurposed for the department of Auxiliary Services in the near future. Previously, Moreland Hall was occupied 24/7 during the academic year and housed around 100 students.

## Building Envelope

### Roof

- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Concrete masonry with a brick façade
- Insulation type and levels not accessible during walk-through

### Windows

- Clear, sliding, aluminum frame windows
  - Primarily double glazed, although some are single glazed

### Doors

- Building entryway doors are clear, double glazed, aluminum frame doors

### Air Infiltration/Leakage

- No excessive infiltration was observed

## Utilities

### Electricity
- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas
- This building does not receive natural gas

### District Steam
- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the Mackin Complex

### Submeters
- None observed during walk-through

## Lighting

### Interior Fixture Types
- Predominant lighting types as follows:
  - Student rooms: Recessed fixtures with compact fluorescent lamps (CFL)
  - Basement: Surface mount fixtures with linear fluorescent lamps

### Interior Lighting Controls
- No automatic controls observed during walk-through

### Exterior Lighting and Controls
- Predominant exterior lighting type is high-intensity discharge (HID)
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System
- Primary heating hot water (HW) system is the steam-to-hot-water converter located in Mackin Dining Hall
- Alternate HW system is the natural gas-fired hydronic boiler located in Mackin Dining Hall

### Central Cooling System
- No space cooling in this building

### Air Handling Units
- None observed during walk-through

### Exhaust Systems
- Several small general exhaust fans with constant speed motors serve the building
- Kitchenette cooking exhaust system
  - Three (3) kitchen exhaust hoods above small stoves in communal kitchenettes

**Zone Heating/Cooling**

- Finned tube radiation provides perimeter heating to student rooms and common spaces
- Cast-iron radiators serve offices and storage spaces
  - Self-contained control valves
- Several spaces were markedly overheated, despite building being unoccupied
  - In particular, the ground floor lounge and recycling room

## HVAC Controls

**Building Automation System**

- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems in the Mackin Complex
  - Only one (1) heating and ventilating unit, exhaust fans, control valves for the perimeter radiation loop, and the domestic hot water (DHW) system are on the BAS

**Operating Schedules**

- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**

- Primary DHW system is the steam bundle storage tank located in Mackin Dining Hall
- Alternate DHW system is the natural gas-fired hydronic boiler located in Mackin Dining Hall

**DHW Load**

- Bathroom hand sinks and showers
- Kitchenette sinks
- Recycling room utility sinks

## Piping and Ductwork

**Piping Systems/Insulation**

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**

- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug Loads**

- Dorm rooms: laptops, chargers, microwaves, mini fridges, coffee makers, televisions, and portable fans
- Laundry room: washing machines and dryers

## Specialty Systems

### Air Compressors
- Two (2) air compressors located in Mackin Dining Hall generate compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

### No Cost/Low Cost Measures
- Setback equipment during academic breaks and when buildings are not in use
- Install low-flow or ultra low-flow showerheads

### Capital Measures
- Upgrade roof insulation to at least code levels during gut rehab project
- Upgrade exterior wall insulation to at least code levels during gut rehab project
- Replace single glazed windows with high performance windows
- Install building-level gas and steam submeters
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Connect remaining building systems to BAS

### O&M Measures
- No O&M opportunities identified during walk-through

# SUNY OSWEGO | ONEIDA HALL BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | Oneida Hall |
| **Year Constructed:** | 1970 |
| **No. of Floors:** | 5 |
| **Est. GSF:** | 105,000 |

**Recent Building Upgrades**
- Exterior renovation – 2010

**Functional Description**
Oneida Hall is a residence hall on West campus. The building encloses two courtyards, one on the eastern side and one on the western side. On the upper four floors, a lounge separates the courtyards, and the building perimeter consists of two-person and 4-person student rooms. Residential staff apartments and offices are located on the first floor. The basement is comprised of storage spaces, a laundry room, a computer room, an electrical room, and mechanical rooms. This residence hall was being used as a COVID-19 isolation dorm at the time of the walk-through in January 2022.

**Occupancy Patterns**
The dorm is occupied 24/7 during the academic year and can house approximately 450 students. As an isolation dorm, the building is temporarily occupied by fewer people on a more consistent daily schedule.

## Building Envelope

**Roof**
- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

**Exterior Walls**
- Concrete masonry with a concrete façade
- Insulation type and levels not accessible during walk-through

**Windows**
- Clear, double glazed, aluminum frame windows
  - Double-hung windows with sidelights in lobbies and perimeter common areas
  - Awning windows in rooms adjacent to courtyards

**Doors**
- Building entryway and courtyard doors are clear, double glazed, aluminum frame doors

**Air Infiltration/Leakage**
- No excessive infiltration was observed

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for backup generator

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

### Submeters

- This building has a campus-managed Electro Industries revenue grade electricity submeter

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Dorms: Student rooms not accessible during walk-through
  - Bathrooms: Bathrooms not accessible during walk-through
  - Corridors and lounges: Surface mount fixtures with compact fluorescent lamps (CFL) and linear T8 fluorescent lamps
  - Basement: Pendant fixtures with CFLs and surface mount fixtures with linear T8 fluorescent lamps

### Interior Lighting Controls

- No automatic controls observed during walk-through

### Exterior Lighting and Controls

- Predominant exterior lighting type is high-intensity discharge (HID)
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- One (1) shell & tube steam-to-hot-water converter generates heating hot water (HW) for most of the building
  - Pneumatic control valve modulates HW supply temperature at the outlet of the converter
  - Hot water pumps P-1 and P-2 circulate HW to building heating terminals. HW pump motors are constant speed.
    - Bell & Gossett base-mounted centrifugal pumps with 10 horsepower (hp) motors, rated for 510 gallons per minute (gpm) at 45 feet of head
  - Appears to utilize reset of HW supply temperature based on outside air (OA) temperature
- One (1) shell & tube steam-to-hot-water converter generates heating HW for Resident Director apartment suite
  - Pneumatic control valve modulates HW supply temperature at the outlet of the converter

- In-line circulating pump with constant speed fractional horsepower motor circulates HW to the apartment

**Central Cooling System**

- No space cooling in this building

**Air Handling Units**

- One (1) heating and ventilating unit HV-1 serves the basement
  - 100% OA unit
  - Constant speed supply fan motor
  - HW heating coil with two-way pneumatic control valve and face & bypass dampers with pneumatic actuators
- One (1) air handling unit MZ-1 serves the first-, second-, and third-floor lounges
  - Constant volume multi-zone unit
  - Constant speed supply and return fan motors
  - HW heating coil

**Exhaust Systems**

- Several small exhaust fans with constant speed motors serve the building

**Zone Heating/Cooling**

- Finned tube radiation provides perimeter heating in dorm rooms and common spaces; temperature control is limited to HW supply temperature control of three (3) building zones
- No sensors or room-level temperature control in dorm rooms

## HVAC Controls

**Building Automation System**

- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems

**Operating Schedules**

- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**

- One (1) steam bundle storage tank
  - Estimated 2,000-gallon capacity
  - 1/3 & 2/3 DDC controlled, electronically actuated steam valves

**DHW Load**

- Bathroom hand sinks and showers
- Common room kitchenette sink

## Piping and Ductwork

**Piping Systems/Insulation**

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**

- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug Loads**

- Offices: computers or laptops, desk phones, desk lamps, etc.
- Dorm rooms: laptops, chargers, microwaves, mini fridges, coffee makers, televisions, and portable fans
- Laundry room: washing machines and dryers
- First-floor lounge: three (3) beverage and snack vending machines, two (2) small refrigerators, and two (2) microwaves

**Elevators**

- One (1) elevator serves the building
- One (1) dumbwaiter serves the first-floor receiving area

## Specialty Systems

**Air Compressors**

- Two (2) air compressors generate compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control
  - Scheduling of HVAC equipment and space temperature setbacks
- Setback equipment during academic breaks
- Install low-flow or ultra low-flow showerheads

**Capital Measures**

- Upgrade roof insulation to at least code levels during gut rehab project
- Upgrade exterior wall insulation to at least code levels during gut rehab project
- Install building-level steam submeter
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces

    - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Install variable frequency drives (VFD) on the motors of HW pumps P-1 and P-2
- Replace HW circulating pump and motor serving Resident Director apartment suite with electronically commutated motor at end of useful life
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Replace and upgrade HVAC system during gut rehab project and consider including exhaust air energy recovery system
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace pneumatic actuators with electric actuators
- Connect remaining building systems to BAS
- Replace DHW heater with semi-instantaneous water heater

**O&M Measures**
- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | ONONDAGA HALL BUILDING ASSESSMENT

## Building Description


**Building Name:** Onondaga Hall

**Year Constructed:** 1968

**No. of Floors:** 10 + 2 Penthouses

**Est. GSF:** 152,548

**Recent Building Upgrades**
- Exterior renovation – 2010

**Functional Description**
Onondaga Hall is a high-rise residence hall on West campus. The upper eight floors each consist of a main hallway joining twelve 6-person suites and two lounges. The first floor is comprised of offices, residential staff apartments, lobby space, and additional student rooms. A larger lounge, laundry room, kitchenette, storage spaces, and main electrical and mechanical rooms are located in the basement.

**Occupancy Patterns**
The dorm is occupied 24/7 during the academic year and can house approximately 600 students.

## Building Envelope

**Roof**
- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

**Exterior Walls**
- Concrete masonry with a concrete façade
- Insulation type and levels not accessible during walk-through

**Windows**
- Clear, double glazed, double-hung, aluminum frame windows with sidelights

**Doors**
- Building entryway under construction during walk-through

**Air Infiltration/Leakage**
- No excessive infiltration was observed

## Utilities

**Electricity**
- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for backup generator

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

### Submeters

- This building has a campus-managed Electro Industries revenue grade electricity submeter

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Dorms: Surface mount fixtures with compact fluorescent lamps (CFL) and floor lamps with LED bulbs
  - Corridors and lounges: Surface mount fixtures with CFLs
  - Basement: Recessed fixtures with U-bend and linear T8 fluorescent lamps

### Interior Lighting Controls

- Manually switched lighting in dorm rooms
- Vacancy sensors located in suite bathrooms
- Lighting fixtures in common spaces dim at set time

### Exterior Lighting and Controls

- Predominant exterior lighting type is high-intensity discharge (HID)
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- One (1) shell & tube steam-to-hot-water converter generates heating hot water (HW) for most of the building
  - Pneumatic control valve modulates HW supply temperature at the outlet of the converter
    - Scheduled to be replaced with an electronically actuated valve by 2023
  - Hot water pumps P-1 and P-2 circulate HW to building heating terminals. HW pump motors are constant speed.
    - Bell & Gossett base-mounted centrifugal pumps with 7.5 horsepower (hp) motors, rated for 316 gallons per minute (gpm) at 45 feet of head
- One (1) shell & tube steam-to-hot-water converter generates heating HW for Resident Director apartment suite
  - Pneumatic control valve modulates HW supply temperature at the outlet of the converter
- HW supply temperature is reset based on outside air (OA) temperature
  - 180°F supply temperature at 30°F OA temperature
  - 140°F supply temperature at 60°F OA temperature

**Central Cooling System**

- One (1) small outside air-cooled chiller
    - R-407C refrigerant
    - Could not verify service during walk-through
- One (1) dry cooler with three (3) fans serves Liebert unit
- No other space cooling in this building

**Air Handling Units**

- One (1) heating and ventilating unit provides make-up air for laundry room exhaust
    - 100% OA unit
    - Supply fan motor controlled by variable frequency drive (VFD) to track exhaust fan VFD
    - HW heating coil with two-way pneumatic control valve
- 11 additional heating and ventilating units supply ventilation air to corridors and common spaces
    - Pneumatic damper actuators
    - Two (2) units have HW heating coils; nine (9) units have direct steam heating coils

**Exhaust Systems**

- Several small exhaust fans with constant speed motors serve the building
- Dedicated laundry room exhaust fan controlled by VFD to maintain duct static pressure

**Zone Heating/Cooling**

- Finned tube radiation provides perimeter heating in dorm rooms and common spaces; temperature control is limited to HW supply temperature reset control
- No sensors or room-level temperature control in dorm rooms
- HW cabinet unit heaters serve the main entryways

## HVAC Controls

**Building Automation System**

- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems
    - Only the laundry room heating and ventilating unit and exhaust system are on the BAS

**Operating Schedules**

- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**

- One (1) steam bundle storage tank
    - Estimated 1,000-gallon capacity
    - 1/3 & 2/3 pneumatically actuated steam valves
    - Storage setpoint of 130°F observed

**DHW Load**

- Bathroom hand sinks and showers

- Common room kitchenette sink

## Piping and Ductwork

**Piping Systems/Insulation**
- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**
- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**
- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug Loads**
- Offices: computers or laptops, desk phones, desk lamps, etc.
- Dorm rooms: laptops, chargers, microwaves, mini fridges, coffee makers, televisions, and portable fans
- Laundry room: washing machines and dryers
- First-floor lobby: three (3) beverage and snack vending machines

**Elevators**
- Four (4) elevators serve the building

## Specialty Systems

**Air Compressors**
- Two (2) air compressors generate compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**
- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control
  - Scheduling of HVAC equipment and space temperature setbacks
- Setback equipment during academic breaks
- Install low-flow or ultra low-flow showerheads

**Capital Measures**
- Upgrade roof insulation to at least code levels during gut rehab project
- Upgrade exterior wall insulation to at least code levels during gut rehab project
- Install building-level steam submeter
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces

  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Install VFDs on the motors of HW pumps P-1 and P-2
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Replace and upgrade HVAC system during gut rehab project and consider including exhaust air energy recovery system
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace pneumatic actuators with electric actuators
- Connect remaining building systems to BAS
- Replace DHW heater with semi-instantaneous water heater

**O&M Measures**
- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | PATHFINDER DINING HALL BUILDING ASSESSMENT

## Building Description


| | |
|---|---|
| **Building Name:** | Pathfinder Dining Hall |
| **Year Constructed:** | 1967 |
| **No. of Floors:** | 1 + Basement |
| **Est. GSF:** | 33,827 |

### Recent Building Upgrades
- Boiler replacement - 1998

### Functional Description
Pathfinder Dining Hall is a building on West Campus comprised of a dining room, commercial kitchen, mechanical rooms, and bathrooms. The basement houses the campus police department.

### Occupancy Patterns
Typically, the dining hall is open from 8 a.m. to 11 p.m. Monday through Thursday, from 8 a.m. to 7:30 p.m. on Fridays, and from 9 a.m. to 11 p.m. on weekends, with closures between meals.

## Building Envelope

### Roof
- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls
- Concrete façade
- Insulation type and levels not accessible during walk-through

### Windows
- Single glazed, metal frame windows
  - Large, nearly floor-to-ceiling
  - Appear to be tinted

### Doors
- Building entryway doors are metal frame, swinging, glass doors

### Air Infiltration/Leakage
- No excessive infiltration was observed

## Utilities

### Electricity
- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for cooking and alternate space heating and domestic hot water (DHW) heating systems

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

### Submeters

- None observed during walk-through

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Dining area: High-bay fixtures with linear fluorescent lamps
  - Kitchen: Linear T8 fluorescent lighting
  - Corridors: Linear T8 fluorescent lighting
  - Police department: Campus police station was not accessible during walk-through

### Interior Lighting Controls

- Occupancy sensors are present throughout the building

### Exterior Lighting

- High-intensity discharge (HID) wall pack fixtures above loading dock and main entryways
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- One (1) steam-to-hot water converter generates heating hot water (HW) for building heating
  - Hot water pumps P-5 and P-6 operate as lead/standby for the air handler coils loop and HW pumps P-7 and P-8 operate as lead/standby for the perimeter radiation loop. All of the HW pump motors are constant speed.
    - P-5 and P-6 have 10 horsepower (hp) motors
    - P-7 and P-8 have 2 hp motors
  - Appears to utilize reset of HW supply temperature based on outside air (OA) temperature
- One (1) boiler serves as alternate HW system when the Central Heating Plant is at capacity
  - The boiler was previously required to supplement the central plant capacity during the coldest days of the year. Since the boiler upgrade at the central plant (around 2007), this satellite boiler at Pathfinder has not been required or used.

### Central Cooling System

- Carrier 126-ton water-cooled chiller generates chilled water (CHW) for building cooling
  - Two (2) constant speed screw compressors
  - R-134A refrigerant
  - Forced-draft cooling tower

- Condenser water (CW) pumps P-1 and P-2 operate as lead/standby for the CW loop and CHW pumps P-3 and P-4 operate as lead/standby for the CHW loop. All four (4) pump motors are constant speed.
  - P-1 and P-2 have 20 hp motors
  - P-3 and P-4 have 15 hp motors

### Air Handling Units

- Two (2) air handling units SF-1 and SF-2 serve the dining area and police department, respectively
  - Constant volume multi-zone units
  - HW heating coils and CHW cooling coils
- One (1) packaged rooftop energy recovery ventilator serves the kitchen

### Exhaust Systems

- General exhaust fans serve the bathrooms and mechanical rooms
- Commercial kitchen cooking exhaust system
  - No automatic kitchen hood controls observed during walk-through

### Zone Heating/Cooling

- Celling diffusers provide airflow to the dining area
- Finned tube radiation provides perimeter heating

## HVAC Controls

### Building Automation System

- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems

### Operating Schedules

- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

### Domestic Water Heaters

- One (1) steam bundle storage tank
  - Estimated 900-gallon capacity
  - 1/3 & 2/3 pneumatically actuated steam valves
  - Storage temperature setpoint is set manually
  - Storage setpoint of 130°F and supply setpoint of 116°F observed

### DHW Load

- Bathroom hand sinks
- Commercial kitchen equipment and dishwasher

## Piping and Ductwork

**Piping Systems/Insulation**

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies
- Some corrosion observed on piping to the DHW tank

**Equipment Insulation**

- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug loads**

- Dining area: vending machines
- Police department: Campus police station was not accessible during walk-through

**Kitchen Equipment**

- Main kitchen: kitchen hoods, one (1) gas stove with standing pilots on each of six (6) burners, ice maker, walk-in coolers and freezers, etc.

## Specialty Systems

**Commercial Kitchen Equipment**

- Direct steam used for kitchen dishwasher booster heater, steam kettles, and steam-heated convection ovens

**Air Compressors**

- Two (2) air compressors generate compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control
  - Optimize cooling tower water temperature control
  - Scheduling of HVAC equipment and space temperature setbacks
  - Scheduling of kitchen exhaust fan operation
- Implement CHW supply temperature reset
- Setback equipment during academic breaks

**Capital Measures**

- Replace single glazed windows with high performance windows
- Install building-level gas and steam submeters
- Replace interior fluorescent light fixtures with LED fixtures

    - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
    - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Install variable frequency drives (VFD) on the motors of HW pumps P-5 and P-6 and CHW pumps P-3 and P-4
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Replace existing chiller with high-efficiency water-cooled variable speed magnetic bearing chiller
    - R-134A refrigerant is being phased out starting January 1, 2024
    - Once manufacturing of R-134A is eliminated, the price of R-134A stock is expected to rise substantially
- If not already implemented, install VFD on cooling tower fan motor to maintain condenser water temperature at setpoint
- Install occupancy-based HVAC controls on SF-1 and SF-2
- Consider installing an exhaust air energy recovery system on SF-1 and SF-2
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace pneumatic actuators with electric actuators
- Consider implementing demand control ventilation in the dining area
- Consider implementing kitchen demand control ventilation on exhaust and makeup air systems
- Connect remaining building systems to BAS
- Replace DHW heater with semi-instantaneous water heater
- Replace refrigeration evaporator fan motors with electronically commutated motors
- Install desuperheater on refrigeration loop to recovery energy for domestic hot water heating

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | RIGGS HALL BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | Riggs Hall |
| **Year Constructed:** | 1960 |
| **No. of Floors:** | 3 + Basement |
| **Est. GSF:** | 58,201 |

**Recent Building Upgrades**
- Full building renovation – 2006

**Functional Description**
Riggs Hall is a residence hall located next to Lake Ontario on SUNY Oswego's main campus. The building consists of dorm rooms, a director's apartment, corridors, mechanical rooms, and storage spaces, with lounge areas and kitchenettes on each floor. The basement houses a laundry room and larger lounge.

**Occupancy Patterns**
The dorm is occupied 24/7 during the academic year and can house approximately 200 students.

## Building Envelope

**Roof**
- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

**Exterior Walls**
- Concrete masonry with a brick façade
- Insulation type and levels not accessible during walk-through

**Windows**
- Double glazed, single-hung, wooden frame windows with aluminum thermal spacers

**Doors**
- Building entryway doors are metal frame, glass doors

**Air Infiltration/Leakage**
- No excessive infiltration was observed

## Utilities

**Electricity**
- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for backup generator and first-floor lounge gas fireplace

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building by a pressure reducing valve (PRV)

### Submeters

- This building has a campus-managed Electro Industries revenue grade electricity submeter
- This building has a campus-managed natural gas submeter, but the submeter is not registering on the building automation system (BAS) as of 1/13/22

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Dorms: Recessed compact fluorescent quad fixtures with electronic ballasts
  - Bathrooms: Surface mount T8 fluorescent fixtures with electronic ballasts and wall mount T8 fluorescent vanity fixtures with electronic ballasts
  - Corridors: Surface mount fluorescent quad fixtures with electronic ballasts
  - Lounges: 4-arm prismatic pendant fluorescent fixtures with electronic ballasts
  - Study rooms: Wall mount T5 fluorescent fixtures with electronic ballasts
  - Stairwells: Surface mount fluorescent quad fixtures with electronic ballasts
  - First-floor lobby: Surface mount compact fluorescent fixture with electronic ballasts
  - First-floor offices: 2x4 recessed troffer fixtures with T8 fluorescent lamps
  - Laundry room: Surface mount T8 fluorescent fixtures with electronic ballasts
  - Mechanical room: Surface mount prismatic T8 fluorescent fixtures
  - Recycling room: Surface mount prismatic T8 fluorescent fixtures

### Interior Lighting Controls

- Lighting is scheduled in the BAS
  - Zoned by floor and section of building
  - Lighting is scheduled on at 7 a.m. and off at 8 p.m. daily
- Occupancy sensors in lounges, study rooms, and laundry room

### Exterior Lighting and Controls

- Metal halide wall pack fixtures above entryway
- Exterior lights on campus are controlled by photosensors and astronomical time clocks
- The campus is installing LEDs in place of the existing compact fluorescent exterior lighting; this is an ongoing project at Riggs Hall

## HVAC

### Central Heating System

- One (1) shell & tube steam-to-hot-water converter HX-1 generates heating hot water (HW) for building heating
  - Hot water pumps HWP-R-1 and HWP-R-2 operate as lead/standby for the HW loop. HW pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure.
    - Bell & Gossett base-mounted centrifugal pumps with 15 horsepower (hp) motors
  - Appears to utilize reset of HW supply temperature based on outside air (OA) temperature
  - Supply temperature of 124°F and return temperature of 122°F observed
- One (1) plate & frame HW-to-hot-glycol converter HX-2 generates hot glycol for building heating
  - Hot glycol pumps GP-R-1 and GP-R-2 circulate hot glycol to the building. Both glycol pumps have VFD control of pump motor speed based on differential pressure.
  - Supply temperature of 120°F observed

### Central Cooling System

- Two (2) 355-ton chillers located in Lakeside Dining Hall generate chilled water (CHW) for building cooling in Lakeside Dining Hall, Johnson Hall common spaces, and Riggs Hall
  - Chilled water pumps CHWP-1 and CHWP-2, located in the Riggs Hall mechanical room, circulate CHW to air handler cooling coils and cooling terminal equipment. CHW pumps have VFD control of pump motor speed based on differential pressure.
    - CHWP-1 and CHWP-2 have 7.5 hp motors

### Air Handling Units

- Air handling unit AHU-R-1 serves the community spaces
  - Supply fan motor controlled by VFD to maintain duct static pressure
  - Return fan motor controlled by VFD to track supply fan VFD
  - HW and CHW coils
- AHU-R-2 provides makeup air for toilet exhaust
  - Cross-flow energy recovery to recover energy from the exhaust airstream
  - Return air bypass to avoid recovery energy when outdoor air conditions permit
  - Constant speed supply and return fan motors
  - HW and CHW coils

### Exhaust Systems

- 11 exhaust fans serve the building
  - Exhaust fans EF-2 and EF-9 are controlled by space temperature setpoint for motor start/stop
  - Other exhaust fans are controlled by timer switch for motor start/stop

### Zone Heating/Cooling

- Variable air volume (VAV) boxes with HW reheat coils provide airflow to common areas
- Finned tube radiation provides perimeter heating lounges
- Valance units prove heating and cooling in dorm rooms and common spaces
- Cabinet unit heaters serve the main entryways and corridors
- Four (4) fan coil units (FCU) serve a corridor, the crawlspace, laundry room, and director's apartment
  - Delta controls maintain room temperature setpoints

  - Two (2) FCUs have HW heating coils; two (2) have hot glycol heating coils
  - FCU-R-2 serving the director's apartment and FCU-R-4 serving the corridor have both heating and cooling coils
  - FCU-R-2 supply fan motor controlled by VFD
- All rooms have temperature sensors and room-level thermostats

## HVAC Controls

**Building Automation System**
- Carrier i-Vu® 8.0 and Trane Tracer® Ensemble™ BAS used for monitoring, direct digital control (DDC), and energy management of HVAC systems

**Operating Schedules**
- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**
- One (1) steam bundle storage tank
  - Receiving pump and tempering valve
  - Supply temperature of 118°F observed
  - One (1) circulating pump

**Domestic Hot Water (DHW) Load**
- Bathroom hand sinks and showers
- Kitchenette sinks

## Piping and Ductwork

**Piping Systems/Insulation**
- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**
- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**
- Spot observations revealed no ductwork leakage issues

## Miscellaneous Loads

**Plug loads**
- Laundry room: washing machines and dryers
- Four (4) kitchenettes: microwaves, stoves, kitchen hoods, and refrigerators
- Basement corridor: dehumidifier
- Data closets: computer equipment, etc.
- Dorms: laptops, chargers, microwaves, mini fridges, coffee makers, televisions, and portable fans

**Elevators**
- One (1) hydraulic elevator serves the building

**Natural Gas Equipment**
- One (1) gas fireplace in the first-floor lounge

## Specialty Systems

**Air Compressors**
- Air compressors generate compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**
- Retro-commissioning of HVAC systems and controls
  - Scheduling of HVAC equipment and space temperature setbacks
- Implement pump differential pressure reset controls on the HW pumps, Glycol pumps, and CHW pumps
- Implement duct static pressure reset controls on AHU-R-1
- Setback equipment during academic breaks
- If not already implemented, implement HW, CHW, and hot glycol supply temperature reset control
- Install low-flow or ultra low-flow showerheads

**Capital Measures**
- Install window film for solar heat gain reduction
- Install building-level steam submeter
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Continue replacing exterior light fixtures with LED fixtures as part of ongoing project
- Install occupancy based thermostatic control to allow for automatic setback of space temperature setpoints when dorm rooms and common areas are unoccupied.
  - Thermostats with integrated passive infrared (PIR) occupancy sensors specifically manufactured for hotel guest room and dorm room systems are readily available in the market.
  - Alternatively, remote PIR occupancy sensors can be installed connected directly or wirelessly with the thermostat.
  - Window sensors can be installed and connected to the thermostat to turn the valance units off when the windows are opened
- Consider replacing FCUs and including electronically commutated motors
- Replace pneumatic actuators with electric actuators
- Replace DHW heater with semi-instantaneous water heater
- Replace DHW circulating pump and motor with electronically commutated motor

### O&M Measures

- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | SCALES HALL BUILDING ASSESSMENT

## Building Description


**Building Name:** Scales Hall

**Year Constructed:** 1961

**No. of Floors:** 4

**Est. GSF:** 57,464

**Recent Building Upgrades**

- Full building renovation – 2017

**Functional Description**

Scales Hall is a residence hall located next to Lake Ontario on SUNY Oswego's main campus. The four floors each consist of a west wing and an east wing, primarily housing two-person student rooms, in addition to a lounge and two shared bathroom alcoves. The first floor includes residential staff apartments, lobby space, offices, a workroom, and a computer room. A laundry room, kitchenette, storage spaces, and electrical and mechanical rooms are located in the basement.

**Occupancy Patterns**

The dorm is occupied 24/7 during the academic year and can house approximately 200 students.

## Building Envelope

**Roof**

- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

**Exterior Walls**

- Concrete masonry with a brick façade
- Insulation type and levels not accessible during walk-through

**Windows**

- Clear, double glazed, sliding or fixed, aluminum frame windows

**Doors**

- Building entryway doors are clear, double glazed, aluminum frame doors

**Air Infiltration/Leakage**

- No excessive infiltration was observed

## Utilities

**Electricity**

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for backup generator

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

### Submeters

- This building has a campus-managed Electro Industries revenue grade electricity submeter
- This building has a campus-managed steam submeter to measure pressure, flow, and temperature of medium pressure steam entering building
- This building has a campus-managed natural gas submeter
- This building has a campus-managed potable water submeter

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Dorms: Flush mount fixtures with LED lamps
  - Bathrooms: Flush mount fixtures with LED lamps and wall mount fluorescent sconces
  - Corridors, stairwells, and common areas: Recessed and surface mount fixtures with LED lamps
  - Lobby: Pendant fixture with LED lamp
  - Mechanical/electrical rooms: Industrial pendant fixtures with linear T8 fluorescent lamps

### Interior Lighting Controls

- Occupancy sensors located in stairwells
- Bi-level lighting with dimming switches in first-floor lounge
- Interior lighting is controlled locally. Interior lights are scheduled to be on from 7 a.m. to 10 p.m. daily.

### Exterior Lighting and Controls

- Recessed LED wall luminaires along exterior staircase
- Streetlights with LED lamps along pedestrian walkway
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- One (1) shell & tube steam-to-hot-water converter HX-1 generates heating hot water (HW) for building heating
  - 1/3 & 2/3 direct digital control (DDC), electronically actuated steam valves modulate HW supply temperature at the outlet of the converter. Zone valves control supply to each of six (6) HW distribution zones.
  - Two (2) primary hot water pumps HWPP-1 and HWPP-2 operate as lead/standby for the HW loop. One (1) secondary hot water pump serves each HW distribution zone. All HW pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure.

    - Primary pumps are base-mounted pumps with 5 horsepower (hp) motors
    - Secondary pumps are in-line pumps with 1.5 hp motors
  - HW supply temperature is reset based on outside air (OA) temperature
    - 170°F supply temperature at 0°F OA temperature
    - 110°F supply temperature at 60°F OA temperature
- One (1) plate & frame HW-to-hot-glycol converter HX-2 generates hot glycol for building heating
  - DDC controlled, electronically actuated HW valve modulates glycol supply temperature at the outlet of the converter
    - Two (2) glycol pumps GHWP-1 and GHWP-2 operate as lead/standby for the hot glycol loop. Both glycol pumps have VFD control of pump motor speed based on differential pressure.
      - In-line pumps with 3 hp motors
  - Hot glycol supply temperature is reset based on OA temperature
    - 180°F supply temperature at 0°F OA temperature
    - 115°F supply temperature at 60°F OA temperature

**Air Handling Units**
- Heating and ventilating unit HV-1 serves the first-floor lounge
  - Single-zone variable air volume (VAV) unit
  - Differential enthalpy economizer
  - Supply fan motor controlled by VFD
  - Return fan motor controlled by VFD to track supply fan VFD
  - Lounge has space $CO_2$ sensor for demand control ventilation
  - HW-glycol heating coil with two-way electronic control valve
  - Duct static pressure reset control disabled during walk-through
- Heating and ventilating unit HV-2 supplies ventilation air to lobbies and corridors
  - 100% OA unit
  - Supply fan motor controlled by VFD
  - HW-glycol heating coil with two-way electronic control valve
- One (1) blower coil unit BCU-1 supplies make-up air to the laundry room
  - 100% OA unit
  - Constant speed supply fan motor
  - HW-glycol heating coil with two-way electronic control valve
- Six (6) split-system air conditioners serve the director's apartment, assistant director's apartment, meeting room, mechanical rooms, and data closets
  - Three (3) rooftop air-cooled condensing units
  - R-410A refrigerant

**Exhaust Systems**
- 11 exhaust fans with constant speed motors serve the building
  - One (1) exhaust fan serves the laundry room
    - ¾ hp motor
    - Controls integrated with BCU-1
  - One (1) exhaust fan serves corridors
    - Fan enabled when average corridor space temperature exceeds 72°F
  - Two (2) exhaust fans serve janitorial closets
  - Four (4) exhaust fans serve bathrooms

- One (1) exhaust fan serves the third-floor kitchenette
- Two (2) exhaust fans serve electrical rooms
  - Fans enabled when space temperatures exceed 72°F

**Zone Heating/Cooling**

- Finned tube radiation provides perimeter heating in dorm rooms and common spaces; temperature control is limited to HW supply temperature control of four (4) general building zones and two (2) residential staff apartment zones
- Two (2) HW unit heaters and one (1) electric unit heater serve the mechanical rooms
- Three (3) HW cabinet unit heaters serve basement common areas and the main entryway

## HVAC Controls

**Building Automation System**

- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, DDC, and energy management of HVAC systems

**Operating Schedules**

- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**

- Primary domestic hot water (DHW) system is one (1) steam bundle storage tank
  - Two (2) small in-line circulating pumps operate as lead/standby
  - 1/3 & 2/3 DDC controlled, electronically actuated steam valves
  - Supply setpoint of 120°F observed
- Alternate DHW system is one (1) electric storage tank water heater
  - 40-gallon capacity

**DHW Load**

- Bathroom hand sinks and showers
- Common room kitchenette sinks

## Piping and Ductwork

**Piping Systems/Insulation**

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**

- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug Loads**

- Offices: computers or laptops, desk phones, desk lamps, etc.
- Common spaces: two (2) beverage and snack vending machines, computers, microwaves, televisions, electric fireplace, etc.
- Dorm rooms: laptops, chargers, microwaves, mini fridges, coffee makers, televisions, and portable fans
- Laundry room: washing machines and dryers

**Elevators**

- One (1) elevator serves the building

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Install automatic interior lighting controls on existing LED fixtures
- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control
  - Optimize hot glycol supply temperature reset control
  - Optimize VFD control of HV-1 and HV-2 fan motors
  - Scheduling of HVAC equipment and space temperature setbacks
- Implement pump differential pressure reset controls on the HW and hot glycol pumps
- Setback equipment during academic breaks
- Install low-flow or ultra low-flow showerheads

**Capital Measures**

- Install window film for solar heat gain reduction
- Consider additional occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
- Install occupancy-based HVAC controls on HV-1
- Consider installing an exhaust air energy recovery system off bathroom exhaust air
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace storage tank DHW heater with semi-instantaneous water heater
- Replace DHW circulating pumps and motors with electronically commutated motors

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | SENECA HALL BUILDING ASSESSMENT

## Building Description

**Building Name:** Seneca Hall

**Year Constructed:** 1967

**No. of Floors:** 10 + Basement

**Est. GSF:** 152,548

### Recent Building Upgrades

- Exterior renovation – 2006
- Roof replacement - 2022

### Functional Description

Seneca Hall is a residence hall on West campus. The building consists of dorm rooms, a director's apartment, corridors, mechanical rooms, and storage spaces. The basement houses a laundry room, larger lounge area, and kitchen.

### Occupancy Patterns

The dorm is occupied 24/7 during the academic year and can house approximately 600 students.

## Building Envelope

### Roof

- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Concrete panel walls
- Insulation type and levels not accessible during walk-through

### Windows

- Double glazed, double-hung windows with sidelights

### Doors

- Building entryway doors are metal frame, glass doors

### Air Infiltration/Leakage

- No excessive infiltration was observed

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

**Natural Gas**

- This building does not receive natural gas

**District Steam**

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

**Submeters**

- None observed during walk-through

## Lighting

**Interior Fixture Types**

- Predominant lighting types as follows:
  - Dorms: Surface mount fixtures with compact fluorescent lamps (CFL) and floor lamps with LED bulbs
  - Corridors and lounges: Surface mount fixtures with CFLs
  - Laundry room: Recessed fluorescent fixtures
  - Basement: Recessed fixtures with U-bend and linear T8 fluorescent lamps

**Interior Lighting Controls**

- Occupancy sensors in some bathrooms
- No other automatic controls observed during walk-through
- Lighting is scheduled on at 7 a.m. and off at 8 p.m. daily

**Exterior Lighting and Controls**

- High-intensity discharge (HID) and compact fluorescent fixtures above entryway
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

**Central Heating System**

- One (1) shell & tube steam-to-hot-water converter generates heating hot water (HW) for most of the building
  - Triple duty valve regulates flow and pressure into the converter
  - Two (2) hot water pumps operate as lead/standby for the HW loop. HW pump motors are constant speed.
  - HW supply temperature is reset based on outside air (OA) temperature
    - 180°F supply temperature at 0°F OA temperature
    - 110°F supply temperature at 50°F OA temperature
    - Reset on local pneumatic gauges
- One (1) shell & tube steam-to-hot-water converter generates heating HW for Resident Director apartment suite

**Central Cooling System**

- One (1) chiller/dry cooler generates chilled glycol at 45°F for cooling data closets
  - Direct digital controls (DDC)

  - Control schedule is reset based on OA temperature
  - Operates in free cooling mode during the winter
- No other space cooling in this building

**Air Handling Units**
- Eight (8) heating and ventilating units HV-1 through HV-8 serve common spaces
  - HV-1 serves the laundry room; HV-2 and HV-3 serve lounges; HV-4 through HV-8 serve corridors and mechanical rooms
  - HV-1 through HV-3 have HW heating coils with two-way control valves; HV-4 through HV-8 have steam heating coils with 3-way control valves

**Exhaust Systems**
- Ten (10) rooftop exhaust fans serve the bathrooms, laundry room, and mechanical and electrical rooms
  - EF-1 serves the laundry room

**Zone Heating/Cooling**
- Ceiling diffusers provide airflow to common areas and corridors
- Finned tube radiation provides perimeter heating in dorm rooms and common spaces
- Unit ventilators serve the lobby and entry halls
- Electric cabinet unit heaters serve the bathrooms
- No sensors or room-level temperature control in dorms or lounges

## HVAC Controls

**Building Automation System**
- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems
  - Only the chiller/dry cooler and laundry room systems are on the BAS; other equipment is monitored through the BAS but operates on pneumatic controls (i.e., domestic hot water (DHW) temperature monitoring)

**Operating Schedules**
- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**
- One (1) steam bundle storage tank
  - Pneumatic controls
  - Supply temperature of 128°F observed
  - Receiving pump and tempering valve
- One (1) electric water heater, located in the recycling room, serves the Resident Director apartment suite

**DHW Load**

- Bathroom hand sinks and showers
- Kitchenette sinks

## Piping and Ductwork

**Piping Systems/Insulation**

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**

- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Steam leak observed near DHW tank
  - Potential issue with a steam trap on condensate return line
- Spot observations revealed no ductwork leakage issues

## Miscellaneous Loads

**Plug loads**

- Laundry room: washing machines and dryers
- Kitchenettes: microwaves, stoves, kitchen hoods, and refrigerators
- Data closets: computer equipment, etc.
- Dorms: laptops, chargers, microwaves, mini fridges, coffee makers, televisions, and portable fans

**Elevators**

- Four (4) elevators serve the building

## Specialty Systems

**Air Compressors**

- Air compressors generate compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control
  - Scheduling of HVAC equipment and space temperature setbacks
- Setback equipment during academic breaks
- Install low-flow or ultra low-flow showerheads

**Capital Measures**

- Upgrade roof insulation to at least code levels during gut rehab project
- Upgrade exterior wall insulation to at least code levels during gut rehab project
- Install building-level steam submeter

- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Install variable frequency drives (VFD) on the HW pump motors
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Replace constant volume heating and ventilating units with variable air volume (VAV) systems during gut rehab project
- Install occupancy-based HVAC controls
- Consider installing an exhaust air energy recovery system for stacked exhaust
  - Six (6) separate ducts of exhaust
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace pneumatic actuators with electric actuators
- Connect remaining building systems to BAS
- Replace DHW heater with semi-instantaneous water heater
- Replace DHW circulating pumps and motors with electronically commutated motors

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives
- Repair piping to stop steam leakage

# SUNY OSWEGO | SHADY SHORE BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | Shady Shore |
| **Year Constructed:** | 1909 |
| **No. of Floors:** | 2 + Basement + Attic |
| **Est. GSF:** | 8,754 |

**Recent Building Upgrades**
- Exterior renovation – 1995, 2006
- Interior renovation – 2006

**Functional Description**
Shady Shore is the university president's residence, located next to Lake Ontario on SUNY Oswego's main campus. The house has two floors and a basement, an attic, and a garage. The residence is usually occupied but was not in use during Ramboll's site visit in February 2022.

**Occupancy Patterns**
The residence is typically occupied 24/7.

## Building Envelope

**Roof**
- Pitched roof with architectural shingles; no roof access during walk-through
- Attic insulation type and levels not accessible during walk-through

**Exterior Walls**
- Wood siding
- Insulation type and levels not accessible during walk-through

**Windows**
- Double-hung, wooden frame windows
  - Primarily double glazed, some single glazed windows in dining room

**Doors**
- Residence entryway door is a wood door
- Patio door is a double glazed glass door

**Air Infiltration/Leakage**
- No excessive infiltration was observed

## Utilities

### Electricity

- Electricity is fed to the residence from the National Grid electric substation on Washington Boulevard

### Natural Gas

- The residence has a National Grid gas service separate from the rest of the campus
  - Used for space heating and domestic hot water (DHW) heating

### District Steam

- The residence does not receive steam from the Central Heating Plant

### Submeters

- None observed during walk-through

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - LED bulbs

### Interior Lighting Controls

- Manually switched lighting; no automatic controls observed during walk-through

### Exterior Lighting and Controls

- Four (4) lamps along the driveway
- Single light above the garage
- Flag light
- Single light on the shed

## HVAC

### Central Heating System

- One (1) natural-draft boiler generates heating hot water (HW) for building heating
  - Well-McLain natural gas-fired hot water boiler
  - Seven (7) in-line circulating pumps
  - No combustion air fan
  - Expansion tank with automatic air separator

### Central Cooling System

- No central cooling in this residence

### Air Handling Units

- One (1) split-system heat pump provides heating and cooling to the residence
  - Outdoor condensing unit

### Exhaust Systems
- No major exhaust systems observed during walk-through

### Zone Heating/Cooling
- Finned tube radiation provides heating throughout the residence
- Zone-level temperature control for seven (7) separate zones through manual thermostats

## HVAC Controls

### Building Automation System
- The residence is not connected to the campus building automation system (BAS)

### Operating Schedules
- HVAC systems operate 24/7 to meet thermostat setpoints

## Domestic/Service Water Heating

### Domestic Water Heaters
- One (1) natural draft, natural gas-fired condensing water heater
  - 50-gallon capacity
  - Small in-line pumps circulate DHW to residence zones

### DHW Load
- Bathroom hand sinks and showers
- Dishwasher
- Washing machine

## Piping and Ductwork

### Piping Systems/Insulation
- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

### Equipment Insulation
- Spot observations of equipment insulation revealed no remarkable deficiencies

### Piping and Ductwork Leaks
- Spot observations revealed no leakage issues

## Miscellaneous Loads

### Plug loads
- Office and living space: desktop computer, laptop, chargers, television, etc.
- Kitchen: refrigerator, oven, dishwasher, etc.
- Basement: dehumidifiers and refrigerator
- Laundry room: washer and dryer

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Retro-commissioning of HVAC systems and controls
    - Setback space temperature when the residence is unoccupied
- Implement HW supply temperature reset
- Install programmable thermostats
- Install low-flow or ultra low-flow showerheads

**Capital Measures**

- Add additional attic insulation to bring insulation level up to at least R-38
- Replace single glazed windows with high performance windows
- Replace interior fluorescent light fixtures with LED fixtures
- Replace exterior light fixtures with LED fixtures
- Replace HW circulating pump and motor with an electronically commutated motor
- Connect remaining building systems to BAS
- Replace DHW circulating pumps and motors with electronically commutated motors

**O&M Measures**

- No O&M opportunities identified during walk-through

# SUNY OSWEGO | THE VILLAGE TOWNHOUSES BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | The Village Townhouses |
| **Year Constructed:** | 2010 |
| **No. of Floors:** | 3 |
| **Est. GSF:** | 150,551 |

### Recent Building Upgrades

- None

### Functional Description

The Village Townhouses are a 12-building residential community on West campus. They consist of four 4-person one-story units, 26 4-person two-story units and 36 6-person 3-story units. Each building has two closets accessible from the exterior that house fire protection and electrical equipment. Each unit is comprised of single-person bedrooms, a full kitchen, a laundry room, a common living space, and one or two shared bathroom(s). Community lounges, storage spaces, bathrooms, offices, meeting rooms, a mail room, and a café are located in Townhouse F. Additional storage and custodial spaces are located in Townhouses B and G. Mechanical equipment for The Townhouses is housed in two standalone one-room buildings next to Townhouses A and H.

### Occupancy Patterns

The townhouses are occupied 24/7 during the academic year and can house approximately 350 students.

## Building Envelope

### Roof

- Pitched roofs with architectural shingles; no roof access during walk-through
- Attic insulation type and levels not accessible during walk-through

### Exterior Walls

- Structural insulated panels with lap siding
- Insulation type and levels not accessible during walk-through

### Windows

- Clear, double glazed, double-hung, aluminum frame windows with blinds
- Townhouse F lounge windows are clear, double glazed, awning, wooden frame windows with interior shades

### Doors

- Building entryway doors are clear, double glazed, aluminum frame doors
- Townhouse F terrace doors are clear, double glazed, wooden frame doors

### Air Infiltration/Leakage
- No excessive infiltration was observed

## Utilities

### Electricity
- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas
- These buildings have two (2) National Grid gas services separate from the rest of the campus
  - Used for space heating, domestic hot water heating, and cooking

### District Steam
- These buildings do not receive steam from the Central Heating Plant

### Submeters
- These buildings have campus-managed Electro Industries revenue grade electricity submeters

## Lighting

### Interior Fixture Types
- Predominant lighting types as follows:
  - Apartments: Student apartments not accessible during walk-through
  - Townhouse F common spaces: Surface mount and recessed fixtures with compact fluorescent lamps (CFL)
  - Mechanical/electrical rooms: Surface mount fixtures with linear fluorescent lamps

### Interior Lighting Controls
- No automatic controls observed during walk-through

### Exterior Lighting and Controls
- The campus has been installing LED bulbs in the exterior fixtures located at the entryway of each apartment; this is an ongoing project with approximately 50% of the fixture upgrades completed as of October 2022
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System
- Four (4) condensing boilers generate heating hot water (HW) for space heating
  - Benchmark 2.0 Low NOx natural gas-fired boilers
  - 2,000 thousand Btus per hour (MBH) output
  - Isolation valves are used to bypass the boilers when the dual temperature loop is in summer mode
  - Appear to utilize reset of HW supply temperature based on outside air (OA) temperature

**Central Cooling System**

- Two (2) AAON air-cooled scroll chillers generate chilled glycol for building cooling
  - R-410A refrigerant
  - Four (4) pumps circulate chilled glycol between the chillers and two (2) plate & frame heat exchangers
    - Armstrong base-mounted centrifugal pumps with 7.5 hp motors
  - One (1) 3-way diverting valve diverts the dual temperature loop through the plate & frame heat exchangers when the dual temperature loop is in summer mode
  - Appear to utilize reset of chilled glycol supply temperature based on OA temperature

**Dual Temperature Loop**

- Two (2) dual temperature loops ("A" Dual Temp System and "H" Dual Temp System) provide heating or cooling to building terminal units
  - "A" Dual Temp System serves buildings A through F; "H" Dual Temp System serves buildings G through L
  - Four (4) dual temperature pumps (two pumps per dual temp system) circulate HW or chilled glycol to building terminal units. All dual temperature pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure.
    - Armstrong base-mounted centrifugal pumps with 15 horsepower (hp) motors, rated for 396 gallons per minute (gpm) at 90 feet of head

**Air Handling Units**

- One (1) heat recovery unit serves Townhouse F
  - Heat wheel recovers energy from the toilet and janitorial closet exhaust airstreams (EF-3 and EF-4, respectively)
  - Supply and return fan motors have VFDs for balancing, and run at a fixed speed
  - HW heating coil with 3-way electronic control valve
    - One (1) small HW coil pump P-6
  - Free cooling capabilities and two-stage direct expansion (DX) mechanical cooling units
    - Dehumidification controls
    - Hot gas reheat coil
- Ductless mini-split systems serve the data closets
  - 18 MBH cooling capacities
  - 21.6 MBH heating capacities
  - R-410A refrigerant

**Exhaust Systems**

- Several small exhaust fans with constant speed motors serve the buildings
- Dedicated exhaust fan for each mechanical room

**Zone Heating/Cooling**

- Two-pipe valance and fan coil units (FCU) provide heating and cooling in apartments
  - Each apartment has two (2) FCUs serving entryways and six (6) or eight (8) valance units serving bedrooms and common spaces
  - Apartments were not accessible during walk-through; assumed to have individual temperature control of each apartment

- Temperature control through electric wall thermostats in data closets

## HVAC Controls

**Building Automation System**
- Carrier i-Vu® 8.0 building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems

**Operating Schedules**
- Dual temperature loop mode of operation is based on calendar date and OA temperature
- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**
- Six (6) direct vent, natural gas-fired condensing storage tank water heaters
  - 124-gallon capacity tanks
  - 285 MBH input
  - 331 gal/hour recovery rate
  - Installed 2010
  - 118°F supply temperature setpoint observed

**DHW Load**
- Bathroom hand sinks and showers
- Kitchen and café sinks

## Piping and Ductwork

**Piping Systems/Insulation**
- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**
- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**
- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug Loads**
- Townhouse F common spaces: two (2) beverage and snack vending machines, computers, monitors, desk phones, desk lamps, etc.
- Apartments: laptops, chargers, microwaves, fridges, ovens, dishwashers, coffee makers, televisions, and portable fans
- Kitchen equipment
  - Café not accessible during walk-through

**Elevators**

- One (1) elevator serves the Townhouse F common spaces

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control
  - Optimize chilled glycol supply temperature reset control
  - Scheduling of HVAC equipment and space temperature setbacks
- Implement pump differential pressure reset controls on the dual temperature pumps
- Setback equipment during academic breaks
- Install low-flow or ultra low-flow showerheads

**Capital Measures**

- Install window film for solar heat gain reduction
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Continue replacing exterior light fixtures with LED fixtures
- Install occupancy-based HVAC controls in Townhouse F common spaces
- Install occupancy based thermostatic control in apartments units to allow for automatic setback of space temperature setpoints when apartments are unoccupied.
  - Thermostats with integrated passive infrared (PIR) occupancy sensors specifically manufactured for hotel guest room and dorm room systems are readily available in the market.
  - Alternatively, remote PIR occupancy sensors can be installed connected directly or wirelessly with the thermostat.
  - Window sensors can be installed and connected to the thermostat to turn the units off when the windows are opened
- Replace DHW heaters with semi-instantaneous water heaters at end of useful life

**O&M Measures**

- No O&M opportunities identified during walk-through

# SUNY OSWEGO | WATERBURY HALL BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | Waterbury Hall |
| **Year Constructed:** | 1960 |
| **No. of Floors:** | 4 |
| **Est. GSF:** | 57,464 |

### Recent Building Upgrades

- Full building renovation – 2016

### Functional Description

Waterbury Hall is a residence hall located next to Lake Ontario on SUNY Oswego's main campus. The four floors each consist of a north wing and a west wing, primarily housing two-person student rooms, in addition to a lounge and two shared bathroom alcoves. The first floor includes residential staff apartments, lobby space, offices, a workroom, and a computer room. A laundry room, kitchenette, storage spaces, and electrical and mechanical rooms are located in the basement.

### Occupancy Patterns

The dorm is occupied 24/7 during the academic year and can house approximately 200 students.

## Building Envelope

### Roof

- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Concrete masonry with a brick façade
- Insulation type and levels not accessible during walk-through

### Windows

- Clear, double glazed, partially operable, aluminum frame windows

### Doors

- Building entryway doors are clear, double glazed, aluminum frame doors

### Air Infiltration/Leakage

- No excessive infiltration was observed

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for backup generator

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building
  - One (1) duplex condensate receiver returns condensate from Waterbury Hall to the Central Heating Plant

### Submeters

- This building has a campus-managed Electro Industries revenue grade electricity submeter
- This building has a campus-managed steam submeter to measure pressure, flow, and temperature of medium pressure steam entering building
- This building has a campus-managed natural gas submeter
- This building has a campus-managed potable water submeter

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Dorms: Student rooms not accessible during walk-through
  - Bathrooms: Surface mount fixtures with LED lamps
  - Corridors and lounges: Surface mount fixtures with LED lamps
  - Mechanical/electrical rooms: Surface mount fixtures with linear T8 fluorescent lamps

### Interior Lighting Controls

- Interior lighting is controlled locally. Interior lights are scheduled to be on from 7 a.m. to 10 p.m. daily.

### Exterior Lighting and Controls

- Recessed LED wall luminaires along exterior staircase
- Streetlights with LED lamps along pedestrian walkway
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- One (1) shell & tube steam-to-hot-water converter HE-1 generates heating hot water (HW) for most of the building

    - 1/3 & 2/3 direct digital control (DDC), electronically actuated steam valves modulate HW supply temperature at the outlet of the converter. Mixing valves control supply temperatures to each of six (6) HW distribution zones.
    - Hot water pumps HWP-6 and HWP-7 operate as lead/standby for the primary HW loop. Secondary HW pumps HWP-1, HWP-2, HWP-3, HWP-4, HWP-5, and HWP-8 each serve one (1) building zone. All of the HW pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure.
        - Bell & Gossett in-line centrifugal pumps with 1 to 2 horsepower (hp) motors
    - HW supply temperature is reset based on outside air (OA) temperature
        - 170°F supply temperature at 0°F OA temperature
        - 100°F supply temperature at 60°F OA temperature
- One (1) plate & frame HW-to-hot-glycol converter HE-2 generates hot glycol for building heating
    - DDC controlled, electronically actuated HW valve modulates glycol supply temperature at the outlet of the converter
        - Two (2) glycol pumps GHWP-1 and GHWP-2 operate as lead/standby for the hot glycol loop. Both glycol pumps have VFD control of pump motor speed based on differential pressure.
            - In-line pumps with 2 hp motors
- System is enabled when OA temperature is below 60°F
- Secondary HW pumps are enabled when OA temperature is below 65°F

**Central Cooling System**

- No central cooling in this building

**Air Handling Units**

- Heating and ventilating unit HV-1 serves the first-floor lounge
    - Single-zone variable air volume (VAV) unit
    - Differential enthalpy economizer
        - Economizer is enabled when OA temperature is above 28°F and below 65°F
    - Supply fan motor controlled by VFD with a temperature-based control scheme
    - Return fan motor controlled by VFD to track supply fan VFD
    - HW-glycol heating coil with two-way electronic control valve
    - Demand controlled ventilation implemented
- Heating and ventilating unit HV-2 supplies ventilation air to corridors
    - 100% OA unit
    - Supply fan motor controlled by VFD
    - HW-glycol heating coil with two-way electronic control valve
    - System is enabled when OA temperature is below 60°F
- One (1) blower coil unit BCU-1 supplies make-up air to the laundry room
    - 100% OA unit
    - Constant speed supply fan motor
    - HW heating coil with two-way electronic control valve
- A variable refrigerant flow (VRF) system serves the resident director's apartment
    - Simultaneous heating and cooling
    - One (1) 6-ton outside air-cooled heat pump
        - 69 thousand Btus per hour (MBH) cooling capacity
        - 73 MBH heating capacity

  - Three (3) indoor, duct-free, wall-mounted units

**Exhaust Systems**
- Six (6) exhaust fans with constant speed motors serve the building
  - One (1) exhaust fan serves the laundry room
    - Controls integrated with BCU-1
  - One (1) exhaust fan serves corridors
  - Two (2) exhaust fans serve janitorial closets
  - Two (2) exhaust fans serve electrical rooms

**Zone Heating/Cooling**
- Finned tube radiation provides perimeter heating in dorm rooms; temperature control is limited to HW supply temperature control of six (6) building zones
- Four (4) HW cabinet unit heaters serve a lounge on each floor and the main entryway

## HVAC Controls

**Building Automation System**
- Trane Tracer® Ensemble™ building automation system (BAS) used for monitoring, DDC, and energy management of HVAC systems

**Operating Schedules**
- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**
- Primary domestic hot water (DHW) system is one (1) steam bundle storage tank
  - Two (2) circulating pumps with fractional hp motors operate as lead/standby
  - One (1) DDC controlled, electronically actuated steam valve
- Alternate DHW system is one (1) electric storage tank water heater
  - 40-gallon capacity

**DHW Load**
- Bathroom hand sinks and showers
- Common room kitchenette sinks

## Piping and Ductwork

**Piping Systems/Insulation**
- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**
- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug Loads**

- Offices: computers or laptops, desk phones, desk lamps, etc.
- Common spaces: three (3) beverage and snack vending machines, computers, microwaves, televisions, electric fireplace, etc.
- Dorm rooms: laptops, chargers, microwaves, mini fridges, coffee makers, televisions, and portable fans
- Laundry room: washing machines and dryers

**Elevators**

- One (1) elevator serves the building

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Install automatic interior lighting controls on existing LED fixtures
- Retro-commissioning of HVAC systems and controls
  - Optimize HW supply temperature reset control
  - Optimize hot glycol supply temperature reset control
  - Scheduling of HVAC equipment and space temperature setbacks
- Implement pump differential pressure reset controls on the HW and glycol pumps
- Implement duct static pressure reset control on HV-2
- Setback equipment during academic breaks
- Install low-flow or ultra low-flow showerheads

**Capital Measures**

- Install window film for solar heat gain reduction
- Consider additional occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
- Install occupancy-based HVAC controls on HV-1
- Consider installing an exhaust air energy recovery system
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace storage tank DHW heater with semi-instantaneous water heater
- Replace DHW circulating pumps and motors with electronically commutated motors

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives
- Replace HV-1 supply fan VFD control panel screen and cover
  - Observed to be missing during walk-through

# SUNY OSWEGO | CENTRAL HEATING PLANT BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | Central Heating Plant |
| **Year Constructed:** | 1958 |
| **No. of Floors:** | 1 + Catwalks |
| **Est. GSF:** | 21,980 |

**Recent Building Upgrades**
- Roof, door, and window replacements – 2019
- Boiler valve replacements & software upgrades – Ongoing
- Phase out of pneumatic controls – Ongoing

**Functional Description**
The Central Heating Plant is located in the center of campus and connected to Lee Hall on its east side. The one-story facility produces steam used for space heating and domestic hot water heating in most buildings on the main campus.

**Occupancy Patterns**
The building is occupied 24/7 by at least one plant operator. Only plant personnel have access to the facility.

## Building Envelope

**Roof**
- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

**Exterior Walls**
- Concrete masonry with a brick façade
- Insulation type and levels not accessible during walk-through

**Windows**
- Clear, awning, metal frame windows
  - Large, nearly floor-to-ceiling

**Doors**
- Building entryway doors are metal doors

**Air Infiltration/Leakage**
- Windows mostly open during walk-through, allowing infiltration

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for steam production

### Submeters

- Plant personnel manually record steam output rates and gas input rates every four (4) hours

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Boiler room: Industrial surface mount fixtures with linear T8 fluorescent lamps

### Interior Lighting Controls

- No automatic controls observed during walk-through

### Exterior Lighting and Controls

- Predominant exterior lighting type is high-intensity discharge (HID)
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- Four (4) primary boilers B-6, B-7, B-8, and B-9 generate steam used for space heating and domestic hot water heating in buildings across campus
  - Cleaver-Brooks high-pressure natural gas-fired water tube boilers
  - All boilers have mechanical gas valve control; no oxygen trim controls
  - B-6, B-7, and B-8 have Natcom dual-fuel burners and controls. The boilers have not been fired with fuel oil since 2012. Existing controls are under consideration for replacement due to age.
  - B-9 has a Coen burner and controls. This boiler runs alone in summer operation; it has better turn-down than the other boilers.
  - B-6 is rated to produce 30,000 lb/hr of steam at 250 psig; B-7 and B-8 are rated to produce 50,000 lb/hr of steam at 250 psig; B-9 is rated to produce 30,000 lb/hr of steam at 260 psig
  - All four (4) boilers are equipped with a feedwater economizer to recover heat from the exhaust gas
  - Forced draft combustion fan motors are controlled by variable frequency drives (VFD)
  - B-7 and B-8 have flue gas recirculation systems
  - B-6, B-7, and B-8 were manufactured in 2007; B-9 was manufactured in 1985
  - On a design load day, typically, three (3) of the four (4) boilers run with the fourth in standby. At the beginning and end of the heating season, two (2) boilers operate with one (1) in standby. All boilers that may be required for the time of year are cycled as needed to maintain a minimum boiler interior temperature. No standby boiler is required in the summer.

- One (1) alternate boiler B-10 can be used to generate steam in the summer for use in Lakeside Dining Hall and for the autoclave at Mary Walker Health Center when the primary boilers are shut down
  - Kewanee skid-mounted high-pressure natural gas-fired fire tube boiler
  - Rated to produce 6,900 lb/hr of steam at 150 psig
  - Firing rate of 8,370 thousand Btus per hour (MBH)
  - Primary boilers used to be shut down every summer from mid-July to late August, but are now only shut down when maintenance is required
  - Approximately ten (10) pressure reducing stations with pneumatically actuated valves reduce the 100 psig high-pressure steam generated by the boilers to 50 psig medium-pressure steam before it is distributed across campus. There is no steam pressure reset. Buildings have their own pressure reducing valves and use steam at approximately 12-13 psig.
  - Four (4) steam distribution lines originate from the plant, serving different areas of the campus:
    - Piez line serving the campus' science and engineering buildings, including Shineman Center, Wilbur Hall, and Park Hall
    - Lakefront line (historically called the North Line) serving the dorms and dining halls located next to Lake Ontario
    - East line serving the oldest buildings located on the east side of the campus
    - The main line (historically the West line and South line), with the largest loads, serving the most buildings on campus
- One (1) shell & tube steam-to-hot-water converter generates heating hot water (HW) for building heating in Lee Hall
  - One (1) two-way pneumatically actuated steam valve modulates HW supply temperature at the outlet of the converter
  - One (1) in-line hot water pump circulates HW from Lee Hall through the converter

**Condensate and Feedwater System**

- One (1) condensate tank collects and stores condensate return
  - Condensate pumps CRP-1 and CRP-2 circulate condensate from the storage tank to the feedwater loop. Both condensate pumps have VFD control of pump motor speed.
    - CRP-1 operates in the winter and is a Weinman base-mounted centrifugal pump with a 25 hp motor
    - CRP-2 operates in the summer and is a Bell & Gossett base-mounted centrifugal pump with a 10 hp motor, rated for 140 gallons per minute (gpm) at 140 feet of head
- Two (2) water softeners remove minerals from the feedwater to prevent hard water scale buildup on boiler tubes
- One (1) makeup water station treats 1,200 to 1,300 gallons of makeup water per day
  - Makeup water is preheated with heat recovered from surface blowdown process
- One (1) deaerator tank removes approximately 95% of dissolved gases from the feedwater loop and stores the treated feedwater
  - Maximum allowable working pressure of 50 psig at 300°F
  - Manufactured by Allied Steel Products, Inc. in 1998
  - Feedwater pumps P-1, P-2, and P-3 circulate feedwater from the deaerator tank to the boilers. All three (3) feedwater pumps have VFD control of pump motor speed based on differential pressure. P-1 and P-2 share the same VFD.
    - P-1 is a Goulds vertical multistage pump with a 50 hp motor
    - P-2 is a Weinman base-mounted centrifugal pump with a 60 hp motor

- P-3 is a Goulds vertical multistage pump with a 25 hp motor
- Feedwater undergoes phosphate treatment to prevent corrosion
  - The plant uses approximately four (4) barrels of phosphate per year

**Central Cooling System**
- No space cooling in this building

**Air Handling Units**
- Two (2) heating and ventilating units provide make-up air to the plant
  - 100% outside air (OA) constant volume single-zone units
  - Constant speed supply fan motors
  - Steam heating coils with 3-way control valves
    - Valves have a minimum position of 15% when OA temperature below 35 °F
  - Units operate as lead/standby when only one (1) boiler is running; both units run when more than one (1) boiler is running

**Exhaust Systems**
- No exhaust fans observed during walk-through

**Zone Heating/Cooling**
- No terminal heating or cooling equipment observed during walk-through

## HVAC Controls

**Building Automation System**
- Rockwell Automation Allen-Bradley® boiler control system and Trane Tracer® Ensemble™ building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems

**Operating Schedules**
- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**
- One (1) steam bundle storage tank serves the plant and Lee Hall
  - One (1) pneumatic control valve with receiver-controller
  - Pneumatic thermostat in tank

**DHW (Domestic Hot Water) Load**
- Bathroom hand sinks and showers

## Piping and Ductwork

**Piping Systems/Insulation**
- Spot observations of ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**

- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug Loads**

- Offices: computers or laptops, desk phones, desk lamps, etc.

## Specialty Systems

**Wastewater Lift Station**

- One (1) lift station serves the campus wastewater system
  - Lift station pumps P-1 and P-2 move wastewater toward the treatment plant

**Air Compressors**

- Three (3) air compressors generate service air at 120 psig and compressed air for pneumatic controls at 36 psig
  - One (1) compressed air storage tank

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Install low-flow or ultra low-flow showerheads

**Capital Measures**

- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Consider implementing oxygen trim control on boilers depending on timeline of clean energy transition. May be most cost-effective as an upgrade to the controls that need replacement due to age.
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
  - Choose high-efficiency pump with beyond premium efficiency motor for backup condensate pump scheduled to be replaced soon
- Replace pneumatic actuators with electric actuators where possible

**O&M Measures**

- Consider laboratory analysis of a boiler tube sample to check on condition of boiler tubes
- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | COMMISSARY (BUILDING 11) BUILDING ASSESSMENT

## Building Description

**Building Name:** Commissary (Building 11)

**Year Constructed:** 1966

**No. of Floors:** 1

**Est. GSF:** 30,836

**Recent Building Upgrades**
- Interior renovation – 2018
- Replacement of coolers and freezers – Ongoing
- Roof renovation – Ongoing

**Functional Description**
The Commissary building, also called Building 11, is a one-story administrative building located on the southern side of Route 104 which houses the campus bakery, cold food storage, and dry food storage. The Commissary consists of storage rooms, a small commercial grade kitchen, walk-in coolers and freezers, offices, and mechanical rooms.

**Occupancy Patterns**
The commissary is occupied from 3 a.m. to 9 p.m. on weekdays and from 8 a.m. to 9 p.m. on weekends.

## Building Envelope

**Roof**
- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

**Exterior Walls**
- Concrete masonry with a stone façade
- Insulation type and levels not accessible during walk-through

**Windows**
- Clear, single glazed, awning and fixed, steel frame windows with shades

**Doors**
- Building entryway doors are metal doors with small, clear, double glazed sidelights

**Air Infiltration/Leakage**
- Many of the spaces in this building are garage spaces with large doors and natural air infiltration

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- The building has a National Grid gas service separate from the rest of the campus
  - Used for space heating, domestic hot water heating, cooking, and steam generation

### District Steam

- This building does not receive steam from the Central Heating Plant

### Submeters

- This building has a campus-managed Electro Industries revenue grade electricity submeter

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Corridors and storage spaces: Linear T8 fluorescent lamps
  - Offices: Mix of LED and linear T8 fluorescent lamps
  - Kitchen: Linear T8 fluorescent lamps
  - Mechanical rooms: Industrial pendant fixtures with compact fluorescent lamps (CFL)

### Interior Lighting Controls

- No automatic controls observed during walk-through

### Exterior Lighting and Controls

- Recessed and surface mount fixtures with high-intensity discharge (HID) lamps
- Recessed fixtures with CFLs along garage doors
- Exterior lights are controlled by photosensors

## HVAC

### Central Heating System

- One (1) cast-iron sectional boiler generates heating hot water (HW) for building heating
  - Weil-McLain Model 688 natural gas-fired hot water boiler
  - 1,413 thousand Btus per hour (MBH) output at 83% rated thermal efficiency
  - Power Flame, Inc. burner with 1,680 MBH input capacity
  - One (1) small in-line pump circulates HW through the boiler
  - One (1) constant speed hot water pump circulates HW to building heating terminals
    - In-line centrifugal pump with 5 horsepower (hp) motor

### Central Cooling System

- No space cooling in this building

### Air Handling Units

- Heating and ventilating unit HV-1 serves the central warehouse
  - 100% OA unit
  - 1 hp supply fan motor
  - Hot water heating coil
- Heating and ventilating unit HV-3 serves the dry bulk storage room
  - 100% OA unit
  - 3 hp supply fan motor
  - Hot water heating coil
  - HV-3 has been disconnected since May 2022

### Exhaust Systems

- One (1) exhaust fan with a constant speed motor serves mechanical room 120
- Commercial kitchen exhaust system

### Zone Heating/Cooling

- One (1) unit ventilator serves storage room 112
  - Economizer control
  - Heating and ventilating only
- Hot water unit heaters serve the mechanical rooms

## HVAC Controls

### Building Automation System

- Trane Tracer® Ensemble™ building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of HVAC systems
  - Only condenser fan, exhaust fan, and unit ventilator are on the BAS

### Operating Schedules

- Kitchen oven and exhaust systems are scheduled to turn on at 2:30 a.m. and off at 6 a.m.
- Other HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

### Domestic Water Heaters

- One (1) natural draft, natural gas-fired tank water heater with an additional external storage tank
  - 225 MBH input
  - Water heater manufactured 1967
  - Storage temperature of 115°F observed

### Domestic Hot Water (DHW) Load

- Bathroom hand sinks
- Break room kitchenette sink
- Commercial kitchen equipment and dishwasher

## Piping and Ductwork

### Piping Systems/Insulation

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

### Equipment Insulation

- Spot observations of equipment insulation revealed no remarkable deficiencies

### Piping and Ductwork Leaks

- Spot observations revealed no leakage issues

## Miscellaneous Loads

### Plug Loads

- Offices: computers or laptops, desk phones, desk lamps, etc.
- Break room: fridge, microwave, coffee maker, etc.
- Kitchen: freezers, coolers, dishwashers, etc.

## Specialty Systems

### Commercial Refrigeration

- One (1) condenser CU-1 generates high-pressure liquid refrigerant for the walk-in coolers and freezers
  - Air-cooled indoor condenser
  - One (1) centrifugal fan with a 25 hp motor controlled by a variable frequency drive (VFD)
  - R-404A refrigerant
  - 28.11 MBH total heat of rejection
  - Five (5) scroll compressors generate high-pressure refrigerant to supply to CU-1
    - Compressors 1, 2, and 5 serve walk-in coolers
    - Compressors 3 and 4 serve walk-in freezers

### Commercial Kitchen Equipment

- One (1) natural gas-fired steam generator used for steam kettles, etc.
- Natural gas deep fryers
- Electric ovens

## Potential Energy Efficiency Measures (EEMs)

### No Cost/Low Cost Measures

- Install automatic interior lighting controls on existing LED fixtures
- Retro-commissioning of HVAC systems and controls
  - Scheduling of HVAC equipment and space temperature setbacks
  - Scheduling of kitchen exhaust fan operation to match kitchen use
- Implement HW supply temperature reset

### Capital Measures

- Replace single glazed windows with high performance windows

- Replace interior fluorescent light fixtures with LED fixtures
    - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
    - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Replace HW boiler circulating pump and motor with electronically commutated motor
- Replace fan motors with beyond premium efficiency motors at end of useful life
- Consider implementing kitchen demand control ventilation on exhaust and makeup air systems
- Connect remaining building systems to BAS
- Replace DHW heater with semi-instantaneous water heater
- Replace refrigeration evaporator fan motors with electronically commutated motors
- Install desuperheater on refrigeration loop to recovery energy for domestic hot water heating

**O&M Measures**
- Change v-belt fan drives to cogged belt fan drives
- Integrate all equipment onto BAS

# SUNY OSWEGO | CULKIN HALL BUILDING ASSESSMENT

## Building Description

**Building Name:** Culkin Hall

**Year Constructed:** 1967

**No. of Floors:** 7 + Basement

**Est. GSF:** 63,591

### Recent Building Upgrades

- Exterior renovation – 2001

### Functional Description

Culkin Hall is the primary administration building on campus and houses various administrative offices, including the provost's office on the seventh floor.

### Occupancy Patterns

Culkin Hall is occupied from 8 a.m. to 5 p.m. on weekdays only.

## Building Envelope

### Roof

- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Concrete panels reinforced with protective concrete coating for additional weather resistance
- Insulation type and levels not accessible during walk-through

### Windows

- Double glazed, aluminum frame windows
  - Mix of clear and tinted glazing

### Doors

- Building entryway doors are automatic revolving doors

### Air Infiltration/Leakage

- No excessive infiltration was observed

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- Natural gas is delivered to the building from the main campus gas service
  - Used for domestic hot water (DHW) heating and backup generator

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building

### Submeters

- This building has a campus-managed potable water submeter

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Lobby: T8 Fluorescent lamps
  - First-floor corridors: Volumetric fixtures with fluorescent lamps
  - Second- through sixth-floor corridors: Recessed prismatic fixtures with U-bend fluorescent lamps
  - Seventh-floor corridors: Volumetric fixtures retrofit with LED lamps
  - Offices: Mix of LED and fluorescent lighting
  - Stairwells: Fluorescent lighting

### Interior Lighting Controls

- No automatic controls observed during walk-through
- Interior lighting is controlled through local panels

### Exterior Lighting and Controls

- Recessed lights on overhang around building perimeter
- High intensity discharge (HID) wall pack fixtures controlled by photosensors

## HVAC

### Central Heating System

- Two (2) steam-to-hot-water converters CV-1 and CV-2 generate heating hot water (HW) for building heating
  - 1/3 & 2/3 direct digital control (DDC), pneumatically actuated steam valves modulate HW supply temperature at the outlet of the converter
  - Two (2) hot water pumps circulate HW from CV-1 to air handler coils. Two (2) additional hot water pumps circulate HW from CV-2 to the radiation heating loop.
    - Double-suction pumps with 7.5 horsepower (hp) motors
- A hot glycol system serves the data center
  - Two (2) glycol pumps operate as lead/standby for the glycol loop

### Central Cooling System

- Trane chiller generates chilled water (CHW) for building cooling
  - Trane Model CVHE water-cooled centrifugal chiller
  - R-123 refrigerant

  - Chilled water pumping arrangement is primary only. Two (2) chilled water pumps circulate CHW to air handler coils. CHW pump motors are constant speed.
    - CHW pumps have 1.5 hp motors
  - One (1) condenser water pump circulates condenser water between the chiller condenser and the cooling tower
    - Condenser water pump has a 2.5 hp motor
  - Cooling tower fan has variable frequency drive (VFD) control of fan motor speed to maintain leaving water temperature
  - Condenser water setpoint of 85°F observed during walk-through
- A server rack cooling system serves the data center

**Air Handling Units**
- Five (5) air handling units AC-1 through AC-5 serve the building
  - AC-1 serves the lower level
    - HW heating coils and CHW cooling coils with two-way pneumatic control valves; HW reheat coils
  - AC-2 serves the computer rooms
    - Dual-duct unit
    - HW heating coils and CHW cooling coils with two-way valves
  - AC-3 serves the commons level
    - Dual-duct unit
    - HW heating coils and CHW cooling coils with two-way valves
  - AC-4 serves the corridors
    - 100% outside air (OA) unit
    - HW heating coils and CHW cooling coils; dual temperature terminal reheat coils
  - AC-5 serves the building interior
    - HW heating coils and CHW cooling coils
- One (1) heating and ventilating unit HV-1 serves the lower level
  - 100% OA system
  - HW heating coils

**Exhaust Systems**
- Four (4) exhaust fans serve mechanical rooms, bathrooms, and general exhaust
  - Exhaust fans EF-2 and EF-3 are connected to the campus building automation system (BAS) and serve bathroom exhaust and general exhaust, respectively

**Zone Heating/Cooling**
- Finned tube radiation provides perimeter heating
- Unit ventilators serve the provost's office and the Housing Office
- Cabinet unit heaters serve the entry vestibules

## HVAC Controls

**Building Automation System**
- Carrier i-Vu® 8.0 BAS used for monitoring, DDC and energy management of the majority of HVAC systems in the building

- Trane Tracer® Ensemble™ BAS used for monitoring, DDC and energy management of the chiller and glycol system

**Operating Schedules**
- HVAC systems are scheduled to operate in occupied mode 24/7

## Domestic/Service Water Heating

**Domestic Water Heaters**
- Two (2) natural gas-fired instantaneous water heaters with an external storage tank
  - Glass-lined steel storage tank

**DHW Load**
- Bathroom hand sinks

## Piping and Ductwork

**Piping Systems/Insulation**
- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**
- Spot observations of equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**
- Spot observations revealed no ductwork leakage issues

## Miscellaneous Loads

**Plug loads**
- Offices: computers or laptops, desk phones, desk lamps, space heaters, microwaves, etc.
- Basement: two (2) vending machines

**Elevators**
- Two (2) elevators serve the building
  - One (1) elevator was out of order during walk-through

## Specialty Systems

**Air Compressors**
- One (1) air compressor pump generates compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**
- Install automatic interior lighting controls on existing LED fixtures
- Retro-commissioning of HVAC systems and controls

  - Optimize cooling tower water temperature control
  - Scheduling of HVAC equipment and space temperature setbacks
- Implement HW and CHW supply temperature reset
- Setback equipment during academic breaks

**Capital Measures**

- Consider installing window film for solar heat gain reduction
- Install building-level gas and steam submeters
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Install VFDs on the motors of dual temperature loop pumps P-4 and P-5 and HW radiation heating loop pumps P-6 and P-7
  - Replace any HW heating coil 3-way valves with two-way valves
  - Implement control of pump motor speed based on differential pressure
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Replace existing chiller with high-efficiency water-cooled variable speed magnetic bearing chiller
  - R-123 refrigerant is being phased out starting January 1, 2020
  - Once manufacturing of R-123 is eliminated, the price of R-123 stock is expected to rise substantially
- Replace air handling units with variable air volume (VAV) systems during gut rehab project
- Consider installing occupancy-based HVAC controls on AC-1 through AC-5
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace pneumatic actuators with electric actuators

**O&M Measures**

- Change v-belt fan drives to cogged belt fan drives

# SUNY OSWEGO | KING HALL BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | King Hall |
| **Year Constructed:** | 1935 |
| **No. of Floors:** | 4 |
| **Est. GSF:** | 7,200 |

**Recent Building Upgrades**
- Interior renovation – 2017

**Functional Description**
King Hall is an administrative building located on the east side of campus. The 3-story building, housing the department of alumni relations, consists of offices, storage space, and an alumni lounge.

**Occupancy Patterns**
The building is occupied from 8 a.m. to 5 p.m. on weekdays only.

## Building Envelope

**Roof**
- Pitched roof with 3-tab asphalt shingles; no attic access during walk-through
- Attic insulation type and levels not accessible during walk-through

**Exterior Walls**
- Wood frame with a brick façade
- Insulation type and levels not accessible during walk-through

**Windows**
- Clear, double-hung, aluminum frame storm windows over clear, single glazed, casement, wooden frame original windows
  - Some offices have interior window shades or curtains

**Doors**
- Building entryway door is a wooden door with a transom window

**Air and Water Infiltration/Leakage**
- Noticeable signs of water leakage through stone foundation
- No excessive air infiltration was observed

## Utilities

**Electricity**
- The building has a National Grid electric service separate from the rest of the campus

### Natural Gas
- The building has a National Grid gas service separate from the rest of the campus
  - Used for space heating and domestic hot water heating

### District Steam
- This building does not receive steam from the Central Heating Plant

### Submeters
- None observed during walk-through

## Lighting

### Interior Fixture Types
- Predominant lighting types as follows:
  - Offices: Surface mount fixtures with linear T8 fluorescent lamps
  - Storage space: Surface mount fixtures with compact fluorescent lamps (CFL)

### Interior Lighting Controls
- No automatic controls observed during walk-through

### Exterior Lighting and Controls
- Exterior light fixtures appear to be high-intensity discharge (HID) type
- Exterior lighting controlled by manual switch

## HVAC

### Central Heating System
- One (1) cast-iron boiler generates heating hot water (HW) for building heating
  - Utica Boilers Model MGB natural gas-fired low-pressure hot water boiler
  - 200 thousand Btus per hour (MBH) input
  - 165 MBH heating capacity
  - 82.5% thermal efficiency
  - Four (4) hot water pumps each serve one of the four floors. All of the HW pump motors are constant speed.
    - Bell & Gossett in-line circulating pumps with fractional horsepower (hp) motors, rated for 22 gallons per minute (gpm) at 15 feet of head

### Central Cooling System
- No central cooling in this building

### Air Handling Units
- None observed during walk-through

### Exhaust Systems
- None observed during walk-through

### Zone Heating/Cooling

- Finned tube radiation provides perimeter heating in basement
- HW radiators serve the upper three (3) floors
  - Zone temperature control through electric wall thermostats
  - Thermostats have programming capabilities, but these do not appear to be in use
- Window air conditioning units cool the upper three (3) floors

## HVAC Controls

### Building Automation System

- This building is not connected to the campus building automation system (BAS)

### Operating Schedules

- HVAC systems operate 24/7 to meet thermostat setpoints

## Domestic/Service Water Heating

### Domestic Water Heaters

- One (1) natural draft, natural gas-fired automatic tank water heater
  - 40-gallon capacity
  - 40 MBH input

### Domestic Hot Water (DHW) Load

- Bathroom hand sinks
- Basement utility sink

## Piping and Ductwork

### Piping Systems/Insulation

- Some HW and DHW piping is missing insulation in basement mechanical room

### Equipment Insulation

- Spot observations of equipment insulation revealed no remarkable deficiencies

### Piping and Ductwork Leaks

- Spot observations revealed no leakage issues

## Miscellaneous Loads

### Plug Loads

- Offices: computers or laptops, printers, desk phones, desk lamps, portable fans, space heaters, etc.
- Common space: microwave, mini fridge, coffee maker, water dispenser, monitor, etc.
- Basement: dehumidifier and sump pump

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Retro-commissioning of HVAC systems and controls
  - Utilize programmable thermostats to setback space temperature when the building is unoccupied
- Implement HW supply temperature reset

**Capital Measures**

- Install window film for solar heat gain reduction
- Repair foundation
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Replace HW circulating pumps and motors with electronically commutated motors
- Consider replacing window AC units with ductless split systems
- Integrate building systems into campus BAS

**O&M Measures**

- Repair missing insulation

# SUNY OSWEGO | MAINTENANCE (BUILDING 12) BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | Maintenance (Building 12) |
| **Year Constructed:** | 1965 |
| **No. of Floors:** | 1 |
| **Est. GSF:** | 20,664 |

### Recent Building Upgrades
- None

### Functional Description
The maintenance building, also called Building 12, is an administrative building located on the southern side of Route 104. The one-story building, housing the department of facilities services, consists of one main hallway joining offices and workspaces.

### Occupancy Patterns
The maintenance building is occupied 24/7, primarily from 7 a.m. to 4 p.m.

## Building Envelope

### Roof
- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls
- Concrete masonry with a stone façade
- Insulation type and levels not accessible during walk-through

### Windows
- Clear, single glazed, awning and fixed, steel frame windows with shades

### Doors
- Building entryway doors are clear, double glazed, aluminum frame doors

### Air Infiltration/Leakage
- No excessive infiltration was observed

## Utilities

### Electricity
- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas
- The building has a National Grid gas service separate from the rest of the campus
  - Used for space heating and domestic hot water heating

### District Steam
- This building does not receive steam from the Central Heating Plant

### Submeters
- None observed during walk-through

## Lighting

### Interior Fixture Types
- Predominant lighting types as follows:
  - Corridor: Surface mount fixtures with LED lamps
  - Offices and workspaces: Prismatic troffer fixtures with linear T8 fluorescent lamps

### Interior Lighting Controls
- No automatic controls observed during walk-through

### Exterior Lighting and Controls
- Recessed and surface mount fixtures with high-intensity discharge (HID) lamps
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System
- One (1) high-efficiency boiler generates heating hot water (HW) for building heating
  - Lochinvar Model PBN1501 natural gas-fired hot water boiler
  - 1,260 thousand Btus per hour (MBH) output
  - 84% thermal efficiency
  - Manufactured 2018
  - Two (2) HW pumps circulate HW to building heating terminals. HW pump motors are constant speed.
    - Bell & Gossett base-mounted centrifugal pumps
  - HW temperature setback from 6 p.m. to 8 a.m.

### Central Cooling System
- No central cooling in this building

### Air Handling Units
- One (1) ductless mini-split system serves the IT Project Manager’s office

### Exhaust Systems
- Several rooftop exhaust fans with constant speed motors serve the building

### Zone Heating/Cooling

- Finned tube radiation provides perimeter heating in offices, workspaces, and storage rooms
- Cabinet unit heaters serve interior offices, workspaces, and entryways
  - Temperature control through non-programmable wall thermostat
    - 62°F setpoint observed during walk-through
- Window air conditioning units serve the offices and workspaces

## HVAC Controls

### Building Automation System

- This building is not connected to the campus building automation system (BAS)

### Operating Schedules

- HW system scheduled to operate in occupied mode from 8 a.m. to 6 p.m.

## Domestic/Service Water Heating

### Domestic Water Heaters

- One (1) natural draft, natural gas-fired automatic tank water heater
  - 50-gallon capacity
  - 40 MBH input
  - Installed 2021

### DHW Load

- Bathroom hand sinks and showers
- Break room kitchenette sinks

## Piping and Ductwork

### Piping Systems/Insulation

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

### Equipment Insulation

- Spot observations of equipment insulation revealed no remarkable deficiencies

### Piping and Ductwork Leaks

- Spot observations revealed no leakage issues

## Miscellaneous Loads

### Plug Loads

- Offices: computers or laptops, desk phones, desk lamps, etc.
- Break rooms: fridges, microwaves, coffee makers, etc.

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Install automatic interior lighting controls on existing LED fixtures
- Retro-commissioning of HVAC systems and controls
  - Enable reset of HW supply temperature based on outside air temperature
- Install low-flow or ultra low-flow showerheads

**Capital Measures**

- Replace single glazed windows with high performance windows
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Integrate building systems into campus BAS

**O&M Measures**

- No O&M opportunities identified during walk-through

# SUNY OSWEGO | MARY WALKER HEALTH CENTER BUILDING ASSESSMENT

## Building Description

| | |
|---|---|
| **Building Name:** | Mary Walker Health Center |
| **Year Constructed:** | 1965 |
| **No. of Floors:** | 1 + Basement |
| **Est. GSF:** | 33,260 |

### Recent Building Upgrades

- Interior renovation – 2021

### Functional Description

Mary Walker Health Center is the campus health care facility, located next to Lake Ontario on SUNY Oswego's main campus. The building houses a waiting area, medical exam rooms, offices, and counseling suite.

### Occupancy Patterns

The building is open from 8:30 a.m. to 4 p.m. on weekdays only.

## Building Envelope

### Roof

- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Brick masonry

### Windows

- Double hung, steel frame windows with tempered insulating glass

### Doors

- Building entryway doors are metal frame doors with tempered insulating glass

### Air Infiltration/Leakage

- No excessive infiltration was observed

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- This building does not receive natural gas

### District Steam

- Steam is distributed to the campus at 50 psig and is reduced to 12-13 psig within the building
  - Condensate is collected and returned from Mary Walker Health Center to the Central Heating Plant

### Submeters

- This building has a campus-managed Electro Industries revenue grade electricity submeter

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Basement: Mix of fluorescent and LED lighting
  - Waiting area: Pendant fixtures with LEDs
  - Offices: Offices were not accessible during walk-through
  - Exam rooms: Exam rooms were not accessible during walk-through

### Interior Lighting Controls

- Occupancy sensors in offices

### Exterior Lighting and Controls

- Predominant exterior lighting type is LED wall pack fixtures
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- One (1) shell & tube steam-to-hot-water converter HX-1 generates heating hot water (HW) for building heating
  - Bell & Gossett heat exchanger, manufactured 2021
  - Two (2) hot water pumps circulate HW to building. Both HW pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure.
    - Bell & Gossett in-line pumps with 5 horsepower (hp) motors, rated for 75 gallons per minute (gpm) at 70 feet of head
  - HW supply temperature is reset based on outside air (OA) temperature
    - 180°F supply temperature at OA temperature of 0°F and below
    - 125°F supply temperature at OA temperature of 50°F and above

### Variable Refrigerant Flow (VRF) System

- A VRF system serves the building
  - Two-pipe simultaneous heating and cooling system
  - Air-cooled condensing unit located outside
  - Indoor units provide heating and cooling to the rooms
    - Wall-mounted and ceiling cassette types

- Two (2) energy recovery ventilators ERV-1 and ERV-2 pre-condition the supply air
  - 100% OA units
  - Supply fan motors controlled by VFDs
  - Exhaust fan motors controlled by VFDs
  - Heat wheels with VFDs recovers heat from the exhaust airstreams
  - HW reheat coils
  - Each unit has separate heating and cooling direct expansion (DX) coils connected to the condensing unit outside

**Air Handling Units**

- One (1) heating and ventilating unit HV-1 serves the waiting area
  - Constant volume single-zone unit
  - Constant speed supply and return fan motors
  - HW preheat and heating coils

**Exhaust Systems**

- Four (4) exhaust fans serve the building
  - EF-1 serves the red bag room
  - EF-2 and EF-4 serve clinic areas
  - EF-3 serves the penthouse
    - Integral damper and direct digital controls (DDC)

**Zone Heating/Cooling**

- Nine (9) HW and steam unit heaters serve the building

## HVAC Controls

**Building Automation System**

- Trane Tracer® Ensemble™ building automation system (BAS) used for monitoring, DDC, and energy management of HVAC systems

**Operating Schedules**

- EF-1 is scheduled to operate in occupied mode 24/7
- Other HVAC systems are scheduled to operate in occupied mode from 7 a.m. to 5:30 p.m. daily

## Domestic/Service Water Heating

**Domestic Water Heaters**

- One (1) Bradford White electric water heater
- One (1) CEMline semi-instantaneous steam-fired water heater
  - 6-gallon capacity

**DHW Load**

- Bathroom hand sinks
- Medical room sinks

## Piping and Ductwork

**Piping Systems/Insulation**

- Spot observations of piping and ductwork insulation revealed no remarkable deficiencies

**Equipment Insulation**

- Steam-to-HW converter, manufactured 2021, was not insulated at the time of the 2022 walk-through
- Spot observations of other equipment insulation revealed no remarkable deficiencies

**Piping and Ductwork Leaks**

- Spot observations revealed no leakage issues

## Miscellaneous Loads

**Plug loads**

- Offices: desktop computers, laptops, chargers, printer/fax machine, etc.
- Medical rooms: autoclave

## Specialty Systems

**Air Compressors**

- One (1) air compressor generates compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

**No Cost/Low Cost Measures**

- Retro-commissioning of HVAC systems and controls
  - Scheduling of HVAC equipment and space temperature setbacks
- Implement pump differential pressure reset controls on the HW pumps
- Setback equipment during academic breaks

**Capital Measures**

- Replace interior fluorescent light fixtures in basement with LED fixtures
- Install building-level steam submeter
- Consider installing occupancy-based HVAC controls
- Convert HV-1 to single-zone variable air volume (VAV) system by installing VFD on system and implementing a temperature-based control scheme to modulate airflow
- Replace pneumatic actuators with electric actuators

**O&M Measures**

- Change any v-belt fan drives to cogged belt fan drives
- If not already implemented, install insulation on the steam-to-HW converter

# SUNY OSWEGO | SERVICE BUILDING 20 BUILDING ASSESSMENT

## Building Description

**Building Name:** Service Building 20

**Year Constructed:** 1971

**No. of Floors:** 2

**Est. GSF:** 14,850

### Recent Building Upgrades

- None

### Functional Description

Service Building 20, also called Garage Building 20, is an administrative building on the east side of campus housing the office of sustainability and the departments of publications, technology, and facility services. The upper floor consists of offices, workspace, and a publications studio. The lower floor is comprised of a bicycle repair shop and a kitchenette primarily used to store campus compost.

### Occupancy Patterns

Service Building 20 is occupied from 8 a.m. to 5 p.m. on weekdays and closed on weekends.

## Building Envelope

### Roof

- Flat roof; no roof access during walk-through
- Insulation type and levels not accessible during walk-through

### Exterior Walls

- Concrete masonry with a brick façade
- Insulation type and levels not accessible during walk-through

### Windows

- Clear, double glazed, fixed and awning, aluminum frame windows
  - Interior window shades or curtains in most offices

### Doors

- Building entryway doors are metal doors with small, clear, double glazed sidelights

### Air Infiltration/Leakage

- No excessive infiltration was observed

## Utilities

### Electricity

- Electricity is fed to the building from the National Grid electric substation on Washington Boulevard

### Natural Gas

- This building has a National Grid gas service separate from the rest of the campus
  - Used for space heating and domestic hot water heating

### District Steam

- This building does not receive steam from the Central Heating Plant

### Submeters

- None observed during walk-through

## Lighting

### Interior Fixture Types

- Predominant lighting types as follows:
  - Corridors: Industrial surface mount fixtures with linear T8 fluorescent lamps
  - Offices: Recessed prismatic fixtures with linear T8 fluorescent lamps

### Interior Lighting Controls

- No automatic controls observed during walk-through

### Exterior Lighting and Controls

- Predominant exterior lighting type is high-intensity discharge (HID)
- Exterior lights on campus are controlled by photosensors and astronomical time clocks

## HVAC

### Central Heating System

- One (1) cast-iron boiler generates heating hot water (HW) for building heating
  - Weil-McLain Model LGB natural gas-fired hot water boiler
  - 650 thousand Btus per hour (MBH) input
  - 526.5 MBH output
  - 81% thermal efficiency
  - Two (2) hot water pumps circulate HW to building heating terminals. Both HW pump motors are constant speed.
    - Bell & Gossett in-line circulating pumps

### Central Cooling System

- No central cooling system

### Air Handling Units

- One (1) rooftop air handling unit serves the building
  - Supply fan motor controlled by variable frequency drive (VFD) to maintain supply flow
  - Roof not accessible during walk-through

### Exhaust Systems

- Several rooftop exhaust fans with constant speed motors serve the building

### Zone Heating/Cooling

- Electric baseboards and HW finned tube radiation provide perimeter heating
  - Electric baseboard heaters have integrated thermostats
- Unit heaters serve the interior rooms
- Linear slot diffusers distribute air across windows

## HVAC Controls

### Building Automation System

- This building is not connected to the campus building automation system (BAS)

### Operating Schedules

- Operating schedules could not be verified during walk-through

## Domestic/Service Water Heating

### Domestic Water Heaters

- One (1) natural draft, natural gas-fired automatic tank water heater
  - 40-gallon capacity
  - 35.5 thousand Btus per hour (MBH) input
  - Manufactured 2009

### DHW (Domestic Hot Water) Load

- Bathroom hand sinks
- Kitchenette sink

## Piping and Ductwork

### Piping Systems/Insulation

- Some DHW piping is missing insulation in several areas
- Spot observations of HW piping and ductwork insulation revealed no remarkable deficiencies

### Equipment Insulation

- Spot observations of equipment insulation revealed no remarkable deficiencies

### Piping and Ductwork Leaks

- Spot observations revealed no leakage issues

## Miscellaneous Loads

### Plug Loads

- Offices: computers or laptops, desk phones, desk lamps, space heaters, etc.
- Production studio: computers, monitors, umbrella and softbox lights, etc.
- Break room: fridge, microwave, coffee maker, etc.

## Specialty Systems

### Air Compressors

- One (1) air compressor generates compressed air for pneumatic controls

## Potential Energy Efficiency Measures (EEMs)

### No Cost/Low Cost Measures

- Retro-commissioning of HVAC systems and controls
  - Scheduling of HVAC equipment and space temperature setbacks
- Implement HW supply temperature reset
- Setback equipment during academic breaks

### Capital Measures

- Install window film for solar heat gain reduction
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity
- Replace exterior light fixtures with LED fixtures
- Replace HW circulating pumps and motors with electronically commutated motors
- Replace fan motors with beyond premium efficiency motors at end of useful life
- Add hot water zone valves for controlling individual spaces served by fin tube radiation
- Replace pneumatic actuators with electric actuators
- Integrate building systems into campus BAS

### O&M Measures

- Change v-belt fan drives to cogged belt fan drives
- Repair missing insulation

# Appendix C
# EEM Supporting Documents

| | |
|---|---|
| EEM-1 | Interior LED Lighting Retrofit |
| EEM-2 | Exterior LED Lighting Retrofit |
| EEM-3 | Retro-Commissioning |
| EEM-4 | HVAC Scheduling |
| EEM-5 | Occupancy Based HVAC Controls |
| EEM-6 | Differential Pressure Reset Controls |
| EEM-7 | Multizone VAV Static Pressure Reset Controls |
| EEM-8 | Implement Demand Controlled Ventilation |
| EEM-9 | Implement Kitchen Demand Controlled Ventilation |
| EEM-10 | Implement Laboratory Demand Controlled Ventilation |
| EEM-11 | Install VFD on Pump Motor |
| EEM-12 | Convert Constant Volume Single Zone System to Single Zone VAV System |
| EEM-13 | Install Pool Dehumidification System |

**SUNY Oswego**
**Summary of Energy Efficiency Measures (EEM)**

| EEM No. | Potential EEM | Buildings Affected | Annual Electrical Savings (kWh/yr) | Electrical Peak Demand Savings (kW) | Annual Natural Gas Savings (Therms/yr) | Annual Energy Savings (MMBtu/year) | Annual Energy Cost Savings ($/yr) | Estimated Capital Cost | Simple Payback Period (years) | SIR | IRR | Annual GHG Reduction (MTCO2e) | Campus Site EUI Reduction (kBtu/GSF/yr) | Percent EUI Reduction | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **LIGHTING** | | | | | | | | | | | | | | |
| **EEM-1** | Interior LED Lighting Retrofit | SHELDON HALL, J C PARK HALL, CAMPUS CENTER, REC & CONVOCATION CTR, J LANIGAN HALL | 142,860 | 55.8 | -1,544 | 333 | $7,805 | $414,177 | 53.1 | 0.3 | -13% | 8 | 0.1 | 0.1% | 1 |
| **EEM-2** | Parking Lot and Roadway LED Retrofit | CAMPUS GROUND | 151,247 | 34.7 | 0 | 516 | $8,924 | $1,998,482 | 224.0 | 0.1 | -23% | 17 | 0.1 | 0.2% | 1 |
| | **LIGHTING SUBTOTAL** | | **205,875** | **63.3** | **-1,081** | **594** | **$11,710** | **$2,412,659** | **206.0** | **0.1** | **-23%** | **18** | **0.2** | **0.2%** | |
| | **HVAC AND CONTROLS** | | | | | | | | | | | | | | |
| **EEM-3** | Retro-Commissioning | Campus Wide | 815,562 | 0.0 | 82,558 | 11,039 | $81,472 | $246,586 | 3.0 | 1.6 | 18% | 532 | 3.2 | 4.1% | 1 |
| **EEM-4** | HVAC Scheduling | Campus Wide | 640,306 | 0.0 | 201,482 | 22,333 | $119,177 | $4,136 | 0.0 | 82.9 | 2845% | 1,144 | 6.4 | 8.3% | 1 |
| **EEM-5** | Occupancy Based HVAC Controls | Campus Wide | 1,838,301 | 0.0 | 207,110 | 26,983 | $192,132 | $3,730,696 | 19.4 | 0.7 | -4% | 1,312 | 7.7 | 10.0% | 1, 2 |
| **EEM-6** | Pump Differential Pressure Reset Control | Campus Wide | 164,705 | 10.2 | 0 | 562 | $9,718 | $37,107 | 3.8 | 3.9 | 25% | 19 | 0.2 | 0.2% | 1 |
| **EEM-7** | Multizone VAV Static Pressure Reset Controls | Campus Wide | 192,792 | 33.8 | 0 | 658 | $11,375 | $24,248 | 2.1 | 7.0 | 46% | 22 | 0.2 | 0.2% | 1 |
| **EEM-8** | Implement Demand Controlled Ventilation | Campus Wide | 728 | 1.0 | 68,951 | 6,898 | $27,899 | $40,655 | 1.5 | 9.4 | 65% | 366 | 2.0 | 2.6% | 1 |
| **EEM-9** | Implement Kitchen Demand Controlled Ventilation | REC & CONVOCATION CTR, PATHFINDER DH, LAKESIDE DH, COOPER DH | 108,195 | 32.2 | 19,498 | 2,319 | $14,261 | $192,867 | 13.5 | 1.1 | 1% | 116 | 0.7 | 0.9% | 1 |
| **EEM-10** | Implement Laboratory Demand Controlled Ventilation | RICHARD S SHINEMAN CENTER | 1,714,816 | 0.0 | 116,014 | 17,452 | $148,044 | $503,100 | 3.4 | 4.3 | 28% | 814 | 5.0 | 6.5% | 1 |
| **EEM-11** | Install VFD on Pump Motor | Campus Wide | 294,149 | 30.7 | 0 | 1,004 | $17,355 | $402,611 | 23.2 | 0.6 | -5% | 34 | 0.3 | 0.4% | 1 |
| **EEM-12** | Convert CVSZ to SZVAV | Campus Wide | 376,296 | 96.7 | 0 | 1,284 | $22,201 | $142,040 | 6.4 | 2.3 | 13% | 43 | 0.4 | 0.5% | 1 |
| **EEM-13** | Install Pool Dehumidification System | LAKER HALL, M V LEE HALL | 4,830 | -48.3 | 38,215 | 3,838 | $15,724 | $1,099,423 | 69.9 | 0.2 | -16% | 204 | 1.1 | 1.4% | 1 |
| | **HVAC AND CONTROLS SUBTOTAL** | | **4,305,476** | **109.4** | **513,680** | **66,058** | **$461,550** | **$6,423,470** | **13.9** | **1.1** | **-3%** | **3,224** | **18.9** | **24.5%** | |
| | **GRAND TOTAL** | | **4,511,351** | **172.7** | **512,599** | **66,653** | **$473,260** | **$8,836,129** | **18.7** | **0.9** | **-6%** | **3,242** | **19.1** | **24.7%** | |
| | BuildSmart 2025 Reduction Goal | | - | - | - | 146,332 | - | - | - | - | - | - | | - | 3 |
| | % of BuildSmart Reduction Goal | | - | - | - | 46% | - | - | - | - | - | - | | - | |
| | **Total of IRR >= 7%** | | **2,733,643** | **99.2** | **328,304** | **42,158** | **$293,920** | **$997,873** | **3.4** | **3.9** | **21%** | **2,058** | **12.0** | **15.6%** | |
| | % of BuildSmart Reduction Goal | | - | - | - | 29% | - | - | - | - | - | - | | - | |

**Notes**

**1** Energy savings will be impacted by interactive effects from other measures. These interactive effects were not considered when calculating energy savings.
**2** Measure assumes EEM-3 HVAC Scheduling would be implemented prior to using occupancy based HVAC controls. Measure only accounts for savings during typical building occupied hours.
**3** Value provided by NYPA. SUNY has an overall goal of ~4.4 TBtu (4,410,860 MMBTU); SUNY Oswego's goal is 146,332 MMBTU.
**4** Subtotals are multiplied by a 0.7 interactive factor to account for interaction between measures.
**5** LCCA performed over the expected useful life of each measure (EUL). Annual escalation rates for the utility costs are based on a US Department of Energy (DOE) rate schedule for commercial buildings in the state of New York (Annual Supplement to Handbook 135, Energy Price Indices and Discount Factors for LCC Analysis, NISTIR 85-3273)

# SUNY OSWEGO | EEM-1 INTERIOR LED LIGHTING RETROFIT

*Energy Opportunity Area:* Lighting

*Buildings Affected:* Sheldon Hall, Park Hall, Marano Campus Center, Lanigan Hall

**Table 1. EEM-1 Summary Data**

| Description | Values | Units |
|---|---|---|
| Annual Electrical Energy Savings | 142,860 | kWh/year |
| Electrical Peak Demand Savings | 55.8 | kW |
| Annual Electrical Energy Cost Savings | $8,429 | $/year |
| Annual Natural Gas Savings | -1,544 | Therms/year |
| Annual Fossil Fuel Cost Savings | ($624) | $/year |
| **Total Annual Energy Cost Savings** | **$7,805** | **$/year** |
| **Estimated Implementation Cost** | **$414,177** | **$** |
| **Simple Payback Period** | **53.1** | **years** |
| **Savings to Investment Ratio** | **0.3** | **-** |

### Existing Conditions/Baseline

A room-by-room survey of areas that underwent a targeted audit was completed to quantify the types of lighting fixtures and controls that exist in the targeted areas and the potential to upgrade the lighting systems to LED technologies.

Campus interior lighting fixtures are predominantly comprised of linear T8 fluorescent and compact fluorescent lamp (CFL) technologies. In general, fluorescent fixtures are near end of life and maintaining the existing fixtures would not be recommended unless there was a hazardous material concern that could not be accommodated. Building areas that have been renovated more recently have been upgraded with LED technologies. Overall, it is estimated that about 50% of the campus interior lighting has been upgraded to LED fixtures.

Interior lighting is locally controlled through manual switches or occupancy sensors; there is no campus wide control of the fixtures through the building automation system. Daylight is available in many spaces, but daylighting controls were not observed in any buildings.

### Recommended Action

Visual comfort and student performance of educational spaces can be improved by replacing fluorescent recessed and surface mounted fixtures with close to the ceiling, linear LED fixtures that provide some uplight on the ceiling in addition to direct illumination on the student work surfaces. Providing vertical illuminance on teaching walls and sidewalls will provide visual relief during presentations and lecture.

Downlights can be replaced with LED retrofit downlights, which are available from several manufacturers in a variety of diameters, trim options, and light output; these formats will minimize ceiling damage.

When purchasing LED fixtures, SUNY Oswego should only consider those that are ENERGY STAR labeled or listed on the DesignLights Consortium (DLC) website. These ratings ensure the fixture meets minimum standards for light quality, reliable life, and energy efficiency, and are typically required by utility energy efficiency programs if incentives are pursued.

In general, enclosed spaces, such as private offices, conference rooms, and classrooms, would benefit from vacancy controls (manual ON, automatic OFF). Open offices and public areas, such as restrooms, would benefit from occupancy controls (automatic ON/OFF). Public circulation, such as corridors, lobbies, entrances, and stairwells can dim to minimum required light levels instead of turning completely off based on sensed occupancy. Alternatively, every other or every third fixture could be controlled by occupancy sensors to maintain minimum light levels. Large open areas, such as lobbies, would benefit from local area controllers to activate zoning options and light level options based on the varying needs of the spaces. Areas with ample daylight, in particular the corridor and the food court of Marano Campus Center, should consider daylighting controls to automatically adjust fixture light levels based on available natural light.

This EEM recommends new LED fixtures be specified with onboard sensing for occupancy/vacancy and daylight controls to provide real-time energy tuning for every space. Implementation of onboard sensing technologies eliminates the need to install remote sensors (ceiling or wall mounted) or a head end control system to realize the energy benefits of sophisticated controls. The specification of a single product will include both the new fixture and the controls. Onboard sensors will dim, or turn off, fixtures when enough light is available in the space and will turn off fixtures on the condition of vacancy. An additional benefit of onboard sensing technologies is that the fixture and the control device are of the same manufacturer and covered under a single warranty.

### Estimated Energy Savings

A lighting survey was conducted for the targeted areas addressed by this measure. Operating hours were estimated for each space type based on observations and discussions with facility personnel. Savings were calculated based on the difference between the existing fixture wattage and proposed LED replacement wattage and reduction in operating hours due to the installation of recommended lighting controls.

Supporting documents include the lighting survey documenting the type and quantity of fixtures and controls located in each space in the building, along with estimated fixture input power and annual equivalent full load hours (EFLH). Proposed LED fixtures and controls are presented as well with fixture input power and EFLH. In addition to direct energy savings from the proposed lighting retrofit, indirect energy savings were calculated to account for the energy impact on the building heating and cooling systems; the reduction in heat gain to the space from the new LED fixtures will reduce cooling energy requirements and increase heating energy requirements. The basis for indirect savings is listed at the bottom of the lighting survey and analysis spreadsheet provided below.

Table 2 presents estimated savings, implementation costs, and simple payback period that could result from the proposed lighting projects.

**Table 2. EEM-1 Savings**

| Building | Annual Electrical Energy Savings (kWh) | Electric Peak Demand Savings (kW) | Total Natural Gas Savings (therms) | Total Annual Energy Cost Savings | Estimated Implementation Cost | Simple Payback Period |
|---|---|---|---|---|---|---|
| 0001 - SHELDON HALL | 13,149 | 9 | -142 | $718 | $13,335 | 18.6 |
| 0002 - J C PARK HALL | 369 | 0 | -4 | $20 | $1,051 | 52.1 |
| 0003 - CAMPUS CENTER | 29,734 | 6 | -321 | $1,624 | $68,918 | 42.4 |
| 003B - REC & CONVOCATION CTR | 59,428 | 12 | -642 | $3,247 | $29,653 | 9.1 |
| 0006 - J LANIGAN HALL | 40,179 | 28 | -434 | $2,195 | $301,221 | 137.2 |

| Building | Annual Electrical Energy Savings (kWh) | Electric Peak Demand Savings (kW) | Total Natural Gas Savings (therms) | Total Annual Energy Cost Savings | Estimated Implementation Cost | Simple Payback Period |
|---|---|---|---|---|---|---|
| **Total** | **142,860** | **55.8** | **-1,544** | **$7,805** | **$414,177** | **53.1** |

## Estimated Project Cost

Costs presented in Table 3 represent the scope of work described previously. Labor costs were estimated based on RS Means 2023. LED fixture costs were estimated based on previous projects and internet research.

**Table 3. EEM-1 Estimated Project Costs**

| Item Description | Quantity | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| Light Fixtures | 1 | Lump Sum | - | $281,453 |
| Motion Sensor Controls | 1 | Lump Sum | - | $6,688 |
| Daylighting Controls | 1 | Lump Sum | - | $1,494 |
| | | | | |
| **Labor and Materials Subtotal** | | | | **$289,635** |
| General Conditions | 10% | | | $28,963 |
| **Labor and Materials Cost Total** | | | | **$318,598** |
| | | | | |
| Architectural & Engineering Fees | 10% | | | $31,860 |
| Construction Management Fees | 10% | | | $31,860 |
| Contingency | 10% | | | $31,860 |
| | | | | |
| **Project Cost Subtotal** | | | | **$414,177** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$414,177** |

## EEM-1 – INTERIOR LED LIGHTING RETROFIT

## SUPPORTING DOCUMENTS

**Fixture Table**

***SUNY Oswego***

| | Existing Fixtures | | | | | | Proposed Fixtures | | | | | | Proposed Replacement | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fixture ID | Description | Lamp Type | Nominal Lamp Watts | # Lamps | Input Watts | Lamp Life (Hrs) | Description | Lamp Type | Nominal Lamp Watts | # Lamps | Input Watts | Lamp/ Fixture Life (Hrs) | Labor | Material | Total |
| A | 4-Lamp F32T8, IS Ballast, NBF | F32T8 | 32 | 4 | 112 | 24,000 | 59W LED Troffer | LED | 59 | 1 | 59 | 50,000 | $235 | $277 | $511 |
| B | 2-Lamp F32T8, IS Ballast, NBF | F32T8 | 32 | 2 | 59 | 24,000 | 40W 4ft LED Pendant | LED | 40 | 1 | 40 | 50,000 | $201 | $210 | $411 |
| C | 1-Lamp MH250 | MH250 | 250 | 1 | 295 | 10,000 | 150W LED Corn Bulb | LED | 150 | 1 | 150 | 50,000 | $64 | $115 | $179 |
| D | 4-Lamp F48T5/HO, PS Ballast | F48T5/HO | 54 | 4 | 234 | 36,000 | 96W 8ft LED Pendant | LED | 96 | 1 | 96 | 50,000 | $165 | $248 | $413 |
| E | 1-Lamp CFQ26W | CFQ26W | 26 | 1 | 27 | 15,000 | 22W LED Recessed Downlight | LED | 22 | 1 | 22 | 50,000 | $111 | $32 | $143 |
| F | 2-Lamp F32T8, IS Ballast, NBF | F32T8 | 32 | 2 | 59 | 24,000 | 36W LED Wall Wash Cove Light | LED | 36 | 1 | 36 | 50,000 | $235 | $230 | $464 |
| G | 1-Lamp F32T8, IS Ballast, NBF | F32T8 | 32 | 1 | 31 | 24,000 | 22W 4ft LED Strip Light | LED | 22 | 1 | 22 | 50,000 | $109 | $39 | $148 |
| H | 1-Lamp F17T8, IS Ballast, NBF | F17T8 | 17 | 1 | 20 | 24,000 | 15W 2ft LED Strip Light | LED | 15 | 1 | 15 | 50,000 | $109 | $36 | $145 |
| I | 6-Lamp CFT40W | CFT40W | 40 | 6 | 276 | 15,000 | 23W LED PL-L | LED | 23 | 6 | 138 | 50,000 | $89 | $111 | $199 |
| J | 2-Lamp CFQ18W | CFQ18W | 18 | 2 | 38 | 15,000 | 22W LED Recessed Downlight | LED | 22 | 1 | 22 | 50,000 | $111 | $32 | $143 |
| K | 50W 4ft LED Pendant | LED | 50 | 1 | 50 | 50,000 | 50W 4ft LED Pendant | LED | 50 | 1 | 50 | 50,000 | $0 | $0 | $0 |
| L | 15W LED Recessed Downlight | LED | 15 | 1 | 15 | 50,000 | 15W LED Recessed Downlight | LED | 15 | 1 | 15 | 50,000 | $0 | $0 | $0 |
| M | 68W Linear LED | LED | 68 | 1 | 68 | 50,000 | 68W Linear LED | LED | 68 | 1 | 68 | 50,000 | $0 | $0 | $0 |
| N | 2-Lamp F32T8, IS Ballast, NBF | F32T8 | 32 | 2 | 59 | 24,000 | 40W 4ft LED Pendant | LED | 40 | 1 | 40 | 50,000 | $201 | $210 | $411 |
| O | 3-Lamp F32T8, IS Ballast, NBF | F32T8 | 32 | 3 | 89 | 24,000 | 50W 4ft LED Pendant | LED | 50 | 1 | 50 | 50,000 | $143 | $107 | $250 |
| P | 1-Lamp CF42W | CF42W | 42 | 1 | 48 | 15,000 | 23W LED PL-L | LED | 23 | 1 | 23 | 50,000 | $15 | $18 | $33 |

## Space Types and Annual Hours

### *SUNY Oswego*

| Space Type | Description | Annual Hours |
|---|---|---|
| OFF | Enclosed Office | 1,549 |
| OP OFF | Open Office | 3,098 |
| STO | Storage | 774 |
| ELEC/MECH | Electrical/Mechanical Space | 943 |
| CONF | Conference Room | 1,162 |
| CLASS | Classroom | 1,549 |
| REST | Restroom | 3,098 |
| CORR | Corridor | 5,260 |
| STAIR | Stairway | 8,760 |
| 24/7 | 24/7 Operation | 8,760 |

# Ramboll - SUNY Oswego | EEM-1 Interior LED Lighting Retrofit

**Lighting Survey and Proposed Upgrades**

***SUNY Oswego***

| Baseline Summary | |
|---|---|
| Total Connected Load (kW) | 72.6 |
| Annual Equivalent Full Load Hours (EFLH) | 2,643 |
| Total Annual Energy Use (kWh) | 191,952 |

| Proposed Summary | |
|---|---|
| Total Connected Load (kW) | 39.5 |
| Annual Equivalent Full Load Hours (EFLH) | 1,601 |
| Total Annual Energy Use without New Controls (kWh) | 101,892 |
| Total Annual Energy Use with New Motion Controls (kWh) | 66,999 |
| Total Annual Energy Use with New Motion + Daylighting Controls (kWh) | 63,249 |

| Savings Summary | |
|---|---|
| Total Connected Load Reduction (kW) | 33.1 |
| Annual Equivalent Full Load Hours (EFLH) | 1,042 |
| Fixture Upgrade Energy Savings (kWh) | 90,059 |
| Motion Control Energy Savings (kWh) | 34,894 |
| Daylighting Control Energy Savings (kWh) | 3,750 |
| Interactive Electric Energy Savings (kWh) | 14,157 |
| Total Electric Energy Savings (kWh) | 142,860 |
| Interactive Fossil Energy Savings (Therms) | -1,544 |

| Ballast Key | |
|---|---|
| ES Mag | Energy Saving Magnetic Ballast |
| IS | Instant Start Electronic Ballast |
| RS | Rapid Start Electronic Ballast |
| PS | Program Start Electronic Ballast |
| LBF | Low Ballast Factor (<0.85) |
| HBF | High Ballast Factor (0.96-1.1) |
| VHBF | Very High Ballast Factor (>1.1) |

| | Basic Project Information | | | Existing Conditions | | | | | | | | | | | | | | Proposed Conditions | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Lighting Control | | | | | | | Foot-Candle | | | | | | Added Lighting Controls | | | | | | | | | | | | | | | |
| Line Item | Building | Room # | Room Name/Type | Fixture ID | Fixture Qty | Fixture Description | Watts/ Fixture | Installed kW | Motion Control | Sensor Quantity | # Fixtures Controlled | Daylighting Control | Sensor Quantity | # Fixtures Controlled | EFLH | High | Low | Fixture Qty | Fixture Description | Watts/ Fixture | Installed kW | Motion Control | Sensor Quantity | # Fixtures Controlled | Daylighting Control | Sensor Quantity | # Fixtures Controlled | EFLH | Connected Load Reduction (kW) | Fixture Upgrade Energy Savings (kWh) | Motion Control Energy Savings (kWh) | Daylighting Control Energy Savings (kWh) | Interactive Electric Energy Savings (kWh) | Total Electric Energy Savings (kWh) | Interactive Fossil Energy Savings | Units | Notes |
| 1 | 0001 - SHELDON HALL | 104 | Historic Lecture Hall | I | 42 | 6-Lamp CFT40W | 276 | 11.6 | NONE | | | NONE | | | 1,549 | TRUE | | 42 | 23W LED PL-L | 138 | 5.8 | CEILING OCC | 1 | 42 | NONE | | | 1,084 | 5.8 | 8,978 | 2,693 | 0 | 1,284 | 12,955 | -140 | Therms | |
| 2 | 0001 - SHELDON HALL | 104 | Historic Lecture Hall | J | 5 | 2-Lamp CFQ18W | 38 | 0.2 | NONE | | | NONE | | | 1,549 | TRUE | | 5 | 22W LED Recessed Downlight | 22 | 0.1 | CEILING OCC | 0 | 5 | NONE | | | 1,084 | 0.1 | 124 | 51 | 0 | 19 | 194 | -2 | Therms | |
| 3 | 0002 - J C PARK HALL | 315 | Lecture Hall | K | 8 | 50W 4ft LED Pendant | 50 | 0.4 | NONE | | | NONE | | | 1,549 | TRUE | | 8 | 50W 4ft LED Pendant | 50 | 0.4 | CEILING OCC | 3 | 8 | NONE | | | 1,084 | 0.0 | 0 | 186 | 0 | 20 | 206 | -2 | Therms | |
| 4 | 0002 - J C PARK HALL | 315 | Lecture Hall | L | 12 | 15W LED Recessed Downlight | 15 | 0.2 | NONE | | | NONE | | | 1,549 | TRUE | | 12 | 15W LED Recessed Downlight | 15 | 0.2 | CEILING OCC | 0 | 12 | NONE | | | 1,084 | 0.0 | 0 | 84 | 0 | 9 | 93 | -1 | Therms | |
| 5 | 0002 - J C PARK HALL | 315 | Lecture Hall | M | 2 | 68W Linear LED | 68 | 0.1 | NONE | | | NONE | | | 1,549 | TRUE | | 2 | 68W Linear LED | 68 | 0.1 | CEILING OCC | 0 | 2 | NONE | | | 1,084 | 0.0 | 0 | 63 | 0 | 7 | 70 | -1 | Therms | |
| 6 | 0003 - CAMPUS CENTER | Corridor | Corridor | O | 20 | 3-Lamp F32T8, IS Ballast, NBF | 89 | 1.8 | NONE | | | NONE | | | 5,260 | TRUE | | 20 | 50W 4ft LED Pendant | 50 | 1.0 | BI-LEVEL OCC | 0 | 20 | DAYLIGHT DIMMING | 0 | 10 | 2,794 | 0.8 | 4,103 | 1,972 | 493 | 722 | 7,291 | -79 | Therms | |
| 7 | 0003 - CAMPUS CENTER | Corridor | Corridor | B | 100 | 2-Lamp F32T8, IS Ballast, NBF | 59 | 5.9 | NONE | | | NONE | | | 5,260 | TRUE | | 100 | 40W 4ft LED Pendant | 40 | 4.0 | BI-LEVEL OCC | 16 | 100 | DAYLIGHT DIMMING | 4 | 39 | 2,903 | 1.9 | 9,993 | 7,890 | 1,538 | 2,136 | 21,558 | -233 | Therms | |
| 8 | 0003 - CAMPUS CENTER | Corridor | Corridor | P | 4 | 1-Lamp CF42W | 48 | 0.2 | NONE | | | NONE | | | 5,260 | TRUE | | 4 | 23W LED PL-L | 23 | 0.1 | BI-LEVEL OCC | 0 | 4 | DAYLIGHT DIMMING | 0 | 4 | 2,301 | 0.1 | 526 | 181 | 91 | 88 | 886 | -10 | Therms | |
| 9 | 003B - REC & CONVOCATION CTR | Food Court | Corridor | C | 11 | 1-Lamp MH250 | 295 | 3.2 | NONE | | | NONE | | | 5,260 | TRUE | | 11 | 150W LED Corn Bulb | 150 | 1.7 | BI-LEVEL OCC | 2 | 11 | DAYLIGHT DIMMING | 2 | 11 | 2,301 | 1.6 | 8,389 | 3,254 | 1,627 | 1,460 | 14,731 | -159 | Therms | |
| 10 | 003B - REC & CONVOCATION CTR | Concourse | Corridor | D | 44 | 4-Lamp F48T5/HO, PS Ballast | 234 | 10.3 | NONE | | | NONE | | | 5,260 | TRUE | | 44 | 96W 8ft LED Pendant | 96 | 4.2 | BI-LEVEL OCC | 0 | 44 | DAYLIGHT DIMMING | 0 | 0 | 3,287 | 6.1 | 31,937 | 8,331 | 0 | 4,430 | 44,698 | -483 | Therms | |
| 11 | 0006 - J LANIGAN HALL | 101 | Lecture Hall | A | 93 | 4-Lamp F32T8, IS Ballast, NBF | 112 | 10.4 | NONE | | | NONE | | | 1,549 | TRUE | | 93 | 59W LED Troffer | 59 | 5.5 | CEILING OCC | 5 | 93 | NONE | | | 1,084 | 4.9 | 7,635 | 2,550 | 0 | 1,120 | 11,305 | -122 | Therms | |
| 12 | 0006 - J LANIGAN HALL | 101 | Lecture Hall | E | 8 | 1-Lamp CFQ26W | 27 | 0.2 | NONE | | | NONE | | | 1,549 | TRUE | | 8 | 22W LED Recessed Downlight | 22 | 0.2 | CEILING OCC | 0 | 8 | NONE | | | 1,084 | 0.0 | 62 | 82 | 0 | 16 | 160 | -2 | Therms | |
| 13 | 0006 - J LANIGAN HALL | 101 | Lecture Hall | F | 24 | 2-Lamp F32T8, IS Ballast, NBF | 59 | 1.4 | NONE | | | NONE | | | 1,549 | TRUE | | 24 | 36W LED Wall Wash Cove Light | 36 | 0.9 | CEILING OCC | 0 | 24 | NONE | | | 1,084 | 0.6 | 855 | 401 | 0 | 138 | 1,395 | -15 | Therms | |
| 14 | 0006 - J LANIGAN HALL | 101 | Lecture Hall | G | 6 | 1-Lamp F32T8, IS Ballast, NBF | 31 | 0.2 | NONE | | | NONE | | | 1,549 | TRUE | | 6 | 22W 4ft LED Strip Light | 22 | 0.1 | CEILING OCC | 0 | 6 | NONE | | | 1,084 | 0.1 | 84 | 61 | 0 | 16 | 161 | -2 | Therms | |
| 15 | 0006 - J LANIGAN HALL | 101 | Lecture Hall | H | 2 | 1-Lamp F17T8, IS Ballast, NBF | 20 | 0.0 | NONE | | | NONE | | | 1,549 | TRUE | | 2 | 15W 2ft LED Strip Light | 15 | 0.0 | CEILING OCC | 0 | 2 | NONE | | | 1,084 | 0.0 | 15 | 14 | 0 | 3 | 33 | 0 | Therms | |
| 16 | 0006 - J LANIGAN HALL | 102 | Lecture Hall | A | 24 | 4-Lamp F32T8, IS Ballast, NBF | 112 | 2.7 | NONE | | | NONE | | | 1,549 | TRUE | | 24 | 59W LED Troffer | 59 | 1.4 | CEILING OCC | 2 | 24 | NONE | | | 1,084 | 1.3 | 1,970 | 658 | 0 | 289 | 2,917 | -32 | Therms | |
| 17 | 0006 - J LANIGAN HALL | 102 | Lecture Hall | E | 6 | 1-Lamp CFQ26W | 27 | 0.2 | NONE | | | NONE | | | 1,549 | TRUE | | 6 | 22W LED Recessed Downlight | 22 | 0.1 | CEILING OCC | 0 | 6 | NONE | | | 1,084 | 0.0 | 46 | 61 | 0 | 12 | 120 | -1 | Therms | |
| 18 | 0006 - J LANIGAN HALL | 102 | Lecture Hall | F | 21 | 2-Lamp F32T8, IS Ballast, NBF | 59 | 1.2 | NONE | | | NONE | | | 1,549 | TRUE | | 21 | 36W LED Wall Wash Cove Light | 36 | 0.8 | CEILING OCC | 0 | 21 | NONE | | | 1,084 | 0.5 | 748 | 351 | 0 | 121 | 1,220 | -13 | Therms | |
| 19 | 0006 - J LANIGAN HALL | 102 | Lecture Hall | G | 5 | 1-Lamp F32T8, IS Ballast, NBF | 31 | 0.2 | NONE | | | NONE | | | 1,549 | TRUE | | 5 | 22W 4ft LED Strip Light | 22 | 0.1 | CEILING OCC | 0 | 5 | NONE | | | 1,084 | 0.0 | 70 | 51 | 0 | 13 | 134 | -1 | Therms | |
| 20 | 0006 - J LANIGAN HALL | 103 | Lecture Hall | A | 24 | 4-Lamp F32T8, IS Ballast, NBF | 112 | 2.7 | NONE | | | NONE | | | 1,549 | TRUE | | 24 | 59W LED Troffer | 59 | 1.4 | CEILING OCC | 2 | 24 | NONE | | | 1,084 | 1.3 | 1,970 | 658 | 0 | 289 | 2,917 | -32 | Therms | |
| 21 | 0006 - J LANIGAN HALL | 103 | Lecture Hall | E | 6 | 1-Lamp CFQ26W | 27 | 0.2 | NONE | | | NONE | | | 1,549 | TRUE | | 6 | 22W LED Recessed Downlight | 22 | 0.1 | CEILING OCC | 0 | 6 | NONE | | | 1,084 | 0.0 | 46 | 61 | 0 | 12 | 120 | -1 | Therms | |
| 22 | 0006 - J LANIGAN HALL | 103 | Lecture Hall | F | 21 | 2-Lamp F32T8, IS Ballast, NBF | 59 | 1.2 | NONE | | | NONE | | | 1,549 | TRUE | | 21 | 36W LED Wall Wash Cove Light | 36 | 0.8 | CEILING OCC | 0 | 21 | NONE | | | 1,084 | 0.5 | 748 | 351 | 0 | 121 | 1,220 | -13 | Therms | |
| 23 | 0006 - J LANIGAN HALL | 103 | Lecture Hall | G | 5 | 1-Lamp F32T8, IS Ballast, NBF | 31 | 0.2 | NONE | | | NONE | | | 1,549 | TRUE | | 5 | 22W 4ft LED Strip Light | 22 | 0.1 | CEILING OCC | 0 | 5 | NONE | | | 1,084 | 0.0 | 70 | 51 | 0 | 13 | 134 | -1 | Therms | |
| 24 | 0006 - J LANIGAN HALL | 104 | Lecture Hall | A | 38 | 4-Lamp F32T8, IS Ballast, NBF | 112 | 4.3 | NONE | | | NONE | | | 1,549 | TRUE | | 38 | 59W LED Troffer | 59 | 2.2 | CEILING OCC | 3 | 38 | NONE | | | 1,084 | 2.0 | 3,120 | 1,042 | 0 | 458 | 4,619 | -50 | Therms | |
| 25 | 0006 - J LANIGAN HALL | 104 | Lecture Hall | E | 8 | 1-Lamp CFQ26W | 27 | 0.2 | NONE | | | NONE | | | 1,549 | TRUE | | 8 | 22W LED Recessed Downlight | 22 | 0.2 | CEILING OCC | 0 | 8 | NONE | | | 1,084 | 0.0 | 62 | 82 | 0 | 16 | 160 | -2 | Therms | |
| 26 | 0006 - J LANIGAN HALL | 104 | Lecture Hall | F | 16 | 2-Lamp F32T8, IS Ballast, NBF | 59 | 0.9 | NONE | | | NONE | | | 1,549 | TRUE | | 16 | 36W LED Wall Wash Cove Light | 36 | 0.6 | CEILING OCC | 0 | 16 | NONE | | | 1,084 | 0.4 | 570 | 268 | 0 | 92 | 930 | -10 | Therms | |
| 27 | 0006 - J LANIGAN HALL | 104 | Lecture Hall | G | 6 | 1-Lamp F32T8, IS Ballast, NBF | 31 | 0.2 | NONE | | | NONE | | | 1,549 | TRUE | | 6 | 22W 4ft LED Strip Light | 22 | 0.1 | CEILING OCC | 0 | 6 | NONE | | | 1,084 | 0.1 | 84 | 61 | 0 | 16 | 161 | -2 | Therms | |
| 28 | 0006 - J LANIGAN HALL | 104 | Lecture Hall | H | 2 | 1-Lamp F17T8, IS Ballast, NBF | 20 | 0.0 | NONE | | | NONE | | | 1,549 | TRUE | | 2 | 15W 2ft LED Strip Light | 15 | 0.0 | CEILING OCC | 0 | 2 | NONE | | | 1,084 | 0.0 | 15 | 14 | 0 | 3 | 33 | 0 | Therms | |
| 29 | 0006 - J LANIGAN HALL | 105 | Lecture Hall | A | 38 | 4-Lamp F32T8, IS Ballast, NBF | 112 | 4.3 | NONE | | | NONE | | | 1,549 | TRUE | | 38 | 59W LED Troffer | 59 | 2.2 | CEILING OCC | 3 | 38 | NONE | | | 1,084 | 2.0 | 3,120 | 1,042 | 0 | 458 | 4,619 | -50 | Therms | |
| 30 | 0006 - J LANIGAN HALL | 105 | Lecture Hall | E | 8 | 1-Lamp CFQ26W | 27 | 0.2 | NONE | | | NONE | | | 1,549 | TRUE | | 8 | 22W LED Recessed Downlight | 22 | 0.2 | CEILING OCC | 0 | 8 | NONE | | | 1,084 | 0.0 | 62 | 82 | 0 | 16 | 160 | -2 | Therms | |
| 31 | 0006 - J LANIGAN HALL | 105 | Lecture Hall | F | 16 | 2-Lamp F32T8, IS Ballast, NBF | 59 | 0.9 | NONE | | | NONE | | | 1,549 | TRUE | | 16 | 36W LED Wall Wash Cove Light | 36 | 0.6 | CEILING OCC | 0 | 16 | NONE | | | 1,084 | 0.4 | 570 | 268 | 0 | 92 | 930 | -10 | Therms | |
| 32 | 0006 - J LANIGAN HALL | 105 | Lecture Hall | G | 6 | 1-Lamp F32T8, IS Ballast, NBF | 31 | 0.2 | NONE | | | NONE | | | 1,549 | TRUE | | 6 | 22W 4ft LED Strip Light | 22 | 0.1 | CEILING OCC | 0 | 6 | NONE | | | 1,084 | 0.1 | 84 | 61 | 0 | 16 | 161 | -2 | Therms | |
| 33 | 0006 - J LANIGAN HALL | 105 | Lecture Hall | H | 2 | 1-Lamp F17T8, IS Ballast, NBF | 20 | 0.0 | NONE | | | NONE | | | 1,549 | TRUE | | 2 | 15W 2ft LED Strip Light | 15 | 0.0 | CEILING OCC | 0 | 2 | NONE | | | 1,084 | 0.0 | 15 | 14 | 0 | 3 | 33 | 0 | Therms | |
| 34 | 0006 - J LANIGAN HALL | 106 | Lecture Hall | A | 24 | 4-Lamp F32T8, IS Ballast, NBF | 112 | 2.7 | NONE | | | NONE | | | 1,549 | TRUE | | 24 | 59W LED Troffer | 59 | 1.4 | CEILING OCC | 2 | 24 | NONE | | | 1,084 | 1.3 | 1,970 | 658 | 0 | 289 | 2,917 | -32 | Therms | |
| 35 | 0006 - J LANIGAN HALL | 106 | Lecture Hall | E | 6 | 1-Lamp CFQ26W | 27 | 0.2 | NONE | | | NONE | | | 1,549 | TRUE | | 6 | 22W LED Recessed Downlight | 22 | 0.1 | CEILING OCC | 0 | 6 | NONE | | | 1,084 | 0.0 | 46 | 61 | 0 | 12 | 120 | -1 | Therms | |
| 36 | 0006 - J LANIGAN HALL | 106 | Lecture Hall | F | 21 | 2-Lamp F32T8, IS Ballast, NBF | 59 | 1.2 | NONE | | | NONE | | | 1,549 | TRUE | | 21 | 36W LED Wall Wash Cove Light | 36 | 0.8 | CEILING OCC | 0 | 21 | NONE | | | 1,084 | 0.5 | 748 | 351 | 0 | 121 | 1,220 | -13 | Therms | |
| 37 | 0006 - J LANIGAN HALL | 106 | Lecture Hall | G | 5 | 1-Lamp F32T8, IS Ballast, NBF | 31 | 0.2 | NONE | | | NONE | | | 1,549 | TRUE | | 5 | 22W 4ft LED Strip Light | 22 | 0.1 | CEILING OCC | 0 | 5 | NONE | | | 1,084 | 0.0 | 70 | 51 | 0 | 13 | 134 | -1 | Therms | |
| 38 | 0006 - J LANIGAN HALL | 107 | Lecture Hall | N | 31 | 2-Lamp F32T8, IS Ballast, NBF | 59 | 1.8 | NONE | | | NONE | | | 1,549 | TRUE | | 31 | 40W 4ft LED Pendant | 40 | 1.2 | CEILING OCC | 2 | 31 | NONE | | | 1,084 | 0.6 | 912 | 576 | 0 | 164 | 1,652 | -18 | Therms | |
| 39 | 0006 - J LANIGAN HALL | 107 | Lecture Hall | E | 6 | 1-Lamp CFQ26W | 27 | 0.2 | NONE | | | NONE | | | 1,549 | TRUE | | 6 | 22W LED Recessed Downlight | 22 | 0.1 | CEILING OCC | 0 | 6 | NONE | | | 1,084 | 0.0 | 46 | 61 | 0 | 12 | 120 | -1 | Therms | |
| 40 | 0006 - J LANIGAN HALL | 107 | Lecture Hall | G | 14 | 1-Lamp F32T8, IS Ballast, NBF | 31 | 0.4 | NONE | | | NONE | | | 1,549 | TRUE | | 14 | 22W 4ft LED Strip Light | 22 | 0.3 | CEILING OCC | 0 | 14 | NONE | | | 1,084 | 0.1 | 195 | 143 | 0 | 37 | 376 | -4 | Therms | |
| | | | | **Total:** | **740** | **-** | **-** | **73** | **-** | **0** | **0** | **-** | **0** | **0** | **2,643** | **-** | **-** | **740** | **-** | **-** | **39.5** | **-** | **41** | **740** | **-** | **6** | **64** | **1,601** | **33.1** | **90,059.5** | **34,893.6** | **3,749.5** | **14,157.3** | **142,859.8** | **-1,544.4** | | |

**Notes:**

1 Lighting control savings caclulated based on the methodology described in the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, V9 (Issued August 30, 2021).
2 Heating and cooling interactive effects caclulated based on the methodology described in the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, V9 (Issued August 30, 2021).
3 Coincident peak demand calculated based on methodology described in the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, V9 (Issued August 30, 2021).

## LIFE CYCLE COST ANALYSIS

| | |
|---|---|
| ECM No.: | EEM-1 |
| ECM Title: | Interior LED Lighting Retrofit |

| General Parameters | |
|---|---|
| Base Date: | 1/1/2023 |
| Service Date: | 1/1/2023 |
| Study Period (Years): | 15 |
| Discount Rate: | 3% |
| Cost Escalation: | 0% |
| FEMP UPV Discount Factor (Elect.): | 14.96 |
| FEMP UPV Discount Factor (NG): | 13.70 |

| Cost Data | Baseline | Proposed | Savings |
|---|---|---|---|
| Initial Capital Cost: | | $414,177 | ($414,177) |
| Annual Electricity Costs: | $11,325 | $3,732 | $7,593 |
| Annual Natural Gas Costs: | $0 | $0 | $0 |
| Annual CHP Natural Gas Costs: | $0 | $0 | $0 |
| Annual CHW Costs: | $0 | $0 | $0 |
| Annual HTHW Costs: | $0 | $0 | $0 |
| Annual Water Costs: | $0 | $0 | $0 |
| Annual OM&R Costs: | $8,444 | $8,444 | $0 |
| Other Recurring Annual Costs: | $0 | $0 | $0 |

| Life Cycle Cost Calculations | Baseline | Proposed | Savings |
|---|---|---|---|
| Present Value Investment Costs, I: | $0 | $414,177 | ($414,177) |
| Present-Value Capital Replacement Cost, Repl: | $0 | $0 | $0 |
| Present Value Residual Cost, Res: | $0 | $0 | $0 |
| Present Value Energy Costs, E: | $169,409 | $55,821 | $113,588 |
| Present Value Water Cost, W: | $0 | $0 | $0 |
| Present Value O&M and Other Recurring Costs, OM&R: | $100,799 | $100,799 | $0 |
| **LCC:** | **$270,208** | **$570,798** | **($300,590)** |

| Savings to Investment Ratio Calculations | |
|---|---|
| Present Value Energy Cost Savings, DE: | $113,588 |
| Present Value Water Cost Savings, DW: | $0 |
| Present Value OM&R Cost Savings, DOM&R: | $0 |
| **SIR:** | **0.27** |

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

# SUNY OSWEGO | EEM-2 PARKING LOT AND ROADWAY LED RETROFIT

*Energy Opportunity Area:* Lighting

*Buildings Affected:* Campus

**Table 1. EEM-2 Summary Data**

| Description | Values | Units |
|---|---|---|
| Annual Electrical Energy Savings | 151,247 | kWh/year |
| Electrical Peak Demand Savings | 0.0 | kW |
| Annual Electrical Energy Cost Savings | $8,924 | $/year |
| Annual Natural Gas Savings | 0 | Therms/year |
| Annual Fossil Fuel Cost Savings | $0 | $/year |
| **Total Annual Energy Cost Savings** | **$8,924** | **$/year** |
| **Estimated Implementation Cost** | **$1,998,482** | **$** |
| **Simple Payback Period** | **224.0** | **years** |
| **Savings to Investment Ratio** | **0.07** | **-** |

### Existing Conditions/Baseline

Campus parking lots and roadways are illuminated with pole mounted lighting fixtures. Most areas have 250W – 400W metal halide or 42W compact fluorescent fixtures. According to facility staff, approximately 30% to 50% of the fixtures have been retrofit with LED fixtures.

### Recommended Action

This measure considers the installation of LED lighting technologies in parking lots and roadways that have not been replaced. New LED fixtures can significantly reduce energy consumption, provide higher quality light, and increase service life compared to existing high intensity discharge (HID) technologies. Significant maintenance savings can be achieved as well because of the higher fixture life of LED technology compared to HID technologies. Many LED fixtures have an expected life of 50,000 hours, compared to 10,000 to 24,000 hours for HID lamps. Some LED fixtures claim to last for 100,000 hours. The LED fixtures can be specified with integrated photocell control.

When purchasing LED fixtures, SUNY Oswego should only consider those that are ENERGY STAR labeled or listed on the DesignLights Consortium (DLC) website. These ratings ensure the fixture meets minimum standards for light quality, reliable life, and energy efficiency, and are typically required by utility energy efficiency programs if incentives are pursued.

### Estimated Energy Savings

A 2010 electrical distribution infrastructure study conducted by C&S Engineers, Inc. was used to inventory parking lot and roadway lighting fixtures. The savings analysis assumes that 40% of the fixtures have already been replaced. Operating hours were estimated based on observations and discussions with facility personnel. Savings were calculated based on the difference between the existing fixture wattage and proposed LED replacement wattage and estimated annual operating hours.

Supporting documents include the lighting survey documenting the type and quantity of fixtures, along with estimated fixture input power and annual equivalent full load hours (EFLH). Proposed LED fixtures are presented as well with fixture input power and EFLH.

Table 2 presents estimated savings, implementation costs, and simple payback period that could result from the proposed project.

**Table 2. EEM-2 Savings**

| | Baseline | Proposed | Savings |
|---|---|---|---|
| Effective Full Load Hours | 4,365 | 4,365 | 0 |
| Connected Load (kW) | 74.2 | 39.6 | 34.7 |
| Exterior Lighting Energy (kWh) | 324,018 | 172,771 | 151,247 |

## Estimated Project Cost

Costs presented in Table 3 are from the 2010 C&S Engineers, Inc infrastructure study and escalated by 34% to 2022 dollars based on historical consumer price index (CPI) published by the United States Bureau of Labor Statistics[1]. This cost includes the replacement of the fixture and any light poles and mounting for fixtures that have not been replaced with LED fixtures. Replacement of light poles greatly increases the project cost but can be justified from an infrastructure renewal perspective since the equipment is near or past its end of life.

**Table 3. EEM-2 Estimated Project Costs**

| Item Description | Quantity | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| Light Fixtures | 1 | Lump Sum | - | $1,397,540 |
| Motion Sensor Controls | 1 | Lump Sum | - | $0 |
| Daylighting Controls | 1 | Lump Sum | - | $0 |
| | | | | |
| **Labor and Materials Subtotal** | | | | **$1,397,540** |
| General Conditions | 10% | | | $139,754 |
| **Labor and Materials Cost Total** | | | | **$1,537,294** |
| | | | | |
| Architectural & Engineering Fees | 10% | | | $153,729 |
| Construction Management Fees | 10% | | | $153,729 |
| Contingency | 10% | | | $153,729 |
| | | | | |
| **Project Cost Subtotal** | | | | **$1,998,482** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$1,998,482** |

[1] https://www.bls.gov/regions/mid-atlantic/data/consumerpriceindexhistorical_us_table.htm
2010 average CPI = 218.1
2022 average CPI = 292.7
34.2% inflation rate from 2010 to 2022

## EEM-2 – PARKING LOT AND ROADWAY LED RETROFIT

## SUPPORTING DOCUMENTS

**Fixture Table**

***SUNY Oswego***

| | Existing Fixtures | | | | | | Proposed Fixtures | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fixture ID | Description | Lamp Type | Nominal Lamp Watts | # Lamps | Input Watts | Lamp Life (Hrs) | Description | Lamp Type | Nominal Lamp Watts | # Lamps | Input Watts | Lamp/ Fixture Life (Hrs) | Cost Per Fixture |
| A | 4-Way Accent Lighting, Fluorescent, 8' height | CFL | 42 | 1 | 48 | 15,000 | 23W LED PL_L Lamp | 0 | 23 | 1 | 23 | 50,000 | $1,072 |
| B | Accent Lighting, 2'x2' Square, 2' height | CFL | 42 | 1 | 48 | 15,000 | 23W LED PL_L Lamp | 0 | 23 | 1 | 23 | 50,000 | $6,030 |
| C | Accent Lighting, Compact Fluorescent, 4' height | CFL | 42 | 1 | 48 | 15,000 | 23W LED PL_L Lamp | 0 | 23 | 1 | 23 | 50,000 | $1,072 |
| D | Dual-Box Head, Metal Halide, 25' height | MH | 250 | 2 | 590 | 10,000 | 2 x 150W LED Box Light | 0 | 150 | 2 | 300 | 50,000 | $7,102 |
| E | Dual-Oval Head, Metal Halide, 20' height | MH | 250 | 2 | 590 | 10,000 | 2 x 150W LED Cobrahead Light | 0 | 150 | 2 | 300 | 50,000 | $7,370 |
| F | Globe Accent Lighting, Fluorescent, 4' height | CFL | 42 | 1 | 48 | 15,000 | 23W LED PL_L Lamp | 0 | 23 | 1 | 23 | 50,000 | $1,340 |
| G | Globe, Fluorescent, 8' height | CFL | 42 | 1 | 48 | 15,000 | 23W LED PL_L Lamp | 0 | 23 | 1 | 23 | 50,000 | $3,350 |
| H | Lamp Post, Compact Fluorescent, 6' height | CFL | 42 | 1 | 48 | 15,000 | 23W LED PL_L Lamp | 0 | 23 | 1 | 23 | 50,000 | $1,005 |
| I | Lamp Post, Fluorescent, 8' height | CFL | 42 | 1 | 48 | 15,000 | 23W LED PL_L Lamp | 0 | 23 | 1 | 23 | 50,000 | $1,340 |
| J | Round, Ground Light, Compact Fluorescent, 8"-10" height | CFL | 42 | 1 | 48 | 15,000 | 23W LED PL_L Lamp | 0 | 23 | 1 | 23 | 50,000 | $174 |
| K | Single-Box Head, Metal Halide, 20'-25' height | MH | 250 | 1 | 295 | 10,000 | 150W LED Box Light | 0 | 150 | 1 | 150 | 50,000 | $6,030 |
| L | Single-Globe, Reflective, 15' height | MH | 100 | 1 | 128 | 10,000 | 80W LED Retrofit Lamp | 0 | 80 | 1 | 80 | 50,000 | $3,350 |
| M | Single-Oval Head, Metal Halide, 20'-25' height | MH | 250 | 1 | 295 | 10,000 | 150W LED Cobrahead Light | 0 | 150 | 1 | 150 | 50,000 | $5,963 |
| N | Triple-Box Head, Metal Halide, 25' height | MH | 250 | 3 | 885 | 10,000 | 3 x 150W LED Box Light | 0 | 150 | 3 | 450 | 50,000 | $8,308 |
| O | Dual-Box Head, Metal Halide, 40'-50' height | MH | 400 | 2 | 916 | 10,000 | 2 x 300W LED Shoebox Light | 0 | 300 | 2 | 600 | 50,000 | $8,040 |
| P | Single-Box Head, Metal Halide, 50' height | MH | 400 | 1 | 458 | 10,000 | 300W LED Shoebox Light | 0 | 300 | 1 | 300 | 50,000 | $6,968 |

## Space Types and Annual Hours

### *SUNY Oswego*

| Space Type | Description | Annual Hours |
|---|---|---|
| EXT_TC | Exterior (Seasonal Timeclock) | 4,563 |
| EXT_PC | Exterior (Photocell Control) | 4,365 |

**Lighting Survey and Proposed Upgrades**

***SUNY Oswego***

| Baseline Summary | |
|---|---|
| Total Connected Load (kW) | 74.2 |
| Annual Equivalent Full Load Hours (EFLH) | 4,365 |
| Total Annual Energy Use (kWh) | 324,018 |

| Proposed Summary | |
|---|---|
| Total Connected Load (kW) | 39.6 |
| Annual Equivalent Full Load Hours (EFLH) | 4,365 |
| Total Annual Energy Use (kWh) | 172,771 |

| Savings Summary | |
|---|---|
| Total Connected Load Reduction (kW) | 34.7 |
| Total Electric Energy Savings (kWh) | 151,247 |

| Ballast Key | |
|---|---|
| ES Mag | Energy Saving Magnetic Ballast |
| IS | Instant Start Electronic Ballast |
| RS | Rapid Start Electronic Ballast |
| PS | Program Start Electronic Ballast |
| LBF | Low Ballast Factor (<0.85) |
| HBF | High Ballast Factor (0.96-1.1) |
| VHBF | Very High Ballast Factor (>1.1) |

| | Basic Project Information | Existing Conditions | | | | | Lighting Control | | | | | | | Foot-Candle | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Line Item | Description | Fixture ID | Fixture Qty | Fixture Description | Watts/ Fixture | Installed kW | Motion Control | Sensor Quantity | # Fixtures Controlled | Daylighting Control | Sensor Quantity | # Fixtures Controlled | EFLH | High | Low |
| 1 | 4-Way Accent Lighting, Fluorescent, 8' height | A | 3 | 4-Way Accent Lighting, Fluorescent, 8' height | 48 | 0.1 | NONE | | | NONE | | | 4,365 | | |
| 2 | Accent Lighting, 2'x2' Square, 2' height | B | 5 | Accent Lighting, 2'x2' Square, 2' height | 48 | 0.2 | NONE | | | NONE | | | 4,365 | | |
| 3 | Accent Lighting, Compact Fluorescent, 4' height | C | 3 | Accent Lighting, Compact Fluorescent, 4' height | 48 | 0.1 | NONE | | | NONE | | | 4,365 | | |
| 4 | Dual-Box Head, Metal Halide, 25' height | D | 27 | Dual-Box Head, Metal Halide, 25' height | 590 | 15.9 | NONE | | | NONE | | | 4,365 | | |
| 5 | Dual-Oval Head, Metal Halide, 20' height | E | 3 | Dual-Oval Head, Metal Halide, 20' height | 590 | 1.8 | NONE | | | NONE | | | 4,365 | | |
| 6 | Globe Accent Lighting, Fluorescent, 4' height | F | 4 | Globe Accent Lighting, Fluorescent, 4' height | 48 | 0.2 | NONE | | | NONE | | | 4,365 | | |
| 7 | Globe, Fluorescent, 8' height | G | 30 | Globe, Fluorescent, 8' height | 48 | 1.4 | NONE | | | NONE | | | 4,365 | | |
| 8 | Lamp Post, Compact Fluorescent, 6' height | H | 6 | Lamp Post, Compact Fluorescent, 6' height | 48 | 0.3 | NONE | | | NONE | | | 4,365 | | |
| 9 | Lamp Post, Fluorescent, 8' height | I | 3 | Lamp Post, Fluorescent, 8' height | 48 | 0.1 | NONE | | | NONE | | | 4,365 | | |
| 10 | Round, Ground Light, Compact Fluorescent, 8"-10" height | J | 3 | Round, Ground Light, Compact Fluorescent, 8"-10" height | 48 | 0.1 | NONE | | | NONE | | | 4,365 | | |
| 11 | Single-Box Head, Metal Halide, 20'-25' height | K | 67 | Single-Box Head, Metal Halide, 20'-25' height | 295 | 19.8 | NONE | | | NONE | | | 4,365 | | |
| 12 | Single-Globe, Reflective, 15' height | L | 34 | Single-Globe, Reflective, 15' height | 128 | 4.4 | NONE | | | NONE | | | 4,365 | | |
| 13 | Single-Oval Head, Metal Halide, 20'-25' height | M | 65 | Single-Oval Head, Metal Halide, 20'-25' height | 295 | 19.2 | NONE | | | NONE | | | 4,365 | | |
| 14 | Triple-Box Head, Metal Halide, 25' height | N | 1 | Triple-Box Head, Metal Halide, 25' height | 885 | 0.9 | NONE | | | NONE | | | 4,365 | | |
| 15 | Dual-Box Head, Metal Halide, 40'-50' height | O | 5 | Dual-Box Head, Metal Halide, 40'-50' height | 916 | 4.6 | NONE | | | NONE | | | 4,365 | | |
| 16 | Single-Box Head, Metal Halide, 50' height | P | 11 | Single-Box Head, Metal Halide, 50' height | 458 | 5.0 | NONE | | | NONE | | | 4,365 | | |
| | **Total:** | | **270** | **-** | **-** | **74.2** | **-** | **0** | **0** | **-** | **0** | **0** | **4,365** | **-** | **-** |

| | Proposed Conditions | | | | Added Lighting Controls | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Line Item | Fixture Qty | Fixture Description | Watts/ Fixture | Installed kW | Motion Control | Sensor Quantity | # Fixtures Controlled | Daylighting Control | Sensor Quantity | # Fixtures Controlled | EFLH | Connected Load Reduction (kW) | Fixture Upgrade Energy Savings (kWh) | Motion Control Energy Savings (kWh) | Daylighting Control Energy Savings (kWh) | Interactive Electric Energy Savings (kWh) | Total Electric Energy Savings (kWh) | Interactive Fossil Energy Savings | Units | Notes |
| 1 | 3 | 23W LED PL_L Lamp | 23 | 0.1 | NONE | | | NONE | | | 4,365 | 0.1 | 327 | 0 | 0 | 0 | 327 | 0 | Therms | |
| 2 | 5 | 23W LED PL_L Lamp | 23 | 0.1 | NONE | | | NONE | | | 4,365 | 0.1 | 546 | 0 | 0 | 0 | 546 | 0 | Therms | |
| 3 | 3 | 23W LED PL_L Lamp | 23 | 0.1 | NONE | | | NONE | | | 4,365 | 0.1 | 327 | 0 | 0 | 0 | 327 | 0 | Therms | |
| 4 | 27 | 2 x 150W LED Box Light | 300 | 8.1 | NONE | | | NONE | | | 4,365 | 7.8 | 34,178 | 0 | 0 | 0 | 34,178 | 0 | Therms | |
| 5 | 3 | 2 x 150W LED Cobrahead Light | 300 | 0.9 | NONE | | | NONE | | | 4,365 | 0.9 | 3,798 | 0 | 0 | 0 | 3,798 | 0 | Therms | |
| 6 | 4 | 23W LED PL_L Lamp | 23 | 0.1 | NONE | | | NONE | | | 4,365 | 0.1 | 437 | 0 | 0 | 0 | 437 | 0 | Therms | |
| 7 | 30 | 23W LED PL_L Lamp | 23 | 0.7 | NONE | | | NONE | | | 4,365 | 0.8 | 3,274 | 0 | 0 | 0 | 3,274 | 0 | Therms | |
| 8 | 6 | 23W LED PL_L Lamp | 23 | 0.1 | NONE | | | NONE | | | 4,365 | 0.2 | 655 | 0 | 0 | 0 | 655 | 0 | Therms | |
| 9 | 3 | 23W LED PL_L Lamp | 23 | 0.1 | NONE | | | NONE | | | 4,365 | 0.1 | 327 | 0 | 0 | 0 | 327 | 0 | Therms | |
| 10 | 3 | 23W LED PL_L Lamp | 23 | 0.1 | NONE | | | NONE | | | 4,365 | 0.1 | 327 | 0 | 0 | 0 | 327 | 0 | Therms | |
| 11 | 67 | 150W LED Box Light | 150 | 10.1 | NONE | | | NONE | | | 4,365 | 9.7 | 42,406 | 0 | 0 | 0 | 42,406 | 0 | Therms | |
| 12 | 34 | 80W LED Retrofit Lamp | 80 | 2.7 | NONE | | | NONE | | | 4,365 | 1.6 | 7,124 | 0 | 0 | 0 | 7,124 | 0 | Therms | |
| 13 | 65 | 150W LED Cobrahead Light | 150 | 9.8 | NONE | | | NONE | | | 4,365 | 9.4 | 41,140 | 0 | 0 | 0 | 41,140 | 0 | Therms | |
| 14 | 1 | 3 x 150W LED Box Light | 450 | 0.5 | NONE | | | NONE | | | 4,365 | 0.4 | 1,899 | 0 | 0 | 0 | 1,899 | 0 | Therms | |
| 15 | 5 | 2 x 300W LED Shoebox Light | 600 | 3.0 | NONE | | | NONE | | | 4,365 | 1.6 | 6,897 | 0 | 0 | 0 | 6,897 | 0 | Therms | |
| 16 | 11 | 300W LED Shoebox Light | 300 | 3.3 | NONE | | | NONE | | | 4,365 | 1.7 | 7,586 | 0 | 0 | 0 | 7,586 | 0 | Therms | |
| **Total:** | **270** | **-** | **-** | **39.6** | **-** | **0** | **0** | **-** | **0** | **0** | **4,365** | **34.7** | **151,247** | **0** | **0** | **0** | **151,247** | **0** | | |

## LIFE CYCLE COST ANALYSIS

| | |
|---|---|
| ECM No.: | EEM-2 |
| ECM Title: | Parking Lot and Roadway LED Retrofit |

| General Parameters | |
|---|---|
| Base Date: | 1/1/2023 |
| Service Date: | 1/1/2023 |
| Study Period (Years): | 15 |
| Discount Rate: | 3% |
| Cost Escalation: | 0% |
| FEMP UPV Discount Factor (Elect.): | 14.96 |
| FEMP UPV Discount Factor (NG): | 13.70 |

| Cost Data | Baseline | Proposed | Savings |
|---|---|---|---|
| Initial Capital Cost: | | $1,998,482 | ($1,998,482) |
| Annual Electricity Costs: | $19,117 | $10,193 | $8,924 |
| Annual Natural Gas Costs: | $0 | $0 | $0 |
| Annual Water Costs: | $0 | $0 | $0 |
| Annual OM&R Costs: | $41,926 | $41,926 | $0 |
| Other Recurring Annual Costs: | $0 | $0 | $0 |

| Life Cycle Cost Calculations | Baseline | Proposed | Savings |
|---|---|---|---|
| Present Value Investment Costs, I: | $0 | $1,998,482 | ($1,998,482) |
| Present-Value Capital Replacement Cost, Repl: | $0 | $0 | $0 |
| Present Value Residual Cost, Res: | $0 | $0 | $0 |
| Present Value Energy Costs, E: | $285,966 | $152,481 | $133,485 |
| Present Value Water Cost, W: | $0 | $0 | $0 |
| Present Value O&M and Other Recurring Costs, OM&R: | $500,512 | $500,512 | $0 |
| **LCC:** | **$786,478** | **$2,651,475** | **($1,864,997)** |

| Savings to Investment Ratio Calculations | |
|---|---|
| Present Value Energy Cost Savings, DE: | $133,485 |
| Present Value Water Cost Savings, DW: | $0 |
| Present Value OM&R Cost Savings, DOM&R: | $0 |
| **SIR:** | **0.07** |

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

## SUNY OSWEGO | EEM-3 RETRO-COMMISSIONING

*Energy Opportunity Area:* HVAC, Building Automation System (BAS), Lighting

*Buildings Affected: Marano Campus Center, Tyler Hall, Rich Hall, The Village Townhouses, Johnson Hall, Riggs Hall, Waterbury Hall, Scales Hall*

**Table 1. EEM-3 Summary Data**

| Description | Values | Units |
|---|---|---|
| Annual Electrical Energy Savings | 815,562 | kWh/year |
| Electrical Peak Demand Savings | 0.0 | kW |
| Annual Electrical Energy Cost Savings | $48,118 | $/year |
| Annual Natural Gas Savings | 82,558 | Therms/year |
| Annual Natural Gas Cost Savings | $33,354 | $/year |
| **Total Annual Energy Cost Savings** | **$81,472** | **$/year** |
| **Estimated Implementation Cost** | **$246,586** | **$** |
| **Simple Payback Period** | **3.0** | **Years** |
| **Savings to Investment Ratio** | **1.6** | **-** |

### Recommended Action

This measure considers retro-commissioning (RCx) the campus buildings. RCx is the application of the commissioning process to existing buildings to meet the Current Facility Requirements (CFR) and optimize the building's energy performance and occupant comfort characteristics. Newly constructed buildings are sometimes commissioned to a set of operating parameters that are not necessarily the most energy efficient. Energy efficiency and occupant comfort deteriorate as control schemes are modified, occupancy loads shift, existing equipment ages, key operating parameters drift away from their ideal operating states or setpoints. Frequently, routine maintenance issues are "solved" by compensating for them in ways that are not energy efficient. An example would be to operate a chiller to cool the building when an AHU's economizer feature is not operating properly. Additionally, if a building was not commissioned when constructed, it may be that it was never operating optimally.

It is not uncommon to find that the operating parameters of a building's sub-systems (*i.e.,* for an HVAC system, the temperature setpoints, air and water flows, valve and damper positions) are not well documented. When design operating conditions are misunderstood or unknown, facility staff may operate the equipment based on assumptions that are incorrect. RCx can include the development or revision of documentation, such as system manuals, that describe the building operating sequences and can serve as a basis for training the technicians who operate and service the building.

When performed correctly, RCx can provide significant benefits for the owner such as:

- Improved energy performance (6% median savings achieved per LBNL Study cited below)
- Improved equipment performance
- Increased asset value
- Improved thermal comfort and indoor air quality
- Training opportunities for building maintenance staff
- Improved building documentation (System Manuals)

The RCx (also referred to as existing building commissioning or EBCx) process involves functionally testing and adjusting building sub-systems and ultimately demonstrating that they are being operated and maintained according to the CFR. According to the newest (2018) research from Lawrence Berkeley National Laboratory (LBNL) and the Building Commissioning Association (BCxA), building commissioning remains a cost-effective way to improve building operations and reduce energy use. The 2018 study (https://www.energy.gov/eere/buildings/articles/new-doe-research-strengthens-business-case-building-commissioning) is an update to the 2009 study entitled "Building Commissioning – A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions" and now includes nearly 1,500 new and existing building Cx projects. Of the 684 existing building Cx projects, 112 are higher education buildings.

The results revealed that the most common problems were associated with the HVAC systems and controls. RCx energy savings typically ranged from 3-10% with a median of 6%. Simple payback typically ranged from 1-4 years with a median of 2.2 years. Higher education projects showed similar savings as the whole population and simple paybacks typically within 2-5 years and a median of 3 years.

Larger buildings with HVAC systems that are less than 20 years old, and those that have DDC control systems, are generally good candidates for retro-commissioning. Small buildings and those with pneumatic controls often lack the type of sensors and controls necessary to implement the type of diagnostics and functional testing that can lead to significant performance improvements. Buildings with HVAC systems older than 20 years are approaching the end of their useful design life and would most likely benefit from a more extensive HVAC renovation or system replacement. Buildings with very simple HVAC infrastructure and control strategies also do not benefit as much. It would be more beneficial to upgrade the HVAC systems of such buildings to include energy saving features such as economizers and VFDs, and commission the systems as part of the upgrade project.

Retro-commissioning can provide many non-energy benefits. These may include improved thermal comfort, indoor environmental quality, and productivity; reduced occupant complaints, absenteeism, emergency repair calls, and liability; extended equipment life; and additional maintenance staff training. It is also an important component of LEED for Existing Buildings: Operations & Maintenance for buildings seeking certification.

To fully realize the benefits that RCx can provide, it is a good idea to address major outstanding repair and maintenance issues prior to implementing the project. Retro-commissioning should be performed every three to five years to maintain top levels of building performance and persistence of energy savings.

**Estimated Energy Savings**

Table 2 presents estimated energy savings that could be potentially achieved from retro-commissioning of campus buildings, along with RCx costs and simple payback periods. The LBNL study referenced above was used as the basis for estimating potential energy savings and costs to perform the commissioning process.

As noted previously, the 2018 LBNL study shows that RCx savings typically range from 3-10% of total building energy use. The percent energy savings were scaled for each building based on the comparison of the actual energy use intensity (EUI) to the CBECS benchmark from the Preliminary Energy Use Analysis (PEA). Buildings that were at or below the CBECS benchmark were assumed to have 3% savings from RCx and buildings that are above the CBECS benchmark are scaled up towards the 10% savings referenced in the LBNL study.

Supporting documents include a detailed analysis spreadsheet showing assumed savings potential (percent savings) and estimated RCx cost for each building and the entire campus, along with simple payback period. Many campus buildings may not be good candidates for RCx, particularly those that are less energy intensive such as residence halls (although kitchen and dining hall HVAC systems and controls could benefit).

**Table 2. EEM-3 Savings**

| Building | Annual Electrical Energy Savings (kWh/year) | Annual Natural Gas Savings (Therms/year) | Total Annual Energy Cost Savings ($/year) | Estimated Implementation Cost | Simple Payback Period |
|---|---|---|---|---|---|
| 0003 - CAMPUS CENTER | 279,628 | 24,769 | 26,505 | $63,820 | 2.4 |
| 003B - REC & CONVOCATION CTR | 108,319 | 16,409 | 13,020 | $33,472 | 2.6 |
| 0007 - J TYLER HALL | 92,893 | 10,912 | 9,889 | $33,475 | 3.4 |
| 0041 - JOHNSON HALL | 60,646 | 5,652 | 5,861 | $17,401 | 3.0 |
| 0014 - RICH HALL | 60,373 | 5,342 | 5,720 | $15,585 | 2.7 |
| 0043 - RIGGS HALL | 45,548 | 4,556 | 4,528 | $12,804 | 2.8 |
| 0044 - WATERBURY HALL | 44,356 | 4,291 | 4,351 | $12,642 | 2.9 |
| 0045 - SCALES HALL | 44,356 | 4,291 | 4,351 | $12,642 | 2.9 |
| 003A - I POUCHER HALL | 42,624 | 4,513 | 4,338 | $11,623 | 2.7 |
| 0037 - THE VILLAGE TOWNHOUSES | 36,818 | 1,822 | 2,908 | $33,121 | 11.4 |
| **Total** | **815,562** | **82,558** | **81,472** | **$246,586** | **3.0** |

Although the actual performance of retro-commissioning was not including in the scope of services for this project, any deficiencies observed during the Level 1 and Level 2 energy audits were recorded and noted in the individual Building Assessment reports. Based on observations made during the energy audits and a review of the BAS, the following deficiencies listed below are examples that would be addressed through retro-commissioning.

- AHUs running at 100% speed on VFDs in Marano Campus Center
- Manual override of setpoints in Tyler Hall, Rich Hall, and Waterbury Hall
- Economizer being disabled in Waterbury Hall
- Waterbury Hall HV-1 supply fan VFD cover missing

Additionally, retro-commissioning may uncover deficiencies not easily observed during a walkthrough survey, such as

- Dampers and valves that are stuck or do not fully open or close
- Faulty sensors or sensor readings
- Issues in BAS programming and controls
- Optimizing sequence of operation and reset schedules

## Estimated Project Cost

Costs presented in Table 3 represent the scope of work described below. According to the 2018 LBNL study previously referenced, the typical cost of commissioning existing buildings ranged from $0.13/GSF to $0.48/GSF with a median cost of $0.25/GSF. The 2018 costs per gross square feet were escalated by 17% to 2022 dollars based on historical consumer price index (CPI) published by the United States

Bureau of Labor Statistics[1]. For this project, RCx costs were scaled based on the building type. Simple buildings, such as dormitories, were assumed to be on the lower end of the cost range, while more complex buildings, such as Marano Campus Center, were assumed to be on the higher end.

The RCx implementation costs include development of a CFR and RCx Plan, functional testing, trend data analysis, estimating energy savings associated with correcting deficiencies, and developing a final report to document findings and present recommendations. The cost to correct deficiencies identified during the RCx process is not included in the estimate (*e.g.,* repairs that require capital expenses), although no cost/low cost measures that can often be done by in-house staff are commonly identified. These may include HVAC system and equipment schedule and setpoint adjustments through the BAS, repairing disconnected damper linkages or bound dampers, releasing manual overrides, revising sequence of operations to improve energy efficiency, etc.

**Table 3. EEM-3 Estimated Project Costs**

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| Retro-Commissioning | 1 | Lump Sum | $246,586 | $246,586 |
| | | | | |
| **Labor and Materials Subtotal** | | | | **$246,586** |
| General Conditions | 0% | | | $0 |
| **Labor and Materials Cost Total** | | | | **$246,586** |
| | | | | |
| Architectural & Engineering Fees | 0% | | | $0 |
| Construction Management Fees | 0% | | | $0 |
| Contingency | 0% | | | $0 |
| | | | | |
| **Project Cost Subtotal** | | | | **$246,586** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$246,586** |

[1] https://www.bls.gov/regions/mid-atlantic/data/consumerpriceindexhistorical_us_table.htm
2018 average CPI = 251.1
2022 average CPI = 292.7
17% inflation rate from 2018 to 2022

## EEM-3 – RETRO-COMMISSIONING

## SUPPORTING DOCUMENTS

## RESULTS: EEM-3 RETRO-COMMISSIONING

| Building | Gross Floor Area (SF) | Annual Energy Use (from PEA) | | | | Retro-Commissioning | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Electric | Natural Gas | Total | EUI | Savings Potential | Electric Savings | Natural Gas Savings | Total Savings | Implementation Cost | | Cost Savings | SPB |
| | | (kWh) | (Therms) | (MMBtu) | (kBtu/SF) | (%) | (kWh) | (Therms) | (MMBtu) | $/SF | $ | $ | Years |
| 0003 - CAMPUS CENTER | 185,524 | 2,796,279 | 247,693 | 34,310 | 184.9 | 10% | 279,628 | 24,769 | 3,431 | $0.34 | $63,820 | $26,505 | 2.4 |
| 003B - REC & CONVOCATION CTR | 115,421 | 1,083,194 | 164,093 | 20,105 | 174.2 | 10% | 108,319 | 16,409 | 2,011 | $0.29 | $33,472 | $13,020 | 2.6 |
| 0007 - J TYLER HALL | 115,430 | 928,926 | 109,123 | 14,082 | 122.0 | 10% | 92,893 | 10,912 | 1,408 | $0.29 | $33,475 | $9,889 | 3.4 |
| 0041 - JOHNSON HALL | 79,097 | 637,247 | 59,385 | 8,113 | 102.6 | 10% | 60,646 | 5,652 | 772 | $0.22 | $17,401 | $5,861 | 3.0 |
| 0014 - RICH HALL | 53,742 | 625,929 | 55,387 | 7,674 | 142.8 | 10% | 60,373 | 5,342 | 740 | $0.29 | $15,585 | $5,720 | 2.7 |
| 0043 - RIGGS HALL | 58,201 | 472,468 | 47,260 | 6,338 | 108.9 | 10% | 45,548 | 4,556 | 611 | $0.22 | $12,804 | $4,528 | 2.8 |
| 0044 - WATERBURY HALL | 57,464 | 465,059 | 44,990 | 6,086 | 105.9 | 10% | 44,356 | 4,291 | 580 | $0.22 | $12,642 | $4,351 | 2.9 |
| 0045 - SCALES HALL | 57,464 | 465,059 | 44,990 | 6,086 | 105.9 | 10% | 44,356 | 4,291 | 580 | $0.22 | $12,642 | $4,351 | 2.9 |
| 003A - I POUCHER HALL | 40,080 | 426,243 | 45,133 | 5,968 | 148.9 | 10% | 42,624 | 4,513 | 597 | $0.29 | $11,623 | $4,338 | 2.7 |
| 0037 - THE VILLAGE TOWNHOUSES | 150,551 | 1,227,258 | 60,731 | 10,261 | 68.2 | 3% | 36,818 | 1,822 | 308 | $0.22 | $33,121 | $2,908 | 11.4 |
| **Campus Total** | **912,974** | **9,127,663** | **878,785** | **119,022** | **130.4** | **9%** | **815,562** | **82,558** | **11,039** | **$0.27** | **$246,586** | **$81,472** | **3.0** |

## LIFE CYCLE COST ANALYSIS

ECM No.: EEM-3

ECM Title: Retro-Commissioning

**General Parameters**

| | |
|---|---|
| Base Date: | 1/1/2023 |
| Service Date: | 1/1/2023 |
| Study Period (Years): | 5 |
| Discount Rate: | 3% |
| Cost Escalation: | 0% |
| FEMP UPV Discount Factor (Elect.): | 4.93 |
| FEMP UPV Discount Factor (NG): | 4.64 |

| Cost Data | Baseline | Proposed | Savings |
|---|---|---|---|
| Initial Capital Cost: | | $246,586 | ($246,586) |
| Annual Electricity Costs: | $538,532 | $490,414 | $48,118 |
| Annual Natural Gas Costs: | $355,029 | $321,676 | $33,354 |
| Annual Water Costs: | $0 | $0 | $0 |
| Annual OM&R Costs: | $7,398 | $7,398 | $0 |
| Other Recurring Annual Costs: | $0 | $0 | $0 |

| Life Cycle Cost Calculations | Baseline | Proposed | Savings |
|---|---|---|---|
| Present Value Investment Costs, I: | $0 | $246,586 | ($246,586) |
| Present-Value Capital Replacement Cost, Repl: | $0 | $0 | $0 |
| Present Value Residual Cost, Res: | $0 | $0 | $0 |
| Present Value Energy Costs, E: | $4,302,557 | $3,910,552 | $392,005 |
| Present Value Water Cost, W: | $0 | $0 | $0 |
| Present Value O&M and Other Recurring Costs, OM&R: | $33,879 | $33,879 | $0 |
| **LCC:** | **$4,336,436** | **$4,191,017** | **$145,419** |

**Savings to Investment Ratio Calculations**

| | |
|---|---|
| Present Value Energy Cost Savings, DE: | $392,005 |
| Present Value Water Cost Savings, DW: | $0 |
| Present Value OM&R Cost Savings, DOM&R: | $0 |
| **SIR:** | **1.59** |

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

# SUNY OSWEGO | EEM-4 HVAC SCHEDULING

*Energy Opportunity Area:* HVAC, Building Automation System (BAS)

*Buildings Affected:* Campus Wide

**Table 1. EEM-4 Summary Data**

| Description | Values | Units |
|---|---|---|
| Annual Electrical Energy Savings | 640,306 | kWh/year |
| Electrical Peak Demand Savings | 0.0 | kW |
| Annual Electrical Energy Cost Savings | $37,778 | $/year |
| Annual Natural Gas Savings | 201,482 | Therms/year |
| Annual Natural Gas Cost Savings | $81,399 | $/year |
| **Total Annual Energy Cost Savings** | **$119,177** | **$/year** |
| **Estimated Implementation Cost** | **$4,136** | **$** |
| **Simple Payback Period** | **0.0** | **years** |
| **Savings to Investment Ratio** | **82.9** | |

## Existing Conditions/Baseline

The campus operates HVAC equipment on various building-specific schedules with setbacks implemented in some buildings where applicable. However, many buildings currently operate the HVAC equipment 24/7 with no setbacks during unoccupied hours. A summary of current operating hours and typical occupancy hours for each building is included in the supporting documents.

Most buildings and HVAC equipment on campus are connected to at least one of two building automation systems (BAS), which provide monitoring, direct digital control (DDC), and energy management of building HVAC systems:

- Trane Tracer® Ensemble™
- Carrier i-Vu® 8.0

## Recommended Action

There is an opportunity to reduce operating hours by adjusting existing HVAC operating schedules to better reflect actual occupancy hours of the buildings, scheduling temperature setbacks during unoccupied periods (*i.e.,* nights, weekends, and holidays), and scheduling equipment to cycle off at night. HVAC scheduling may be done through the existing building automation systems. Even slight temperature and cycling setbacks could considerably reduce operating costs. The setbacks do not have to be extreme. This will allow space temperatures to float between heating and cooling setpoints so building systems do not have to run. A global reset of space heating and cooling temperature setpoints to the default setpoints for any zones that have local overrides can also have a significant impact on operating costs.

Additionally, this measure considers:

- Scheduling equipment off during unoccupied periods and allowing systems to cycle on to meet unoccupied setpoints.
- Closing outdoor air dampers during unoccupied periods.

### Estimated Energy Savings

An hourly analysis was performed using Syracuse-Hancock International Airport TMY3 (Typical Meteorological Year) hourly weather data. Heating and cooling loads were estimated based on assumed load profiles and the application of psychrometric routines. Performance curves were applied to adjust equipment input power for off-design conditions. This measure results in AHU fan, heating, and cooling energy savings and terminal reheat savings.

Supporting documents include a summary of assumptions for this measure and savings for individual buildings. Individual building savings were determine based on percent reduction in building operating hours available. New building operating hours were determined by assuming an operating schedule which better reflects typical building occupancy. Some campus buildings did not have an opportunity to reduce operating hours due to existing HVAC scheduling, required 24/7 building operation, or because they are not currently integrated into the BAS. These buildings were not included in the savings summary.

Table 2 summarizes the baseline and post-retrofit energy consumption and estimated energy savings that result from the measure.

**Table 2. EEM-4 Savings**

| | Baseline | Proposed | Savings |
|---|---|---|---|
| Operating Hours | 7,632 | 5,466 | 2,166 |
| Fan Energy (kWh) | 1,542,480 | 1,108,605 | 433,875 |
| Cooling Energy (kWh) | 993,209 | 845,207 | 148,002 |
| Electric Heating Energy (kWh) | 1,215,646 | 1,157,217 | 58,429 |
| **Total Electrical Energy (kWh)** | **10,798,824** | **10,158,518** | **640,306** |
| **Natural Gas Heating Consumption (therms)** | **528,335** | **326,853** | **201,482** |

### Estimated Project Cost

Costs presented in Table 3 represent the scope of work described previously and are based on BAS Engineering Labor costs published in RS Means 2023.

**Table 3. EEM-4 Estimated Project Costs**

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| HVAC Scheduling | 40 | Hrs. | $94 | $3,760 |
| **Labor and Materials Subtotal** | | | | **$3,760** |
| General Conditions | 0% | | | $0 |
| **Labor and Materials Cost Total** | | | | **$3,760** |

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| Architectural & Engineering Fees | 0% | | | $0 |
| Construction Management Fees | 0% | | | $0 |
| Contingency | 10% | | | $376 |
| **Project Cost Subtotal** | | | | **$4,136** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$4,136** |

## EEM-4 – HVAC SCHEDULING

## SUPPORTING DOCUMENTS

## SUMMARY INPUTS: ECM-4 HVAC SCHEDULING - CAMPUS

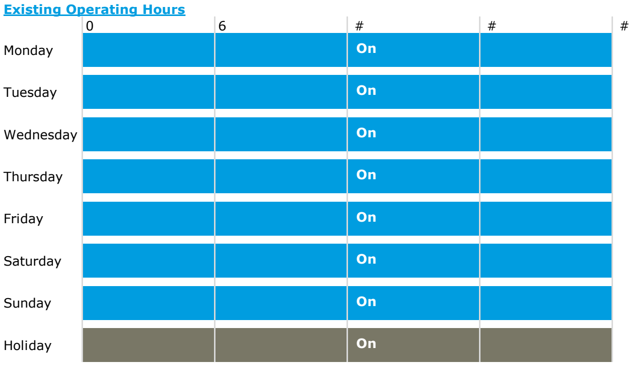
**Baseline Space Temperature Setpoints**

| | Heating | Cooling |
|---|---|---|
| Occupied | 68-72 | 73-77 |
| Unoccupied | 65 | 80 |

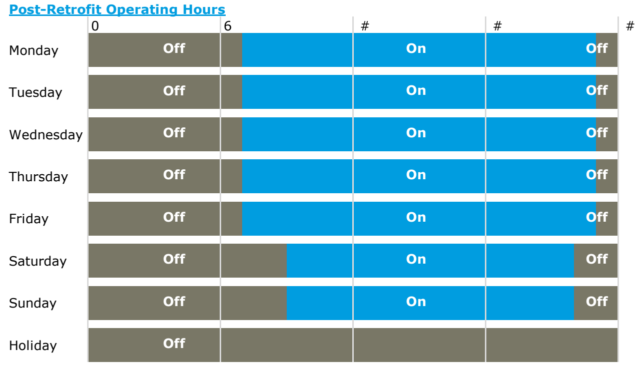
**Post-Retrofit Space Temperature Setpoints**

| | Heating | Cooling |
|---|---|---|
| Occupied | 68-72 | 73-77 |
| Unoccupied | 65 | 80 |

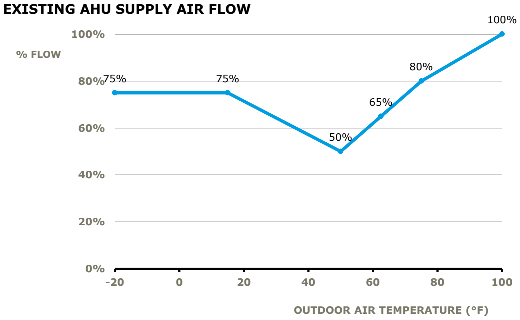
**Existing Operating Hours**



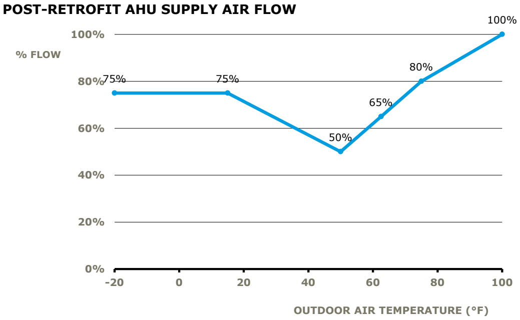

**Post-Retrofit Operating Hours**



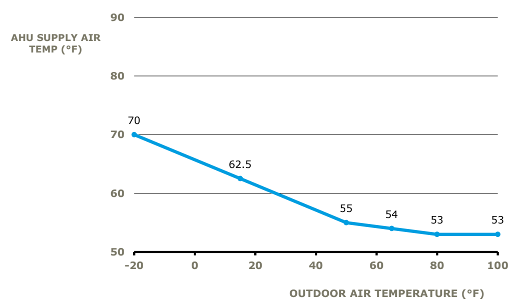

**EXISTING AHU SUPPLY AIR FLOW**



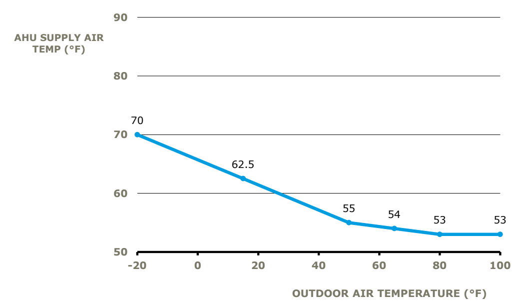

**POST-RETROFIT AHU SUPPLY AIR FLOW**



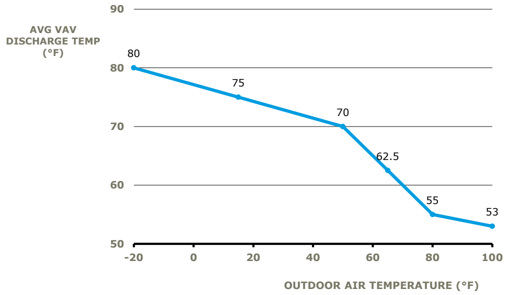

**EXISTING AHU SUPPLY TEMPERATURE**



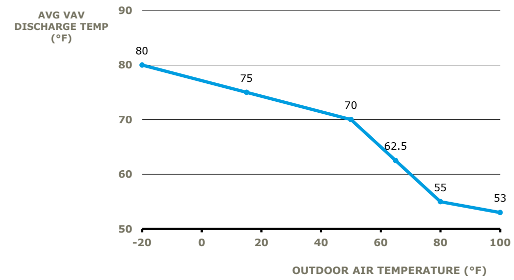

**POST-RETROFIT AHU SUPPLY TEMPERATURE**



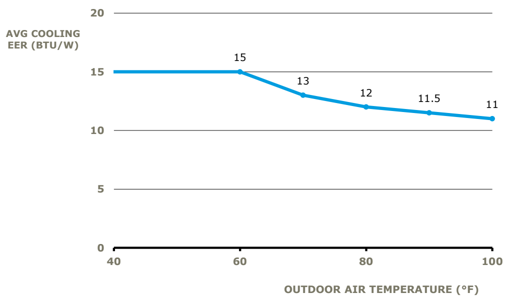
**EXISTING AVERAGE VAV DISCHARGE TEMPERATURE**



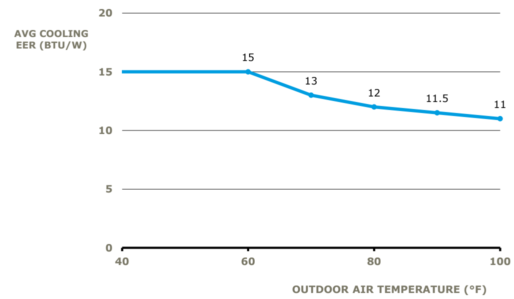

**POST-RETROFIT AVERAGE VAV DISCHARGE TEMPERATURE**



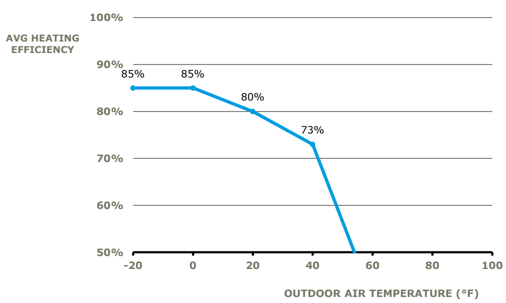

**EXISTING COOLING EFFICIENCY**



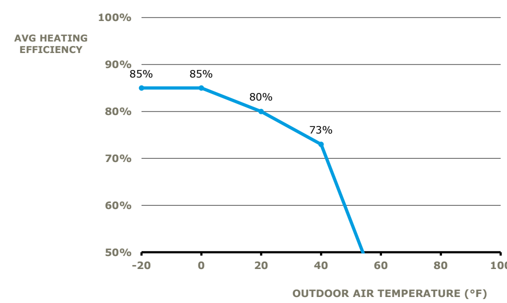

**POST-RETROFIT COOLING EFFICIENCY**




**EXISTING HEATING EFFICIENCY**




**POST-RETROFIT HEATING EFFICIENCY**



## RESULTS: EEM-4 HVAC SCHEDULING - CAMPUS

| | | | | | Baseline EUI | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Electricity | | | | Natural Gas | | All Fuels | Electric Savings | | | | Natural Gas Savings | Final EUI | | |
| **Building** | **Building Type** | **Total Building GSF** | **Typical Weekly Occupied** | **Current Operating Hours** | **Heating EUI** | **Clg EUI** | **Fan EUI** | **Total EUI** | **Heating EUI** | **Total EUI** | **Total EUI** | **Heating (kWh)** | **Cooling (kWh)** | **Fan (kWh)** | **Total (kWh)** | **Heating (Therms)** | **Electric** | **Natural Gas** | **Total** |
| 0003 - REC & CONVOCATION CTR, I POUCHER HALL, CAMPUS CENTER | ACADEMIC | 341,025 | 126 | 168 | 0.0 | 4.0 | 7.4 | 46.4 | 88.6 | 128.8 | 175.2 | 0 | 55,915 | 104,571 | 160,487 | 54,805 | 44.8 | 112.7 | 157.5 |
| 0004 - M V LEE HALL | ACADEMIC | 65,000 | 90 | 168 | 0.0 | 0.0 | 2.6 | 14.8 | 61.5 | 64.6 | 79.4 | 0 | 0 | 15,850 | 15,850 | 16,215 | 14.0 | 39.7 | 53.6 |
| 0014 - RICH HALL | ACADEMIC | 53,742 | 75 | 168 | 0.0 | 4.7 | 7.9 | 38.5 | 82.8 | 99.0 | 137.5 | 0 | 27,183 | 47,415 | 74,598 | 21,538 | 33.8 | 58.9 | 92.7 |
| 0015 - MACKIN HALL | DINING | 41,984 | 126 | 168 | 0.0 | 0.0 | 6.2 | 35.9 | 65.5 | 125.0 | 160.8 | 0 | 0 | 12,965 | 12,965 | 6,009 | 34.8 | 110.7 | 145.5 |
| 0019 - LAKER HALL | ACADEMIC | 196,608 | 90 | 168 | 0.0 | 0.0 | 2.4 | 14.5 | 64.8 | 68.1 | 82.6 | 0 | 0 | 44,621 | 44,621 | 51,718 | 13.8 | 41.7 | 55.5 |
| 0021 - ROMNEY FIELD HOUSE | ACADEMIC | 55,000 | 90 | 168 | 0.0 | 0.0 | 19.6 | 129.7 | 99.1 | 104.1 | 233.8 | 0 | 0 | 100,561 | 100,561 | 22,119 | 123.5 | 63.9 | 187.3 |
| 0023A - RICE CREEK FIELD STATION | ACADEMIC | 7,500 | 77 | 168 | 56.1 | 8.0 | 9.2 | 118.0 | 0.0 | 0.0 | 118.0 | 58,429 | 6,363 | 7,504 | 72,296 | 0 | 85.1 | 0.0 | 85.1 |
| 0026 - CULKIN HALL | ADMIN | 63,591 | 55 | 168 | 0.0 | 4.7 | 8.1 | 33.8 | 46.6 | 50.6 | 84.4 | 0 | 39,082 | 69,591 | 108,673 | 17,442 | 28.0 | 23.2 | 51.2 |
| 0031 - PATHFINDER DH | DINING | 33,827 | 126 | 168 | 0.0 | 4.7 | 7.4 | 56.0 | 56.6 | 158.6 | 214.6 | 0 | 7,727 | 12,548 | 20,275 | 4,184 | 54.0 | 146.2 | 200.2 |
| 0042 - LAKESIDE DH | DINING | 27,870 | 126 | 168 | 0.0 | 4.7 | 6.6 | 53.2 | 52.5 | 154.2 | 207.4 | 0 | 6,366 | 9,164 | 15,531 | 3,195 | 51.3 | 142.7 | 194.0 |
| 0047 - COOPER DH | DINING | 33,546 | 126 | 168 | 0.0 | 3.3 | 5.4 | 49.3 | 58.1 | 160.0 | 209.3 | 0 | 5,364 | 9,086 | 14,450 | 4,257 | 47.8 | 147.3 | 195.1 |
| **Campus** | | **919,693** | | | **4.8** | **3.9** | **6.1** | **42.8** | **61.3** | **83.8** | **126.5** | **58,429** | **148,002** | **433,875** | **640,306** | **201,482** | **40.4** | **61.9** | **102.2** |

## Existing Schedule Summary

| Building | HVAC Operating Schedule Description | Observed Occupancy Schedule Description |
|---|---|---|
| 0047 - COOPER DH | 24/7 | 8a.m. - 8:30 p.m. M-F, 10 a.m. - 8:30 p.m. weekends |
| 0031 - PATHFINDER DH | 24/7 | 8 a.m. - 11 p.m. M-Th, 8 a.m. - 7:30 p.m. F, 9 a.m.- 11 p.m. weekends |
| 0042 - LAKESIDE DH | 24/7 | 7 a.m. - 11 p.m. M-F, 9 a.m. - 11 p.m. weekends |
| 0003 - REC & CONVOCATION CTR, I POUCHER HALL, CAMPUS CENTER | AHU-1 is scheduled to operate in occupied mode 7 a.m. - 11 p.m. daily, other HVAC systems are 24/7 | 6:30 a.m. - 1:30 a.m. daily during academic year, 6:30 a.m. - 9 p.m. M-F during summer break |
| 0004 - M V LEE HALL | 24/7 | 6 a.m. - 9 p.m. daily during academic year. Gym operating hours: 11:30 a.m. - 10 p.m. daily. |
| 0019 - LAKER HALL | 24/7 | 6 a.m. - 11 p.m. M-F, 7 a.m. - 11 p.m. weekends |
| 0021 - ROMNEY FIELD HOUSE | 24/7 | Open 7 days with varying occupancy dependent on sport team practice schedules |
| 0017 - J PENFIELD LIB | 24/7 | Building occupied 24/7 during academic year. Library operating hours: 8 a.m. - 11 p.m. M-Th, 8 a.m. - 7 p.m. F, 11 a.m. - 7 p.m Sa, 11 a.m. - 11 p.m. Sun |
| 0032 - SENECA HALL | 24/7 | 24/7 during academic year |
| 0033 - CAYUGA HALL | 24/7 | 24/7 during academic year |
| 0041 - JOHNSON HALL | 24/7 | 24/7 during academic year |
| 0043 - RIGGS HALL | 24/7 | 24/7 during academic year |
| 0044 - WATERBURY HALL | 24/7 | 24/7 during academic year |
| 0045 - SCALES HALL | 24/7 | 24/7 during academic year |
| 0037 - TOWNHOUSES | 24/7 | 24/7 during academic year |
| 0001 - SHELDON HALL | Occupied mode 5 a.m. - 10 p.m. daily | 6 a.m. - 9 p.m. daily during academic year |
| 0002 - J C PARK HALL | 24/7 | Occupied 24/7 during academic year with highest occupancy 8 a.m. - 9 p.m. M-F |
| 0006 - J LANIGAN HALL | 24/7 | 24/7 during academic year |
| 0007 - J TYLER HALL | 24/7 | Occupied 24/7 during academic year with highest occupancy 8 a.m. - 9 p.m. M-F |
| 0008 - RICHARD S SHINEMAN CEN | 24/7 | Occupied 24/7 during academic year with highest occupancy 8 a.m. - 9 p.m. M-F |
| 0009 - WILBER HALL | 24/7 with unoccupied & nighttime setbacks determined in BAS | Occupied 24/7 during academic year with highest occupancy 8 a.m. - 9 p.m. M-F |
| 0010 - MARY WALKER HEALTH CEN | Occupied mode 7 a.m. - 5:30 p.m. daily | 8:30 a.m - 4 p.m. M-F |
| 0013 - M E MAHAR HALL | 7 a.m. - 10 p.m. M-F | 8 a.m. - 9 p.m. M-Th, 8 a.m. - 4 p.m. F |
| 0014 - RICH HALL | 24/7 | 8 a.m. - 9 p.m. M-Th, 8 a.m. - 4 p.m. F |
| 0026 - CULKIN HALL | 24/7 | 8 a.m. - 5 p.m. M-F |
| 0011 - COMMISSARY BLDG | 24/7 | 3 a.m. - 9 p.m. M-F, 8 a.m. - 9 p.m. weekends |
| 0012 - MAINTENANCE BLDG | Occupied mode 8 a.m. - 6 p.m. | 7 a.m. - 4 p.m. daily |
| 0015 - MACKIN HALL | unk | Dining Hall open 3 p.m. - 7 p.m M-Th. Offices/classrooms/lounges on upper floors open more regularly. Actual operating hours not listed. |
| 0020 - GAR-20 | unk | 8 a.m. - 5 p.m. M-F |
| 0022 - KING HALL | 24/7 | 8 a.m. - 5 p.m. M-F |
| 0023A - RICE CREEK FIELD STATIO | 24/7 | 8 a.m. - 4:30 p.m. M-F, 9 a.m. - 3 p.m. Sat, closed Sun |
| 0035 - LITTLEPAGE DH | 6 a.m. - 11 p.m. M-F, 8 a.m. - 1 a.m. weekends | 7 a.m. - 8 p.m. M-F, 9 a.m. - 12 a.m. weekends |

## LIFE CYCLE COST ANALYSIS

| | |
|---|---|
| ECM No.: | EEM-4 |
| ECM Title: | HVAC Scheduling |

**General Parameters**

| | |
|---|---|
| Base Date: | 1/1/2023 |
| Service Date: | 1/1/2023 |
| Study Period (Years): | 3 |
| Discount Rate: | 3% |
| Cost Escalation: | 0% |
| FEMP UPV Discount Factor (Elect.): | 2.95 |
| FEMP UPV Discount Factor (NG): | 2.84 |

| Cost Data | Baseline | Proposed | Savings |
|---|---|---|---|
| Initial Capital Cost: | | $4,136 | ($4,136) |
| Annual Electricity Costs: | $637,131 | $599,353 | $37,778 |
| Annual Natural Gas Costs: | $213,447 | $132,049 | $81,399 |
| Annual OM&R Costs: | $113 | $113 | $0 |
| Other Recurring Annual Costs: | $0 | $0 | $0 |

| Life Cycle Cost Calculations | Baseline | Proposed | Savings |
|---|---|---|---|
| Present Value Investment Costs, I: | $0 | $4,136 | ($4,136) |
| Present-Value Capital Replacement Cost, Repl: | $0 | $0 | $0 |
| Present Value Residual Cost, Res: | $0 | $0 | $0 |
| Present Value Energy Costs, E: | $2,488,447 | $2,145,414 | $343,033 |
| Present Value Water Cost, W: | $0 | $0 | $0 |
| Present Value O&M and Other Recurring Costs, OM&R: | $319 | $319 | $0 |
| **LCC:** | **$2,488,766** | **$2,149,869** | **$338,897** |

| Savings to Investment Ratio Calculations | |
|---|---|
| Present Value Energy Cost Savings, DE: | $343,033 |
| Present Value Water Cost Savings, DW: | $0 |
| Present Value OM&R Cost Savings, DOM&R: | $0 |
| **SIR:** | **82.94** |

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

# SUNY OSWEGO | EEM-5 OCCUPANCY-BASED HVAC CONTROLS

*Energy Opportunity Area:* HVAC, Building Automation System (BAS)

*Buildings Affected:* Rec & Convocation Center/Poucher Hall/Campus Center, Lee Hall, Laker Hall. Romney Field House, Penfield Library, Sheldon Hall, Park Hall, Lanigan Hall, Tyler Hall, Shineman Center, Wilber Hall, Mary Walker Health Center, Mahar Hall, Rich Hall, Culkin Hall

**Table 1. EEM-5 Summary Data**

| Description | Values | Units |
|---|---|---|
| Annual Electrical Energy Savings | 1,838,301 | kWh/year |
| Electrical Peak Demand Savings | 0.0 | kW |
| Annual Electrical Energy Cost Savings | $108,460 | $/year |
| Annual Natural Gas Savings | 207,110 | Therms/year |
| Annual Natural Gas Cost Savings | $83,672 | $/year |
| **Total Annual Energy Cost Savings** | **$192,132** | **$/year** |
| **Estimated Implementation Cost** | **$3,730,696** | **$** |
| **Simple Payback Period** | **19.4** | **years** |
| **Savings to Investment Ratio** | **0.74** | |

## Existing Conditions/Baseline

Currently, the campus operates HVAC equipment on various building-specific schedules with setbacks in place in some buildings where applicable. Table 2 presents a summary of each building's HVAC operating schedule description and typical occupancy schedule. This information is based on on-site observations, BAS observations and campus staff knowledge.

**Table 2. Building Schedule Summary**

| Building | HVAC Operating Schedule Description | Observed Occupancy Schedule Description |
|---|---|---|
| 0003 - REC & CONVOCATION CTR, I POUCHER HALL, CAMPUS CENTER | AHU-1 is scheduled to operate in occupied mode 7 a.m. - 11 p.m. daily, other HVAC systems are 24/7 | 6:30 a.m. - 1:30 a.m. daily during academic year, 6:30 a.m. - 9 p.m. M-F during summer break |
| 0004 - M V LEE HALL | 24/7 | 6 a.m. - 9 p.m. daily during academic year. Gym operating hours: 11:30 a.m. - 10 p.m. daily. |
| 0019 - LAKER HALL | 24/7 | 6 a.m. - 11 p.m. M-F, 7 a.m. - 11 p.m. weekends |
| 0021 - ROMNEY FIELD HOUSE | 24/7 | Open 7 days with varying occupancy dependent on sport team practice schedules |
| 0017 - J PENFIELD LIB | 24/7 | Building occupied 24/7 during academic year. Library operating hours: 8 a.m. - 11 p.m. M-Th, 8 a.m. - 7 p.m. F, 11 a.m. - 7 p.m Sa, 11 a.m. - 11 p.m. Sun |
| 0001 - SHELDON HALL | Occupied mode 5 a.m. - 10 p.m. daily | 6 a.m. - 9 p.m. daily during academic year |
| 0002 - J C PARK HALL | 24/7 | Occupied 24/7 during academic year with highest occupancy 8 a.m. - 9 p.m. M-F |

| Building | HVAC Operating Schedule Description | Observed Occupancy Schedule Description |
|---|---|---|
| 0006 - J LANIGAN HALL | 24/7 | 24/7 during academic year |
| 0007 - J TYLER HALL | 24/7 | Occupied 24/7 during academic year with highest occupancy 8 a.m. - 9 p.m. M-F |
| 0008 - RICHARD S SHINEMAN CENTER | 24/7 | Occupied 24/7 during academic year with highest occupancy 8 a.m. - 9 p.m. M-F |
| 0009 - WILBER HALL | 24/7 with unoccupied & nighttime setbacks determined in BAS | Occupied 24/7 during academic year with highest occupancy 8 a.m. - 9 p.m. M-F |
| 0010 - MARY WALKER HEALTH CENTER | Occupied mode 7 a.m. - 5:30 p.m. daily | 8:30 a.m - 4 p.m. M-F |
| 0013 - M E MAHAR HALL | 7 a.m. - 10 p.m. M-F | 8 a.m. - 9 p.m. M-Th, 8 a.m. - 4 p.m. F |
| 0014 - RICH HALL | 24/7 | 8 a.m. - 9 p.m. M-Th, 8 a.m. - 4 p.m. F |
| 0026 - CULKIN HALL | 24/7 | 8 a.m. - 5 p.m. M-F |

Most buildings and HVAC equipment on campus are connected to at least one of two building automation systems (BAS), which provide monitoring, direct digital control (DDC), and energy management of building HVAC systems:

- Trane Tracer® Ensemble™
- Carrier i-Vu® 8.0

### Recommended Action

This measure estimates the impact of installing occupancy sensors integrated into the BAS for control of HVAC system space temperatures. Occupancy based controls can be installed on HVAC systems to allow for automatic setback of space temperature setpoints in unoccupied zones during normal occupied mode periods. Ceiling mounted occupancy sensors are typical for this application. They can be integrated into the BAS and programmed to automatically provide unoccupied mode control individual zones during scheduled occupancy, when appropriate. When a sensor registers that a space is unoccupied for a certain period (e.g., ten minutes) the space temperature setpoints can revert to unoccupied setpoints until the senor indicates occupancy. The same occupancy sensors can be used to control lighting in the room by using dual contact sensors.

Any zone equipment that serves multiple rooms would need to receive an unoccupied signal from each room before enabling temperature setback in that zone.

Dorm buildings were not considered in this measure given the system types present and lack of room level temperature control in residential buildings throughout campus.

### Estimated Energy Savings

An hourly analysis was performed using Syracuse-Hancock International Airport TMY3 (Typical Meteorological Year) hourly weather data. Heating and cooling loads were estimated based on assumed load profiles and the application of psychrometric routines. Performance curves were applied to adjust equipment input power for off-design conditions. This measure results in AHU fan, heating, and cooling energy savings and terminal reheat savings.

Occupancy schedules were generated based on current building occupancy hours and space types looked at in this measure. Energy savings from implementing occupancy-based HVAC controls were estimated under the assumption that EEM-4 HVAC Scheduling is implemented in each building prior to/in conjunction with occupancy-based HVAC controls. EEM-4 reflects savings from operating hour reductions in HVAC schedules. This measure (EEM-5) reflects savings from additional HVAC setbacks during typical building occupied hours in applicable building areas.

Savings are generally higher for single zone HVAC systems and terminal equipment. When applied to multi-zone variable air volume (VAV) systems, VAV terminal box dampers can be closed when the corresponding zone is unoccupied, saving central air handling unit fan energy. Savings are limited on VAV boxes that serve multiple rooms, as all rooms need to be unoccupied to initiate setback.

Supporting documents include assumptions for the measure and individual building energy and cost savings, implementation costs, and simple payback.

Table **3** summarizes the baseline and post-retrofit energy consumption and estimated energy savings that result from the measure.

**Table 3. EEM-5 Savings**

| | Baseline | Proposed | Savings |
|---|---|---|---|
| Fan Energy (kWh) | 2,609,723 | 1,924,392 | 685,331 |
| Cooling Energy (kWh) | 3,443,284 | 2,290,315 | 1,152,969 |
| Electric Heating Energy (kWh) | 0 | 0 | 0 |
| **Total Electrical Energy (kWh)** | **6,053,007** | **4,214,707** | **1,838,301** |
| **Natural Gas Heating Consumption (therms)** | **934,963** | **727,853** | **207,110** |

## Estimated Project Cost

Aggregated costs for this measure across all buildings are presented in Table 4. These costs represent the scope of work described previously and are based on costs published in RS Means 2023. The number of sensors and control points were estimated based on building square footage relevant to this EEM.

**Table 4. EEM-5 Estimated Project Costs**

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| Dual Technology Occupancy Sensor (ceiling mounted) | 3,345 | Ea. | $245 | $819,455 |
| BAS I/O Points, Engineering, Calibration, Start-up/Checkout Labor | 3,345 | Lump Sum | $769 | $2,572,087 |
| **Labor and Materials Subtotal** | | | | **$3,391,542** |
| General Conditions | | | | $0 |
| **Labor and Materials Cost Total** | | | | **$3,391,542** |
| Architectural & Engineering Fees | 0% | | | $0 |
| Construction Management Fees | 0% | | | $0 |
| Contingency | 10% | | | $339,154 |
| **Project Cost Subtotal** | | | | **$3,730,696** |
| Agency Administrative Fee | 10% | | | $0 |
| **Total Project Cost** | | | | **$3,730,696** |

## EEM-5 – OCCUPANCY-BASED HVAC CONTROLS

## SUPPORTING DOCUMENTS

## SUMMARY INPUTS: ECM-5 OCCUPANCY BASED HVAC CONTROLS - ACADEMIC

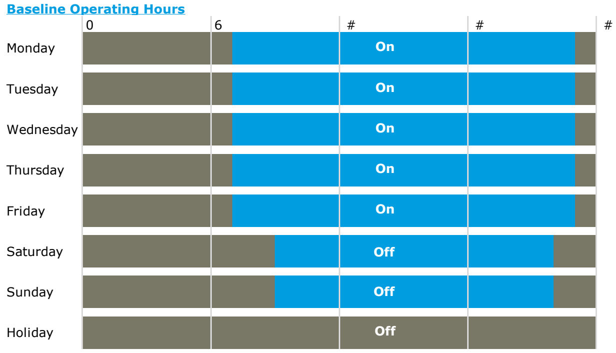
**Existing Space Temperature Setpoints**

| | Heating | Cooling |
|---|---|---|
| Occupied | 69.5 | 75 |
| Unoccupied Setback | 65.5 | 80.5 |

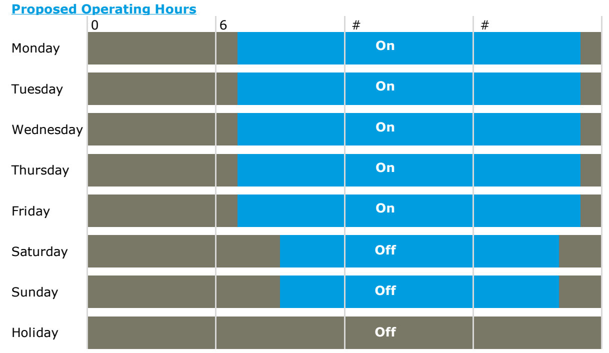
**Proposed Space Temperature Setpoints**

| | Heating | Cooling |
|---|---|---|
| Occupied | 69.5 | 75 |
| Unoccupied Setback | 65.5 | 80.5 |

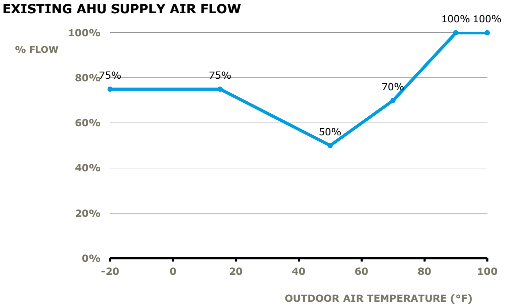
**Baseline Operating Hours**



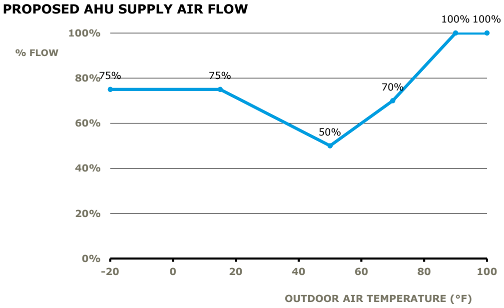

**Proposed Operating Hours**



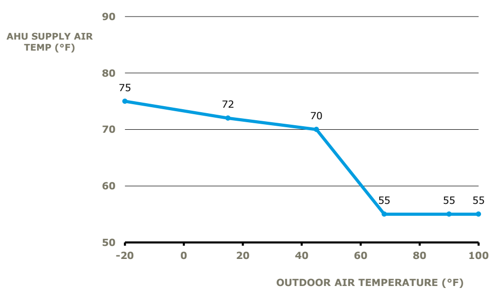

**EXISTING AHU SUPPLY AIR FLOW**



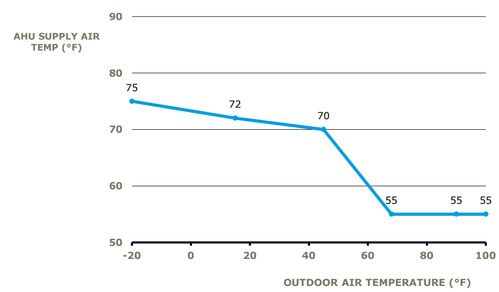

**PROPOSED AHU SUPPLY AIR FLOW**



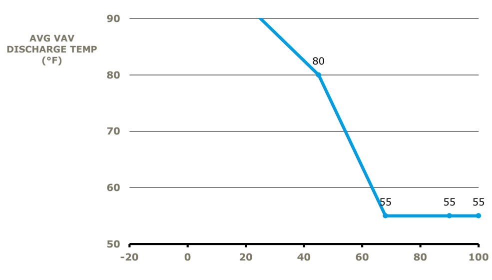

**EXISTING AHU SUPPLY TEMPERATURE**



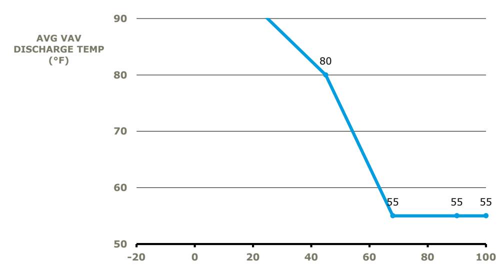

**PROPOSED AHU SUPPLY TEMPERATURE**




**EXISTING AVERAGE VAV DISCHARGE TEMPERATURE**

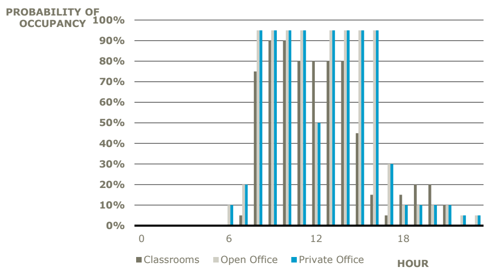



**PROPOSED AVERAGE VAV DISCHARGE TEMPERATURE**

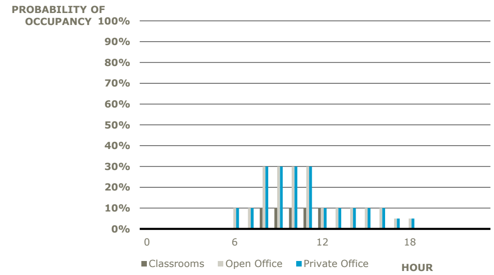


## SUMMARY INPUTS: ECM-5 OCCUPANCY BASED HVAC CONTROLS - ACADEMIC

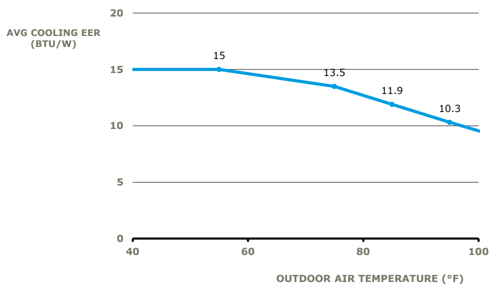
**PROBABILITY OF ROOMS BEING OCCUPIED (WEEKDAY)**



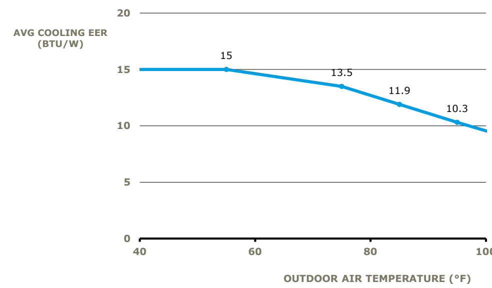

**PROBABILITY OF ROOMS BEING OCCUPIED (WEEKEND)**



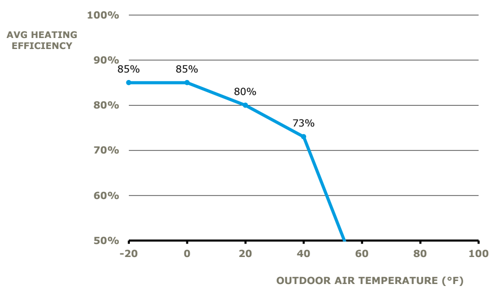

**EXISTING COOLING EFFICIENCY**



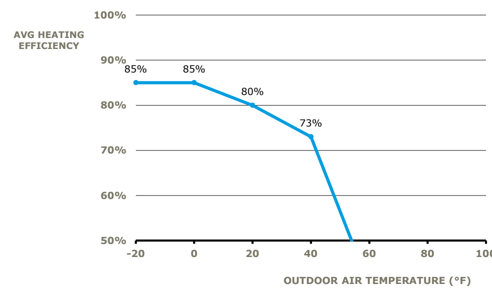

**POST-RETROFIT COOLING EFFICIENCY**




**EXISTING HEATING EFFICIENCY**




**POST-RETROFIT HEATING EFFICIENCY**



## RESULTS: ECM-5 - OCCUPANCY BASED HVAC CONTROLS

| Building | Building Total GSF | Building Type | Building GSF Included in Measure | Electric Savings | | | | Natural Gas Savings | Cost Savings | Implementation Cost | SPB (Years) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Heating (kWh) | Cooling (kWh) | Fan (kWh) | Total (kWh) | Heating (Therms) | | | |
| 0003 - REC & CONVOCATION CTR, I POUCHER HALL, CAMPUS CENTER | 341,025 | ACADEMIC | 341,025 | 0 | 306,084 | 249,679 | 555,763 | 51,422 | $ 53,564 | $ 950,948 | 17.8 |
| 0004 - M V LEE HALL | 65,000 | RECREATION | 21,938 | 0 | 21,822 | 0 | 21,822 | 4,128 | $ 2,955 | $ 61,173 | 20.7 |
| 0019 - LAKER HALL | 196,608 | RECREATION | 1,400 | 0 | 1,600 | 0 | 1,600 | 648 | $ 356 | $ 3,904 | 11.0 |
| 0021 - ROMNEY FIELD HOUSE | 55,000 | RECREATION | 52,250 | 0 | 50,920 | 0 | 50,920 | 7,876 | $ 6,186 | $ 145,699 | 23.6 |
| 0017 - J PENFIELD LIB | 192,298 | ACADEMIC | 163,453 | 0 | 135,624 | 0 | 135,624 | 18,613 | $ 15,522 | $ 455,790 | 29.4 |
| 0001 - SHELDON HALL | 119,211 | ACADEMIC | 59,606 | 0 | 49,386 | 45,195 | 94,581 | 6,683 | $ 8,280 | $ 166,210 | 20.1 |
| 0002 - J C PARK HALL | 66,979 | ACADEMIC | 3,350 | 0 | 3,587 | 3,311 | 6,898 | 526 | $ 619 | $ 9,341 | 15.1 |
| 0006 - J LANIGAN HALL | 88,200 | ACADEMIC | 88,200 | 0 | 73,078 | 0 | 73,078 | 9,888 | $ 8,307 | $ 245,946 | 29.6 |
| 0007 - J TYLER HALL | 115,430 | ACADEMIC | 115,430 | 0 | 96,269 | 87,521 | 183,790 | 13,058 | $ 16,119 | $ 321,877 | 20.0 |
| 0008 - RICHARD S SHINEMAN CENTER | 235,860 | ACADEMIC | 235,860 | 0 | 220,942 | 178,836 | 399,777 | 64,168 | $ 49,511 | $ 657,696 | 13.3 |
| 0009 - WILBER HALL | 108,933 | ACADEMIC | 35,948 | 0 | 29,785 | 27,257 | 57,041 | 4,030 | $ 4,994 | $ 100,241 | 20.1 |
| 0010 - MARY WALKER HEALTH CENTER | 33,260 | HEALTH | 28,271 | 0 | 10,295 | 8,272 | 18,566 | 4,980 | $ 3,107 | $ 78,834 | 25.4 |
| 0013 - M E MAHAR HALL | 91,530 | ACADEMIC | 82,377 | 0 | 65,976 | 53,720 | 119,696 | 8,739 | $ 10,592 | $ 229,708 | 21.7 |
| 0014 - RICH HALL | 53,742 | ACADEMIC | 48,368 | 0 | 38,340 | 31,542 | 69,882 | 4,459 | $ 5,924 | $ 134,874 | 22.8 |
| 0026 - CULKIN HALL | 63,591 | ADMIN | 60,411 | 0 | 49,263 | 0 | 49,263 | 7,893 | $ 6,095 | $ 168,457 | 27.6 |
| **Campus** | **1,826,667** | | **1,337,886** | **0** | **1,152,969** | **685,331** | **1,838,301** | **207,110** | **$ 192,132** | **$ 3,730,696** | **19.4** |

## LIFE CYCLE COST ANALYSIS

| | | | | |
|---|---|---|---|---|
| ECM No.: | EEM-4 | | | |
| ECM Title: | HVAC Scheduling | | | |
| **General Parameters** | | | | |
| Base Date: | 1/1/2023 | | | |
| Service Date: | 1/1/2023 | | | |
| Study Period (Years): | 15 | | | |
| Discount Rate: | 3% | | | |
| Cost Escalation: | 0% | | | |
| FEMP UPV Discount Factor (Elect.): | 14.96 | | | |
| FEMP UPV Discount Factor (NG): | 13.70 | | | |
| **Cost Data** | **Baseline** | **Proposed** | **Savings** | |
| Initial Capital Cost: | | $3,730,696 | ($3,730,696) | |
| Annual Electricity Costs: | | | $108,460 | |
| Annual Natural Gas Costs: | | | $83,672 | |
| Annual OM&R Costs: | $101,746 | $101,746 | $0 | |
| Other Recurring Annual Costs: | $0 | $0 | $0 | |
| **Life Cycle Cost Calculations** | **Baseline** | **Proposed** | **Savings** | |
| Present Value Investment Costs, I: | $0 | $3,730,696 | ($3,730,696) | |
| Present-Value Capital Replacement Cost, Repl: | $0 | $0 | $0 | |
| Present Value Residual Cost, Res: | $0 | $0 | $0 | |
| Present Value Energy Costs, E: | $0 | $0 | $2,768,859 | |
| Present Value Water Cost, W: | $0 | $0 | $0 | |
| Present Value O&M and Other Recurring Costs, OM&R: | $1,214,640 | $1,214,640 | $0 | |
| **LCC:** | **$1,214,640** | **$4,945,337** | **($961,837)** | |
| **Savings to Investment Ratio Calculations** | | | | |
| Present Value Energy Cost Savings, DE: | $2,768,859 | | | |
| Present Value Water Cost Savings, DW: | $0 | | | |
| Present Value OM&R Cost Savings, DOM&R: | $0 | | | |
| **SIR:** | **0.74** | | | |

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

# SUNY OSWEGO | EEM-6 PUMP DIFFERENTIAL PRESSURE RESET CONTROLS

*Energy Opportunity Area:* HVAC, Building Automation System (BAS)

*Buildings Affected: Sheldon Hall, Park Hall, Marano Campus Center, Tyler Hall, Richard S Shineman Center, Wilber Hall, Marty Walker Health Center, Mahar Hall, The Village Townhouses, Johnson Hall, Riggs Hall Scales Hall, Funnelle Hall*

**Table 1. EEM-6 Summary Data**

| Description | Values | Units |
|---|---|---|
| Annual Electrical Energy Savings | 164,705 | kWh/year |
| Electrical Peak Demand Savings | 10 | |
| Annual Electrical Energy Cost Savings | $9,718 | $/year |
| Annual Fossil Fuel Energy Savings | 0 | therms/year |
| Annual Fossil Fuel Cost Savings | $0 | $/year |
| **Total Annual Energy Cost Savings** | **$9,718** | **$/year** |
| **Estimated Implementation Cost** | **$37,107** | **$** |
| **Simple Payback Period** | **3.8** | **years** |
| **Savings to Investment Ratio** | **3.9** | **-** |

## Existing Conditions/Baseline

The variable flow chilled water (CHW) and hot water (HW) pumps listed in Table 2 are controlled by variable frequency drives (VFDs) that modulate pump speed (and flow) through the building automation system (BAS) to maintain a constant differential pressure across their associated water loops. These pumps deliver chilled or hot water (or glycol) to cooling and heating coils controlled by electronic two-way valves.

**Table 2. Chilled Water and Hot Water Pumps Controlled by VFDs**

| Building | Tag | System | Pump Qty | Pump HP | Fluid |
|---|---|---|---|---|---|
| 0001 - SHELDON HALL | P-5, P-6 | CHW | 2 | 5 | Water |
| 0002 - J C PARK HALL | CHP-1, CHP-2 | CHW | 2 | 30 | 20% PG |
| 0003 - CAMPUS CENTER | P-2A, P-2B | HW | 2 | 10 | 40% PG |
| 0003 - CAMPUS CENTER | P-3A, P-3B | HW | 2 | 15 | Water |
| 0003 - CAMPUS CENTER | P-1A, P-1B | CHW | 2 | 25 | Water |
| 003A - I POUCHER HALL | P-1, P-2 | HW | 2 | 5 | Water |
| 003A - I POUCHER HALL | P-5, P-6 | CHW | 2 | 8 | Water |
| 003B - REC & CONVOCATION CTR | P-1, P-2 | HW | 2 | 15 | Water |
| 003B - REC & CONVOCATION CTR | P-3, P-4 | HW | 2 | 20 | Water |
| 003B - REC & CONVOCATION CTR | P-5, P-6 | HW | 2 | 15 | 40% PG |
| 003B - REC & CONVOCATION CTR | P-7, P-9 | CHW | 2 | 25 | Water |
| 0007 - J TYLER HALL | HWP-1, HWP-2 | HW | 2 | 15 | Water |
| 0008 - RICHARD S SHINEMAN CENTER | P-11, P-12 | Dual Temp | 2 | 50 | Water |
| 0008 - RICHARD S SHINEMAN CENTER | P-7, P-8 | Dual Temp | 2 | 100 | Water |
| 0008 - RICHARD S SHINEMAN CENTER | P-1, P-2 | HW | 2 | 20 | Water |
| 0008 - RICHARD S SHINEMAN CENTER | P-5, P-6 | HW | 2 | 30 | Water |
| 0008 - RICHARD S SHINEMAN CENTER | P-3, P-4 | HW | 2 | 20 | 40% PG |
| 0009 - WILBER HALL | HWP-1, HWP-2 | HW | 2 | 15 | Water |
| 0009 - WILBER HALL | P-1, P-2 | HW | 2 | 10 | 35% PG |
| 0009 - WILBER HALL | P-5, P-6 | HW | 2 | 5 | 35% PG |
| 0009 - WILBER HALL | CWP-3, CWP-4 | CHW | 2 | 20[1] | Water |
| 0010 - MARY WALKER HEALTH CENTER | HW Pumps | HW | 2 | 5 | Water |
| 0013 - M E MAHAR HALL | P-1, P-2 | CHW | 2 | 10 | Water |

| Building | Tag | System | Pump Qty | Pump HP | Fluid |
|---|---|---|---|---|---|
| 0037 - THE VILLAGE TOWNHOUSES | P-1A, P-1B | Dual Temp | 2 | 15 | Water |
| 0037 - THE VILLAGE TOWNHOUSES | P-2A, P-2B | Dual Temp | 2 | 15 | Water |
| 0037 - THE VILLAGE TOWNHOUSES | P-3A, P-3B | CHW | 2 | 8 | 35% PG |
| 0037 - THE VILLAGE TOWNHOUSES | P-4A, P-4B | CHW | 2 | 8 | 35% PG |
| 0041 - JOHNSON HALL | HX1-HWP1, HX1-HWP2 | HW | 2 | 15 | Water |
| 0043 - RIGGS HALL | HWP-R-1, HWP-R-2 | HW | 2 | 15 | Water |
| 0043 - RIGGS HALL | GWP-R-1, GWP-R-2 | HW | 2 | 5 | 35% PG |
| 0045 - SCALES HALL | HWPP-1, HWPP-2 | HW | 2 | 5 | Water |
| 0048 - FUNNELLE HALL | P-1, P-2 | HW | 2 | 8 | Water |
| 0048 - FUNNELLE HALL | P-3 | HW | 1 | 8 | Water |
| 0048 - FUNNELLE HALL | P-4, P-5 | HW | 2 | 5 | Water |

1. Motor hp estimated based on building size

### Recommended Action

Differential pressure setpoints for the variable flow pumping systems addressed by this measure are maintained at a constant value through the BAS typically based on original design conditions. At all other conditions a lower setpoint would satisfy all coil loads and reduce pumping energy. This measure considers implementing a differential pressure reset control scheme, which polls the position of each valve in the system through the BAS and dynamically resets the differential pressure setpoint lower until the worst-case valve is nearly fully open. This is the minimum pressure that will satisfy all zones and use the least amount of pumping energy.

### Estimated Energy Savings

An hourly analysis was performed to estimate energy savings using Syracuse Hancock International Airport TMY3 (Typical Meteorological Year) hourly weather data. Chilled and hot water flow and pump motor input power were estimated based on assumed load profiles that relate percent flow to outdoor air dry-bulb temperature and a power versus flow curve obtained from the Pacific Northwest National Laboratory PNNL-26917 reference manual document. The baseline analysis uses the "Default (VSD, No Reset)" curve and the proposed differential pressure reset analysis uses the "VSD, DP Reset" curve. The resulting average reduction in differential pressure reduces pump energy use while still maintaining adequate flow through the coils.

Supporting documents include a summary of the assumptions and monthly baseline and post-retrofit conditions. Table 3 summarizes estimated energy and cost savings, implementation cost, and simple payback period for each building considered for this measure.

**Table 3. EEM-6 Savings**

| Building | Annual Electrical Energy Savings (kWh/year) | Electrical Peak Demand Savings (kW) | Total Annual Energy Cost Savings ($/year) | Estimated Implementation Cost | Simple Payback Period |
|---|---|---|---|---|---|
| 0001 - SHELDON HALL | 848 | 0.1 | $50 | $1,102 | 22.0 |
| 0002 - J C PARK HALL | 7,033 | 0.8 | $415 | $1,102 | 2.7 |
| 0003 - CAMPUS CENTER | 8,240 | 0.8 | $486 | $3,307 | 6.8 |
| 003A - I POUCHER HALL | 2,649 | 0.3 | $156 | $2,204 | 14.1 |
| 003B - REC & CONVOCATION CTR | 16,374 | 1.4 | $966 | $4,409 | 4.6 |
| 0007 - J TYLER HALL | 3,836 | 0.3 | $226 | $1,102 | 4.9 |
| 0008 - RICHARD S SHINEMAN CENTER | 86,579 | 3.7 | $5,108 | $5,511 | 1.1 |
| 0009 - WILBER HALL | 9,462 | 0.8 | $558 | $4,409 | 7.9 |

| Building | Annual Electrical Energy Savings (kWh/year) | Electrical Peak Demand Savings (kW) | Total Annual Energy Cost Savings ($/year) | Estimated Implementation Cost | Simple Payback Period |
|---|---|---|---|---|---|
| 0010 - MARY WALKER HEALTH CENTER | 436 | 0.1 | $26 | $1,102 | 42.8 |
| 0013 - M E MAHAR HALL | 1,599 | 0.3 | $94 | $1,102 | 11.7 |
| 0037 - THE VILLAGE TOWNHOUSES | 13,848 | 1.0 | $817 | $4,409 | 5.4 |
| 0041 - JOHNSON HALL | 2,753 | 0.2 | $162 | $1,102 | 6.8 |
| 0043 - RIGGS HALL | 4,433 | 0.3 | $262 | $2,204 | 8.4 |
| 0045 - SCALES HALL | 1,491 | 0.1 | $88 | $1,102 | 12.5 |
| 0048 - FUNNELLE HALL | 5,124 | 0.3 | $302 | $2,939 | 9.7 |
| **Total** | **164,705** | **10.2** | **$9,718** | **$37,107** | **3.8** |

## Estimated Project Cost

Costs presented in Table 4 represent the scope of work described previously. The project cost was estimated based on BAS engineering labor costs published in RS Means 2023.

**Table 4. EEM-6 Estimated Project Costs**

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| BAS Programming | 34 | Lump Sum | $992 | $33,734 |
| | | | | |
| **Materials and Labor Subtotal** | | | | **$33,734** |
| General Conditions | 0% | | | $0 |
| **Materials and Installation Cost Total** | | | | **$33,734** |
| | | | | |
| Architectural & Engineering Fees | 0% | | | $0 |
| Construction Management Fees | 0% | | | $0 |
| Contingency | 10% | | | $3,373 |
| | | | | |
| **Project Cost Subtotal** | | | | **$37,107** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$37,107** |

## EEM-6 – PUMP DIFFERENTIAL PRESSURE RESET CONTROLS

## SUPPORTING DOCUMENTS

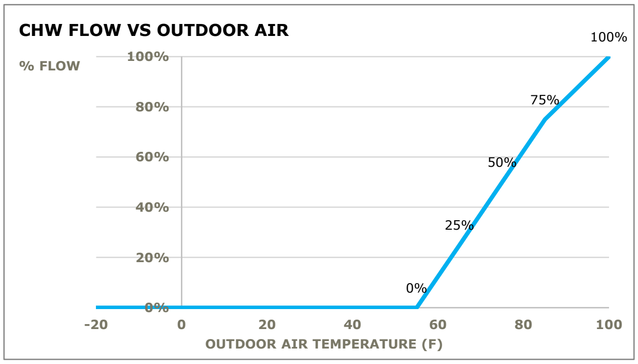
## SUMMARY INPUTS: EEM-6 PUMP DIFFERENTIAL PRESSURE RESET CONTROLS

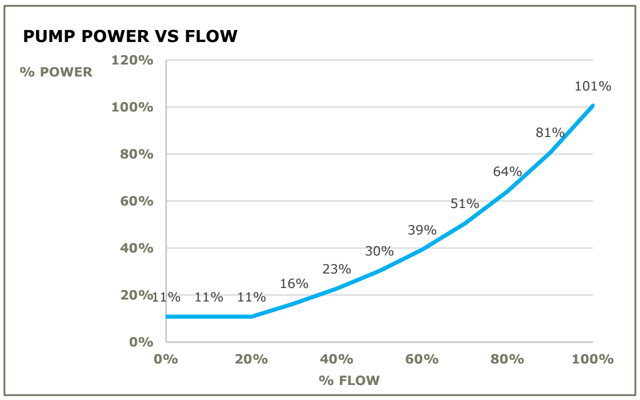
| Building | Tag | Flow (GPM) | Motor HP | Head (ft) | Motor kW |
|---|---|---|---|---|---|
| 0001 - SHELDON HALL | P-5, P-6 | 225 | 5 | 38 | 3.0 |
| 0002 - J C PARK HALL | CHP-1, CHP-2 | 650 | 30 | 119 | 19.7 |
| 0003 - CAMPUS CENTER | P-2A, P-2B | 238 | 10 | 65 | 4.7 |
| 0003 - CAMPUS CENTER | P-3A, P-3B | 280 | 15 | 65 | 4.9 |
| 0003 - CAMPUS CENTER | P-1A, P-1B | 647 | 25 | 75 | 12.2 |
| 003A - I POUCHER HALL | P-1, P-2 | 100 | 5 | 60 | 2.1 |
| 003A - I POUCHER HALL | P-5, P-6 | 275 | 7.5 | 60 | 5.3 |
| 003B - REC & CONVOCATION CTR | P-1, P-2 | 384 | 15 | 75 | 7.8 |
| 003B - REC & CONVOCATION CTR | P-3, P-4 | 384 | 20 | 110 | 10.7 |
| 003B - REC & CONVOCATION CTR | P-5, P-6 | 500 | 15 | 69 | 9.6 |
| 003B - REC & CONVOCATION CTR | P-7, P-9 | 600 | 25 | 92 | 13.9 |
| 0007 - J TYLER HALL | HWP-1, HWP-2 | 500 | 15 | 70 | 9.5 |
| 0008 - RICHARD S SHINEMAN CENTER | P-11, P-12 | 2,300 | 50 | 56 | 32.1 |
| 0008 - RICHARD S SHINEMAN CENTER | P-7, P-8 | 2,300 | 100 | 99 | 56.2 |
| 0008 - RICHARD S SHINEMAN CENTER | P-1, P-2 | 708 | 20 | 60 | 10.8 |
| 0008 - RICHARD S SHINEMAN CENTER | P-5, P-6 | 708 | 30 | 83 | 14.7 |
| 0008 - RICHARD S SHINEMAN CENTER | P-3, P-4 | 600 | 20 | 71 | 11.2 |
| 0009 - WILBER HALL | HWP-1, HWP-2 | 230 | 15 | 118 | 7.3 |
| 0009 - WILBER HALL | P-1, P-2 | 150 | 10 | 93 | 4.2 |
| 0009 - WILBER HALL | P-5, P-6 | 125 | 5 | 50 | 2.3 |
| 0009 - WILBER HALL | CWP-3, CWP-4 | 622 | 20 | 70 | 11.0 |
| 0010 - MARY WALKER HEALTH CENTER | HW Pumps | 75 | 5 | 70 | 1.8 |
| 0013 - M E MAHAR HALL | P-1, P-2 | 322 | 10 | 76 | 7.2 |
| 0037 - THE VILLAGE TOWNHOUSES | P-1A, P-1B | 396 | 15 | 90 | 9.6 |
| 0037 - THE VILLAGE TOWNHOUSES | P-2A, P-2B | 396 | 15 | 90 | 9.6 |
| 0037 - THE VILLAGE TOWNHOUSES | P-3A, P-3B | 240 | 7.5 | 55 | 4.3 |
| 0037 - THE VILLAGE TOWNHOUSES | P-4A, P-4B | 240 | 7.5 | 55 | 4.3 |
| 0041 - JOHNSON HALL | HX1-HWP1, HX1-HWP2 | 330 | 15 | 65 | 5.8 |
| 0043 - RIGGS HALL | HWP-R-1, HWP-R-2 | 340 | 15 | 80 | 7.3 |
| 0043 - RIGGS HALL | GWP-R-1, GWP-R-2 | 95 | 5 | 60 | 2.1 |
| 0045 - SCALES HALL | HWPP-1, HWPP-2 | 210 | 5 | 50 | 3.3 |
| 0048 - FUNNELLE HALL | P-1, P-2 | 188 | 7.5 | 75 | 4.3 |
| 0048 - FUNNELLE HALL | P-3 | 188 | 7.5 | 75 | 4.3 |
| 0048 - FUNNELLE HALL | P-4, P-5 | 125 | 5 | 63 | 2.4 |

## SUMMARY INPUTS: EEM-6 PUMP DIFFERENTIAL PRESSURE RESET CONTROLS

**Existing Conditions**

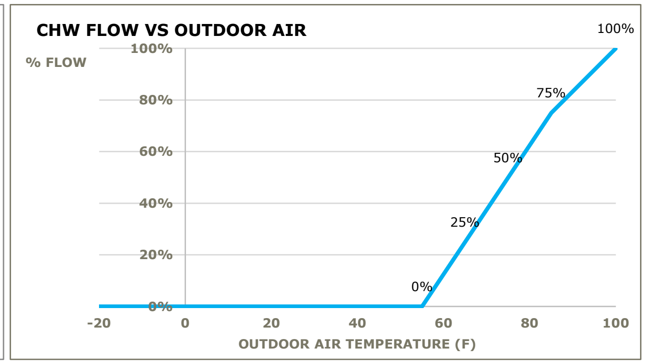
Minimum Flow Ratio: 0.5

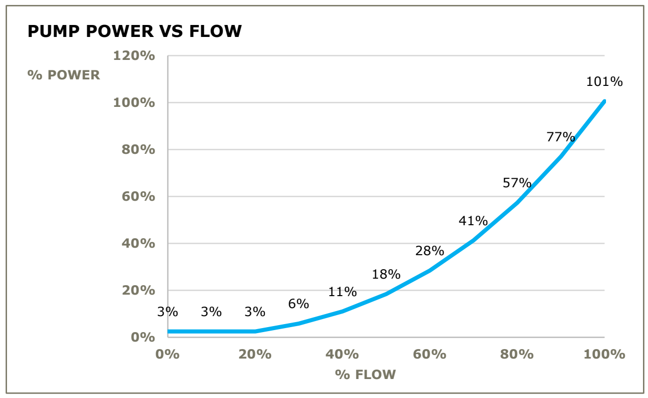



**Post-Retrofit Conditions**

Minimum Flow Ratio: 0.5

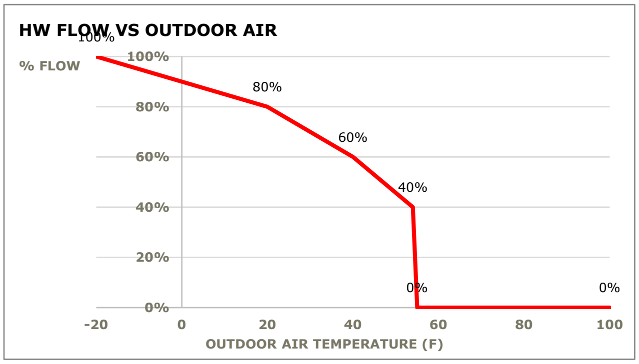


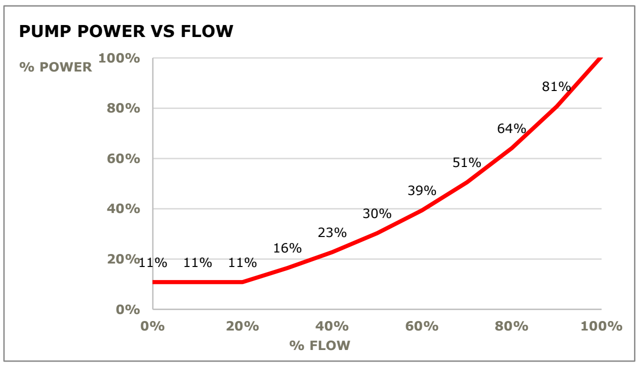



## SUMMARY INPUTS: EEM-6 PUMP DIFFERENTIAL PRESSURE RESET CONTROLS

**Existing Conditions**

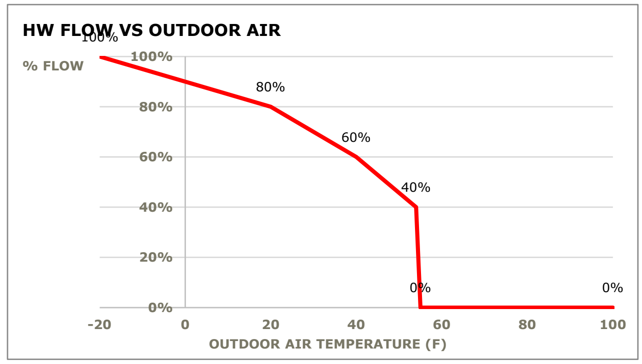
Minimum Flow Ratio: 0.5

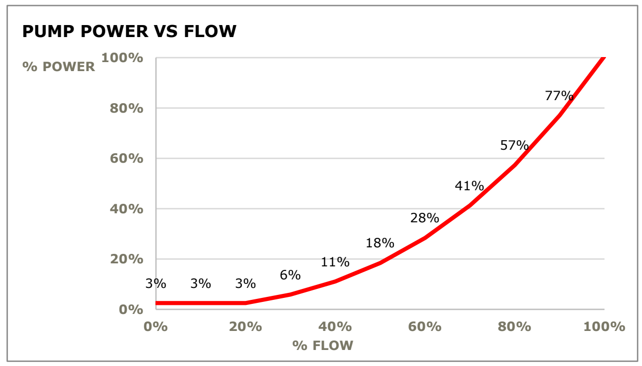



**Post-Retrofit Conditions**

Minimum Flow Ratio: 0.5



## RESULTS: EEM-6 PUMP DIFFERENTIAL PRESSURE RESET CONTROLS

| Building | Service | Baseline Pumping Energy (kWh) | Baseline Demand (kW) | Proposed Pumping Energy (kWh) | Proposed Demand (kW) | Pumping Energy Savings (kWh) | Demand Savings (kW) |
|---|---|---|---|---|---|---|---|
| 0001 - SHELDON HALL | CHW | 2,093 | 2.3 | 1,245 | 2.2 | 848 | 0.1 |
| 0002 - J C PARK HALL | CHW | 27,523 | 15.6 | 20,491 | 14.8 | 7,033 | 0.8 |
| 0003 - CAMPUS CENTER | HW | 18,230 | 8.1 | 14,357 | 7.8 | 3,873 | 0.3 |
| 0003 - CAMPUS CENTER | CHW | 10,186 | 9.6 | 5,820 | 9.2 | 4,367 | 0.5 |
| 003A - I POUCHER HALL | HW | 3,869 | 1.7 | 3,047 | 1.7 | 822 | 0.1 |
| 003A - I POUCHER HALL | CHW | 4,263 | 4.0 | 2,436 | 3.8 | 1,827 | 0.2 |
| 003B - REC & CONVOCATION CTR | HW | 53,687 | 23.9 | 42,281 | 23.1 | 11,406 | 0.8 |
| 003B - REC & CONVOCATION CTR | CHW | 11,588 | 11.0 | 6,620 | 10.4 | 4,967 | 0.6 |
| 0007 - J TYLER HALL | HW | 18,055 | 8.0 | 14,219 | 7.8 | 3,836 | 0.3 |
| 0008 - RICHARD S SHINEMAN CENTER | Dual Temp | 268,963 | 76.8 | 197,313 | 74.2 | 71,650 | 2.6 |
| 0008 - RICHARD S SHINEMAN CENTER | HW | 70,267 | 31.3 | 55,338 | 30.2 | 14,929 | 1.1 |
| 0009 - WILBER HALL | HW | 26,093 | 11.6 | 20,549 | 11.2 | 5,544 | 0.4 |
| 0009 - WILBER HALL | CHW | 9,140 | 8.7 | 5,222 | 8.2 | 3,918 | 0.4 |
| 0010 - MARY WALKER HEALTH CENTER | HW | 1,993 | 1.5 | 1,557 | 1.5 | 436 | 0.1 |
| 0013 - M E MAHAR HALL | CHW | 6,359 | 5.5 | 4,759 | 5.2 | 1,599 | 0.3 |
| 0037 - THE VILLAGE TOWNHOUSES | Dual Temp | 51,842 | 16.4 | 39,424 | 15.8 | 12,418 | 0.6 |
| 0037 - THE VILLAGE TOWNHOUSES | CHW | 2,833 | 6.2 | 1,403 | 5.8 | 1,430 | 0.4 |
| 0041 - JOHNSON HALL | HW | 13,071 | 4.9 | 10,318 | 4.8 | 2,753 | 0.2 |
| 0043 - RIGGS HALL | HW | 21,047 | 7.9 | 16,614 | 7.7 | 4,433 | 0.3 |
| 0045 - SCALES HALL | HW | 7,080 | 2.7 | 5,589 | 2.6 | 1,491 | 0.1 |
| 0048 - FUNNELLE HALL | HW | 24,325 | 9.2 | 19,202 | 8.9 | 5,124 | 0.3 |
| **Subtotal** | **CHW** | **73,985** | **62.9** | **47,995** | **59.6** | **25,990** | **3.3** |
| **Subtotal** | **HW** | **257,719** | **111.0** | **203,071** | **107.2** | **54,648** | **3.8** |
| **Subtotal** | **Dual Temp** | **320,805** | **93.2** | **236,737** | **90.0** | **84,068** | **3.2** |
| | **Total** | **652,509** | **267.0** | **487,804** | **256.8** | **164,705** | **10.2** |

## LIFE CYCLE COST ANALYSIS

ECM No.: EEM-6

ECM Title: Pump Differential Pressure Reset Controls

| General Parameters | |
|---|---|
| Base Date: | 1/1/2023 |
| Service Date: | 1/1/2023 |
| Study Period (Years): | 15 |
| Discount Rate: | 3% |
| Cost Escalation: | 0% |
| FEMP UPV Discount Factor (Elect.): | 14.96 |
| FEMP UPV Discount Factor (NG): | 13.70 |

| Cost Data | Baseline | Proposed | Savings |
|---|---|---|---|
| Initial Capital Cost: | | $37,107 | ($37,107) |
| Annual Electricity Costs: | $38,498 | $28,780 | $48,118 |
| Annual Natural Gas Costs: | $0 | $0 | $0 |
| Annual Water Costs: | $0 | $0 | $0 |
| Annual OM&R Costs: | $1,012 | $1,012 | $0 |
| Other Recurring Annual Costs: | $0 | $0 | $0 |

| Life Cycle Cost Calculations | Baseline | Proposed | Savings |
|---|---|---|---|
| Present Value Investment Costs, I: | $0 | $37,107 | ($37,107) |
| Present-Value Capital Replacement Cost, Repl: | $0 | $0 | $0 |
| Present Value Residual Cost, Res: | $0 | $0 | $0 |
| Present Value Energy Costs, E: | $575,879 | $430,516 | $145,363 |
| Present Value Water Cost, W: | $0 | $0 | $0 |
| Present Value O&M and Other Recurring Costs, OM&R: | $12,081 | $12,081 | $0 |
| **LCC:** | **$587,960** | **$479,705** | **$108,255** |

| Savings to Investment Ratio Calculations | |
|---|---|
| Present Value Energy Cost Savings, DE: | $145,363 |
| Present Value Water Cost Savings, DW: | $0 |
| Present Value OM&R Cost Savings, DOM&R: | $0 |
| **SIR:** | **3.92** |

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

# SUNY OSWEGO | EEM-7 MULTIZONE VAV DUCT STATIC PRESSURE RESET

*Energy Opportunity Area:* HVAC, Building Automation System (BAS)

*Buildings Affected:* Sheldon Hall, Park Hall, Campus Center, Poucher Hall, Rec. & Convocation Center, Tyler Hall, Wilber Hall, Mahar Hall, Rich Hall, Lakeside Dining Hall, Riggs Hall

**Table 1. EEM-7 Summary Data**

| Description | Values | Units |
|---|---|---|
| Annual Electrical Energy Savings | 192,792 | kWh/year |
| Electrical Peak Demand Savings | 33.8 | kW |
| Annual Electrical Energy Cost Savings | $11,375 | $/year |
| Annual Natural Gas Savings | 0 | Therms/year |
| Annual Natural Gas Cost Savings | $0 | $/year |
| **Total Annual Energy Cost Savings** | **$11,375** | **$/year** |
| **Estimated Implementation Cost** | **$24,248** | **$** |
| **Simple Payback Period** | **2.1** | **years** |
| **Savings to Investment Ratio** | **7.0** | **-** |

## Existing Conditions/Baseline

The multizone variable air volume (VAV) system fans listed in Table 2 are controlled by variable frequency drives (VFDs) that modulate fan speed (and air flow) to maintain duct static pressure at a constant setpoint. These systems are controlled through the building automation system (BAS).

**Table 2. Multizone VAV Systems**

| Building | Unit | SF Motor HP | RF Motor HP |
|---|---|---|---|
| 0001 - SHELDON HALL | AHU-1 | 7.5 | 3 |
| 0001 - SHELDON HALL | AHU-2 | 7.5 | 3 |
| 0001 - SHELDON HALL | AHU-3 | 7.5 | 3 |
| 0001 - SHELDON HALL | AHU-4 | 7.5 | 3 |
| 0002 - J C PARK HALL | AHU-7 | 7.5 | 3 |
| 0003 - CAMPUS CENTER | AHU-1 | 10[1] | 5 |
| 0003 - CAMPUS CENTER | AHU-1A | 15 | 5 |
| 0003 - CAMPUS CENTER | AHU-1B | 15 | 5 |
| 0003 - CAMPUS CENTER | AHU-1C | 10 | 5 |
| 0003 - CAMPUS CENTER | AHU-2 | 30 | 10 |
| 0003 - CAMPUS CENTER | AHU-3 | 25 | 7.5 |
| 0003 - CAMPUS CENTER | AHU-5 | 20 | 10 |
| 003A - I POUCHER HALL | AHU-1 | 15 | - |
| 003B - REC & CONVOCATION CTR | AHU-1 | 40 | 20 |
| 0007 - J TYLER HALL | AHU-1 | 10 | 5 |
| 0007 - J TYLER HALL | AHU-2 | 15 | 7.5 |

| Building | Unit | SF Motor HP | RF Motor HP |
|---|---|---|---|
| 0007 - J TYLER HALL | AHU-4 | 5 | 2 |
| 0009 - WILBER HALL | AHU-2 | 15 | 7.5 |
| 0013 - M E MAHAR HALL | AC-1 | 15 | - |
| 0014 - RICH HALL | AHU-1 | 50 | 20 |
| 0014 - RICH HALL | AHU-2 | 30 | 15 |
| 0042 - LAKESIDE DH | AHU-1 | 10 | - |
| 0043 - RIGGS HALL | AHU-R-1 | 20 | 10 |

1. Motor hp estimated based on space served area

### Recommended Action

Duct static pressure setpoints for the VAV systems addressed by this measure are maintained at a constant value through the BAS typically based on original design conditions. VAV terminal box dampers modulate as necessary based on zone heating and cooling requirements and operate at less than maximum design flows most of the time. This measure considers implementing a static pressure reset control scheme, that polls the position of all VAV box dampers on the system and dynamically adjusts the static pressure setpoint so that the worst-case damper is nearly fully open. This is the minimum pressure that will satisfy all zones and use the least amount of fan energy.

### Estimated Energy Savings

An hourly analysis was performed to estimate energy savings using Syracuse Hancock International Airport TMY3 (Typical Meteorological Year) hourly weather data. Supply air flow and fan motor input power were estimated based on assumed load profiles that relate percent flow to outdoor air dry-bulb temperature and a power versus flow curve obtained from the Pacific Northwest National Laboratory PNNL-26917 reference manual document. The baseline analysis uses the “Multi Zone VAV with VSD and fixed SP setpoint” curve and the proposed static pressure reset analysis uses the “Multi zone VAV with static pressure reset” curve. The resulting average reduction in duct static pressure reduces fan energy while still maintaining VAV box supply air flow requirements.

Supporting documents include a summary of the assumptions and monthly baseline and post-retrofit conditions.

Table 3 summarizes estimated energy savings, implementation cost, and simple payback period.

**Table 3. EEM-7  Multizone VAV Static Pressure Reset Savings**

| Building | Annual Electrical Energy Savings (kWh/year) | Electrical Peak Demand Savings (kW) | Total Annual Energy Cost Savings ($/year) | Estimated Implementation Cost | Simple Payback Period (years) |
|---|---|---|---|---|---|
| 0001 - SHELDON HALL | 15,362 | 2.7 | $906 | $4,409 | 4.9 |
| 0002 - J C PARK HALL | 3,732 | 0.7 | $220 | $1,102 | 5.0 |
| 0003 - CAMPUS CENTER | 58,679 | 10.3 | $3,462 | $7,715 | 2.2 |
| 003A - I POUCHER HALL | 4,334 | 0.8 | $256 | $735 | 2.9 |
| 003B - REC & CONVOCATION CTR | 21,597 | 3.8 | $1,274 | $1,102 | 0.9 |
| 0007 - J TYLER HALL | 15,041 | 2.6 | $887 | $3,307 | 3.7 |

| Building | Annual Electrical Energy Savings (kWh/year) | Electrical Peak Demand Savings (kW) | Total Annual Energy Cost Savings ($/year) | Estimated Implementation Cost | Simple Payback Period (years) |
|---|---|---|---|---|---|
| 0009 - WILBER HALL | 7,728 | 1.4 | $456 | $1,102 | 2.4 |
| 0013 - M E MAHAR HALL | 6,927 | 1.2 | $409 | $735 | 1.8 |
| 0014 - RICH HALL | 46,464 | 8.1 | $2,741 | $2,204 | 0.8 |
| 0042 - LAKESIDE DH | 2,408 | 0.7 | $142 | $735 | 5.2 |
| 0043 - RIGGS HALL | 10,519 | 1.6 | $621 | $1,102 | 1.8 |
| **Total** | **192,792** | **33.8** | **$11,375** | **$24,248** | **2.1** |

## Estimated Project Cost

Costs presented in Table 4 represent the scope of work described previously and are based on costs published in RS Means 2023.

**Table 4. EEM-7 Estimated Project Costs**

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| BAS I/O Points, Engineering, Calibration, Start-up/Checkout Labor | 23 | Ea. | $958 | $22,044 |
| | | | | |
| **Labor and Materials Subtotal** | | | | **$22,044** |
| General Conditions | 0% | | | $0 |
| **Labor and Materials Cost Total** | | | | **$22,044** |
| | | | | |
| Architectural & Engineering Fees | 0% | | | $0 |
| Construction Management Fees | 0% | | | $0 |
| Contingency | 10% | | | $2,204 |
| | | | | |
| **Project Cost Subtotal** | | | | **$24,248** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$24,248** |

# EEM-7 – MULTIZONE VAV DUCT STATIC PRESSURE RESET

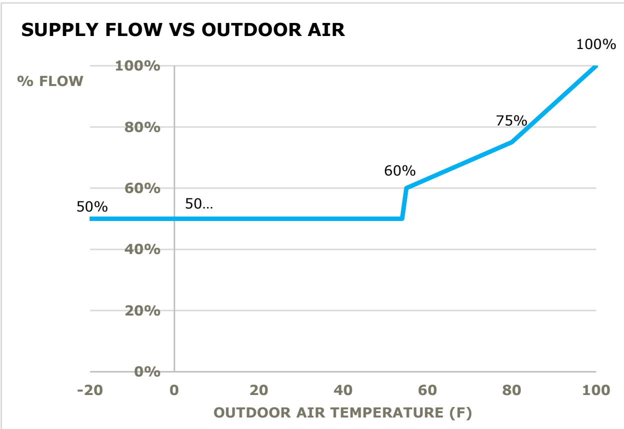
# SUPPORTING DOCUMENTS

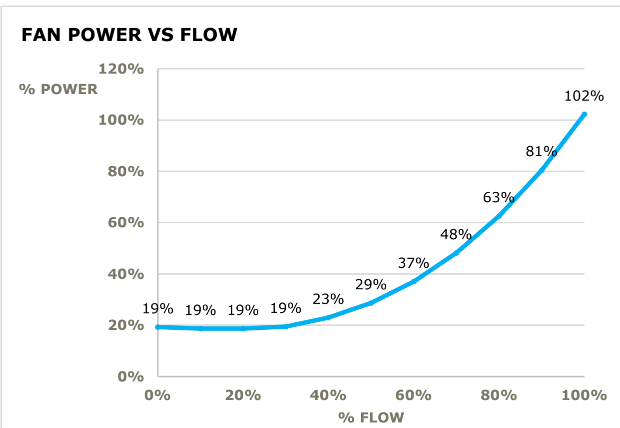
## SUMMARY INPUTS: EEM-7 MULTIZONE VAV STATIC PRESSURE RESET CONTROLS

| Building | Unit | Supply CFM | Supply Fan HP | Supply Fan kW | Return CFM | Return Fan HP | Return Fan kW |
|---|---|---|---|---|---|---|---|
| 0001 - SHELDON HALL | AHU-1 | 4,390 | 7.5 | 4.3 | 4,090 | 3 | 1.7 |
| 0001 - SHELDON HALL | AHU-2 | 4,975 | 7.5 | 5.7 | 4,350 | 3 | 2.0 |
| 0001 - SHELDON HALL | AHU-3 | 4,765 | 7.5 | 5.0 | 3,450 | 3 | 1.9 |
| 0001 - SHELDON HALL | AHU-4 | 4,500 | 7.5 | 4.5 | 4,375 | 3 | 1.8 |
| 0002 - J C PARK HALL | AHU-7 | 5,600 | 7.5 | 4.6 | 5,600 | 3 | 1.9 |
| 0003 - CAMPUS CENTER | AHU-1 | 9,635 | 10 | 6.5 | 8,086 | 5 | 2.2 |
| 0003 - CAMPUS CENTER | AHU-1A | 7,250 | 15 | 7.4 | 6,100 | 5 | 2.5 |
| 0003 - CAMPUS CENTER | AHU-1B | 6,750 | 15 | 8.5 | 5,200 | 5 | 2.4 |
| 0003 - CAMPUS CENTER | AHU-1C | 5,300 | 10 | 4.7 | 4,300 | 5 | 1.9 |
| 0003 - CAMPUS CENTER | AHU-2 | 15,740 | 30 | 18.7 | 12,600 | 10 | 6.2 |
| 0003 - CAMPUS CENTER | AHU-3 | 11,700 | 25 | 15.8 | 9,400 | 8 | 3.7 |
| 0003 - CAMPUS CENTER | AHU-5 | 11,200 | 20 | 14.9 | 11,025 | 10 | 4.9 |
| 003A - I POUCHER HALL | AHU-1 | 10,000 | 15 | 7.4 | - | - | - |
| 003B - REC & CONVOCATION CTR | AHU-1 | 30,000 | 40 | 25.8 | 21,000 | 20 | 10.6 |
| 0007 - J TYLER HALL | AHU-1 | 20,350 | 10 | 8.0 | 15,550 | 5 | 2.3 |
| 0007 - J TYLER HALL | AHU-2 | 21,000 | 15 | 9.2 | 19,700 | 8 | 2.9 |
| 0007 - J TYLER HALL | AHU-4 | 6,900 | 5 | 2.4 | 5,590 | 2 | 1.2 |
| 0009 - WILBER HALL | AHU-2 | 9,000 | 15 | 8.7 | 9,000 | 8 | 4.6 |
| 0013 - M E MAHAR HALL | AC-1 | 14,400 | 15 | 11.8 | - | - | - |
| 0014 - RICH HALL | AHU-1 | 24,700 | 50 | 32.6 | 24,700 | 20 | 14.4 |
| 0014 - RICH HALL | AHU-2 | 13,300 | 30 | 22.1 | 13,300 | 15 | 9.1 |
| 0042 - LAKESIDE DH | AHU-1 | 9,120 | 10 | 5.8 | - | - | - |
| 0043 - RIGGS HALL | AHU-R-1 | 12,000 | 20 | 13.5 | 12,000 | 10 | 7.2 |

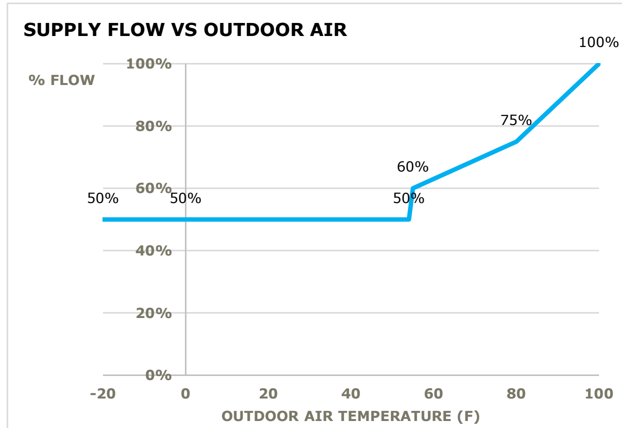
## SUMMARY INPUTS: EEM-7 MULTIZONE VAV STATIC PRESSURE RESET CONTROLS

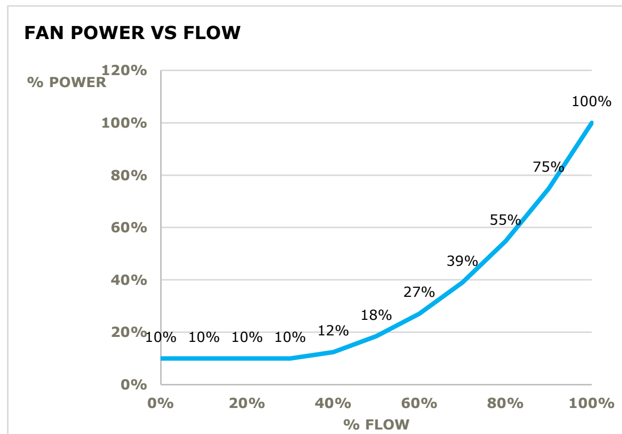
**Exisitng Conditions**




**Post-Retrofit Conditions**



# RESULTS: EEM-7 MULTIZONE VAV STATIC PRESSURE RESET CONTROLS

| Building | Baseline Fan Energy (kWh) | Proposed Fan Energy (kWh) | Fan Savings (kWh) |
|---|---|---|---|
| 0001 - SHELDON HALL | 49,076 | 33,714 | 15,362 |
| 0002 - J C PARK HALL | 11,923 | 8,191 | 3,732 |
| 0003 - CAMPUS CENTER | 187,452 | 128,774 | 58,679 |
| 003A - I POUCHER HALL | 13,847 | 9,512 | 4,334 |
| 003B - REC & CONVOCATION CTR | 68,993 | 47,396 | 21,597 |
| 0007 - J TYLER HALL | 48,050 | 33,008 | 15,041 |
| 0009 - WILBER HALL | 24,689 | 16,960 | 7,728 |
| 0013 - M E MAHAR HALL | 22,129 | 15,202 | 6,927 |
| 0014 - RICH HALL | 148,433 | 101,969 | 46,464 |
| 0042 - LAKESIDE DH | 7,020 | 4,612 | 2,408 |
| 0043 - RIGGS HALL | 29,754 | 19,235 | 10,519 |
| **Total** | **611,365** | **418,573** | **192,792** |

## LIFE CYCLE COST ANALYSIS

| | |
|---|---|
| ECM No.: | EEM-7 |
| ECM Title: | Multizone VAV Static Pressure Reset Controls |

| General Parameters | |
|---|---|
| Base Date: | 1/1/2023 |
| Service Date: | 1/1/2023 |
| Study Period (Years): | 15 |
| Discount Rate: | 3% |
| Cost Escalation: | 0% |
| FEMP UPV Discount Factor (Elect.): | 14.96 |
| FEMP UPV Discount Factor (NG): | 13.70 |

| Cost Data | Baseline | Proposed | Savings |
|---|---|---|---|
| Initial Capital Cost: | | $24,248 | ($24,248) |
| Annual Electricity Costs: | $36,071 | $24,696 | $11,375 |
| Annual Natural Gas Costs: | $0 | $0 | $0 |
| Annual CHP Natural Gas Costs: | $0 | $0 | $0 |
| Annual CHW Costs: | $0 | $0 | $0 |
| Annual HTHW Costs: | $0 | $0 | $0 |
| Annual Water Costs: | $0 | $0 | $0 |
| Annual OM&R Costs: | $661 | $661 | $0 |
| Other Recurring Annual Costs: | $0 | $0 | $0 |

| Life Cycle Cost Calculations | Baseline | Proposed | Savings |
|---|---|---|---|
| Present Value Investment Costs, I: | $0 | $24,248 | ($24,248) |
| Present-Value Capital Replacement Cost, Repl: | $0 | $0 | $0 |
| Present Value Residual Cost, Res: | $0 | $0 | $0 |
| Present Value Energy Costs, E: | $539,567 | $369,416 | $170,151 |
| Present Value Water Cost, W: | $0 | $0 | $0 |
| Present Value O&M and Other Recurring Costs, OM&R: | $7,895 | $7,895 | $0 |
| **LCC:** | **$547,462** | **$401,560** | **$145,902** |

| Savings to Investment Ratio Calculations | |
|---|---|
| Present Value Energy Cost Savings, DE: | $170,151 |
| Present Value Water Cost Savings, DW: | $0 |
| Present Value OM&R Cost Savings, DOM&R: | $0 |
| **SIR:** | **7.02** |

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

# SUNY OSWEGO | EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION

*Energy Opportunity Area:* HVAC, Building Automation System (BAS)

*Buildings Affected:* Campus Center, Cayuga Hall, Cooper Dining Hall, Lee Hall, Lanigan Hall, Laker Hall, Pathfinder Dining Hall, Romney Field House

**Table 1. EEM-8 Summary Data**

| Description | Values | Units |
|---|---|---|
| Annual Electrical Energy Savings | 728 | kWh/year |
| Electrical Peak Demand Savings | 1.0 | kW |
| Annual Electrical Energy Cost Savings | $43 | $/year |
| Annual Natural Gas Savings | 68,951 | Therms/year |
| Annual Natural Gas Cost Savings | $27,856 | $/year |
| **Total Annual Energy Cost Savings** | **$27,899** | **$/year** |
| **Total Project Cost** | **$40,655** | **$** |
| **Simple Payback Period** | **1.5** | **Years** |
| **Savings to Investment Ratio** | **9.4** | **-** |

### Existing Conditions/Baseline

Table 2 presents the air handling units (AHU) that serve densely occupied spaces in the buildings analyzed as part of the targeted energy audits completed for this study.

The Swetman Gym units provide heating and ventilation to the gymnasium. Based on a review of campus-provided drawings, the units together provide 12,000 cfm to the space with a combined minimum outside air flow of 7,500 cfm.

The Cayuga Hall units provide heating and ventilation to four lounges in the dorm. Based on a review of campus-provided drawings, the units together provide 4,200 cfm with an estimated combined minimum outside air flow of 1,210 cfm.

The Cooper Dining Hall unit provides heating, cooling, and ventilation to the dining area. Based on a review of campus-provided drawings, the unit provides 20,700 cfm to the space with an estimated minimum outside air flow of 8,733 cfm.

The Lee Hall unit provides heating and ventilation to the main gymnasium. Based on a review of campus-provided drawings, the unit provides 18,000 cfm to the space with an estimated minimum outside airflow of 2,880 cfm.

The Lanigan Hall unit provides heating, cooling, and ventilation to Lecture Hall 101. Based on a review of campus-provided drawings, the unit provides 12,350 cfm to the space with an estimated minimum outside air flow of 3,549 cfm.

Three of the Laker Hall units provide heating and ventilation to the main gymnasium. Based on a review of campus-provided drawings, the units together provide 90,000 cfm to the space with a combined minimum outside air flow of 37,500 cfm.

The fourth Laker Hall unit provides heating and ventilation to the auxiliary gymnasium. Based on a review of campus-provided drawings, the unit provides 29,000 cfm to the space with a minimum outside air flow of 5,800 cfm.

The Pathfinder Dining Hall unit provides heating, cooling, and ventilation to the dining area. Based on a review of campus-provided drawings, the unit provides 31,892 cfm to the space with an estimated minimum outside air flow of 6,924 cfm.

The Romney Field House unit provides heating and ventilation to the field house. Based on the building's size and outside air ventilation requirements, it is estimated that the unit provides 44,000 cfm to the space with a minimum outside air flow of 14,080 cfm.

**Table 2. AHUs Serving Densely Occupied Spaces**

| Building | Unit | Serves | Supply Fan CFM | Estimated Minimum Outside Air CFM |
|---|---|---|---|---|
| 0003 – CAMPUS CENTER | S-3 | Swetman Gym (North) | 6,000 | 3,750 |
| 0003 – CAMPUS CENTER | S-4 | Swetman Gym (South) | 6,000 | 3,750 |
| 0033 – CAYUGA HALL | HV-2 | East Lounge | 600 | 207 |
| 0033 – CAYUGA HALL | HV-3 | West Lounge | 600 | 242 |
| 0033 – CAYUGA HALL | HV-4 | Main Lounge | 1,500 | 393 |
| 0033 – CAYUGA HALL | HV-5 | Basement Lounge | 1,500 | 368 |
| 0047 – COOPER DINING HALL | AC-2 | Dining Area | 20,700 | 8,733 |
| 0004 – M V LEE HALL | HV-2 | Main Gym | 18,000 | 2,880 |
| 0006 – J LANIGAN HALL | AC-3 | Lecture Hall 101 | 12,350 | 3,549 |
| 0019 – LAKER HALL | HV-4 | Main Gym (East) | 30,000 | 12,500 |
| 0019 – LAKER HALL | HV-5 | Main Gym (Center) | 30,000 | 12,500 |
| 0019 – LAKER HALL | HV-6 | Main Gym (West) | 30,000 | 12,500 |
| 0019 – LAKER HALL | HV-7 | Auxiliary Gym | 29,000 | 5,800 |
| 0031 – PATHFINDER DINING HALL | SF-1 | Dining Area | 31,892 | 6,924 |
| 0021 – ROMNEY FIELD HOUSE | AHU-1 | Field House | 44,000 | 14,080 |

### Recommended Action

This measure considers the implementation of demand controlled ventilation (DCV) to vary outside air volume through mixed air damper control based on space carbon dioxide ($CO_2$) concentration and exhaust air requirements. The DCV routine would allow the outside air dampers to close below the minimum ventilation position when space carbon dioxide concentration is below an upper setpoint (e.g., 800 ppm), reducing heating and cooling energy requirements. Additionally, outside air dampers can be closed completely during morning warm up before occupants arrive further reducing energy requirements.

Typically, single zone air handling systems that serve densely occupied spaces that experience widely varying occupancy patterns, including assembly areas such as lecture halls, auditoriums, dining halls, and gymnasiums, are good candidates for DCV. The units listed in Table 2 were identified as potential candidates for DCV.

$CO_2$ sensors would be provided in the return ductwork of the AHU serving the space or directly in the space. $CO_2$ sensors already exist in Romney Field House but may not be communicating with the AHU dampers. Outputs from the $CO_2$ sensors would indicate to the BAS the level of outside air necessary to satisfy ventilation requirements for the actual occupancy. Ongoing BAS programming support and periodic calibration of the $CO_2$ sensors are recommended to ensure persistent energy savings from DCV.

Ramboll did not study implementing DCV on multizone AHUs, as multiple $CO_2$ sensors and outdoor airflow measuring stations would be required to ensure zones are not under ventilated, increasing the cost of the measure considerably. The outside air fraction would need to be reset to satisfy the worst performing zone, reducing the energy savings potential. These two issues combined typically result in longer than desired paybacks.

## Estimated Energy Savings

An hourly analysis was performed using Syracuse Hancock International Airport TMY3 (Typical Meteorological Year) hourly weather data. Heating and cooling loads were estimated based on assumed load profiles and the application of psychrometric routines. Performance curves were applied to adjust equipment input power for off-design conditions. The analysis estimates potential ventilation air flow reductions that can be achieved through DCV. Savings are generated by the reduction in ventilation heating and cooling loads.

Supporting documents include a summary of the assumptions and monthly baseline and post-retrofit conditions. Romney Field House is not included in the supporting documents because AHU specifications were not available. Savings for this building were estimated based on the results of the DCV analyses for the other gyms.

Table 3 summarizes estimated energy savings, implementation cost, and simple payback period.

**Table 3. EEM-8 Savings**

| Building | Annual Electrical Energy Savings (kWh/year) | Annual Natural Gas Savings (Therms/year) | Total Annual Energy Cost Savings ($/year) | Estimated Implementation Cost | Simple Payback Period |
|---|---|---|---|---|---|
| 0003 – CAMPUS CENTER | 0 | 6,739 | $2,723 | $4,772 | 1.8 |
| 0033 – CAYUGA HALL | 0 | 1,322 | $534 | $9,545 | 17.9 |
| 0047 – COOPER DINING HALL | 389 | 11,110 | $4,511 | $8,869 | 2.0 |
| 0004 – M V LEE HALL | 0 | 866 | $350 | $2,386 | 6.8 |
| 0006 – J LANIGAN HALL | 125 | 858 | $354 | $2,386 | 6.7 |

| Building | Annual Electrical Energy Savings (kWh/year) | Annual Natural Gas Savings (Therms/year) | Total Annual Energy Cost Savings ($/year) | Estimated Implementation Cost | Simple Payback Period |
|---|---|---|---|---|---|
| 0019 – LAKER HALL | 0 | 38,302 | $15,474 | $9,545 | 0.6 |
| 0031 – PATHFINDER DINING HALL | 214 | 6,303 | $2,559 | $2,386 | 0.9 |
| 0021 – ROMNEY FIELD HOUSE | 0 | 3,451 | $1,394 | $766 | 0.5 |
| **Total** | **728** | **68,951** | **$27,899** | **$40,655** | **1.5** |

## Estimated Project Cost

Costs presented in Table 4 represent the scope of work described previously. The project cost was estimated based on duct mounted $CO_2$ sensors from Grainger and BAS engineering labor costs published in RS Means 2023.

**Table 4. EEM-8 Estimated Project Costs**

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| Duct Mounted $CO_2$ Sensor | 18 | Ea. | $497 | $8,952 |
| BAS I/O Points, Engineering, Calibration, Start-up/Checkout Labor | 1 | Lump Sum | $28,008 | $28,008 |
| **Labor and Materials Subtotal** | | | | **$36,960** |
| General Conditions | 0% | | | $0 |
| **Labor and Materials Cost Total** | | | | **$36,960** |
| Architectural & Engineering Fees | 0% | | | $0 |
| Construction Management Fees | 0% | | | $0 |
| Contingency | 10% | | | $3,696 |
| **Project Cost Subtotal** | | | | **$40,655** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$40,655** |

## EEM-8 – IMPLEMENT DEMAND CONTROLLED VENTILATION

## SUPPORTING DOCUMENTS

# SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - MARANO CAMPUS CENTER

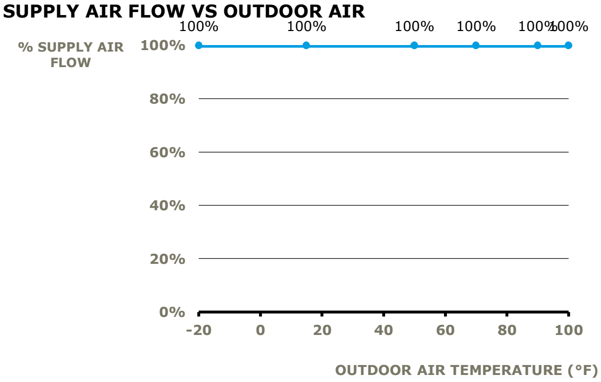
**Baseline**

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM |
|---|---|---|
| S-3 | 6,000 | 3,750 |
| S-4 | 6,000 | 3,750 |
| **Total** | **12,000** | **7,500** |

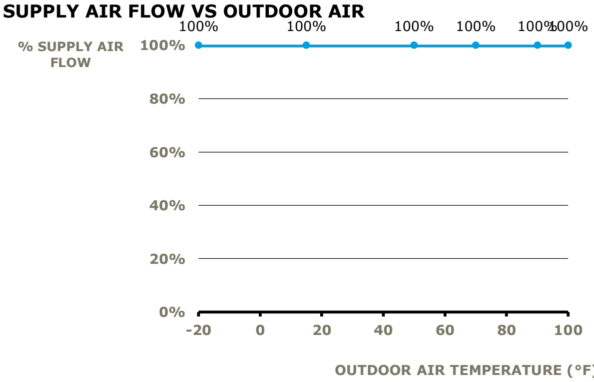
**Post-Retrofit**

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM | DCV Minimum Outdoor Air Flow CFM |
|---|---|---|---|
| S-3 | 6,000 | 3,750 | 864 |
| S-4 | 6,000 | 3,750 | 864 |
| **Total** | **12,000** | **7,500** | **1,728** |

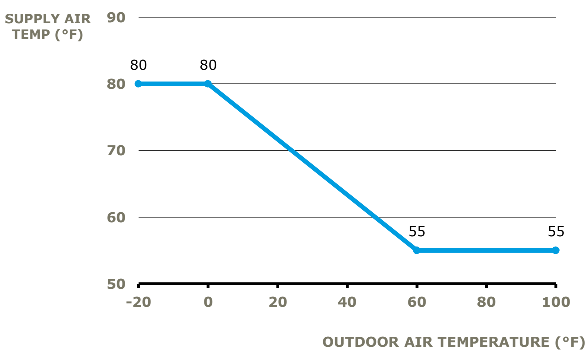
**BASELINE**
**SUPPLY AIR FLOW VS OUTDOOR AIR**



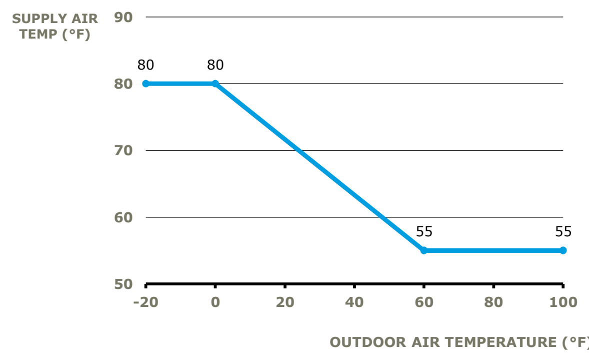

**POST-RETROFIT**
**SUPPLY AIR FLOW VS OUTDOOR AIR**



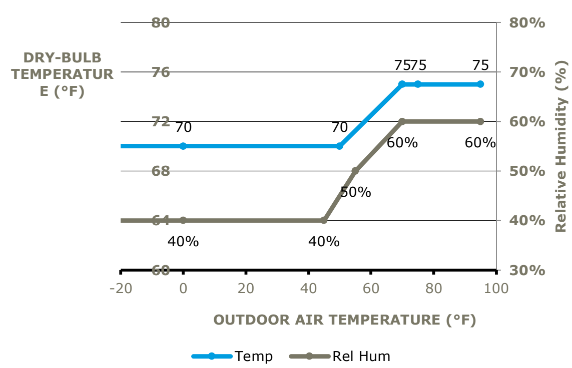

**BASELINE**
**SUPPLY AIR TEMPERATURE VS OUTDOOR AIR**



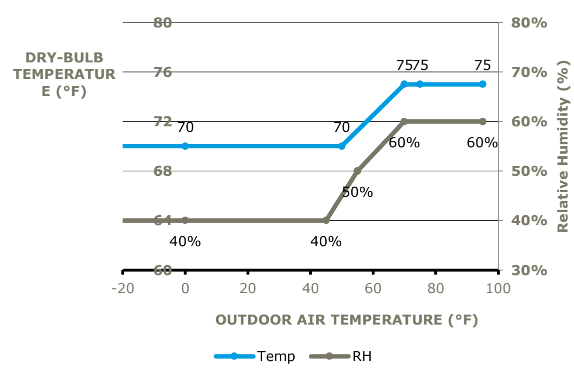

**POST-RETROFIT**
**SUPPLY AIR TEMPERATURE VS OUTDOOR AIR**




**BASELINE RETURN AIR CONDITIONS**




**BASELINE RETURN AIR CONDITIONS**



## SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - MARANO CAMPUS CENTER

**Baseline Hourly Fraction of Design Outdoor Air Flow**

| | Weekday | | Weekend | |
|---|---|---|---|---|
| **Hour Beginning** | **Unit On/Off** | **Outdoor Air** | **Unit On/Off** | **Outdoor Air** |
| 0 | 0 | 0% | 0 | 0% |
| 1 | 0 | 0% | 0 | 0% |
| 2 | 0 | 0% | 0 | 0% |
| 3 | 0 | 0% | 0 | 0% |
| 4 | 0 | 0% | 0 | 0% |
| 5 | 0 | 0% | 0 | 0% |
| 6 | 0 | 0% | 0 | 0% |
| 7 | 1 | 100% | 0 | 0% |
| 8 | 1 | 100% | 0 | 0% |
| 9 | 1 | 100% | 1 | 100% |
| 10 | 1 | 100% | 1 | 100% |
| 11 | 1 | 100% | 1 | 100% |
| 12 | 1 | 100% | 1 | 100% |
| 13 | 1 | 100% | 1 | 100% |
| 14 | 1 | 100% | 1 | 100% |
| 15 | 1 | 100% | 1 | 100% |
| 16 | 1 | 100% | 1 | 100% |
| 17 | 1 | 100% | 1 | 100% |
| 18 | 1 | 100% | 1 | 100% |
| 19 | 1 | 100% | 1 | 100% |
| 20 | 1 | 100% | 1 | 100% |
| 21 | 1 | 100% | 1 | 100% |
| 22 | 1 | 100% | 0 | 0% |
| 23 | 0 | 0% | 0 | 0% |

**Post-Retrofit Hourly Fraction of Design Outdoor Air Flow**

| | Weekday | | Weekend | |
|---|---|---|---|---|
| **Hour Beginning** | **Unit On/Off** | **Outdoor Air** | **Unit On/Off** | **Outdoor Air** |
| 0 | 0 | 0% | 0 | 0% |
| 1 | 0 | 0% | 0 | 0% |
| 2 | 0 | 0% | 0 | 0% |
| 3 | 0 | 0% | 0 | 0% |
| 4 | 0 | 0% | 0 | 0% |
| 5 | 0 | 0% | 0 | 0% |
| 6 | 0 | 0% | 0 | 0% |
| 7 | 1 | 23% | 0 | 0% |
| 8 | 1 | 25% | 0 | 0% |
| 9 | 1 | 25% | 1 | 26% |
| 10 | 1 | 25% | 1 | 26% |
| 11 | 1 | 25% | 1 | 28% |
| 12 | 1 | 26% | 1 | 28% |
| 13 | 1 | 26% | 1 | 29% |
| 14 | 1 | 28% | 1 | 29% |
| 15 | 1 | 28% | 1 | 28% |
| 16 | 1 | 29% | 1 | 28% |
| 17 | 1 | 29% | 1 | 26% |
| 18 | 1 | 29% | 1 | 26% |
| 19 | 1 | 29% | 1 | 26% |
| 20 | 1 | 29% | 1 | 26% |
| 21 | 1 | 28% | 1 | 23% |
| 22 | 1 | 26% | 0 | 0% |
| 23 | 0 | 0% | 0 | 0% |

# RESULTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - MARANO CAMPUS CENTER

## Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 457 | 12,000 | 7,536 | 0 | 1,923 |
| **Feb** | 25.4 | 424 | 12,000 | 7,500 | 0 | 1,817 |
| **Mar** | 37.4 | 451 | 12,000 | 7,901 | 0 | 1,127 |
| **Apr** | 47.9 | 450 | 12,000 | 8,909 | 0 | 479 |
| **May** | 59.9 | 316 | 12,000 | 10,122 | 0 | 9 |
| **Jun** | 66.4 | 320 | 12,000 | 9,217 | 0 | 2 |
| **Jul** | 71.8 | 336 | 12,000 | 8,384 | 0 | 0 |
| **Aug** | 68.0 | 316 | 12,000 | 8,853 | 0 | 0 |
| **Sep** | 60.7 | 437 | 12,000 | 9,930 | 0 | 46 |
| **Oct** | 49.5 | 466 | 12,000 | 9,275 | 0 | 310 |
| **Nov** | 40.9 | 444 | 12,000 | 8,197 | 0 | 881 |
| **Dec** | 27.7 | 433 | 12,000 | 7,526 | 0 | 1,725 |
| **Annual** | **48.6** | **4,850** | **12,000** | **8,561** | **0** | **8,319** |

## Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 457 | 12,000 | 2,229 | 0 | 454 |
| **Feb** | 25.4 | 424 | 12,000 | 2,117 | 0 | 438 |
| **Mar** | 37.4 | 451 | 12,000 | 3,706 | 0 | 192 |
| **Apr** | 47.9 | 450 | 12,000 | 6,269 | 0 | 25 |
| **May** | 59.9 | 316 | 12,000 | 8,222 | 0 | 0 |
| **Jun** | 66.4 | 320 | 12,000 | 5,981 | 0 | 0 |
| **Jul** | 71.8 | 336 | 12,000 | 3,956 | 0 | 0 |
| **Aug** | 68.0 | 316 | 12,000 | 4,982 | 0 | 0 |
| **Sep** | 60.7 | 437 | 12,000 | 8,208 | 0 | 0 |
| **Oct** | 49.5 | 466 | 12,000 | 7,784 | 0 | 7 |
| **Nov** | 40.9 | 444 | 12,000 | 4,738 | 0 | 113 |
| **Dec** | 27.7 | 433 | 12,000 | 2,115 | 0 | 351 |
| **Annual** | **48.6** | **4,850** | **12,000** | **4,961** | **0** | **1,579** |

## Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | - | 0 | 0 | 5,306 | 0 | 1,469 |
| **Feb** | - | 0 | 0 | 5,383 | 0 | 1,380 |
| **Mar** | - | 0 | 0 | 4,195 | 0 | 935 |
| **Apr** | - | 0 | 0 | 2,640 | 0 | 454 |
| **May** | - | 0 | 0 | 1,900 | 0 | 9 |
| **Jun** | - | 0 | 0 | 3,236 | 0 | 2 |
| **Jul** | - | 0 | 0 | 4,428 | 0 | 0 |
| **Aug** | - | 0 | 0 | 3,870 | 0 | 0 |
| **Sep** | - | 0 | 0 | 1,722 | 0 | 46 |
| **Oct** | - | 0 | 0 | 1,491 | 0 | 304 |
| **Nov** | - | 0 | 0 | 3,459 | 0 | 768 |
| **Dec** | - | 0 | 0 | 5,411 | 0 | 1,374 |
| **Annual** | **-** | **0** | **0** | **3,600** | **0** | **6,739** |

1. Average air flow rates over hours when fan operates, including economizer operation.

## SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - CAYUGA HALL

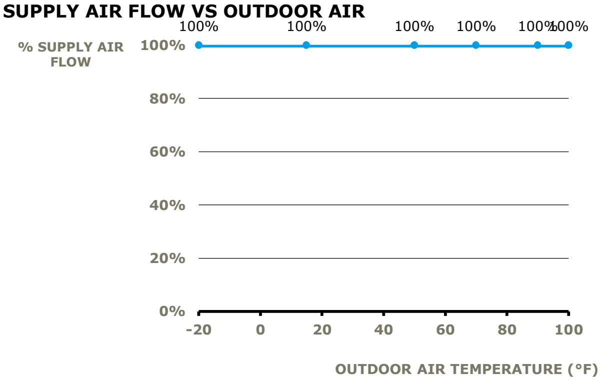
**Baseline**

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM |
|---|---|---|
| HV-2 | 600 | 207 |
| HV-3 | 600 | 242 |
| HV-4 | 1,500 | 393 |
| HV-5 | 1,500 | 368 |
| **Total** | **4,200** | **1,210** |

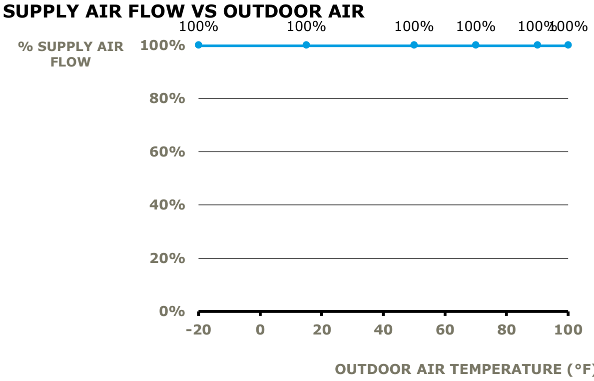
**Post-Retrofit**

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM | DCV Minimum Outdoor Air Flow CFM |
|---|---|---|---|
| HV-2 | 600 | 207 | 44 |
| HV-3 | 600 | 242 | 51 |
| HV-4 | 1,500 | 393 | 83 |
| HV-5 | 1,500 | 368 | 77 |
| **Total** | **4,200** | **1,210** | **255** |

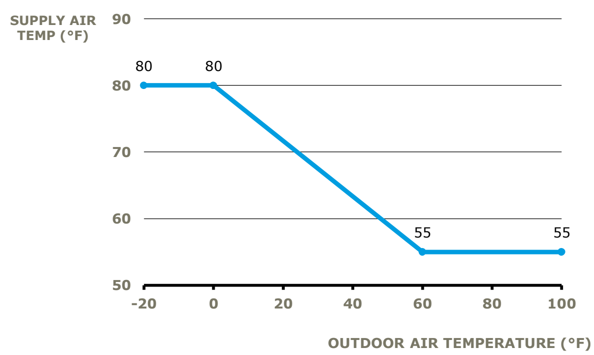
**BASELINE**
**SUPPLY AIR FLOW VS OUTDOOR AIR**



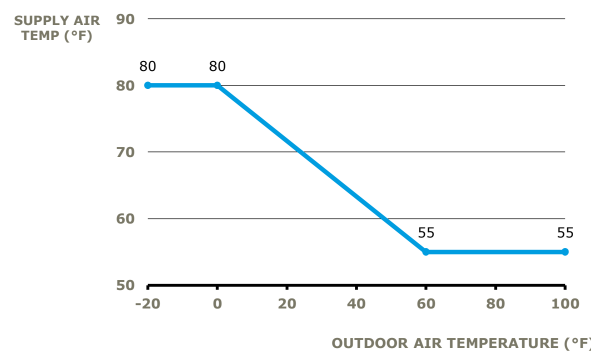

**POST-RETROFIT**
**SUPPLY AIR FLOW VS OUTDOOR AIR**



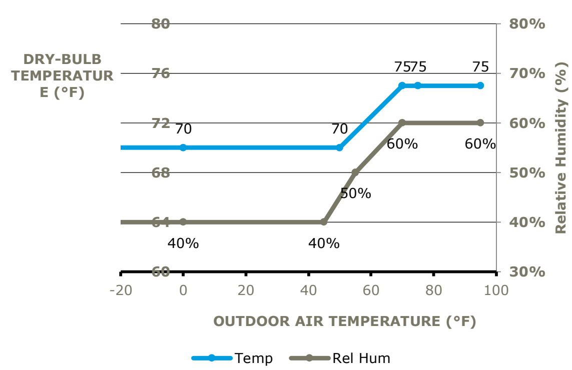

**BASELINE**
**SUPPLY AIR TEMPERATURE VS OUTDOOR AIR**



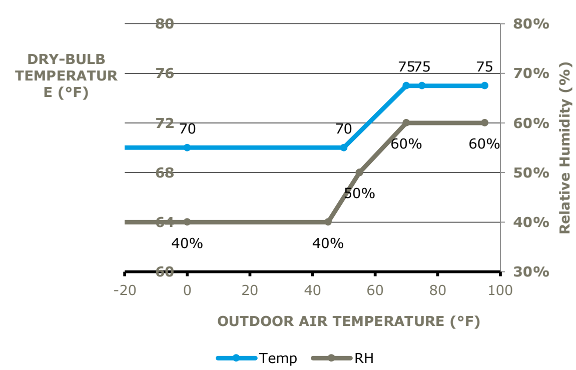

**POST-RETROFIT**
**SUPPLY AIR TEMPERATURE VS OUTDOOR AIR**




**BASELINE RETURN AIR CONDITIONS**




**BASELINE RETURN AIR CONDITIONS**



# SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - CAYUGA HALL

**Baseline Hourly Fraction of Design Outdoor Air Flow**

| | Weekday | | Weekend | |
|---|---|---|---|---|
| **Hour Beginning** | **Unit On/Off** | **Outdoor Air** | **Unit On/Off** | **Outdoor Air** |
| 0 | 1 | 100% | 1 | 100% |
| 1 | 1 | 100% | 1 | 100% |
| 2 | 1 | 100% | 1 | 100% |
| 3 | 1 | 100% | 1 | 100% |
| 4 | 1 | 100% | 1 | 100% |
| 5 | 1 | 100% | 1 | 100% |
| 6 | 1 | 100% | 1 | 100% |
| 7 | 1 | 100% | 1 | 100% |
| 8 | 1 | 100% | 1 | 100% |
| 9 | 1 | 100% | 1 | 100% |
| 10 | 1 | 100% | 1 | 100% |
| 11 | 1 | 100% | 1 | 100% |
| 12 | 1 | 100% | 1 | 100% |
| 13 | 1 | 100% | 1 | 100% |
| 14 | 1 | 100% | 1 | 100% |
| 15 | 1 | 100% | 1 | 100% |
| 16 | 1 | 100% | 1 | 100% |
| 17 | 1 | 100% | 1 | 100% |
| 18 | 1 | 100% | 1 | 100% |
| 19 | 1 | 100% | 1 | 100% |
| 20 | 1 | 100% | 1 | 100% |
| 21 | 1 | 100% | 1 | 100% |
| 22 | 1 | 100% | 1 | 100% |
| 23 | 1 | 100% | 1 | 100% |

**Post-Retrofit Hourly Fraction of Design Outdoor Air Flow**

| | Weekday | | Weekend | |
|---|---|---|---|---|
| **Hour Beginning** | **Unit On/Off** | **Outdoor Air** | **Unit On/Off** | **Outdoor Air** |
| 0 | 1 | 29% | 1 | 29% |
| 1 | 1 | 25% | 1 | 25% |
| 2 | 1 | 25% | 1 | 25% |
| 3 | 1 | 25% | 1 | 25% |
| 4 | 1 | 25% | 1 | 25% |
| 5 | 1 | 25% | 1 | 25% |
| 6 | 1 | 25% | 1 | 25% |
| 7 | 1 | 25% | 1 | 25% |
| 8 | 1 | 29% | 1 | 29% |
| 9 | 1 | 41% | 1 | 41% |
| 10 | 1 | 41% | 1 | 41% |
| 11 | 1 | 41% | 1 | 41% |
| 12 | 1 | 41% | 1 | 41% |
| 13 | 1 | 41% | 1 | 41% |
| 14 | 1 | 41% | 1 | 41% |
| 15 | 1 | 41% | 1 | 41% |
| 16 | 1 | 45% | 1 | 45% |
| 17 | 1 | 61% | 1 | 61% |
| 18 | 1 | 92% | 1 | 92% |
| 19 | 1 | 92% | 1 | 92% |
| 20 | 1 | 92% | 1 | 92% |
| 21 | 1 | 68% | 1 | 68% |
| 22 | 1 | 53% | 1 | 53% |
| 23 | 1 | 29% | 1 | 29% |

# RESULTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - CAYUGA HALL

## Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 744 | 4,200 | 1,240 | 0 | 509 |
| **Feb** | 25.4 | 672 | 4,200 | 1,219 | 0 | 475 |
| **Mar** | 37.4 | 744 | 4,200 | 1,578 | 0 | 277 |
| **Apr** | 47.9 | 720 | 4,200 | 2,161 | 0 | 81 |
| **May** | 59.9 | 432 | 4,200 | 3,044 | 0 | 7 |
| **Jun** | 66.4 | 0 | 4,200 | 2,623 | 0 | 0 |
| **Jul** | 71.8 | 0 | 4,200 | 2,915 | 0 | 0 |
| **Aug** | 68.0 | 144 | 4,200 | 2,533 | 0 | 0 |
| **Sep** | 60.7 | 720 | 4,200 | 1,825 | 0 | 7 |
| **Oct** | 49.5 | 744 | 4,200 | 1,234 | 0 | 41 |
| **Nov** | 40.9 | 720 | 4,200 | 1,939 | 0 | 174 |
| **Dec** | 27.7 | 744 | 0 | 0 | 0 | 457 |
| **Annual** | **48.6** | **6,384** | **0** | **0** | **0** | **2,029** |

## Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 744 | 4,200 | 573 | 0 | 196 |
| **Feb** | 25.4 | 672 | 4,200 | 578 | 0 | 204 |
| **Mar** | 37.4 | 744 | 4,200 | 1,139 | 0 | 97 |
| **Apr** | 47.9 | 720 | 4,200 | 1,941 | 0 | 13 |
| **May** | 59.9 | 432 | 4,200 | 2,914 | 0 | 0 |
| **Jun** | 66.4 | 0 | 4,200 | 2,316 | 0 | 0 |
| **Jul** | 71.8 | 0 | 4,200 | 2,749 | 0 | 0 |
| **Aug** | 68.0 | 144 | 4,200 | 2,440 | 0 | 0 |
| **Sep** | 60.7 | 720 | 4,200 | 1,513 | 0 | 0 |
| **Oct** | 49.5 | 744 | 4,200 | 536 | 0 | 5 |
| **Nov** | 40.9 | 720 | 4,200 | 1,556 | 0 | 51 |
| **Dec** | 27.7 | 744 | 0 | 0 | 0 | 141 |
| **Annual** | **48.6** | **6,384** | **0** | **0** | **0** | **707** |

## Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | - | 0 | 0 | 667 | 0 | 313 |
| **Feb** | - | 0 | 0 | 641 | 0 | 271 |
| **Mar** | - | 0 | 0 | 439 | 0 | 180 |
| **Apr** | - | 0 | 0 | 220 | 0 | 68 |
| **May** | - | 0 | 0 | 130 | 0 | 7 |
| **Jun** | - | 0 | 0 | 307 | 0 | 0 |
| **Jul** | - | 0 | 0 | 166 | 0 | 0 |
| **Aug** | - | 0 | 0 | 93 | 0 | 0 |
| **Sep** | - | 0 | 0 | 312 | 0 | 7 |
| **Oct** | - | 0 | 0 | 699 | 0 | 36 |
| **Nov** | - | 0 | 0 | 383 | 0 | 124 |
| **Dec** | - | 0 | 0 | 0 | 0 | 316 |
| **Annual** | **-** | **0** | **0** | **0** | **0** | **1,322** |

1. Average air flow rates over hours when fan operates, including economizer operation.

## SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - COOPER DINING HALL

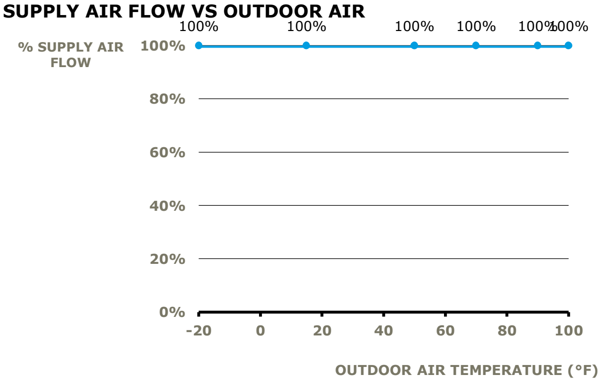
### Baseline

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM |
|---|---|---|
| AC-2 | 20,700 | 8,733 |
| **Total** | **20,700** | **8,733** |

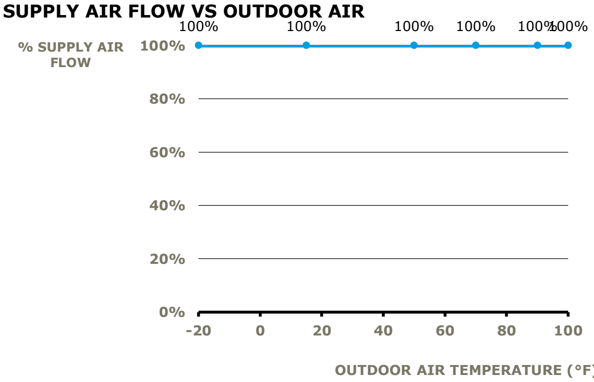
### Post-Retrofit

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM | DCV Minimum Outdoor Air Flow CFM |
|---|---|---|---|
| AC-2 | 20,700 | 8,733 | 1,690 |
| **Total** | **20,700** | **8,733** | **1,690** |

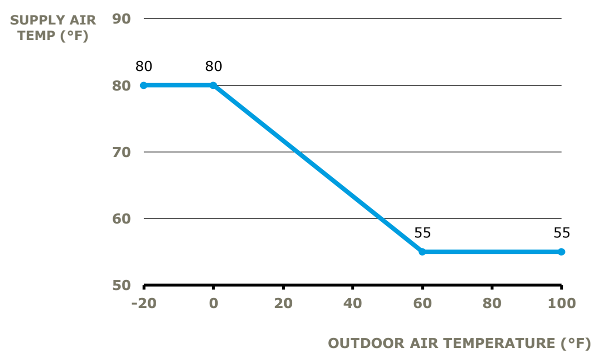
**BASELINE**
**SUPPLY AIR FLOW VS OUTDOOR AIR**



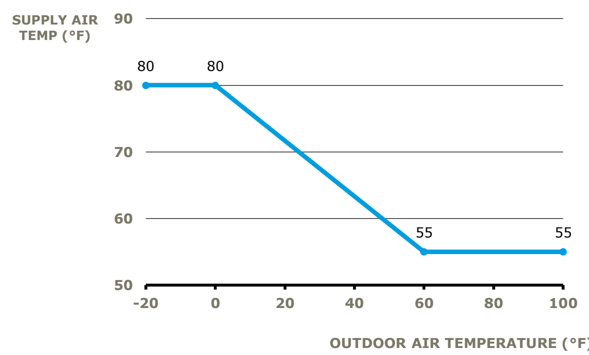

**POST-RETROFIT**
**SUPPLY AIR FLOW VS OUTDOOR AIR**



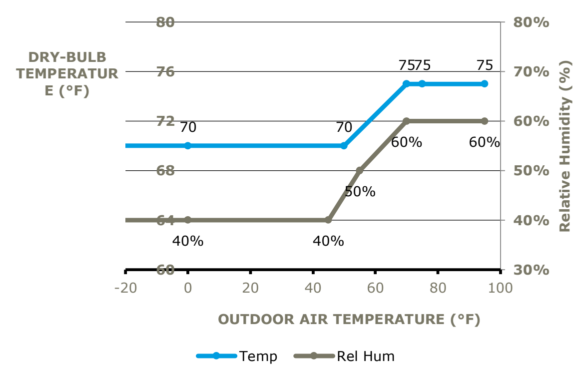

**BASELINE**
**SUPPLY AIR TEMPERATURE VS OUTDOOR AIR**



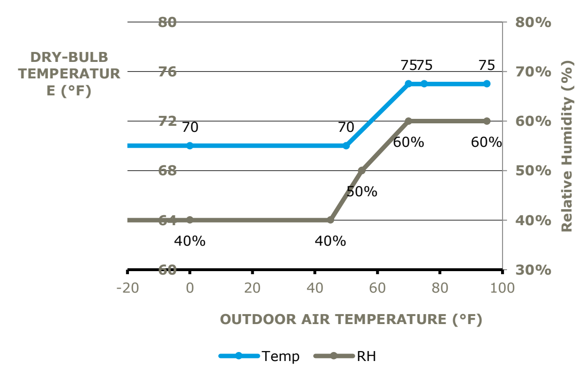

**POST-RETROFIT**
**SUPPLY AIR TEMPERATURE VS OUTDOOR AIR**




**BASELINE RETURN AIR CONDITIONS**




**BASELINE RETURN AIR CONDITIONS**



## SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - COOPER DINING HALL

### Baseline Hourly Fraction of Design Outdoor Air Flow

| | Weekday | | Weekend | |
|---|---|---|---|---|
| Hour Beginning | Unit On/Off | Outdoor Air | Unit On/Off | Outdoor Air |
| 0 | 1 | 100% | 1 | 100% |
| 1 | 1 | 100% | 1 | 100% |
| 2 | 1 | 100% | 1 | 100% |
| 3 | 1 | 100% | 1 | 100% |
| 4 | 1 | 100% | 1 | 100% |
| 5 | 1 | 100% | 1 | 100% |
| 6 | 1 | 100% | 1 | 100% |
| 7 | 1 | 100% | 1 | 100% |
| 8 | 1 | 100% | 1 | 100% |
| 9 | 1 | 100% | 1 | 100% |
| 10 | 1 | 100% | 1 | 100% |
| 11 | 1 | 100% | 1 | 100% |
| 12 | 1 | 100% | 1 | 100% |
| 13 | 1 | 100% | 1 | 100% |
| 14 | 1 | 100% | 1 | 100% |
| 15 | 1 | 100% | 1 | 100% |
| 16 | 1 | 100% | 1 | 100% |
| 17 | 1 | 100% | 1 | 100% |
| 18 | 1 | 100% | 1 | 100% |
| 19 | 1 | 100% | 1 | 100% |
| 20 | 1 | 100% | 1 | 100% |
| 21 | 1 | 100% | 1 | 100% |
| 22 | 1 | 100% | 1 | 100% |
| 23 | 1 | 100% | 1 | 100% |

### Post-Retrofit Hourly Fraction of Design Outdoor Air Flow

| | Weekday | | Weekend | |
|---|---|---|---|---|
| Hour Beginning | Unit On/Off | Outdoor Air | Unit On/Off | Outdoor Air |
| 0 | 1 | 19% | 1 | 19% |
| 1 | 1 | 19% | 1 | 19% |
| 2 | 1 | 19% | 1 | 19% |
| 3 | 1 | 19% | 1 | 19% |
| 4 | 1 | 19% | 1 | 19% |
| 5 | 1 | 23% | 1 | 19% |
| 6 | 1 | 27% | 1 | 19% |
| 7 | 1 | 52% | 1 | 19% |
| 8 | 1 | 52% | 1 | 23% |
| 9 | 1 | 52% | 1 | 27% |
| 10 | 1 | 35% | 1 | 56% |
| 11 | 1 | 60% | 1 | 60% |
| 12 | 1 | 84% | 1 | 60% |
| 13 | 1 | 76% | 1 | 48% |
| 14 | 1 | 52% | 1 | 44% |
| 15 | 1 | 35% | 1 | 35% |
| 16 | 1 | 40% | 1 | 76% |
| 17 | 1 | 60% | 1 | 92% |
| 18 | 1 | 84% | 1 | 76% |
| 19 | 1 | 84% | 1 | 72% |
| 20 | 1 | 60% | 1 | 48% |
| 21 | 1 | 27% | 1 | 27% |
| 22 | 1 | 23% | 1 | 23% |
| 23 | 1 | 19% | 1 | 19% |

# RESULTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - COOPER DINING HALL

## Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 744 | 20,700 | 8,820 | 0 | 3,747 |
| **Feb** | 25.4 | 672 | 20,700 | 8,745 | 0 | 3,477 |
| **Mar** | 37.4 | 744 | 20,700 | 9,990 | 1,835 | 2,231 |
| **Apr** | 47.9 | 720 | 20,700 | 12,093 | 2,945 | 850 |
| **May** | 59.9 | 432 | 20,700 | 15,681 | 5,056 | 90 |
| **Jun** | 66.4 | 0 | 20,700 | 14,370 | 0 | 0 |
| **Jul** | 71.8 | 0 | 20,700 | 15,226 | 0 | 0 |
| **Aug** | 68.0 | 144 | 20,700 | 13,337 | 5,452 | 0 |
| **Sep** | 60.7 | 720 | 20,700 | 10,777 | 12,607 | 121 |
| **Oct** | 49.5 | 744 | 20,700 | 8,792 | 1,959 | 502 |
| **Nov** | 40.9 | 720 | 20,700 | 11,373 | 734 | 1,522 |
| **Dec** | 27.7 | 744 | 0 | 0 | 0 | 3,449 |
| **Annual** | **48.6** | **6,384** | **0** | **0** | **30,588** | **15,988** |

## Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 744 | 20,700 | 3,585 | 0 | 1,320 |
| **Feb** | 25.4 | 672 | 20,700 | 3,824 | 0 | 1,404 |
| **Mar** | 37.4 | 744 | 20,700 | 6,094 | 1,906 | 665 |
| **Apr** | 47.9 | 720 | 20,700 | 9,845 | 2,989 | 127 |
| **May** | 59.9 | 432 | 20,700 | 14,678 | 5,093 | 2 |
| **Jun** | 66.4 | 0 | 20,700 | 12,343 | 0 | 0 |
| **Jul** | 71.8 | 0 | 20,700 | 13,866 | 0 | 0 |
| **Aug** | 68.0 | 144 | 20,700 | 12,075 | 5,226 | 0 |
| **Sep** | 60.7 | 720 | 20,700 | 7,816 | 12,272 | 3 |
| **Oct** | 49.5 | 744 | 20,700 | 3,125 | 1,959 | 45 |
| **Nov** | 40.9 | 720 | 20,700 | 8,129 | 754 | 387 |
| **Dec** | 27.7 | 744 | 0 | 0 | 0 | 926 |
| **Annual** | **48.6** | **6,384** | **0** | **0** | **30,199** | **4,878** |

## Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | - | 0 | 0 | 5,235 | 0 | 2,426 |
| **Feb** | - | 0 | 0 | 4,921 | 0 | 2,073 |
| **Mar** | - | 0 | 0 | 3,896 | -71 | 1,566 |
| **Apr** | - | 0 | 0 | 2,247 | -44 | 723 |
| **May** | - | 0 | 0 | 1,003 | -37 | 88 |
| **Jun** | - | 0 | 0 | 2,027 | 0 | 0 |
| **Jul** | - | 0 | 0 | 1,359 | 0 | 0 |
| **Aug** | - | 0 | 0 | 1,262 | 226 | 0 |
| **Sep** | - | 0 | 0 | 2,961 | 336 | 118 |
| **Oct** | - | 0 | 0 | 5,667 | 0 | 457 |
| **Nov** | - | 0 | 0 | 3,244 | -20 | 1,136 |
| **Dec** | - | 0 | 0 | 0 | 0 | 2,523 |
| **Annual** | **-** | **0** | **0** | **0** | **389** | **11,110** |

1. Average air flow rates over hours when fan operates, including economizer operation.

## SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - LAKER HALL

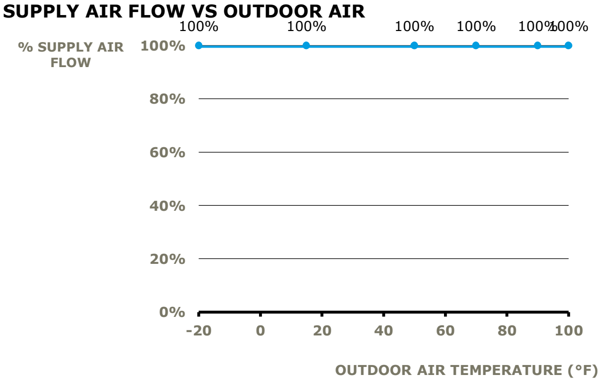
**Baseline**

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM |
|---|---|---|
| HV-7 | 29,000 | 5,800 |
| **Total** | **29,000** | **5,800** |

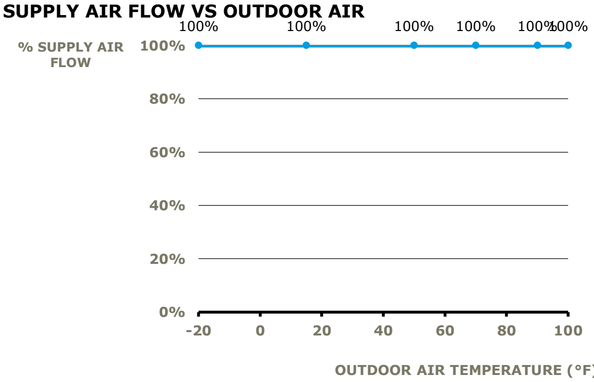
**Post-Retrofit**

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM | DCV Minimum Outdoor Air Flow CFM |
|---|---|---|---|
| HV-7 | 29,000 | 5,800 | 1,260 |
| **Total** | **29,000** | **5,800** | **1,260** |

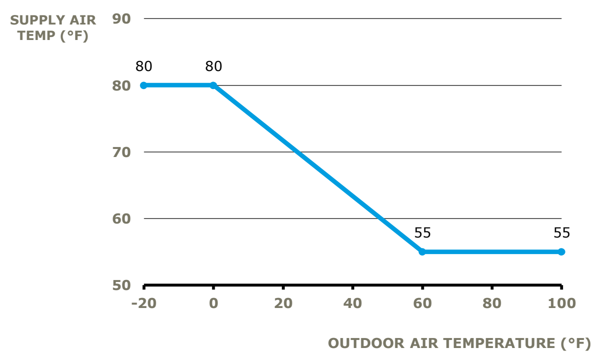
**BASELINE**
**SUPPLY AIR FLOW VS OUTDOOR AIR**



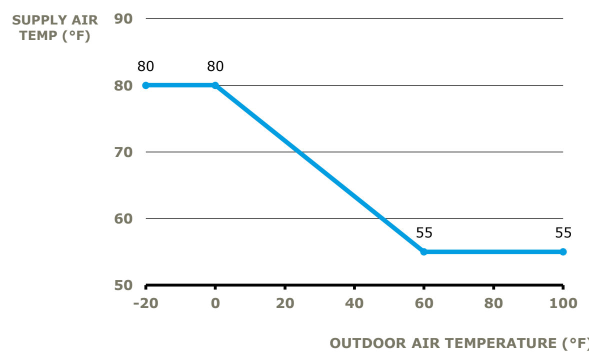

**POST-RETROFIT**
**SUPPLY AIR FLOW VS OUTDOOR AIR**



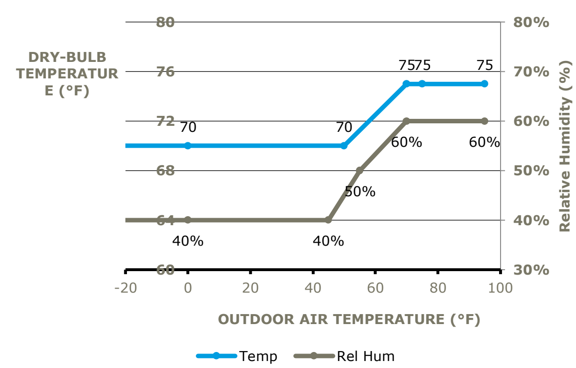

**BASELINE**
**SUPPLY AIR TEMPERATURE VS OUTDOOR AIR**



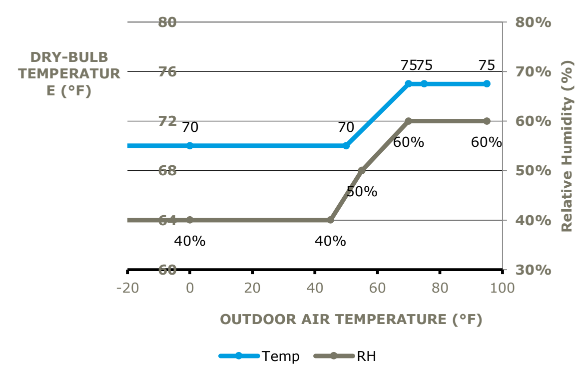

**POST-RETROFIT**
**SUPPLY AIR TEMPERATURE VS OUTDOOR AIR**




**BASELINE RETURN AIR CONDITIONS**




**BASELINE RETURN AIR CONDITIONS**



## SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - LAKER HALL

### Baseline Hourly Fraction of Design Outdoor Air Flow

| | Weekday | | Weekend | |
|---|---|---|---|---|
| Hour Beginning | Unit On/Off | Outdoor Air | Unit On/Off | Outdoor Air |
| 0 | 0 | 0% | 0 | 0% |
| 1 | 0 | 0% | 0 | 0% |
| 2 | 0 | 0% | 0 | 0% |
| 3 | 0 | 0% | 0 | 0% |
| 4 | 0 | 0% | 0 | 0% |
| 5 | 0 | 0% | 0 | 0% |
| 6 | 0 | 0% | 0 | 0% |
| 7 | 1 | 100% | 0 | 0% |
| 8 | 1 | 100% | 0 | 0% |
| 9 | 1 | 100% | 1 | 100% |
| 10 | 1 | 100% | 1 | 100% |
| 11 | 1 | 100% | 1 | 100% |
| 12 | 1 | 100% | 1 | 100% |
| 13 | 1 | 100% | 1 | 100% |
| 14 | 1 | 100% | 1 | 100% |
| 15 | 1 | 100% | 1 | 100% |
| 16 | 1 | 100% | 1 | 100% |
| 17 | 1 | 100% | 1 | 100% |
| 18 | 1 | 100% | 1 | 100% |
| 19 | 1 | 100% | 1 | 100% |
| 20 | 1 | 100% | 1 | 100% |
| 21 | 1 | 100% | 1 | 100% |
| 22 | 1 | 100% | 0 | 0% |
| 23 | 0 | 0% | 0 | 0% |

### Post-Retrofit Hourly Fraction of Design Outdoor Air Flow

| | Weekday | | Weekend | |
|---|---|---|---|---|
| Hour Beginning | Unit On/Off | Outdoor Air | Unit On/Off | Outdoor Air |
| 0 | 0 | 0% | 0 | 0% |
| 1 | 0 | 0% | 0 | 0% |
| 2 | 0 | 0% | 0 | 0% |
| 3 | 0 | 0% | 0 | 0% |
| 4 | 0 | 0% | 0 | 0% |
| 5 | 0 | 0% | 0 | 0% |
| 6 | 0 | 0% | 0 | 0% |
| 7 | 1 | 25% | 0 | 0% |
| 8 | 1 | 25% | 0 | 0% |
| 9 | 1 | 25% | 1 | 25% |
| 10 | 1 | 23% | 1 | 28% |
| 11 | 1 | 23% | 1 | 28% |
| 12 | 1 | 23% | 1 | 28% |
| 13 | 1 | 23% | 1 | 28% |
| 14 | 1 | 23% | 1 | 28% |
| 15 | 1 | 25% | 1 | 28% |
| 16 | 1 | 28% | 1 | 28% |
| 17 | 1 | 28% | 1 | 28% |
| 18 | 1 | 28% | 1 | 28% |
| 19 | 1 | 28% | 1 | 28% |
| 20 | 1 | 28% | 1 | 25% |
| 21 | 1 | 25% | 1 | 25% |
| 22 | 1 | 23% | 0 | 0% |
| 23 | 0 | 0% | 0 | 0% |

# RESULTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - LAKER HALL

## Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 457 | 29,000 | 6,344 | 0 | 1,409 |
| **Feb** | 25.4 | 424 | 29,000 | 5,992 | 0 | 1,324 |
| **Mar** | 37.4 | 451 | 29,000 | 9,531 | 0 | 615 |
| **Apr** | 47.9 | 450 | 29,000 | 15,409 | 0 | 103 |
| **May** | 59.9 | 454 | 29,000 | 21,233 | 0 | 1 |
| **Jun** | 66.4 | 450 | 29,000 | 15,797 | 0 | 0 |
| **Jul** | 71.8 | 469 | 29,000 | 12,280 | 0 | 0 |
| **Aug** | 68.0 | 454 | 29,000 | 15,748 | 0 | 0 |
| **Sep** | 60.7 | 447 | 29,000 | 20,035 | 0 | 1 |
| **Oct** | 49.5 | 466 | 29,000 | 18,862 | 0 | 29 |
| **Nov** | 40.9 | 444 | 29,000 | 11,818 | 0 | 375 |
| **Dec** | 27.7 | 433 | 29,000 | 6,241 | 0 | 1,173 |
| **Annual** | **48.6** | **5,399** | **29,000** | **13,340** | **0** | **5,030** |

## Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 457 | 29,000 | 3,011 | 0 | 408 |
| **Feb** | 25.4 | 424 | 29,000 | 2,502 | 0 | 366 |
| **Mar** | 37.4 | 451 | 29,000 | 7,607 | 0 | 148 |
| **Apr** | 47.9 | 450 | 29,000 | 14,616 | 0 | 1 |
| **May** | 59.9 | 454 | 29,000 | 20,144 | 0 | 0 |
| **Jun** | 66.4 | 450 | 29,000 | 13,503 | 0 | 0 |
| **Jul** | 71.8 | 469 | 29,000 | 9,163 | 0 | 0 |
| **Aug** | 68.0 | 454 | 29,000 | 13,271 | 0 | 0 |
| **Sep** | 60.7 | 447 | 29,000 | 18,849 | 0 | 0 |
| **Oct** | 49.5 | 466 | 29,000 | 18,746 | 0 | 0 |
| **Nov** | 40.9 | 444 | 29,000 | 10,636 | 0 | 69 |
| **Dec** | 27.7 | 433 | 29,000 | 3,167 | 0 | 316 |
| **Annual** | **48.6** | **5,399** | **29,000** | **11,344** | **0** | **1,308** |

## Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | - | 0 | 0 | 3,332 | 0 | 1,001 |
| **Feb** | - | 0 | 0 | 3,490 | 0 | 959 |
| **Mar** | - | 0 | 0 | 1,924 | 0 | 467 |
| **Apr** | - | 0 | 0 | 793 | 0 | 102 |
| **May** | - | 0 | 0 | 1,089 | 0 | 1 |
| **Jun** | - | 0 | 0 | 2,294 | 0 | 0 |
| **Jul** | - | 0 | 0 | 3,117 | 0 | 0 |
| **Aug** | - | 0 | 0 | 2,477 | 0 | 0 |
| **Sep** | - | 0 | 0 | 1,186 | 0 | 1 |
| **Oct** | - | 0 | 0 | 116 | 0 | 29 |
| **Nov** | - | 0 | 0 | 1,182 | 0 | 306 |
| **Dec** | - | 0 | 0 | 3,075 | 0 | 857 |
| **Annual** | **-** | **0** | **0** | **1,997** | **0** | **3,723** |

1. Average air flow rates over hours when fan operates, including economizer operation.

# SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - LAKER HALL

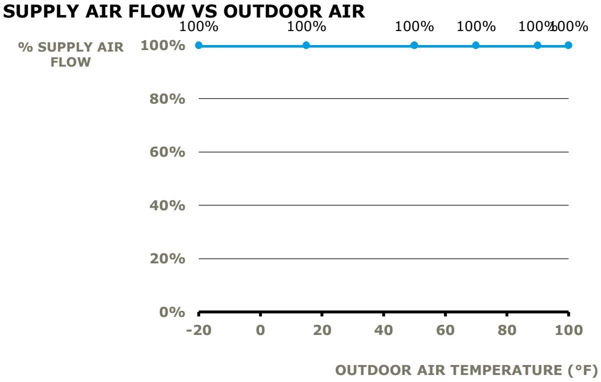
## Baseline

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM |
|---|---|---|
| HV-4 | 30,000 | 12,500 |
| HV-5 | 30,000 | 12,500 |
| HV-6 | 30,000 | 12,500 |
| **Total** | **90,000** | **37,500** |

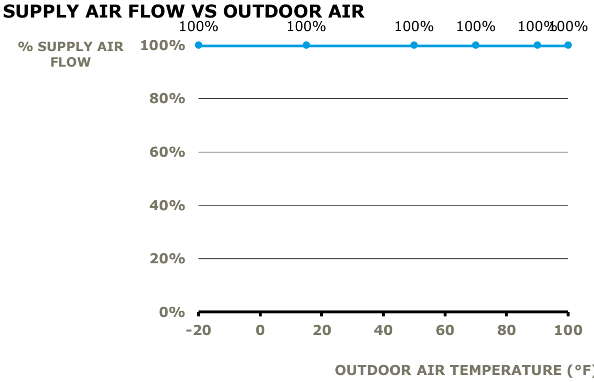
## Post-Retrofit

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM | DCV Minimum Outdoor Air Flow CFM |
|---|---|---|---|
| HV-4 | 30,000 | 12,500 | 1,320 |
| HV-5 | 30,000 | 12,500 | 1,320 |
| HV-6 | 30,000 | 12,500 | 1,320 |
| **Total** | **90,000** | **37,500** | **3,960** |

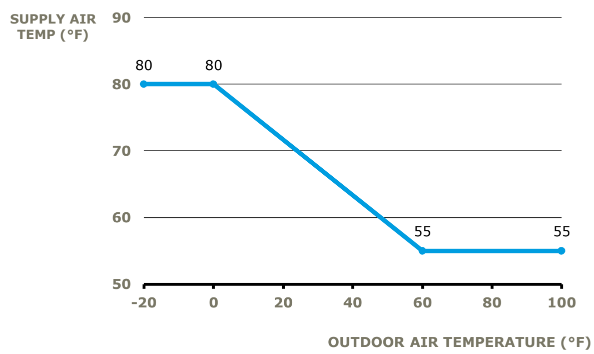
**BASELINE**
**SUPPLY AIR FLOW VS OUTDOOR AIR**



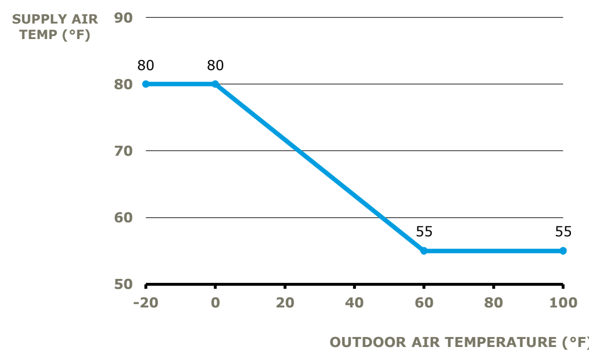

**POST-RETROFIT**
**SUPPLY AIR FLOW VS OUTDOOR AIR**



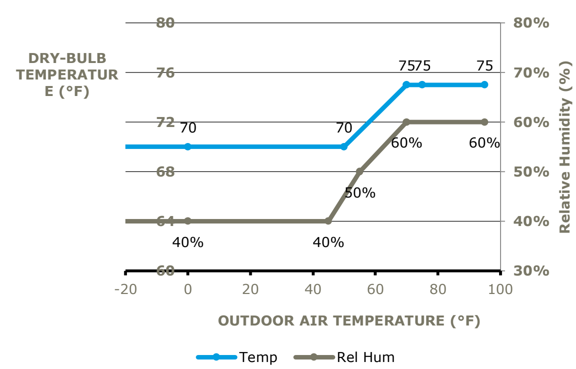

**BASELINE**
**SUPPLY AIR TEMPERATURE VS OUTDOOR AIR**



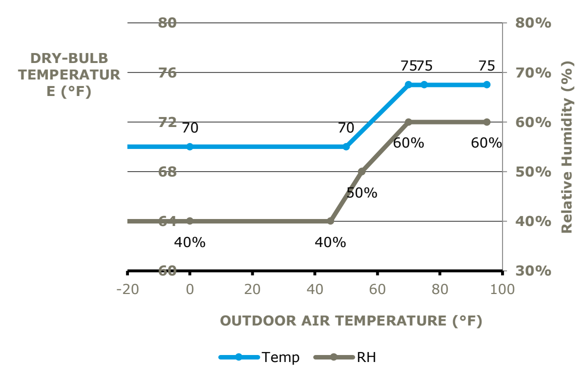

**POST-RETROFIT**
**SUPPLY AIR TEMPERATURE VS OUTDOOR AIR**




**BASELINE RETURN AIR CONDITIONS**




**BASELINE RETURN AIR CONDITIONS**



## SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - LAKER HALL

**Baseline Hourly Fraction of Design Outdoor Air Flow**

| | Weekday | | Weekend | |
|---|---|---|---|---|
| Hour Beginning | Unit On/Off | Outdoor Air | Unit On/Off | Outdoor Air |
| 0 | 0 | 0% | 0 | 0% |
| 1 | 0 | 0% | 0 | 0% |
| 2 | 0 | 0% | 0 | 0% |
| 3 | 0 | 0% | 0 | 0% |
| 4 | 0 | 0% | 0 | 0% |
| 5 | 0 | 0% | 0 | 0% |
| 6 | 0 | 0% | 0 | 0% |
| 7 | 1 | 100% | 0 | 0% |
| 8 | 1 | 100% | 0 | 0% |
| 9 | 1 | 100% | 1 | 100% |
| 10 | 1 | 100% | 1 | 100% |
| 11 | 1 | 100% | 1 | 100% |
| 12 | 1 | 100% | 1 | 100% |
| 13 | 1 | 100% | 1 | 100% |
| 14 | 1 | 100% | 1 | 100% |
| 15 | 1 | 100% | 1 | 100% |
| 16 | 1 | 100% | 1 | 100% |
| 17 | 1 | 100% | 1 | 100% |
| 18 | 1 | 100% | 1 | 100% |
| 19 | 1 | 100% | 1 | 100% |
| 20 | 1 | 100% | 1 | 100% |
| 21 | 1 | 100% | 1 | 100% |
| 22 | 1 | 100% | 0 | 0% |
| 23 | 0 | 0% | 0 | 0% |

**Post-Retrofit Hourly Fraction of Design Outdoor Air Flow**

| | Weekday | | Weekend | |
|---|---|---|---|---|
| Hour Beginning | Unit On/Off | Outdoor Air | Unit On/Off | Outdoor Air |
| 0 | 0 | 0% | 0 | 0% |
| 1 | 0 | 0% | 0 | 0% |
| 2 | 0 | 0% | 0 | 0% |
| 3 | 0 | 0% | 0 | 0% |
| 4 | 0 | 0% | 0 | 0% |
| 5 | 0 | 0% | 0 | 0% |
| 6 | 0 | 0% | 0 | 0% |
| 7 | 1 | 12% | 0 | 0% |
| 8 | 1 | 12% | 0 | 0% |
| 9 | 1 | 12% | 1 | 12% |
| 10 | 1 | 12% | 1 | 13% |
| 11 | 1 | 12% | 1 | 13% |
| 12 | 1 | 12% | 1 | 13% |
| 13 | 1 | 12% | 1 | 13% |
| 14 | 1 | 12% | 1 | 13% |
| 15 | 1 | 12% | 1 | 13% |
| 16 | 1 | 13% | 1 | 13% |
| 17 | 1 | 13% | 1 | 13% |
| 18 | 1 | 13% | 1 | 13% |
| 19 | 1 | 13% | 1 | 13% |
| 20 | 1 | 13% | 1 | 12% |
| 21 | 1 | 12% | 1 | 12% |
| 22 | 1 | 12% | 0 | 0% |
| 23 | 0 | 0% | 0 | 0% |

## RESULTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - LAKER HALL

### Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 457 | 90,000 | 38,130 | 0 | 9,653 |
| **Feb** | 25.4 | 424 | 90,000 | 37,594 | 0 | 9,140 |
| **Mar** | 37.4 | 451 | 90,000 | 43,421 | 0 | 5,120 |
| **Apr** | 47.9 | 450 | 90,000 | 55,672 | 0 | 1,692 |
| **May** | 59.9 | 454 | 90,000 | 71,040 | 0 | 74 |
| **Jun** | 66.4 | 450 | 90,000 | 59,482 | 0 | 10 |
| **Jul** | 71.8 | 469 | 90,000 | 52,164 | 0 | 0 |
| **Aug** | 68.0 | 454 | 90,000 | 59,955 | 0 | 0 |
| **Sep** | 60.7 | 447 | 90,000 | 67,828 | 0 | 68 |
| **Oct** | 49.5 | 466 | 90,000 | 61,715 | 0 | 776 |
| **Nov** | 40.9 | 444 | 90,000 | 47,467 | 0 | 3,695 |
| **Dec** | 27.7 | 433 | 90,000 | 37,954 | 0 | 8,530 |
| **Annual** | **48.6** | **5,399** | **90,000** | **52,842** | **0** | **38,759** |

### Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 457 | 90,000 | 9,452 | 0 | 1,301 |
| **Feb** | 25.4 | 424 | 90,000 | 7,902 | 0 | 1,174 |
| **Mar** | 37.4 | 451 | 90,000 | 23,679 | 0 | 476 |
| **Apr** | 47.9 | 450 | 90,000 | 45,386 | 0 | 4 |
| **May** | 59.9 | 454 | 90,000 | 62,563 | 0 | 0 |
| **Jun** | 66.4 | 450 | 90,000 | 42,018 | 0 | 0 |
| **Jul** | 71.8 | 469 | 90,000 | 28,596 | 0 | 0 |
| **Aug** | 68.0 | 454 | 90,000 | 41,317 | 0 | 0 |
| **Sep** | 60.7 | 447 | 90,000 | 58,558 | 0 | 0 |
| **Oct** | 49.5 | 466 | 90,000 | 58,177 | 0 | 0 |
| **Nov** | 40.9 | 444 | 90,000 | 33,038 | 0 | 223 |
| **Dec** | 27.7 | 433 | 90,000 | 9,897 | 0 | 1,002 |
| **Annual** | **48.6** | **5,399** | **90,000** | **35,283** | **0** | **4,179** |

### Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | - | 0 | 0 | 28,678 | 0 | 8,352 |
| **Feb** | - | 0 | 0 | 29,692 | 0 | 7,966 |
| **Mar** | - | 0 | 0 | 19,742 | 0 | 4,644 |
| **Apr** | - | 0 | 0 | 10,287 | 0 | 1,689 |
| **May** | - | 0 | 0 | 8,477 | 0 | 74 |
| **Jun** | - | 0 | 0 | 17,464 | 0 | 10 |
| **Jul** | - | 0 | 0 | 23,568 | 0 | 0 |
| **Aug** | - | 0 | 0 | 18,638 | 0 | 0 |
| **Sep** | - | 0 | 0 | 9,270 | 0 | 68 |
| **Oct** | - | 0 | 0 | 3,538 | 0 | 776 |
| **Nov** | - | 0 | 0 | 14,429 | 0 | 3,473 |
| **Dec** | - | 0 | 0 | 28,058 | 0 | 7,528 |
| **Annual** | **-** | **0** | **0** | **17,559** | **0** | **34,580** |

1. Average air flow rates over hours when fan operates, including economizer operation.

## SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - LANIGAN HALL

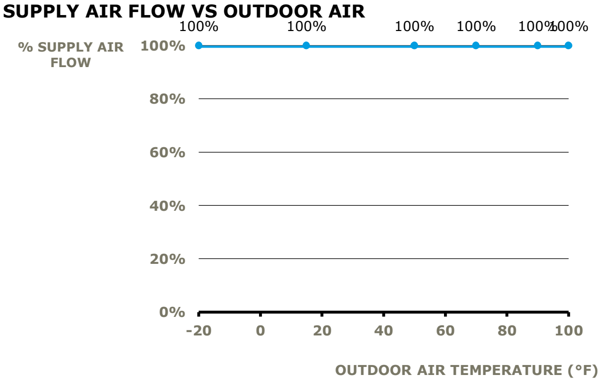
**Baseline**

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM |
|---|---|---|
| AC-3 | 12,350 | 3,549 |
| **Total** | **12,350** | **3,549** |

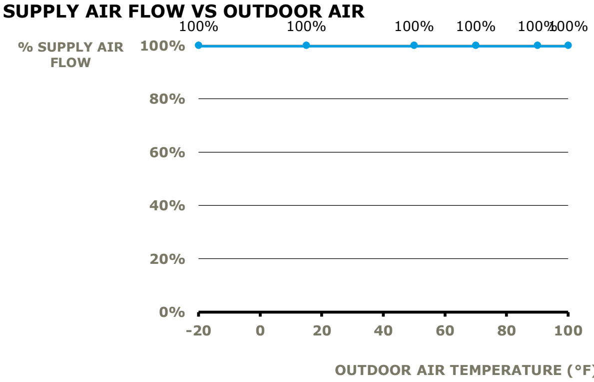
**Post-Retrofit**

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM | DCV Minimum Outdoor Air Flow CFM |
|---|---|---|---|
| AC-3 | 12,350 | 3,549 | 324 |
| **Total** | **12,350** | **3,549** | **324** |

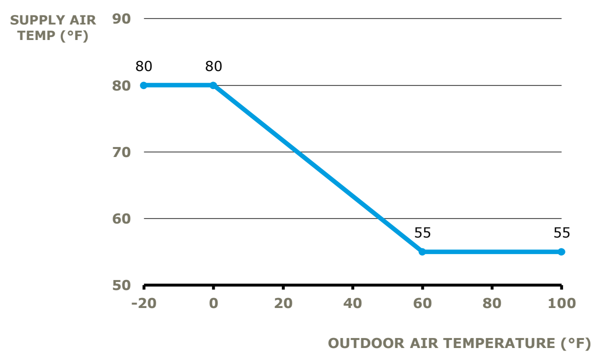
### BASELINE
### SUPPLY AIR FLOW VS OUTDOOR AIR



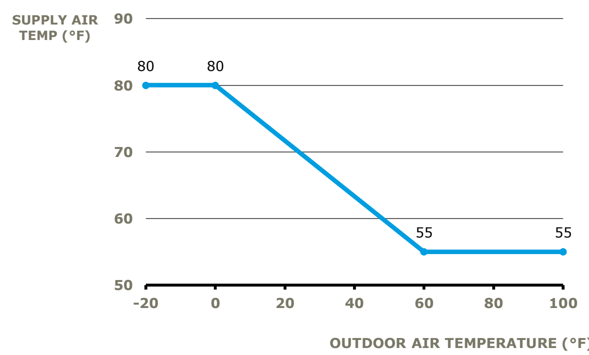

### POST-RETROFIT
### SUPPLY AIR FLOW VS OUTDOOR AIR



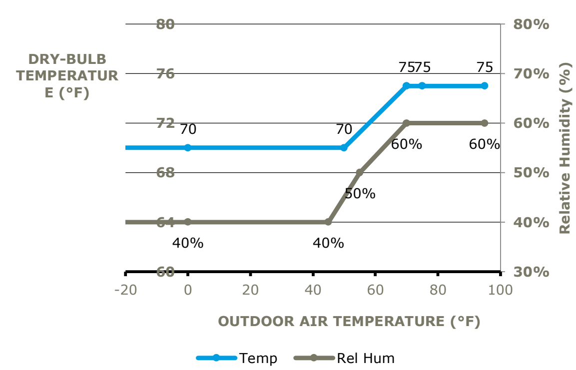

### BASELINE
### SUPPLY AIR TEMPERATURE VS OUTDOOR AIR



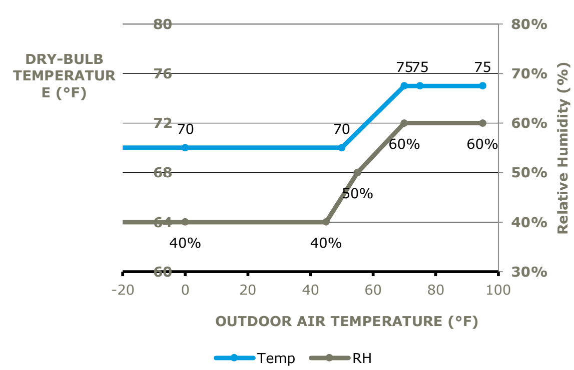

### POST-RETROFIT
### SUPPLY AIR TEMPERATURE VS OUTDOOR AIR




### BASELINE RETURN AIR CONDITIONS




### BASELINE RETURN AIR CONDITIONS



## SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - LANIGAN HALL

**Baseline Hourly Fraction of Design Outdoor Air Flow**

| | Weekday | | Weekend | |
|---|---|---|---|---|
| **Hour Beginning** | **Unit On/Off** | **Outdoor Air** | **Unit On/Off** | **Outdoor Air** |
| 0 | 0 | 0% | 0 | 0% |
| 1 | 0 | 0% | 0 | 0% |
| 2 | 0 | 0% | 0 | 0% |
| 3 | 0 | 0% | 0 | 0% |
| 4 | 0 | 0% | 0 | 0% |
| 5 | 0 | 0% | 0 | 0% |
| 6 | 0 | 0% | 0 | 0% |
| 7 | 1 | 100% | 0 | 0% |
| 8 | 1 | 100% | 0 | 0% |
| 9 | 1 | 100% | 0 | 0% |
| 10 | 1 | 100% | 0 | 0% |
| 11 | 1 | 100% | 0 | 0% |
| 12 | 1 | 100% | 0 | 0% |
| 13 | 1 | 100% | 0 | 0% |
| 14 | 1 | 100% | 0 | 0% |
| 15 | 1 | 100% | 0 | 0% |
| 16 | 1 | 100% | 0 | 0% |
| 17 | 1 | 100% | 0 | 0% |
| 18 | 1 | 100% | 0 | 0% |
| 19 | 1 | 100% | 0 | 0% |
| 20 | 1 | 100% | 0 | 0% |
| 21 | 1 | 100% | 0 | 0% |
| 22 | 0 | 0% | 0 | 0% |
| 23 | 0 | 0% | 0 | 0% |

**Post-Retrofit Hourly Fraction of Design Outdoor Air Flow**

| | Weekday | | Weekend | |
|---|---|---|---|---|
| **Hour Beginning** | **Unit On/Off** | **Outdoor Air** | **Unit On/Off** | **Outdoor Air** |
| 0 | 0 | 0% | 0 | 0% |
| 1 | 0 | 0% | 0 | 0% |
| 2 | 0 | 0% | 0 | 0% |
| 3 | 0 | 0% | 0 | 0% |
| 4 | 0 | 0% | 0 | 0% |
| 5 | 0 | 0% | 0 | 0% |
| 6 | 0 | 0% | 0 | 0% |
| 7 | 1 | 9% | 0 | 0% |
| 8 | 1 | 95% | 0 | 0% |
| 9 | 1 | 95% | 0 | 0% |
| 10 | 1 | 95% | 0 | 0% |
| 11 | 1 | 95% | 0 | 0% |
| 12 | 1 | 95% | 0 | 0% |
| 13 | 1 | 95% | 0 | 0% |
| 14 | 1 | 95% | 0 | 0% |
| 15 | 1 | 95% | 0 | 0% |
| 16 | 1 | 23% | 0 | 0% |
| 17 | 1 | 23% | 0 | 0% |
| 18 | 1 | 23% | 0 | 0% |
| 19 | 1 | 23% | 0 | 0% |
| 20 | 1 | 23% | 0 | 0% |
| 21 | 1 | 9% | 0 | 0% |
| 22 | 0 | 0% | 0 | 0% |
| 23 | 0 | 0% | 0 | 0% |

# RESULTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - LANIGAN HALL

## Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 270 | 12,350 | 3,797 | 0 | 491 |
| **Feb** | 25.4 | 300 | 12,350 | 3,607 | 0 | 586 |
| **Mar** | 37.4 | 240 | 12,350 | 4,712 | 681 | 276 |
| **Apr** | 47.9 | 300 | 12,350 | 6,907 | 1,502 | 83 |
| **May** | 59.9 | 243 | 12,350 | 9,149 | 2,668 | 2 |
| **Jun** | 66.4 | 240 | 12,350 | 7,669 | 4,378 | 0 |
| **Jul** | 71.8 | 264 | 12,350 | 5,449 | 7,333 | 0 |
| **Aug** | 68.0 | 219 | 12,350 | 5,679 | 6,207 | 0 |
| **Sep** | 60.7 | 285 | 12,350 | 9,102 | 3,939 | 0 |
| **Oct** | 49.5 | 315 | 12,350 | 8,168 | 656 | 26 |
| **Nov** | 40.9 | 270 | 12,350 | 5,199 | 233 | 202 |
| **Dec** | 27.7 | 150 | 12,350 | 3,583 | 0 | 314 |
| **Annual** | **48.6** | **3,096** | **12,350** | **6,190** | **27,597** | **1,981** |

## Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 270 | 12,350 | 2,659 | 0 | 295 |
| **Feb** | 25.4 | 300 | 12,350 | 2,322 | 0 | 343 |
| **Mar** | 37.4 | 240 | 12,350 | 3,832 | 694 | 155 |
| **Apr** | 47.9 | 300 | 12,350 | 6,485 | 1,524 | 33 |
| **May** | 59.9 | 243 | 12,350 | 8,908 | 2,708 | 0 |
| **Jun** | 66.4 | 240 | 12,350 | 7,215 | 4,417 | 0 |
| **Jul** | 71.8 | 264 | 12,350 | 4,646 | 7,232 | 0 |
| **Aug** | 68.0 | 219 | 12,350 | 4,968 | 6,099 | 0 |
| **Sep** | 60.7 | 285 | 12,350 | 8,815 | 3,908 | 0 |
| **Oct** | 49.5 | 315 | 12,350 | 8,032 | 656 | 4 |
| **Nov** | 40.9 | 270 | 12,350 | 4,548 | 234 | 102 |
| **Dec** | 27.7 | 150 | 12,350 | 2,320 | 0 | 191 |
| **Annual** | **48.6** | **3,096** | **12,350** | **5,526** | **27,472** | **1,123** |

## Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | - | 0 | 0 | 1,138 | 0 | 196 |
| **Feb** | - | 0 | 0 | 1,285 | 0 | 243 |
| **Mar** | - | 0 | 0 | 880 | -13 | 121 |
| **Apr** | - | 0 | 0 | 422 | -22 | 50 |
| **May** | - | 0 | 0 | 241 | -40 | 2 |
| **Jun** | - | 0 | 0 | 454 | -39 | 0 |
| **Jul** | - | 0 | 0 | 803 | 101 | 0 |
| **Aug** | - | 0 | 0 | 711 | 108 | 0 |
| **Sep** | - | 0 | 0 | 287 | 31 | 0 |
| **Oct** | - | 0 | 0 | 136 | 0 | 21 |
| **Nov** | - | 0 | 0 | 651 | -1 | 100 |
| **Dec** | - | 0 | 0 | 1,263 | 0 | 124 |
| **Annual** | **-** | **0** | **0** | **664** | **125** | **858** |

1. Average air flow rates over hours when fan operates, including economizer operation.

# SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - LEE HALL

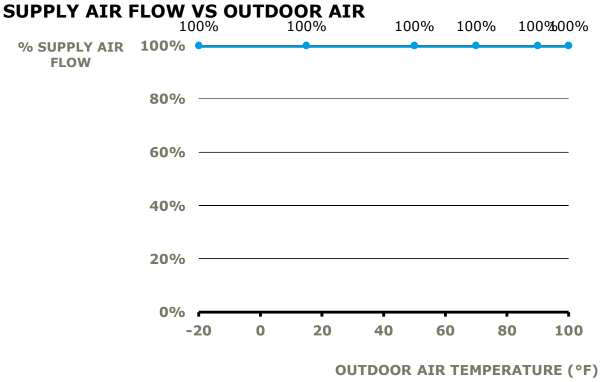
## Baseline

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM |
|---|---|---|
| HV-2 | 18,000 | 2,880 |
| **Total** | **18,000** | **2,880** |

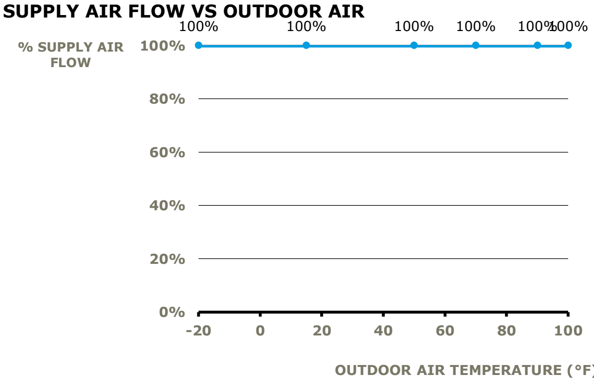
## Post-Retrofit

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM | DCV Minimum Outdoor Air Flow CFM |
|---|---|---|---|
| HV-2 | 18,000 | 2,880 | 1,620 |
| **Total** | **18,000** | **2,880** | **1,620** |

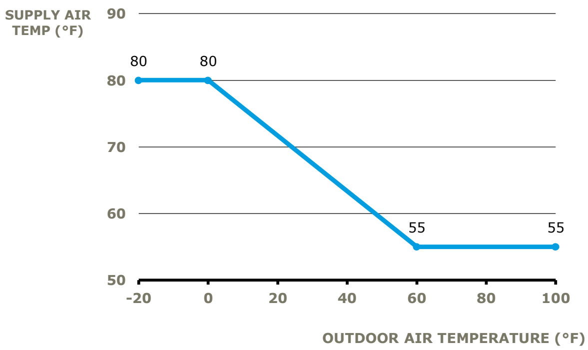
**BASELINE**
**SUPPLY AIR FLOW VS OUTDOOR AIR**



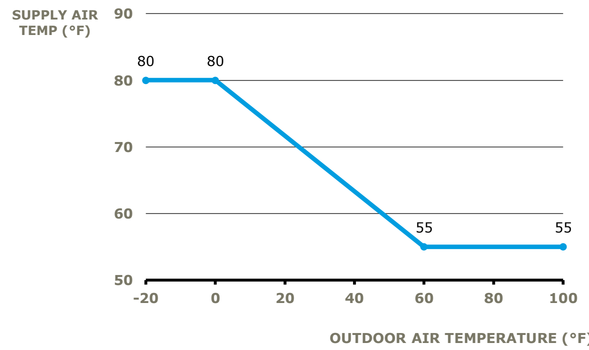

**POST-RETROFIT**
**SUPPLY AIR FLOW VS OUTDOOR AIR**



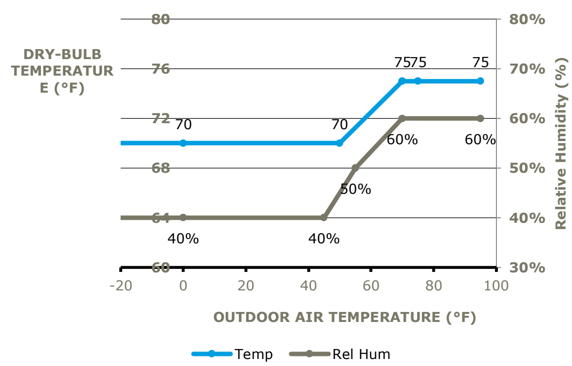

**BASELINE**
**SUPPLY AIR TEMPERATURE VS OUTDOOR AIR**



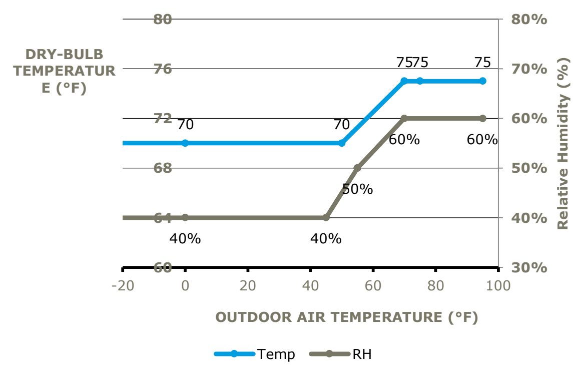

**POST-RETROFIT**
**SUPPLY AIR TEMPERATURE VS OUTDOOR AIR**




**BASELINE RETURN AIR CONDITIONS**




**BASELINE RETURN AIR CONDITIONS**



## SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - LEE HALL

### Baseline Hourly Fraction of Design Outdoor Air Flow

| | Weekday | | Weekend | |
|---|---|---|---|---|
| Hour Beginning | Unit On/Off | Outdoor Air | Unit On/Off | Outdoor Air |
| 0 | 0 | 0% | 0 | 0% |
| 1 | 0 | 0% | 0 | 0% |
| 2 | 0 | 0% | 0 | 0% |
| 3 | 0 | 0% | 0 | 0% |
| 4 | 0 | 0% | 0 | 0% |
| 5 | 0 | 0% | 0 | 0% |
| 6 | 0 | 0% | 0 | 0% |
| 7 | 1 | 100% | 0 | 0% |
| 8 | 1 | 100% | 0 | 0% |
| 9 | 1 | 100% | 1 | 100% |
| 10 | 1 | 100% | 1 | 100% |
| 11 | 1 | 100% | 1 | 100% |
| 12 | 1 | 100% | 1 | 100% |
| 13 | 1 | 100% | 1 | 100% |
| 14 | 1 | 100% | 1 | 100% |
| 15 | 1 | 100% | 1 | 100% |
| 16 | 1 | 100% | 1 | 100% |
| 17 | 1 | 100% | 1 | 100% |
| 18 | 1 | 100% | 1 | 100% |
| 19 | 1 | 100% | 1 | 100% |
| 20 | 1 | 100% | 1 | 100% |
| 21 | 1 | 100% | 1 | 100% |
| 22 | 1 | 100% | 0 | 0% |
| 23 | 0 | 0% | 0 | 0% |

### Post-Retrofit Hourly Fraction of Design Outdoor Air Flow

| | Weekday | | Weekend | |
|---|---|---|---|---|
| Hour Beginning | Unit On/Off | Outdoor Air | Unit On/Off | Outdoor Air |
| 0 | 0 | 0% | 0 | 0% |
| 1 | 0 | 0% | 0 | 0% |
| 2 | 0 | 0% | 0 | 0% |
| 3 | 0 | 0% | 0 | 0% |
| 4 | 0 | 0% | 0 | 0% |
| 5 | 0 | 0% | 0 | 0% |
| 6 | 0 | 0% | 0 | 0% |
| 7 | 1 | 56% | 0 | 0% |
| 8 | 1 | 56% | 0 | 0% |
| 9 | 1 | 56% | 1 | 56% |
| 10 | 1 | 56% | 1 | 56% |
| 11 | 1 | 68% | 1 | 68% |
| 12 | 1 | 72% | 1 | 72% |
| 13 | 1 | 72% | 1 | 72% |
| 14 | 1 | 72% | 1 | 72% |
| 15 | 1 | 72% | 1 | 72% |
| 16 | 1 | 72% | 1 | 72% |
| 17 | 1 | 72% | 1 | 72% |
| 18 | 1 | 72% | 1 | 72% |
| 19 | 1 | 72% | 1 | 72% |
| 20 | 1 | 72% | 1 | 72% |
| 21 | 1 | 72% | 1 | 72% |
| 22 | 1 | 64% | 0 | 0% |
| 23 | 0 | 0% | 0 | 0% |

# RESULTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - LEE HALL

## Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 457 | 18,000 | 3,309 | 0 | 671 |
| **Feb** | 25.4 | 424 | 18,000 | 3,053 | 0 | 625 |
| **Mar** | 37.4 | 451 | 18,000 | 5,531 | 0 | 280 |
| **Apr** | 47.9 | 450 | 18,000 | 9,384 | 0 | 34 |
| **May** | 59.9 | 316 | 18,000 | 12,322 | 0 | 0 |
| **Jun** | 66.4 | 320 | 18,000 | 8,888 | 0 | 0 |
| **Jul** | 71.8 | 336 | 18,000 | 5,850 | 0 | 0 |
| **Aug** | 68.0 | 316 | 18,000 | 7,426 | 0 | 0 |
| **Sep** | 60.7 | 437 | 18,000 | 12,278 | 0 | 0 |
| **Oct** | 49.5 | 466 | 18,000 | 11,668 | 0 | 8 |
| **Nov** | 40.9 | 444 | 18,000 | 7,072 | 0 | 161 |
| **Dec** | 27.7 | 433 | 18,000 | 3,244 | 0 | 542 |
| **Annual** | **48.6** | **4,850** | **18,000** | **7,406** | **0** | **2,322** |

## Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 457 | 18,000 | 2,508 | 0 | 438 |
| **Feb** | 25.4 | 424 | 18,000 | 2,244 | 0 | 410 |
| **Mar** | 37.4 | 451 | 18,000 | 5,083 | 0 | 175 |
| **Apr** | 47.9 | 450 | 18,000 | 9,200 | 0 | 10 |
| **May** | 59.9 | 316 | 18,000 | 11,991 | 0 | 0 |
| **Jun** | 66.4 | 320 | 18,000 | 8,336 | 0 | 0 |
| **Jul** | 71.8 | 336 | 18,000 | 5,078 | 0 | 0 |
| **Aug** | 68.0 | 316 | 18,000 | 6,737 | 0 | 0 |
| **Sep** | 60.7 | 437 | 18,000 | 12,028 | 0 | 0 |
| **Oct** | 49.5 | 466 | 18,000 | 11,638 | 0 | 1 |
| **Nov** | 40.9 | 444 | 18,000 | 6,795 | 0 | 91 |
| **Dec** | 27.7 | 433 | 18,000 | 2,455 | 0 | 331 |
| **Annual** | **48.6** | **4,850** | **18,000** | **6,924** | **0** | **1,456** |

## Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | - | 0 | 0 | 801 | 0 | 233 |
| **Feb** | - | 0 | 0 | 809 | 0 | 215 |
| **Mar** | - | 0 | 0 | 448 | 0 | 105 |
| **Apr** | - | 0 | 0 | 184 | 0 | 24 |
| **May** | - | 0 | 0 | 330 | 0 | 0 |
| **Jun** | - | 0 | 0 | 552 | 0 | 0 |
| **Jul** | - | 0 | 0 | 772 | 0 | 0 |
| **Aug** | - | 0 | 0 | 689 | 0 | 0 |
| **Sep** | - | 0 | 0 | 250 | 0 | 0 |
| **Oct** | - | 0 | 0 | 30 | 0 | 7 |
| **Nov** | - | 0 | 0 | 277 | 0 | 70 |
| **Dec** | - | 0 | 0 | 790 | 0 | 212 |
| **Annual** | **-** | **0** | **0** | **482** | **0** | **866** |

1. Average air flow rates over hours when fan operates, including economizer operation.

## SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - PATHFINDER DINING HALL

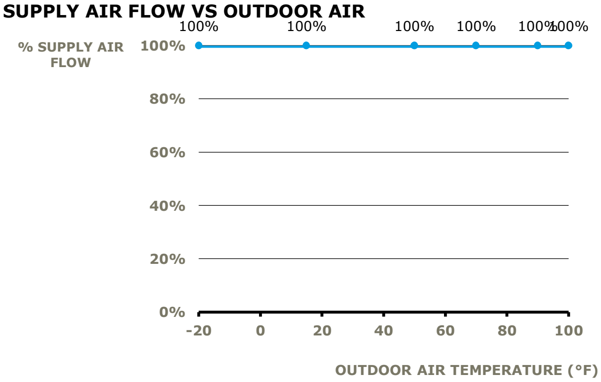
### Baseline

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM |
|---|---|---|
| SF-1 | 31,892 | 6,924 |
| **Total** | **31,892** | **6,924** |

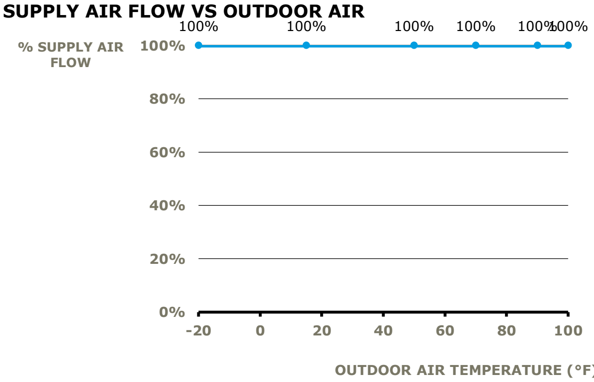
### Post-Retrofit

| Unit | Supply CFM | Minimum Outdoor Air Flow CFM | DCV Minimum Outdoor Air Flow CFM |
|---|---|---|---|
| SF-1 | 31,892 | 6,924 | 1,340 |
| **Total** | **31,892** | **6,924** | **1,340** |

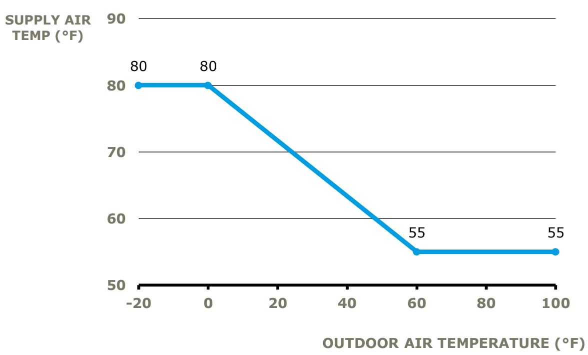
**BASELINE**
**SUPPLY AIR FLOW VS OUTDOOR AIR**



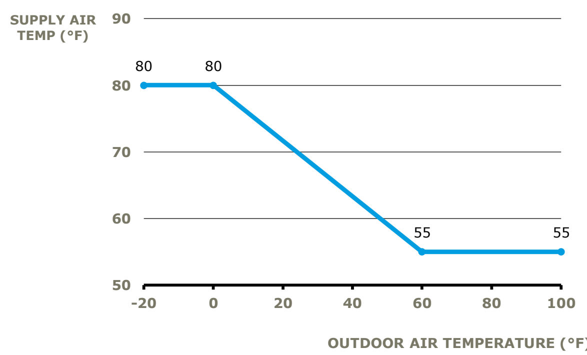

**POST-RETROFIT**
**SUPPLY AIR FLOW VS OUTDOOR AIR**



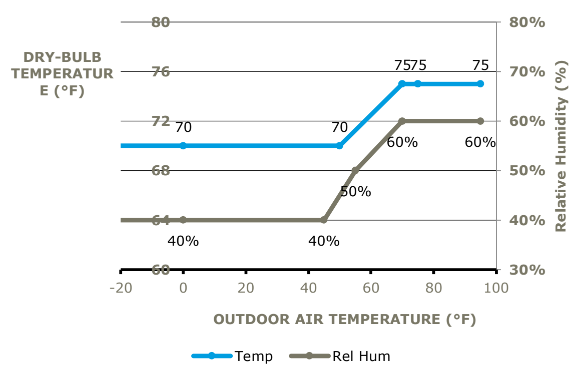

**BASELINE**
**SUPPLY AIR TEMPERATURE VS OUTDOOR AIR**



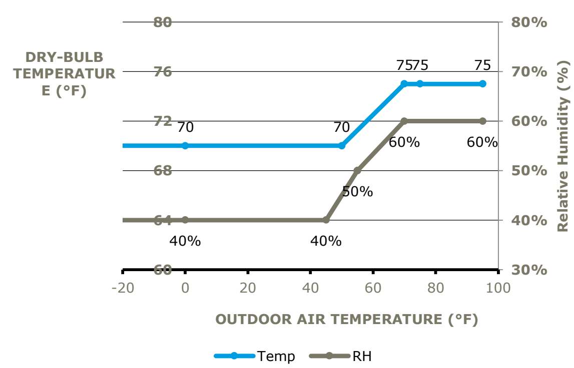

**POST-RETROFIT**
**SUPPLY AIR TEMPERATURE VS OUTDOOR AIR**




**BASELINE RETURN AIR CONDITIONS**




**BASELINE RETURN AIR CONDITIONS**



## SUMMARY INPUTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - PATHFINDER DINING HALL

**Baseline Hourly Fraction of Design Outdoor Air Flow**

| | Weekday | | Weekend | |
|---|---|---|---|---|
| **Hour Beginning** | **Unit On/Off** | **Outdoor Air** | **Unit On/Off** | **Outdoor Air** |
| 0 | 1 | 100% | 1 | 100% |
| 1 | 1 | 100% | 1 | 100% |
| 2 | 1 | 100% | 1 | 100% |
| 3 | 1 | 100% | 1 | 100% |
| 4 | 1 | 100% | 1 | 100% |
| 5 | 1 | 100% | 1 | 100% |
| 6 | 1 | 100% | 1 | 100% |
| 7 | 1 | 100% | 1 | 100% |
| 8 | 1 | 100% | 1 | 100% |
| 9 | 1 | 100% | 1 | 100% |
| 10 | 1 | 100% | 1 | 100% |
| 11 | 1 | 100% | 1 | 100% |
| 12 | 1 | 100% | 1 | 100% |
| 13 | 1 | 100% | 1 | 100% |
| 14 | 1 | 100% | 1 | 100% |
| 15 | 1 | 100% | 1 | 100% |
| 16 | 1 | 100% | 1 | 100% |
| 17 | 1 | 100% | 1 | 100% |
| 18 | 1 | 100% | 1 | 100% |
| 19 | 1 | 100% | 1 | 100% |
| 20 | 1 | 100% | 1 | 100% |
| 21 | 1 | 100% | 1 | 100% |
| 22 | 1 | 100% | 1 | 100% |
| 23 | 1 | 100% | 1 | 100% |

**Post-Retrofit Hourly Fraction of Design Outdoor Air Flow**

| | Weekday | | Weekend | |
|---|---|---|---|---|
| **Hour Beginning** | **Unit On/Off** | **Outdoor Air** | **Unit On/Off** | **Outdoor Air** |
| 0 | 1 | 23% | 1 | 19% |
| 1 | 1 | 19% | 1 | 19% |
| 2 | 1 | 19% | 1 | 19% |
| 3 | 1 | 19% | 1 | 19% |
| 4 | 1 | 19% | 1 | 19% |
| 5 | 1 | 23% | 1 | 19% |
| 6 | 1 | 27% | 1 | 23% |
| 7 | 1 | 40% | 1 | 27% |
| 8 | 1 | 52% | 1 | 40% |
| 9 | 1 | 52% | 1 | 52% |
| 10 | 1 | 35% | 1 | 68% |
| 11 | 1 | 60% | 1 | 84% |
| 12 | 1 | 84% | 1 | 84% |
| 13 | 1 | 76% | 1 | 60% |
| 14 | 1 | 52% | 1 | 35% |
| 15 | 1 | 35% | 1 | 44% |
| 16 | 1 | 40% | 1 | 44% |
| 17 | 1 | 60% | 1 | 68% |
| 18 | 1 | 84% | 1 | 84% |
| 19 | 1 | 84% | 1 | 35% |
| 20 | 1 | 84% | 1 | 76% |
| 21 | 1 | 60% | 1 | 72% |
| 22 | 1 | 48% | 1 | 64% |
| 23 | 1 | 35% | 1 | 48% |

# RESULTS: EEM-8 IMPLEMENT DEMAND CONTROLLED VENTILATION - PATHFINDER DINING HALL

## Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 744 | 31,892 | 7,267 | 0 | 2,874 |
| **Feb** | 25.4 | 672 | 31,892 | 7,041 | 0 | 2,682 |
| **Mar** | 37.4 | 744 | 31,892 | 10,407 | 2,618 | 1,470 |
| **Apr** | 47.9 | 720 | 31,892 | 15,528 | 4,138 | 340 |
| **May** | 59.9 | 432 | 31,892 | 22,643 | 7,053 | 24 |
| **Jun** | 66.4 | 0 | 31,892 | 18,738 | 0 | 0 |
| **Jul** | 71.8 | 0 | 31,892 | 21,560 | 0 | 0 |
| **Aug** | 68.0 | 144 | 31,892 | 18,837 | 7,201 | 0 |
| **Sep** | 60.7 | 720 | 31,892 | 12,641 | 17,057 | 21 |
| **Oct** | 49.5 | 744 | 31,892 | 7,227 | 2,707 | 168 |
| **Nov** | 40.9 | 720 | 31,892 | 13,402 | 1,049 | 856 |
| **Dec** | 27.7 | 744 | 0 | 0 | 0 | 2,514 |
| **Annual** | **48.6** | **6,384** | **0** | **0** | **41,824** | **10,949** |

## Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | 26.0 | 744 | 31,892 | 4,025 | 0 | 1,335 |
| **Feb** | 25.4 | 672 | 31,892 | 3,855 | 0 | 1,322 |
| **Mar** | 37.4 | 744 | 31,892 | 8,413 | 2,664 | 632 |
| **Apr** | 47.9 | 720 | 31,892 | 14,624 | 4,181 | 58 |
| **May** | 59.9 | 432 | 31,892 | 22,102 | 7,110 | 0 |
| **Jun** | 66.4 | 0 | 31,892 | 17,220 | 0 | 0 |
| **Jul** | 71.8 | 0 | 31,892 | 20,791 | 0 | 0 |
| **Aug** | 68.0 | 144 | 31,892 | 18,455 | 7,049 | 0 |
| **Sep** | 60.7 | 720 | 31,892 | 11,270 | 16,835 | 0 |
| **Oct** | 49.5 | 744 | 31,892 | 3,909 | 2,707 | 14 |
| **Nov** | 40.9 | 720 | 31,892 | 11,611 | 1,064 | 294 |
| **Dec** | 27.7 | 744 | 0 | 0 | 0 | 991 |
| **Annual** | **48.6** | **6,384** | **0** | **0** | **41,610** | **4,646** |

## Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Average Supply Air Flow (CFM)[1] | Average Outdoor Air Flow (CFM)[1] | Electric Consumption (kWh) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|---|
| **Jan** | - | 0 | 0 | 3,242 | 0 | 1,539 |
| **Feb** | - | 0 | 0 | 3,186 | 0 | 1,360 |
| **Mar** | - | 0 | 0 | 1,994 | -46 | 838 |
| **Apr** | - | 0 | 0 | 904 | -43 | 282 |
| **May** | - | 0 | 0 | 541 | -57 | 24 |
| **Jun** | - | 0 | 0 | 1,518 | 0 | 0 |
| **Jul** | - | 0 | 0 | 769 | 0 | 0 |
| **Aug** | - | 0 | 0 | 382 | 152 | 0 |
| **Sep** | - | 0 | 0 | 1,370 | 222 | 21 |
| **Oct** | - | 0 | 0 | 3,318 | 0 | 154 |
| **Nov** | - | 0 | 0 | 1,791 | -14 | 562 |
| **Dec** | - | 0 | 0 | 0 | 0 | 1,523 |
| **Annual** | **-** | **0** | **0** | **0** | **214** | **6,303** |

1. Average air flow rates over hours when fan operates, including economizer operation.

## LIFE CYCLE COST ANALYSIS

| | | | |
|---|---|---|---|
| ECM No.: | EEM-8 | | |
| ECM Title: | Implement Demand Controlled Ventilation | | |
| **General Parameters** | | | |
| Base Date: | 1/1/2023 | | |
| Service Date: | 1/1/2023 | | |
| Study Period (Years): | 15 | | |
| Discount Rate: | 3% | | |
| Cost Escalation: | 0% | | |
| FEMP UPV Discount Factor (Elect.): | 14.96 | | |
| FEMP UPV Discount Factor (NG): | 13.70 | | |
| **Cost Data** | **Baseline** | **Proposed** | **Savings** |
| Initial Capital Cost: | | $40,655 | ($40,655) |
| Annual Electricity Costs: | $537,695 | $537,652 | $43 |
| Annual Natural Gas Costs: | $317,191 | $289,335 | $27,856 |
| Annual Water Costs: | $0 | $0 | $0 |
| Annual OM&R Costs: | $1,109 | $1,109 | $0 |
| Other Recurring Annual Costs: | $0 | $0 | $0 |
| **Life Cycle Cost Calculations** | **Baseline** | **Proposed** | **Savings** |
| Present Value Investment Costs, I: | $0 | $40,655 | ($40,655) |
| Present-Value Capital Replacement Cost, Repl: | $0 | $0 | $0 |
| Present Value Residual Cost, Res: | $0 | $0 | $0 |
| Present Value Energy Costs, E: | $12,389,228 | $12,006,909 | $382,320 |
| Present Value Water Cost, W: | $0 | $0 | $0 |
| Present Value O&M and Other Recurring Costs, OM&R: | $13,237 | $13,237 | $0 |
| **LCC:** | **$12,402,465** | **$12,060,801** | **$341,664** |
| **Savings to Investment Ratio Calculations** | | | |
| Present Value Energy Cost Savings, DE: | $382,320 | | |
| Present Value Water Cost Savings, DW: | $0 | | |
| Present Value OM&R Cost Savings, DOM&R: | $0 | | |
| **SIR:** | **9.40** | | |

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

# SUNY OSWEGO | EEM-9 IMPLEMENT KITCHEN DEMAND CONTROL VENTILATION

*Energy Opportunity Area:* HVAC, Building Automation System (BAS)

*Buildings Affected:* Marano Campus Center, Pathfinder Dining Hall, Lakeside Dining Hall, Cooper Dining Hall

**Table 1. EEM-9 Summary Data**

| Description | Values | Units |
|---|---|---|
| Annual Electrical Energy Savings | 108,195 | kWh/year |
| Electrical Peak Demand Savings | 32.2 | kW |
| Annual Electrical Energy Cost Savings | $6,384 | $/year |
| Annual Natural Gas Savings | 19,498 | Therms/year |
| Annual Natural Gas Cost Savings | $7,877 | $/year |
| **Total Annual Energy Cost Savings** | **$14,261** | **$/year** |
| **Estimated Implementation Cost** | **$192,867** | **$** |
| **Simple Payback Period** | **13.5** | **years** |
| **Savings to Investment Ratio** | **1.1** | **-** |

## Existing Conditions/Baseline

The exhaust fans (EF) listed in Table 2 are connected to various kitchen hoods to help remove air contaminants resulted from cooking. These exhaust fans, along with their respective makeup air units (MAU) are currently scheduled through the building automation system (BAS) to run at full speed during building operation hours.

Marano Campus Center does not have dedicated makeup air units serving the kitchen and café, and the air volume supplied to the space through terminal units is inadequate to replace the air exhausted by the kitchen hoods. The makeup air to these spaces is assumed to be transfer air coming from the food court on the lower level and the lobby on the main level. Pathfinder Dining Hall, Lakeside Dining Hall, and Cooper Dining Hall all have makeup air units that serve their kitchen area. In the case of Pathfinder Dining Hall and Lakeside Dining Hall where exhaust air is more than makeup air supplied directly to the space, remaining makeup air is assumed to be transfer air from nearby dining area.

**Table 2. Exhaust Fans and Makeup Air Units Serving Kitchens**

| Building | Location | EF Tag | EF CFM | MAU Tag | MAU CFM |
|---|---|---|---|---|---|
| 003B - REC & CONVOCATION CTR | Crossroad Café | EF-15 | 3,650 | - | - |
| 003B - REC & CONVOCATION CTR | Palates | EF-17 | 1,750 | - | - |
| 003B - REC & CONVOCATION CTR | Kitchen | EF-13 | 10,490 | - | - |
| 003B - REC & CONVOCATION CTR | Kitchen | EF-16 | 2,750 | - | - |
| 003B - REC & CONVOCATION CTR | Dishwasher | EF-19 | 750 | - | - |
| 0031 - PATHFINDER DH | Kitchen | HRU-1 | 11,205 | HRU-1 | 8,964 |
| 0042 - LAKESIDE DH | Kitchen | EF-1 | 15,000 | MAU-1 | 12,000 |

| Building | Location | EF Tag | EF CFM | MAU Tag | MAU CFM |
|---|---|---|---|---|---|
| 0042 - LAKESIDE DH | Kitchen | EF-2 | 2,100 | - | - |
| 0042 - LAKESIDE DH | Kitchen | EF-3 | 1,750 | - | - |
| 0042 - LAKESIDE DH | Kitchen | EF-4 | 1,500 | - | - |
| 0042 - LAKESIDE DH | Dishwasher | EF-5 | 1,100 | - | - |
| 0047 - COOPER DH | Kitchen | E-1 | 5,290 | HV-1 | 13,870 |
| 0047 - COOPER DH | Kitchen | E-2 | 6,750 | - | - |

The Commissary Building kitchen exhaust system was original included in the study, but the implementation of the measure for this system is unwarranted because of the building's low exhaust volume and short hours of operation.

The exhaust fans and makeup air unit do not need to operate at full speed in order to properly capture cooking heat and odors. The systems are designed to meet the exhaust and makeup needs at full speed when all the cooking equipment is being used. Most hours, the cooking equipment below the hoods is not fully utilized, so a reduced flow rate (and fan speed) would suffice.

### Recommended Action

This measure considers installing controls that automatically vary exhaust and makeup air fan speed, and air volume through variable frequency drives (VFDs) or electronically commuted motors based on monitored hood exhaust temperature and detected cooking vapor. This system can substantially reduce fan energy for the exhaust and makeup air fans and would also reduce the amount of heating and cooling energy required because of reduced makeup air volume. A system with heat and particulate sensors can provide signals to control fan speed and/or outdoor air damper position automatically.

Additionally, the units should be rebalanced to ensure they are meeting the proper makeup air requirements. The systems should be properly commissioned to ensure they are operating as intended by the original sequence of operations and any adjustments to the programming for the additional controls recommended under this measure.

### Estimated Energy Savings

An hourly analysis was performed using Syracuse Hancock International Airport TMY3 (Typical Meteorological Year) hourly weather data. Air flow and fan power were reduced from the design conditions based on the observed occupancy schedule. Design exhaust flows and makeup air supplied directly to the spaces were taken from design drawings. Transfer air is assumed to contribute to fan energy savings, but not heating and cooling energy savings.

Supporting documents include a summary of the assumptions and monthly baseline and post-retrofit conditions. Table 3 summarizes the baseline and post-retrofit energy consumption and estimated energy savings that result from the reduced makeup air flow for each building.

**Table 3. EEM-9 Savings**

| Building | Annual Electrical Energy Savings (kWh/year) | Annual Natural Gas Savings (Therms/year) | Total Annual Energy Cost Savings ($/year) | Estimated Implementation Cost | Simple Payback Period (years) |
|---|---|---|---|---|---|
| 003B - REC & CONVOCATION CTR | 13,997 | 0 | $826 | $55,988 | 67.8 |
| 0031 - PATHFINDER DH | 23,668 | 5,236 | $3,512 | $36,360 | 10.4 |
| 0042 - LAKESIDE DH | 55,707 | 7,875 | $6,468 | $61,727 | 9.5 |
| 0047 - COOPER DH | 14,823 | 6,387 | $3,455 | $38,792 | 11.2 |
| **Total** | **108,195** | **19,498** | **$14,261** | **$192,867** | **13.5** |

The analysis for the Marano Campus Center shows a high payback period because a large portion of this measure’s savings comes from reduced makeup air fan energy and heating/cooling energy, both of which does not apply for this building. The remaining buildings make good candidates for this measure.

## Estimated Project Cost

Costs presented in Table 4 represent the scope of work described previously. The cost estimate is based on RS Means 2023 and previous vendor estimates for the purchase, installation, commissioning, and owner training related to a demand-controlled kitchen exhaust and ventilation air system retrofit. Detailed cost estimation for individual building system can be found in supporting documents.

**Table 4. EEM-9 Estimated Project Costs**

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| 003B - REC & CONVOCATION CTR | 1 | Lump Sum | $39,152 | $39,152 |
| 0031 - PATHFINDER DH | 1 | Lump Sum | $25,427 | $25,427 |
| 0042 - LAKESIDE DH | 1 | Lump Sum | $43,166 | $43,166 |
| 0047 - COOPER DH | 1 | Lump Sum | $27,127 | $27,127 |
| | | | | |
| **Labor and Materials Subtotal** | | | | **$134,872** |
| General Conditions | 10% | | | $13,487 |
| **Labor and Materials Cost Total** | | | | **$148,359** |
| | | | | |
| Architectural & Engineering Fees | 10% | | | $14,836 |
| Construction Management Fees | 10% | | | $14,836 |
| Contingency | 10% | | | $14,836 |
| | | | | |
| **Project Cost Subtotal** | | | | **$192,867** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$192,867** |

## EEM-9 – IMPLEMENT KITCHEN DEMAND CONTROL VENTILATION

## SUPPORTING DOCUMENTS

# SUMMARY INPUTS: EEM-9 IMPLEMENT KITCHEN DEMAND CONTROL VENTILATION - REC AND CONVOCATION CTR

## Existing Exhaust Fan Design Conditions

| Location | Exhaust Fan | Exhaust CFM | Motor HP | Motor Eff. | Motor kW | Motor Control | Makeup Air System |
|---|---|---|---|---|---|---|---|
| Crossroad Café | EF-15 | 3,650 | 3 | 86.5% | 1.6 | None | - |
| Palates | EF-17 | 1,750 | 2 | 84.0% | 0.8 | None | - |
| Kitchen | EF-13 | 10,490 | 8 | 88.5% | 4.3 | None | - |
| Kitchen | EF-16 | 2,750 | 2 | 84.0% | 1.4 | None | - |
| Dishwasher | EF-19 | 750 | 1 | 82.5% | 0.1 | None | - |

## Existing Makeup Air Design Conditions

| Unit | Outdoor Air CFM | Motor HP | Motor Eff | Motor kW | Notes |
|---|---|---|---|---|---|
| - | - | - | - | - | |

## Existing Transfer Air Design Conditions

| Unit | Suuply CFM | Motor HP | Motor Eff | Motor kW | Notes |
|---|---|---|---|---|---|
| AHU-1 | 30,000 | 40 | 93.0% | 26.2 | |

## Calculation Inputs

| | |
|---|---|
| Exhaust CFM | 19,390 |
| Exhaust kW | 8.22 |
| | |
| Makeup Air CFM | - |
| Makeup Air kW | - |
| | |
| Transfer Air CFM | 19,390 |
| Transfer Air kW | 16.90 |

## Hourly Exhaust Flow

### Weekdays

| | | % of Full Flow | |
|---|---|---|---|
| Hour | On/Off Schedule | Baseline | Post-Retrofit |
| 0 to 1 | 0 | 1.0 | 0.0 |
| 1 to 2 | 0 | 1.0 | 0.0 |
| 2 to 3 | 0 | 1.0 | 0.0 |
| 3 to 4 | 0 | 1.0 | 0.0 |
| 4 to 5 | 0 | 1.0 | 0.1 |
| 5 to 6 | 0 | 1.0 | 0.3 |
| 6 to 7 | 1 | 1.0 | 0.5 |
| 7 to 8 | 1 | 1.0 | 0.8 |
| 8 to 9 | 1 | 1.0 | 1.0 |
| 9 to 10 | 1 | 1.0 | 0.7 |
| 10 to 11 | 1 | 1.0 | 0.5 |
| 11 to 12 | 1 | 1.0 | 0.3 |
| 12 to 13 | 1 | 1.0 | 0.9 |
| 13 to 14 | 1 | 1.0 | 0.6 |
| 14 to 15 | 1 | 1.0 | 0.3 |
| 15 to 16 | 1 | 1.0 | 0.4 |
| 16 to 17 | 1 | 1.0 | 1.0 |
| 17 to 18 | 1 | 1.0 | 0.8 |
| 18 to 19 | 1 | 1.0 | 0.6 |
| 19 to 20 | 0 | 1.0 | 0.3 |
| 20 to 21 | 0 | 1.0 | 0.2 |
| 21 to 22 | 0 | 1.0 | 0.2 |
| 22 to 23 | 0 | 1.0 | 0.1 |
| 23 to 24 | 0 | 1.00 | 0.0 |

### Weekends

| | | % of Full Flow | |
|---|---|---|---|
| Hour | On/Off Schedule | Baseline | Post-Retrofit |
| 0 to 1 | 0 | 1.0 | 0.0 |
| 1 to 2 | 0 | 1.0 | 0.0 |
| 2 to 3 | 0 | 1.0 | 0.0 |
| 3 to 4 | 0 | 1.0 | 0.0 |
| 4 to 5 | 0 | 1.0 | 0.1 |
| 5 to 6 | 0 | 1.0 | 0.3 |
| 6 to 7 | 0 | 1.0 | 0.5 |
| 7 to 8 | 0 | 1.0 | 0.8 |
| 8 to 9 | 0 | 1.0 | 1.0 |
| 9 to 10 | 0 | 1.0 | 0.7 |
| 10 to 11 | 0 | 1.0 | 0.5 |
| 11 to 12 | 0 | 1.0 | 0.3 |
| 12 to 13 | 0 | 1.0 | 0.9 |
| 13 to 14 | 0 | 1.0 | 0.6 |
| 14 to 15 | 0 | 1.0 | 0.3 |
| 15 to 16 | 0 | 1.0 | 0.4 |
| 16 to 17 | 0 | 1.0 | 1.0 |
| 17 to 18 | 0 | 1.0 | 0.8 |
| 18 to 19 | 0 | 1.0 | 0.6 |
| 19 to 20 | 0 | 1.0 | 0.3 |
| 20 to 21 | 0 | 1.0 | 0.2 |
| 21 to 22 | 0 | 1.0 | 0.2 |
| 22 to 23 | 0 | 1.0 | 0.1 |
| 23 to 24 | 0 | 1.0 | 0.0 |

# RESULTS: EEM-9 IMPLEMENT KITCHEN DEMAND CONTROL VENTILATION - REC AND CONVOCATION CTR

## Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) | Natural Gas Consumption |
|---|---|---|---|---|---|
| **Jan** | 26.0 | 234 | 1,924 | 8.2 | 0 |
| **Feb** | 25.4 | 260 | 2,138 | 8.2 | 0 |
| **Mar** | 37.4 | 208 | 1,710 | 8.2 | 0 |
| **Apr** | 47.9 | 260 | 2,138 | 8.2 | 0 |
| **May** | 59.9 | 221 | 1,817 | 8.2 | 0 |
| **Jun** | 66.4 | 260 | 2,138 | 8.2 | 0 |
| **Jul** | 71.8 | 286 | 2,351 | 8.2 | 0 |
| **Aug** | 68.0 | 221 | 1,817 | 8.2 | 0 |
| **Sep** | 60.7 | 247 | 2,031 | 8.2 | 0 |
| **Oct** | 49.5 | 273 | 2,244 | 8.2 | 0 |
| **Nov** | 40.9 | 234 | 1,924 | 8.2 | 0 |
| **Dec** | 27.7 | 130 | 1,069 | 8.2 | 0 |
| **Annual** | **48.6** | **2,834** | **23,299** | **8.2** | **0** |

## Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) | Natural Gas Consumption |
|---|---|---|---|---|---|
| **Jan** | 26.0 | 234 | 965 | 8.4 | 0 |
| **Feb** | 25.4 | 260 | 1,072 | 8.4 | 0 |
| **Mar** | 37.4 | 208 | 857 | 8.4 | 0 |
| **Apr** | 47.9 | 260 | 1,072 | 8.4 | 0 |
| **May** | 59.9 | 221 | 454 | 8.4 | 0 |
| **Jun** | 66.4 | 260 | 420 | 1.7 | 0 |
| **Jul** | 71.8 | 286 | 462 | 1.7 | 0 |
| **Aug** | 68.0 | 221 | 357 | 1.7 | 0 |
| **Sep** | 60.7 | 247 | 1,018 | 8.4 | 0 |
| **Oct** | 49.5 | 273 | 1,125 | 8.4 | 0 |
| **Nov** | 40.9 | 234 | 965 | 8.4 | 0 |
| **Dec** | 27.7 | 130 | 536 | 8.4 | 0 |
| **Annual** | **48.6** | **2,834** | **9,302** | **8.4** | **0** |

## Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) | Natural Gas Consumption |
|---|---|---|---|---|---|
| **Jan** | - | 0 | 959 | -0.2 | 0 |
| **Feb** | - | 0 | 1,066 | -0.2 | 0 |
| **Mar** | - | 0 | 853 | -0.2 | 0 |
| **Apr** | - | 0 | 1,066 | -0.2 | 0 |
| **May** | - | 0 | 1,362 | -0.2 | 0 |
| **Jun** | - | 0 | 1,718 | 6.5 | 0 |
| **Jul** | - | 0 | 1,890 | 6.5 | 0 |
| **Aug** | - | 0 | 1,460 | 6.5 | 0 |
| **Sep** | - | 0 | 1,012 | -0.2 | 0 |
| **Oct** | - | 0 | 1,119 | -0.2 | 0 |
| **Nov** | - | 0 | 959 | -0.2 | 0 |
| **Dec** | - | 0 | 533 | -0.2 | 0 |
| **Annual** | **-** | **0** | **13,997** | **6.5** | **0** |

## COST ESTIMATE: EEM-9 IMPLEMENT KITCHEN DEMAND CONTROL VENTILATION - REC AND CONVOCATION CTR

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| Variable frequency drive, 3 hp | 1 | Ea. | $2,925 | $2,925 |
| Variable frequency drive, 7.5 hp | 1 | Ea. | $3,850 | $3,850 |
| Inverter drive, 0.5 hp | 1 | Ea. | $1,091 | $1,091 |
| Inverter drive, 1 hp | 1 | Ea. | $1,141 | $1,141 |
| Inverter drive, 2 hp | 1 | Ea. | $1,152 | $1,152 |
| System controller, sensors, low voltage cabling, system commissioning and owner training | 1 | Lump Sum | $25,987 | $25,987 |
| BAS I/O Points, Engineering, Calibration, Start-up/Checkout Labor | 9 | Per Point | $334 | $3,006 |
| | | | | |
| **Labor and Materials Subtotal** | | | | **$39,152** |
| General Conditions | 10% | | | $3,915 |
| **Labor and Materials Cost Total** | | | | **$43,068** |
| | | | | |
| Architectural & Engineering Fees | 10% | | | $4,307 |
| Construction Management Fees | 10% | | | $4,307 |
| Contingency | 10% | | | $4,307 |
| | | | | |
| **Project Cost Subtotal** | | | | **$55,988** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$55,988** |

# SUMMARY INPUTS: EEM-9 IMPLEMENT KITCHEN DEMAND CONTROL VENTILATION - PATHFINDER DH

## Existing Exhaust Fan Design Conditions

| Location | Exhaust Fan | Exhaust CFM | Motor HP | Motor Eff. | Motor kW | Motor Control | Makeup Air System |
|---|---|---|---|---|---|---|---|
| Kitchen | HRU-1 | 11,205 | 10 | 89.5% | 6.7 | None | HRU-1 |

## Existing Makeup Air Design Conditions

| Unit | Outdoor Air CFM | Motor HP | Motor Eff | Motor kW | Notes |
|---|---|---|---|---|---|
| HRU-1 | 8,964 | 5 | 87.5% | 3.4 | |

## Existing Transfer Air Design Conditions

| Unit | Suuply CFM | Motor HP | Motor Eff | Motor kW | Notes |
|---|---|---|---|---|---|
| AHU-1 | 31,829 | 20 | 91.0% | 6.6 | |

## Calculation Inputs

| | |
|---|---|
| Exhaust CFM | 11205 |
| Exhaust kW | 6.67 |
| | |
| Makeup Air CFM | 8964 |
| Makeup Air kW | 3.41 |
| | |
| Transfer Air CFM | 2241 |
| Transfer Air kW | 0.46 |

## Hourly Exhaust Flow

### Weekdays

| | | % of Full Flow | |
|---|---|---|---|
| Hour | On/Off Schedule | Baseline | Post-Retrofit |
| 0 to 1 | 0 | 1.0 | 0.0 |
| 1 to 2 | 0 | 1.0 | 0.0 |
| 2 to 3 | 0 | 1.0 | 0.0 |
| 3 to 4 | 0 | 1.0 | 0.0 |
| 4 to 5 | 0 | 1.0 | 0.1 |
| 5 to 6 | 1 | 1.0 | 0.3 |
| 6 to 7 | 1 | 1.0 | 0.5 |
| 7 to 8 | 1 | 1.0 | 0.8 |
| 8 to 9 | 1 | 1.0 | 1.0 |
| 9 to 10 | 1 | 1.0 | 0.7 |
| 10 to 11 | 1 | 1.0 | 0.5 |
| 11 to 12 | 1 | 1.0 | 0.3 |
| 12 to 13 | 1 | 1.0 | 0.9 |
| 13 to 14 | 1 | 1.0 | 0.6 |
| 14 to 15 | 1 | 1.0 | 0.3 |
| 15 to 16 | 1 | 1.0 | 0.4 |
| 16 to 17 | 1 | 1.0 | 1.0 |
| 17 to 18 | 1 | 1.0 | 0.8 |
| 18 to 19 | 1 | 1.0 | 0.6 |
| 19 to 20 | 1 | 1.0 | 0.3 |
| 20 to 21 | 1 | 1.0 | 0.2 |
| 21 to 22 | 1 | 1.0 | 0.2 |
| 22 to 23 | 1 | 1.0 | 0.1 |
| 23 to 24 | 0 | 1.0 | 0.0 |

### Weekends

| | | % of Full Flow | |
|---|---|---|---|
| Hour | On/Off Schedule | Baseline | Post-Retrofit |
| 0 to 1 | 0 | 1.0 | 0.0 |
| 1 to 2 | 0 | 1.0 | 0.0 |
| 2 to 3 | 0 | 1.0 | 0.0 |
| 3 to 4 | 0 | 1.0 | 0.0 |
| 4 to 5 | 0 | 1.0 | 0.1 |
| 5 to 6 | 0 | 1.0 | 0.3 |
| 6 to 7 | 1 | 1.0 | 0.5 |
| 7 to 8 | 1 | 1.0 | 0.8 |
| 8 to 9 | 1 | 1.0 | 1.0 |
| 9 to 10 | 1 | 1.0 | 0.7 |
| 10 to 11 | 1 | 1.0 | 0.5 |
| 11 to 12 | 1 | 1.0 | 0.3 |
| 12 to 13 | 1 | 1.0 | 0.9 |
| 13 to 14 | 1 | 1.0 | 0.6 |
| 14 to 15 | 1 | 1.0 | 0.3 |
| 15 to 16 | 1 | 1.0 | 0.4 |
| 16 to 17 | 1 | 1.0 | 1.0 |
| 17 to 18 | 1 | 1.0 | 0.8 |
| 18 to 19 | 1 | 1.0 | 0.6 |
| 19 to 20 | 1 | 1.0 | 0.3 |
| 20 to 21 | 1 | 1.0 | 0.2 |
| 21 to 22 | 1 | 1.0 | 0.2 |
| 22 to 23 | 1 | 1.0 | 0.1 |
| 23 to 24 | 0 | 1.0 | 0.0 |

# RESULTS: EEM-9 IMPLEMENT KITCHEN DEMAND CONTROL VENTILATION - PATHFINDER DH

## Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|
| **Jan** | 26.0 | 426 | 4,293 | 10.1 | 2,002 |
| **Feb** | 25.4 | 496 | 4,999 | 10.1 | 2,391 |
| **Mar** | 37.4 | 407 | 4,102 | 10.1 | 1,507 |
| **Apr** | 47.9 | 462 | 4,656 | 10.1 | 1,076 |
| **May** | 59.9 | 319 | 3,215 | 10.1 | 322 |
| **Jun** | 66.4 | 0 | 0 | 0.0 | 0 |
| **Jul** | 71.8 | 0 | 0 | 0.0 | 0 |
| **Aug** | 68.0 | 107 | 1,078 | 10.1 | 6 |
| **Sep** | 60.7 | 495 | 4,989 | 10.1 | 465 |
| **Oct** | 49.5 | 514 | 5,180 | 10.1 | 1,147 |
| **Nov** | 40.9 | 460 | 4,636 | 10.1 | 1,449 |
| **Dec** | 27.7 | 231 | 2,328 | 10.1 | 1,122 |
| **Annual** | **48.6** | **3,917** | **39,477** | **10.1** | **11,487** |

## Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|
| **Jan** | 26.0 | 426 | 1,801 | 10.3 | 1,106 |
| **Feb** | 25.4 | 496 | 2,099 | 10.3 | 1,324 |
| **Mar** | 37.4 | 407 | 1,723 | 10.3 | 827 |
| **Apr** | 47.9 | 462 | 1,952 | 10.3 | 582 |
| **May** | 59.9 | 319 | 830 | 10.3 | 124 |
| **Jun** | 66.4 | 0 | 0 | 0.0 | 0 |
| **Jul** | 71.8 | 0 | 0 | 0.0 | 0 |
| **Aug** | 68.0 | 107 | 211 | 2.1 | 2 |
| **Sep** | 60.7 | 495 | 2,097 | 10.3 | 243 |
| **Oct** | 49.5 | 514 | 2,174 | 10.3 | 623 |
| **Nov** | 40.9 | 460 | 1,948 | 10.3 | 800 |
| **Dec** | 27.7 | 231 | 976 | 10.3 | 619 |
| **Annual** | **48.6** | **3,917** | **15,810** | **10.3** | **6,250** |

## Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) | Natural Gas Consumption (Therms) |
|---|---|---|---|---|---|
| **Jan** | - | 0 | 2,493 | -0.2 | 896 |
| **Feb** | - | 0 | 2,900 | -0.2 | 1,067 |
| **Mar** | - | 0 | 2,379 | -0.2 | 680 |
| **Apr** | - | 0 | 2,705 | -0.2 | 494 |
| **May** | - | 0 | 2,385 | -0.2 | 197 |
| **Jun** | - | 0 | 0 | 0.0 | 0 |
| **Jul** | - | 0 | 0 | 0.0 | 0 |
| **Aug** | - | 0 | 867 | 8.0 | 4 |
| **Sep** | - | 0 | 2,892 | -0.2 | 222 |
| **Oct** | - | 0 | 3,006 | -0.2 | 524 |
| **Nov** | - | 0 | 2,688 | -0.2 | 648 |
| **Dec** | - | 0 | 1,352 | -0.2 | 503 |
| **Annual** | **-** | **0** | **23,668** | **8.0** | **5,236** |

## COST ESTIMATE: EEM-9 IMPLEMENT KITCHEN DEMAND CONTROL VENTILATION - PATHFINDER DH

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| Variable frequency drive, 5 hp | 1 | Ea. | $3,175 | $3,175 |
| Variable frequency drive, 10 hp | 1 | Ea. | $4,100 | $4,100 |
| System controller, sensors, low voltage cabling, system commissioning and owner training | 1 | Lump Sum | $16,816 | $16,816 |
| BAS I/O Points, Engineering, Calibration, Start-up/Checkout Labor | 4 | Per Point | $334 | $1,336 |
| | | | | |
| **Labor and Materials Subtotal** | | | | **$25,427** |
| General Conditions | 10% | | | $2,543 |
| **Labor and Materials Cost Total** | | | | **$27,969** |
| | | | | |
| Architectural & Engineering Fees | 10% | | | $2,797 |
| Construction Management Fees | 10% | | | $2,797 |
| Contingency | 10% | | | $2,797 |
| | | | | |
| **Project Cost Subtotal** | | | | **$36,360** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$36,360** |

# SUMMARY INPUTS: EEM-9 IMPLEMENT KITCHEN DEMAND CONTROL VENTILATION - LAKESIDE DH

## Existing Exhaust Fan Design Conditions

| Location | Exhaust Fan | Exhaust CFM | Motor HP | Motor Eff. | Motor kW | Motor Control | Makeup Air System |
|---|---|---|---|---|---|---|---|
| Kitchen | EF-1 | 15,000 | 10 | 89.5% | 5.5 | None | MUA-1 |
| Kitchen | EF-2 | 2,100 | 2 | 84.0% | 1.4 | None | MUA-1 |
| Kitchen | EF-3 | 1,750 | 2 | 84.0% | 1.5 | None | MUA-1 |
| Kitchen | EF-4 | 1,500 | 1 | 82.5% | 0.9 | None | MUA-1 |
| Dishwasher | EF-5 | 1,100 | 0 | 82.5% | 0.2 | None | MUA-1 |

## Existing Makeup Air Design Conditions

| Unit | Outdoor Air CFM | Motor HP | Motor Eff | Motor kW | Notes |
|---|---|---|---|---|---|
| MUA-1 | 12,000 | 10 | 89.5% | 5.7 | |

## Existing Transfer Air Design Conditions

| Unit | Suuply CFM | Motor HP | Motor Eff | Motor kW | Notes |
|---|---|---|---|---|---|
| AHU-1 | 9,120 | 10 | 89.5% | 5.9 | |

## Calculation Inputs

| | |
|---|---|
| Exhaust CFM | 21,450 |
| Exhaust kW | 9.54 |
| | |
| Makeup Air CFM | 12,000 |
| Makeup Air kW | 5.67 |
| | |
| Transfer Air CFM | 9,450 |
| Transfer Air kW | 5.92 |

## Hourly Exhaust Flow

### Weekdays

| | | % of Full Flow | |
|---|---|---|---|
| Hour | On/Off Schedule | Baseline | Post-Retrofit |
| 0 to 1 | 0 | 1.0 | 0.0 |
| 1 to 2 | 0 | 1.0 | 0.0 |
| 2 to 3 | 0 | 1.0 | 0.0 |
| 3 to 4 | 0 | 1.0 | 0.0 |
| 4 to 5 | 1 | 1.0 | 0.1 |
| 5 to 6 | 1 | 1.0 | 0.3 |
| 6 to 7 | 1 | 1.0 | 0.5 |
| 7 to 8 | 1 | 1.0 | 0.8 |
| 8 to 9 | 1 | 1.0 | 1.0 |
| 9 to 10 | 1 | 1.0 | 0.7 |
| 10 to 11 | 1 | 1.0 | 0.5 |
| 11 to 12 | 1 | 1.0 | 0.3 |
| 12 to 13 | 1 | 1.0 | 0.9 |
| 13 to 14 | 1 | 1.0 | 0.6 |
| 14 to 15 | 1 | 1.0 | 0.3 |
| 15 to 16 | 1 | 1.0 | 0.4 |
| 16 to 17 | 1 | 1.0 | 1.0 |
| 17 to 18 | 1 | 1.0 | 0.8 |
| 18 to 19 | 1 | 1.0 | 0.6 |
| 19 to 20 | 1 | 1.0 | 0.3 |
| 20 to 21 | 1 | 1.0 | 0.2 |
| 21 to 22 | 1 | 1.0 | 0.2 |
| 22 to 23 | 1 | 1.0 | 0.1 |
| 23 to 24 | 0 | 1.0 | 0.0 |

### Weekends

| | | % of Full Flow | |
|---|---|---|---|
| Hour | On/Off Schedule | Baseline | Post-Retrofit |
| 0 to 1 | 0 | 1.0 | 0.0 |
| 1 to 2 | 0 | 1.0 | 0.0 |
| 2 to 3 | 0 | 1.0 | 0.0 |
| 3 to 4 | 0 | 1.0 | 0.0 |
| 4 to 5 | 0 | 1.0 | 0.1 |
| 5 to 6 | 0 | 1.0 | 0.3 |
| 6 to 7 | 1 | 1.0 | 0.5 |
| 7 to 8 | 1 | 1.0 | 0.8 |
| 8 to 9 | 1 | 1.0 | 1.0 |
| 9 to 10 | 1 | 1.0 | 0.7 |
| 10 to 11 | 1 | 1.0 | 0.5 |
| 11 to 12 | 1 | 1.0 | 0.3 |
| 12 to 13 | 1 | 1.0 | 0.9 |
| 13 to 14 | 1 | 1.0 | 0.6 |
| 14 to 15 | 1 | 1.0 | 0.3 |
| 15 to 16 | 1 | 1.0 | 0.4 |
| 16 to 17 | 1 | 1.0 | 1.0 |
| 17 to 18 | 1 | 1.0 | 0.8 |
| 18 to 19 | 1 | 1.0 | 0.6 |
| 19 to 20 | 1 | 1.0 | 0.3 |
| 20 to 21 | 1 | 1.0 | 0.2 |
| 21 to 22 | 1 | 1.0 | 0.2 |
| 22 to 23 | 1 | 1.0 | 0.1 |
| 23 to 24 | 0 | 1.0 | 0.0 |

# RESULTS: EEM-9 IMPLEMENT KITCHEN DEMAND CONTROL VENTILATION - LAKESIDE DH

## Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) | Natural Gas Consumption |
|---|---|---|---|---|---|
| **Jan** | 26.0 | 444 | 6,750 | 15.2 | 2,801 |
| **Feb** | 25.4 | 516 | 7,845 | 15.2 | 3,340 |
| **Mar** | 37.4 | 423 | 6,431 | 15.2 | 2,120 |
| **Apr** | 47.9 | 482 | 7,328 | 15.2 | 1,534 |
| **May** | 59.9 | 408 | 6,203 | 15.2 | 534 |
| **Jun** | 66.4 | 550 | 8,362 | 15.2 | 307 |
| **Jul** | 71.8 | 554 | 8,423 | 15.2 | 50 |
| **Aug** | 68.0 | 408 | 6,203 | 15.2 | 44 |
| **Sep** | 60.7 | 514 | 7,815 | 15.2 | 664 |
| **Oct** | 49.5 | 535 | 8,134 | 15.2 | 1,617 |
| **Nov** | 40.9 | 478 | 7,267 | 15.2 | 2,030 |
| **Dec** | 27.7 | 241 | 3,664 | 15.2 | 1,572 |
| **Annual** | **48.6** | **5,553** | **84,426** | **15.2** | **16,614** |

## Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) | Natural Gas Consumption |
|---|---|---|---|---|---|
| **Jan** | 26.0 | 444 | 2,770 | 15.5 | 1,517 |
| **Feb** | 25.4 | 516 | 3,225 | 15.5 | 1,814 |
| **Mar** | 37.4 | 423 | 2,647 | 15.5 | 1,138 |
| **Apr** | 47.9 | 482 | 3,003 | 15.5 | 807 |
| **May** | 59.9 | 408 | 1,516 | 15.5 | 198 |
| **Jun** | 66.4 | 550 | 1,638 | 3.1 | 93 |
| **Jul** | 71.8 | 554 | 1,650 | 3.1 | 15 |
| **Aug** | 68.0 | 408 | 1,215 | 3.1 | 13 |
| **Sep** | 60.7 | 514 | 3,219 | 15.5 | 338 |
| **Oct** | 49.5 | 535 | 3,342 | 15.5 | 858 |
| **Nov** | 40.9 | 478 | 2,991 | 15.5 | 1,098 |
| **Dec** | 27.7 | 241 | 1,502 | 15.5 | 849 |
| **Annual** | **48.6** | **5,553** | **28,719** | **15.5** | **8,739** |

## Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) | Natural Gas Consumption |
|---|---|---|---|---|---|
| **Jan** | - | 0 | 3,981 | -0.3 | 1,284 |
| **Feb** | - | 0 | 4,620 | -0.3 | 1,526 |
| **Mar** | - | 0 | 3,784 | -0.3 | 983 |
| **Apr** | - | 0 | 4,325 | -0.3 | 726 |
| **May** | - | 0 | 4,687 | -0.3 | 336 |
| **Jun** | - | 0 | 6,724 | 12.1 | 215 |
| **Jul** | - | 0 | 6,773 | 12.1 | 35 |
| **Aug** | - | 0 | 4,988 | 12.1 | 31 |
| **Sep** | - | 0 | 4,595 | -0.3 | 326 |
| **Oct** | - | 0 | 4,792 | -0.3 | 759 |
| **Nov** | - | 0 | 4,276 | -0.3 | 931 |
| **Dec** | - | 0 | 2,162 | -0.3 | 723 |
| **Annual** | **-** | **0** | **55,707** | **12.1** | **7,875** |

## COST ESTIMATE: EEM-9 IMPLEMENT KITCHEN DEMAND CONTROL VENTILATION - LAKESIDE DH

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| Variable frequency drive, 10 hp | 2 | Ea. | $4,100 | $8,200 |
| Inverter drive, 1 hp | 1 | Ea. | $1,107 | $1,107 |
| Inverter drive, 2 hp | 2 | Ea. | $1,152 | $2,304 |
| System controller, sensors, low voltage cabling, system commissioning and owner training | 1 | Lump Sum | $27,881 | $27,881 |
| BAS I/O Points, Engineering, Calibration, Start-up/Checkout Labor | 11 | Per Point | $334 | $3,674 |
| | | | | |
| **Labor and Materials Subtotal** | | | | **$43,166** |
| General Conditions | 10% | | | $4,317 |
| **Labor and Materials Cost Total** | | | | **$47,482** |
| | | | | |
| Architectural & Engineering Fees | 10% | | | $4,748 |
| Construction Management Fees | 10% | | | $4,748 |
| Contingency | 10% | | | $4,748 |
| | | | | |
| **Project Cost Subtotal** | | | | **$61,727** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$61,727** |

# SUMMARY INPUTS: EEM-9 IMPLEMENT KITCHEN DEMAND CONTROL VENTILATION - COOPER DH

## Existing Exhaust Fan Design Conditions

| Location | Exhaust Fan | Exhaust CFM | Motor HP | Motor Eff. | Motor kW | Motor Control | Makeup Air System |
|---|---|---|---|---|---|---|---|
| Kitchen | E-1 | 5,290 | 2 | 84.0% | 1.4 | None | HV-1 |
| Kitchen | E-2 | 6,750 | 3 | 86.5% | 2.1 | None | HV-1 |

## Existing Makeup Air Design Conditions

| Unit | Outdoor Air CFM | Motor HP | Motor Eff | Motor kW | Notes |
|---|---|---|---|---|---|
| HV-1 | 13,870 | 5 | 87.5% | 3.4 | |

## Existing Transfer Air Design Conditions

| Unit | Suuply CFM | Motor HP | Motor Eff | Motor kW | Notes |
|---|---|---|---|---|---|
| N/A | - | - | - | - | |

## Calculation Inputs

| | |
|---|---|
| Exhaust CFM | 12,040 |
| Exhaust kW | 3.49 |
| | |
| Makeup Air CFM | 13,870 |
| Makeup Air kW | 3.41 |
| | |
| Transfer Air CFM | - |
| Transfer Air kW | - |

## Hourly Exhaust Flow

### Weekdays

| | | % of Full Flow | |
|---|---|---|---|
| Hour | On/Off Schedule | Baseline | Post-Retrofit |
| 0 to 1 | 0 | 1.0 | 0.0 |
| 1 to 2 | 0 | 1.0 | 0.0 |
| 2 to 3 | 0 | 1.0 | 0.0 |
| 3 to 4 | 0 | 1.0 | 0.0 |
| 4 to 5 | 0 | 1.0 | 0.1 |
| 5 to 6 | 1 | 1.0 | 0.3 |
| 6 to 7 | 1 | 1.0 | 0.5 |
| 7 to 8 | 1 | 1.0 | 0.8 |
| 8 to 9 | 1 | 1.0 | 1.0 |
| 9 to 10 | 1 | 1.0 | 0.7 |
| 10 to 11 | 1 | 1.0 | 0.5 |
| 11 to 12 | 1 | 1.0 | 0.3 |
| 12 to 13 | 1 | 1.0 | 0.9 |
| 13 to 14 | 1 | 1.0 | 0.6 |
| 14 to 15 | 1 | 1.0 | 0.3 |
| 15 to 16 | 1 | 1.0 | 0.4 |
| 16 to 17 | 1 | 1.0 | 1.0 |
| 17 to 18 | 1 | 1.0 | 0.8 |
| 18 to 19 | 1 | 1.0 | 0.6 |
| 19 to 20 | 1 | 1.0 | 0.3 |
| 20 to 21 | 1 | 1.0 | 0.2 |
| 21 to 22 | 0 | 1.0 | 0.2 |
| 22 to 23 | 0 | 1.0 | 0.1 |
| 23 to 24 | 0 | 1.0 | 0.0 |

### Weekends

| | | % of Full Flow | |
|---|---|---|---|
| Hour | On/Off Schedule | Baseline | Post-Retrofit |
| 0 to 1 | 0 | 1.0 | 0.0 |
| 1 to 2 | 0 | 1.0 | 0.0 |
| 2 to 3 | 0 | 1.0 | 0.0 |
| 3 to 4 | 0 | 1.0 | 0.0 |
| 4 to 5 | 0 | 1.0 | 0.1 |
| 5 to 6 | 0 | 1.0 | 0.3 |
| 6 to 7 | 0 | 1.0 | 0.5 |
| 7 to 8 | 1 | 1.0 | 0.8 |
| 8 to 9 | 1 | 1.0 | 1.0 |
| 9 to 10 | 1 | 1.0 | 0.7 |
| 10 to 11 | 1 | 1.0 | 0.5 |
| 11 to 12 | 1 | 1.0 | 0.3 |
| 12 to 13 | 1 | 1.0 | 0.9 |
| 13 to 14 | 1 | 1.0 | 0.6 |
| 14 to 15 | 1 | 1.0 | 0.3 |
| 15 to 16 | 1 | 1.0 | 0.4 |
| 16 to 17 | 1 | 1.0 | 1.0 |
| 17 to 18 | 1 | 1.0 | 0.8 |
| 18 to 19 | 1 | 1.0 | 0.6 |
| 19 to 20 | 1 | 1.0 | 0.3 |
| 20 to 21 | 1 | 1.0 | 0.2 |
| 21 to 22 | 0 | 1.0 | 0.2 |
| 22 to 23 | 0 | 1.0 | 0.1 |
| 23 to 24 | 0 | 1.0 | 0.0 |

# RESULTS: EEM-9 IMPLEMENT KITCHEN DEMAND CONTROL VENTILATION - COOPER DH

## Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) | Natural Gas Consumption |
|---|---|---|---|---|---|
| Jan | 26.0 | 372 | 2,567 | 6.9 | 2,694 |
| Feb | 25.4 | 432 | 2,981 | 6.9 | 3,205 |
| Mar | 37.4 | 354 | 2,443 | 6.9 | 1,999 |
| Apr | 47.9 | 404 | 2,788 | 6.9 | 1,417 |
| May | 59.9 | 278 | 1,918 | 6.9 | 394 |
| Jun | 66.4 | 0 | 0 | 0.0 | 0 |
| Jul | 71.8 | 0 | 0 | 0.0 | 0 |
| Aug | 68.0 | 342 | 2,360 | 6.9 | 23 |
| Sep | 60.7 | 430 | 2,967 | 6.9 | 568 |
| Oct | 49.5 | 448 | 3,092 | 6.9 | 1,488 |
| Nov | 40.9 | 400 | 2,760 | 6.9 | 1,931 |
| Dec | 27.7 | 202 | 1,394 | 6.9 | 1,512 |
| **Annual** | **48.6** | **3,662** | **25,272** | **6.9** | **15,231** |

## Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) | Natural Gas Consumption |
|---|---|---|---|---|---|
| Jan | 26.0 | 372 | 1,157 | 7.1 | 1,581 |
| Feb | 25.4 | 432 | 1,346 | 7.1 | 1,887 |
| Mar | 37.4 | 354 | 1,104 | 7.1 | 1,170 |
| Apr | 47.9 | 404 | 1,255 | 7.1 | 821 |
| May | 59.9 | 278 | 512 | 7.1 | 160 |
| Jun | 66.4 | 0 | 0 | 0.0 | 0 |
| Jul | 71.8 | 0 | 0 | 0.0 | 0 |
| Aug | 68.0 | 342 | 463 | 1.4 | 7 |
| Sep | 60.7 | 430 | 1,343 | 7.1 | 325 |
| Oct | 49.5 | 448 | 1,395 | 7.1 | 870 |
| Nov | 40.9 | 400 | 1,248 | 7.1 | 1,137 |
| Dec | 27.7 | 202 | 627 | 7.1 | 885 |
| **Annual** | **48.6** | **3,662** | **10,448** | **7.1** | **8,843** |

## Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) | Natural Gas Consumption |
|---|---|---|---|---|---|
| Jan | - | 0 | 1,411 | -0.2 | 1,112 |
| Feb | - | 0 | 1,635 | -0.2 | 1,318 |
| Mar | - | 0 | 1,339 | -0.2 | 829 |
| Apr | - | 0 | 1,533 | -0.2 | 597 |
| May | - | 0 | 1,407 | -0.2 | 234 |
| Jun | - | 0 | 0 | 0.0 | 0 |
| Jul | - | 0 | 0 | 0.0 | 0 |
| Aug | - | 0 | 1,897 | 5.5 | 16 |
| Sep | - | 0 | 1,625 | -0.2 | 243 |
| Oct | - | 0 | 1,697 | -0.2 | 618 |
| Nov | - | 0 | 1,513 | -0.2 | 794 |
| Dec | - | 0 | 767 | -0.2 | 627 |
| **Annual** | **-** | **0** | **14,823** | **5.5** | **6,387** |

# COST ESTIMATE: EEM-9 IMPLEMENT KITCHEN DEMAND CONTROL VENTILATION - COOPER DH

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| Variable frequency drive, 3 hp | 1 | Ea. | $2,925 | $2,925 |
| Variable frequency drive, 5 hp | 1 | Ea. | $3,175 | $3,175 |
| Inverter drive, 2 hp | 1 | Ea. | $1,152 | $1,152 |
| System controller, sensors, low voltage cabling, system commissioning and owner training | 1 | Lump Sum | $17,871 | $17,871 |
| BAS I/O Points, Engineering, Calibration, Start-up/Checkout Labor | 6 | Per Point | $334 | $2,004 |
| | | | | |
| **Labor and Materials Subtotal** | | | | **$27,127** |
| General Conditions | 10% | | | $2,713 |
| **Labor and Materials Cost Total** | | | | **$29,840** |
| | | | | |
| Architectural & Engineering Fees | 10% | | | $2,984 |
| Construction Management Fees | 10% | | | $2,984 |
| Contingency | 10% | | | $2,984 |
| | | | | |
| **Project Cost Subtotal** | | | | **$38,792** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$38,792** |

## LIFE CYCLE COST ANALYSIS

ECM No.: EEM-9

ECM Title: Implement Kitchen Demand Control Ventilation

| General Parameters | |
|---|---|
| Base Date: | 1/1/2023 |
| Service Date: | 1/1/2023 |
| Study Period (Years): | 15 |
| Discount Rate: | 3% |
| Cost Escalation: | 0% |
| FEMP UPV Discount Factor (Elect.): | 14.96 |
| FEMP UPV Discount Factor (NG): | 13.70 |

| Cost Data | Baseline | Proposed | Savings |
|---|---|---|---|
| Initial Capital Cost: | | $192,867 | ($192,867) |
| Annual Electricity Costs: | $10,176 | $3,792 | $6,384 |
| Annual Natural Gas Costs: | $17,506 | $9,628 | $7,877 |
| Annual CHP Natural Gas Costs: | $0 | $0 | $0 |
| Annual CHW Costs: | $0 | $0 | $0 |
| Annual HTHW Costs: | $0 | $0 | $0 |
| Annual Water Costs: | $0 | $0 | $0 |
| Annual OM&R Costs: | $4,046 | $4,046 | $0 |
| Other Recurring Annual Costs: | $0 | $0 | $0 |

| Life Cycle Cost Calculations | Baseline | Proposed | Savings |
|---|---|---|---|
| Present Value Investment Costs, I: | $0 | $192,867 | ($192,867) |
| Present-Value Capital Replacement Cost, Repl: | $0 | $0 | $0 |
| Present Value Residual Cost, Res: | $0 | $0 | $0 |
| Present Value Energy Costs, E: | $392,074 | $188,655 | $203,419 |
| Present Value Water Cost, W: | $0 | $0 | $0 |
| Present Value O&M and Other Recurring Costs, OM&R: | $48,303 | $48,303 | $0 |
| **LCC:** | **$440,377** | **$429,824** | **$10,553** |

| Savings to Investment Ratio Calculations | |
|---|---|
| Present Value Energy Cost Savings, DE: | $203,419 |
| Present Value Water Cost Savings, DW: | $0 |
| Present Value OM&R Cost Savings, DOM&R: | $0 |
| **SIR:** | **1.05** |

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

# SUNY OSWEGO | EEM-10 LABORATORY DEMAND CONTROLLED VENTILATION

*Energy Opportunity Area:* HVAC, Building Automation System (BAS), Special Systems (Laboratories)

*Buildings Affected:* Richard S. Shineman Center

**Table 1. EEM-10 Summary Data**

| Description | Values | Units |
|---|---|---|
| Annual Electrical Energy Savings | 1,714,816 | kWh/year |
| Electrical Peak Demand Savings | 489 | kW |
| Annual Electrical Energy Cost Savings | $101,174 | $/year |
| Annual Natural Gas Savings | 116,014 | Therms/year |
| Annual Natural Gas Cost Savings | $46,870 | $/year |
| **Total Annual Energy Cost Savings** | **$148,044** | **$/year** |
| **Estimated Implementation Cost** | **$503,100** | **$** |
| **Simple Payback Period** | **3.4** | **Years** |
| **Savings to Investment Ratio** | **4.3** | **-** |

### Existing Conditions/Baseline

Richard S. Shineman Center is an academic building opened in 2013 which houses classrooms and lab spaces for the University's science and engineering departments. Building research facilities include lab spaces for molecular and cell culture biology, chemistry, earth science, botany and zoology, and biochemistry.

Heating, ventilation, and air conditioning (HVAC) systems in the building include two air handling units (AHU) which serve variable air volume (VAV) boxes in all building lab spaces. Other HVAC systems serve non-lab space types throughout the building and are not included in this measure. Lab air handling units AHU-3 and AHU-4 are 100% outdoor air units serving VAV boxes ranging from 300 cfm to 7,500 cfm. AHU-3 and AHU-4 operate in conjunction with lab exhaust fans LEF-1, LEF-2, LEF-3 and LEF-4. General zone exhaust ranges from 250 cfm to 3,900 cfm.

AHUs operate in occupied mode 24/7 and are controlled through Trane Tracer® Ensemble™ building automation system (BAS).

### Recommended Action

Laboratory spaces require vast amounts of outdoor air and high air change rates to maintain a safe and healthy environment for occupants. Due to this, buildings which house lab spaces are energy intensive and present a significant opportunity for energy savings and carbon reduction.

Laboratory demand controlled ventilation (DCV) based on sensed contaminant uses an air sampling system with a centralized suite of sensors. The system measures critical lab air quality parameters in real time and dynamically adjusts ventilation rates to provide the appropriate amount of air needed to the space. This system can significantly reduce a space's minimum air change rate when the lab room air is sensed to be "clean" and results in energy savings during those periods, which is about 98% of the time in a typical campus lab space. Lab DCV also enhances occupant safety when contaminants are detected by increasing the space's air change rates during those periods to meet ASHRAE lab ventilation requirements.

In addition to energy savings, EHS professional staff would have access to indoor environmental quality (IEQ) data, enabling them to verify safety and proper lab protocols. This strategy of optimizing air flows based on real-time conditions is a fundamental component of a “Smart Lab” approach. It is currently being applied successfully in over one thousand laboratory buildings including various SUNY labs (Binghamton (3), Stony Brook (4), Oneonta, Plattsburgh).

## Estimated Energy Savings

The Lab DCV control combines real-time sensing and continuous monitoring of indoor environments with existing VAV air distribution system controls to allow reductions to baseline air exchange rates, resulting in heating, cooling, and fan energy savings. Shineman lab spaces analyzed under this EEM currently have VAV terminals for both supply and general lab exhaust and some variable flow fume hoods.

Savings were estimated using a calculation tool developed by Aircuity that accounts for weather, supply and exhaust air flow, applicable lab zone space volume, fume hoods, utility rates, thermal loads by zone, fan system data, and several other inputs. The tool estimates potential air flow reductions that can be achieved during occupied and unoccupied periods using ambient OA temperature bin models to quantify the associated heating, cooling, and fan energy savings. The full analysis is included in the Supporting Documents. Table 2 and Table 3 summarize the estimated reduction in air change rates and overall air flow from implementing Lab DCV.

**Table 2. EEM-10 Reduction in Air Change Rates**

| | Day Supply ACH | Night Supply ACH | High Ventilation Max/Purge Supply ACH |
|---|---|---|---|
| Baseline | 10 | 10 | N/A |
| Proposed | 4 | 4 | 12 |

**Table 3. EEM-10 Estimated Air Flow Savings**

| | Average Day CFM | Average Night CFM | Average CFM |
|---|---|---|---|
| Baseline | 79,687 | 79,687 | 79,687 |
| Proposed | 36,229 | 33,712 | 34,611 |
| **Savings** | **43,459** | **45,976** | **45,077** |

## Estimated Project Cost

The estimated project cost is a turnkey solution provided by Aircuity, and includes:

- Equipment
- Installation Labor
- Engineering
- Project Management
- BMS Integration

- Start up / Commissioning

A net capital cost of $503,100 was quoted for Lab DCV implementation in Shineman lab spaces.

**Table 4. EEM-10 Estimated Project Costs**

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| Aircuity Lab DCV Budget Estimate | 1 | Lump Sum | $503,100 | **$503,100** |
| | | | | |
| **Labor and Materials Subtotal** | | | | **$503,100** |
| General Conditions | 0% | | | $0 |
| **Labor and Materials Cost Total** | | | | **$503,100** |
| | | | | |
| Architectural & Engineering Fees | 0% | | | $0 |
| Construction Management Fees | 0% | | | $0 |
| Contingency | 0% | | | $0 |
| | | | | |
| **Project Cost Subtotal** | | | | **$503,100** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$503,100** |

## EEM-10 – LABORATORY DEMAND CONTROLLED VENTILATION

## SUPPORTING DOCUMENTS

## LIFE CYCLE COST ANALYSIS

| | | | | |
|---|---|---|---|---|
| ECM No.: | EEM-10 | | | |
| ECM Title: | Laboratory Demand Controlled Ventilation | | | |
| **General Parameters** | | | | |
| Base Date: | 1/1/2023 | | | |
| Service Date: | 1/1/2023 | | | |
| Study Period (Years): | 15 | | | |
| Discount Rate: | 3% | | | |
| Cost Escalation: | 0% | | | |
| FEMP UPV Discount Factor (Elect.): | 14.96 | | | |
| FEMP UPV Discount Factor (NG): | 13.70 | | | |

| Cost Data | Baseline | Proposed | Savings |
|---|---|---|---|
| Initial Capital Cost: | | $503,100 | ($503,100) |
| Annual Electricity Costs: | $154,726 | $53,552 | $101,174 |
| Annual Natural Gas Costs: | $61,657 | $14,787 | $46,870 |
| Annual CHP Natural Gas Costs: | $0 | $0 | $0 |
| Annual CHW Costs: | $0 | $0 | $0 |
| Annual HTHW Costs: | $0 | $0 | $0 |
| Annual Water Costs: | $0 | $0 | $0 |
| Annual OM&R Costs: | $15,093 | $15,093 | $0 |
| Other Recurring Annual Costs: | $0 | $0 | $0 |

| Life Cycle Cost Calculations | Baseline | Proposed | Savings |
|---|---|---|---|
| Present Value Investment Costs, I: | $0 | $503,100 | ($503,100) |
| Present-Value Capital Replacement Cost, Repl: | $0 | $0 | $0 |
| Present Value Residual Cost, Res: | $0 | $0 | $0 |
| Present Value Energy Costs, E: | $3,159,289 | $1,003,669 | $2,155,620 |
| Present Value Water Cost, W: | $0 | $0 | $0 |
| Present Value O&M and Other Recurring Costs, OM&R: | $180,179 | $180,179 | $0 |
| **LCC:** | **$3,339,468** | **$1,686,948** | **$1,652,520** |

| Savings to Investment Ratio Calculations | |
|---|---|
| Present Value Energy Cost Savings, DE: | $2,155,620 |
| Present Value Water Cost Savings, DW: | $0 |
| Present Value OM&R Cost Savings, DOM&R: | $0 |
| **SIR:** | **4.3** |

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

# Laboratory Ventilation Savings Analysis

for

## SUNY Oswego
## Shineman

**City Location is Oswego**
**(Using weather data from Syracuse, New York)**

**Submitted by**
**Walt King**

**May 5, 2023**

**Copyright 2023**

Confidentiality Note: This document, and the software program that created it, is copyrighted and intended for use only by the individual or entity to which it is addressed and may contain information that is privileged, confidential, and exempt from disclosure under applicable law. If the reader is not the intended recipient or the employee or agent responsible for delivering the document to the intended recipient, you are hereby notified that any dissemination, distribution or copying of this communication is strictly prohibited. If you have received this communication in error, please contact the sender immediately and destroy the material in its entirety, whether electronic or hard copy.

AIRCUITY®

## Aircuity Energy Savings and ROI Budget Estimate

Re: SUNY Oswego, Shineman Optimization Project – Budget Estimate

Aircuity is pleased to provide this Budget Estimate for your critical environment. Aircuity's enabling technology will increase lab safety while providing your organization significant carbon and energy reduction to help achieve mission critical objectives.

This Budget Estimate is based upon:

- Assumption of an existing or separately installed VAV lab control system
- Energy costs of $ 0.06/kWh & $ 0.40/Therm
- 39 lab spaces and a total approximate demand controlled area of 30,537 square feet
- Current or Baseline Minimum Air change rate of 15.80 ACH Occupied & 15.80 ACH Unocc periods.
- Proposed minimum air change rate of 4.00 ACH Day and 4.00 ACH Night periods.
- "Rule of thumb" installation pricing
- Conservative estimate for air change rate reduction

This budgetary estimate does not include:

- Utility rebate incentives
- Localized installation pricing variations
- Further potential air change rate reduction

The goal of this budgetary estimate is to provide you with an approximate cost and payback analysis for a typical project given the provided parameters. Should you wish to proceed with a more detailed conceptual and/or investment grade analysis, please contact us.

**Budget Estimate Financial Overview**

| | |
|---|---|
| **Project Cost:** | **$503,100** |
| **Capital Savings from Downsizing HVAC if applicable:** | |
| **Utility Rebate Incentive if applicable:** | |
| **Net Capital Cost:** | **$503,100** |
| | |
| **Projected Annual Energy Savings:** | **$149,120** |
| **Simple Energy Payback:** | **3.3 years** |
| **CO2 Reduction in Metric tons of CO2:** | **1,435** |
| **CO2 Reduction in equivalent avg. cars:** | **278** |
| **Reduction from Baseline HVAC Energy:** | **68%** |

Note: Aircuity's Budgetary Analysis has proven to reasonably accurate based on the quality of the assumptions used, and is an approved incentive tool by some utilities, but it should be utilized at this stage to simply gauge interest and confirm desire to proceed with more detailed analysis.

Thank You!

***Thank you for your interest in Aircuity's Safe, Smart and Efficient Airside Solutions!***

Aircuity, Inc. 55 Chapel Street, Newton, Ma 02468 (617) 641-8800

## Proposed Laboratory System Cashflow Savings Analysis

AIRCUITY

May 5, 2023

| | |
|---|---|
| Customer Name | **SUNY Oswego** |
| Project Name | **Shineman** |
| City | **Oswego (Using weather data from Syracuse, New York)** |
| Submitted by | **Walt King** |

| | |
|---|---|
| Project Capital Costs | $503,100 |
| Diversity Savings & Dpt Sensors | $0 |
| Utility Incentive/Rebate | $0 |
| Net Capital Cost (Savings) | **$503,100** |

**Energy Units Saved:**
1,714,816 kWh Electricity saved annually
116,014 Therms Heating saved annually
489 kW peak reduction via Max Bin Method

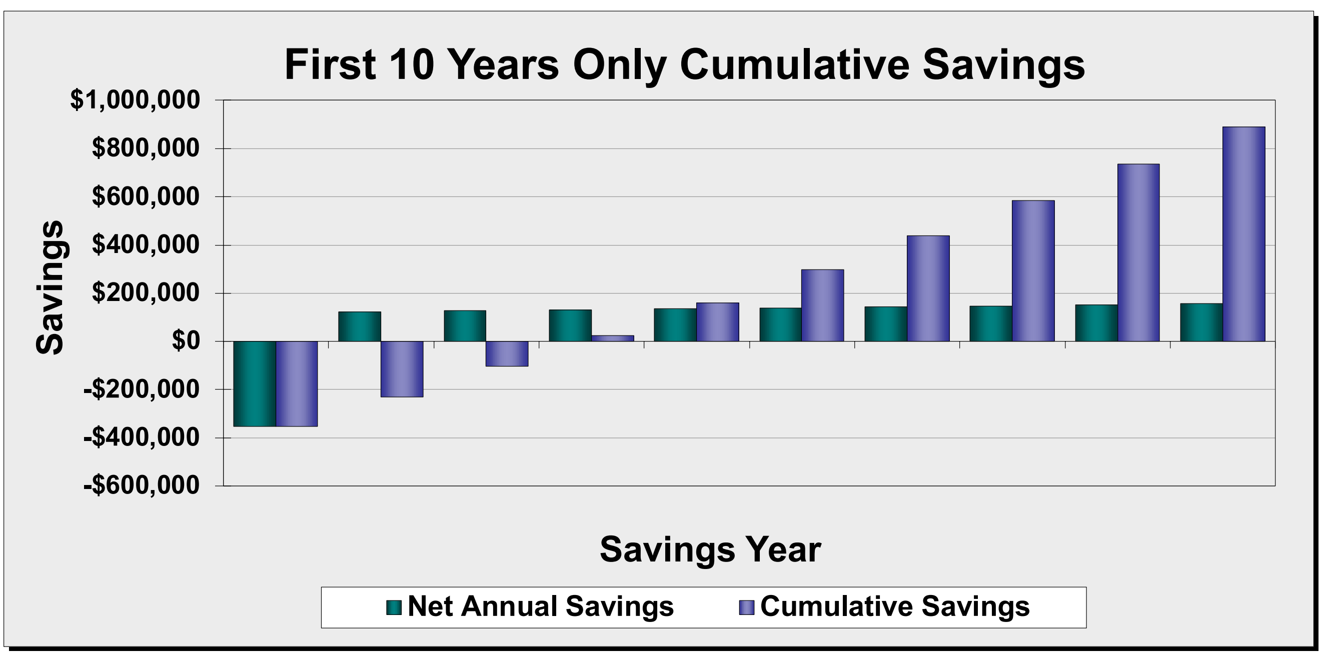
| | |
|---|---|
| **1st Year Savings** | **$149,120** |
| **Simple Energy Payback** | **3.3 years** |

### 10 Years of Cashflow Analysis

| Year | Energy Savings | Net Recurring Costs | Annual Savings | Net Capital Costs | Net Annual Savings | Cumulative Savings |
|---|---|---|---|---|---|---|
| 2023 | $149,120 | $0 | $149,120 | ($503,100) | ($353,980) | ($353,980) |
| 2024 | $153,593 | ($31,092) | $122,502 | | $122,502 | ($231,479) |
| 2025 | $158,201 | ($32,024) | $126,177 | | $126,177 | ($105,302) |
| 2026 | $162,947 | ($32,985) | $129,962 | | $129,962 | $24,659 |
| 2027 | $167,835 | ($33,975) | $133,861 | | $133,861 | $158,520 |
| 2028 | $172,870 | ($34,994) | $137,877 | | $137,877 | $296,397 |
| 2029 | $178,056 | ($36,044) | $142,013 | | $142,013 | $438,410 |
| 2030 | $183,398 | ($37,125) | $146,273 | | $146,273 | $584,683 |
| 2031 | $188,900 | ($38,239) | $150,661 | | $150,661 | $735,344 |
| 2032 | $194,567 | ($39,386) | $155,181 | | $155,181 | $890,525 |
| **Totals** | **$1,709,488** | **($315,863)** | **$1,393,625** | **($503,100)** | **$890,525** | **$890,525** |

**1st year energy savings represents a 68% reduction from base case.**

| | |
|---|---|
| **10 Yrs NPV =** | **$422,814** |
| **10 Yrs IRR =** | **23.9%** |
| **10 Yrs Cum. Savings** | **$890,525** |



## Environmental Impact

AIRCUITY

May 5, 2023

| | |
|---|---|
| Customer | **SUNY Oswego** |
| Project | **Shineman** |
| City | **Oswego (Using weather data from Syracuse, New York)** |
| Submitted by | **Walt King** |

| Annual CO2 Emission Rates for Power Generation in New York | | US National Average |
|---|---|---|
| $CO_2$ (lb/MWh) | 439.1 | 997.1 |

| Fossil Fuel Used | lb $CO_2$ / MMBtu |
|---|---|
| Heating: Gas | 207.91 |
| Reheat: SameAsHeating | 207.91 |
| Other Fuel Type: | |

### Base Design Annual Emissions

| Annual Energy Units | | Equivalent MMBTUs | Equivalent MBTUs | $CO_2$ Lbs | $CO_2$ Short Tons | $CO_2$ Metric Tons | Carbon Lbs | Carbon Short Tons | Carbon Metric Tons |
|---|---|---|---|---|---|---|---|---|---|
| Total kWh | 2,622,472 | 8,950 | 8,950,495 | 1,151,637 | 576 | 522 | 314,083 | 157 | 142 |
| Total Therms | 152,616 | 15,262 | 15,261,619 | 3,173,043 | 1,587 | 1,439 | 865,375 | 433 | 392 |
| Total Units | | 24,212 | 24,212,115 | 4,324,681 | 2,162 | 1,961 | 1,179,458 | 590 | 535 |

### Proposed Design Annual Emissions

| Annual Energy Units | | Equivalent MMBTUs | Equivalent MBTUs | $CO_2$ Lbs | $CO_2$ Short Tons | $CO_2$ Metric Tons | Carbon Lbs | Carbon Short Tons | Carbon Metric Tons |
|---|---|---|---|---|---|---|---|---|---|
| Total kWh | 907,655 | 3,098 | 3,097,827 | 398,589 | 199 | 181 | 108,706 | 54 | 49 |
| Total Therms | 36,602 | 3,660 | 3,660,208 | 760,994 | 380 | 345 | 207,544 | 104 | 94 |
| Total Units | | 6,758 | 6,758,035 | 1,159,583 | 580 | 526 | 316,250 | 158 | 143 |

# Annual Lab DCV Emissions Savings

| Annual Energy Units Saved | | Equivalent MMBTUs | Equivalent MBTUs | $CO_2$ Lbs | $CO_2$ Short Tons | $CO_2$ Metric Tons | Carbon Lbs | Carbon Short Tons | Carbon Metric Tons |
|---|---|---|---|---|---|---|---|---|---|
| **Total kWh** | **1,714,816** | **5,853** | **5,852,669** | **753,048** | **377** | **342** | **205,377** | **103** | **93** |
| **Total Therms** | **116,014** | **11,601** | **11,601,411** | **2,412,049** | **1,206** | **1,094** | **657,832** | **329** | **298** |
| **Total Units** | | **17,454** | **17,454,079** | **3,165,097** | **1,583** | **1,435** | **863,208** | **432** | **391** |

**Saving 1,435 metric tons of CO2 emissions is equivalent to:**

- ✓ **175,083 gallons of gasoline burned (278 average cars).**
- ✓ **391 metric tons of carbon.**
- ✓ **The annual CO2 emissions from 122 average American households.**

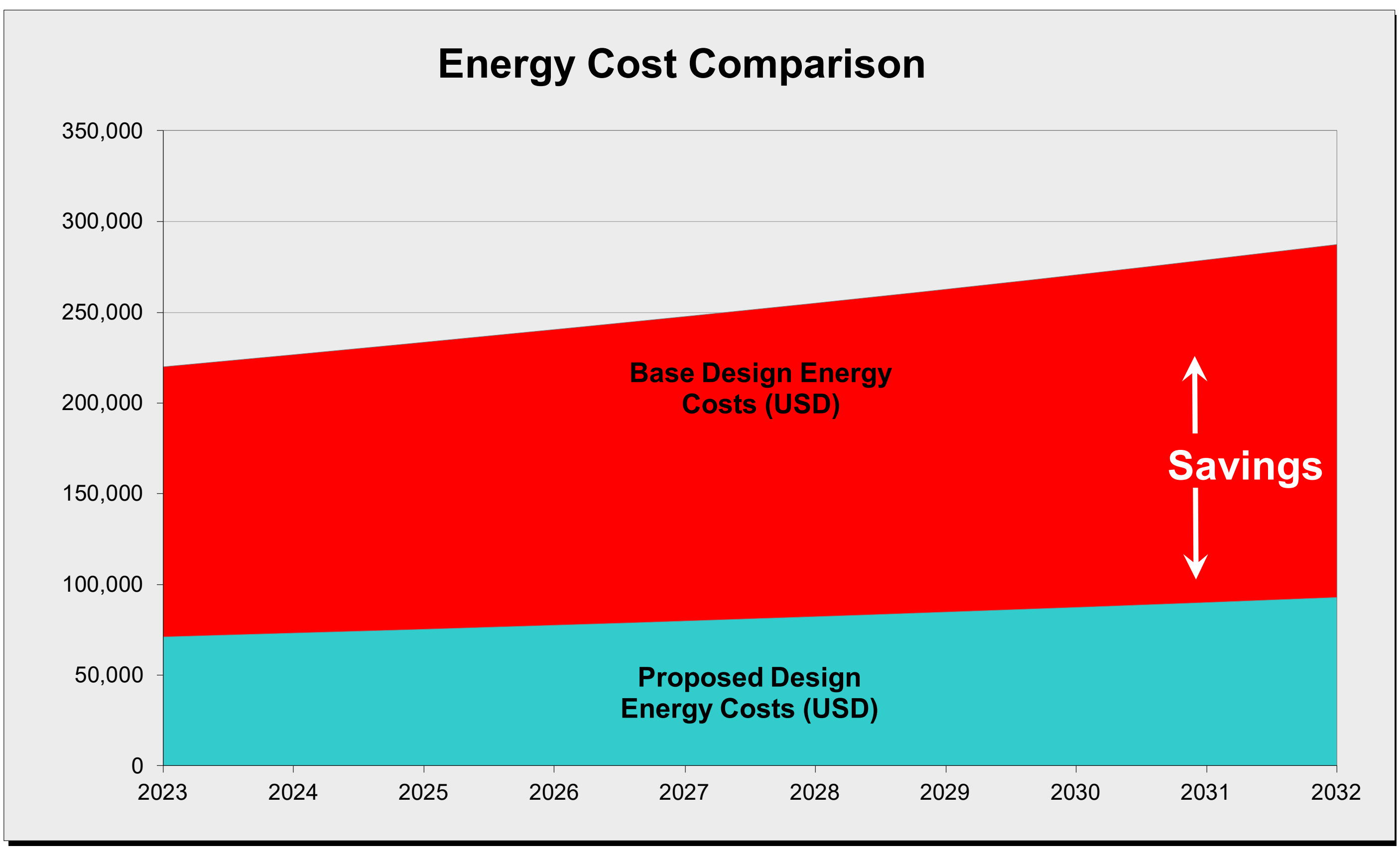
## Base and Proposed System Energy Cost Savings Summary

May 5, 2023

| | |
|---|---|
| Customer Name | **SUNY Oswego** |
| Project Name | **Shineman** |
| City | **Oswego (Using weather data from Syracuse, New York)** |
| Submitted by | **Walt King** |

| | Base Design in CFM | Proposed Design in CFM | CFM Flow Savings |
|---|---|---|---|
| Average Day Airflow | 88,689.2 | 35,575.1 | 53,114.1 |
| Average Night Airflow | 88,689.2 | 33,154.7 | 55,534.5 |
| Average Airflow | 88,689.2 | 34,019.2 | 54,670.1 |
| Average Annual $/CFM | $ 2.48 | $ 2.09 | $ 2.73 |
| Energy Inflation Rate | 3.0% | | |

| Year | Base Design Energy Costs (USD) | Proposed Design Energy Costs (USD) | Energy Savings (USD) | Cumulative Savings (USD) |
|---|---|---|---|---|
| 2023 | 220,106 | 70,986 | 149,120 | 149,120 |
| 2024 | 226,709 | 73,116 | 153,593 | 302,713 |
| 2025 | 233,510 | 75,309 | 158,201 | 460,914 |
| 2026 | 240,515 | 77,569 | 162,947 | 623,860 |
| 2027 | 247,731 | 79,896 | 167,835 | 791,696 |
| 2028 | 255,163 | 82,292 | 172,870 | 964,566 |
| 2029 | 262,818 | 84,761 | 178,056 | 1,142,623 |
| 2030 | 270,702 | 87,304 | 183,398 | 1,326,021 |
| 2031 | 278,823 | 89,923 | 188,900 | 1,514,921 |
| 2032 | 287,188 | 92,621 | 194,567 | 1,709,488 |
| 10 Yr Savings | $ 2,523,265 | $ 813,777 | $ 1,709,488 | $ 1,709,488 |



# Energy Savings & Capital Cost Analysis Basic Assumptions

AIRCUITY

May 5, 2023

| | | | |
|---|---|---|---|
| Customer Name | SUNY Oswego | | For US Weather Stations, Actual Airport Location: |
| Project Name | Shineman | | Syracuse Hancock International Airport |
| City | Oswego | Weather Station: | New York, Syracuse |
| Submitted by | Walt King | | Budget Estimate |

## Building & Financial Assumptions

| | | |
|---|---|---|
| Number of Zones | 39 | |
| Avg Zone Area (sq. ft.) | 783 | |
| Total sq. ft (calculated) | 30,537 | |
| Avg Ceiling Height | 10.00 | |
| Total # of Fume Hoods | 35 | |
| Avg FH Max CFM | 800 | |
| Avg FH Min CFM | 800 | |
| Avg Day FH Sash Opening | 60% | Open |
| Avg Nite FH Sash Opening | 25% | Open |
| Annual Inflation Rate | 3% | |
| Energy Inflation Rate | 3% | |
| Hurdle Rate | 8% | |
| Financial Analysis Period | 10 Yrs | |
| Incentive/Rebate $/kWh | | |
| Incentive/Rebate $/Therm | $ - | |
| Incentive/Rebate $/kW | $ - | |

## Baseline & Proposed Design Data

| Thermal Loads by Zone Type | Normal Activity, Low Load | Moderate Activity, Medium Load | High Activity, High Load |
|---|---|---|---|
| % of Zones | 80% | 10% | 10% |
| Number of Zones | 31 | 4 | 4 |
| Room Peak W/ft$^2$ (Day) | 6.00 | 10.00 | 12.00 |
| Avg Peak W/ft$^2$ (Day) | 4.00 | 8.00 | 12.00 |
| Avg W/ft$^2$ (Day) | 3.00 | 6.00 | 9.00 |
| Avg Peak W/ft$^2$ Nite | 2.00 | 4.00 | 9.00 |
| Avg Watts/ft$^2$ Nite | 1.50 | 3.00 | 6.00 |
| Base Day Supply ACH | 15.80 | 15.80 | 15.80 |
| Base Night Supply ACH | 15.80 | 15.80 | 15.80 |
| Proposed Normal Day Sup. ACH | 4.00 | 4.00 | 4.00 |
| Proposed Normal Night Sup. ACH | 4.00 | 4.00 | 4.00 |
| High Vent Max/Purge Sup. ACH | 12.00 | 12.00 | 12.00 |

## Energy Cost & HVAC System Assumptions

| | | |
|---|---|---|
| Cooling Method | Electric | |
| Heating Method | Gas | |
| ReHeat Method | SameAsHeating | |
| Electric $/kWh | $ 0.0600 | |
| Chilled Water $/Ton-Hour | $ 0.1817 | *(Not used)* |
| Gas/Oil/Other Fuel $/Therm | $ 0.4000 | |
| Steam $/1,000 lb. | $ 12.4000 | *(Not used)* |
| Evaporative Cooling *(Triggers Wet Bulb Recalc)* | None | |
| Proposed Room Cooling Method | VAV Air System | |
| Base Design Room Cooling Method | SameAsProposed | |
| OA Humidification | None | |
| Humidification RH Set Point | 45% | |

| | | |
|---|---|---|
| Occ Cooling Set Point | 72 | ºF |
| Occ Heating/Reheat Set Point | 72 | ºF |
| UnOcc Cooling Set Point | 72 | ºF |
| UnOcc Heating/Reheat Set Point | 72 | ºF |
| Base SA Temp | 55 | ºF |
| Proposed SA Temp | 55 | ºF |
| COP of Refrigeration System | 3.3 | |
| Heating Efficiency / Heat Pump COP | 0.75 | |
| Heat Recovery System Type | Sensible Only | |
| Heat Recovery Efficiency | 75% | |
| Heat Recovery Installed Price | $ 443,446 | |
| Annual Heat Recovery Costs | $ 8,900 | |
| Extra Static from Heat Recovery | 0.75 | in. |

## Fan System Assumptions & Data

| | | |
|---|---|---|
| Supply Fan Total Static - (No HR) | 5.00 | in w.c. |
| Supply Fan Efficiency | 70% | |
| Exhaust Fan Total Static - (No HR) | 4.50 | in w.c. |
| Exhaust Fan Efficiency | 60% | |

**Exhaust Fan Control Strategy:**

**Staged Fans w/ Bypass Damper**

| | |
|---|---|
| Show Exhaust Fan Control Savings | No |
| Number of Exhaust Fans | 4 |

## Capital Cost Savings & Diversity Assumptions (Diversity not included)

| | | |
|---|---|---|
| Include Diversity Savings | No | |
| Design % | 99.90% | |
| Baseline CFM/Ton of Cooling | 193 | |
| $/Ton: Cooling System | $ 1,750 | |
| $/Watt Cost for Hydronic Room Cooling | $ 1.00 | |
| $/MBH: Heating System | $ 40 | |
| Subtract Cost of Dewpoint Sensors | No | |
| *Dewpoint Sensor Cost Installed | $ 1,500 | |
| Proposed Installed System Price | $ 503,100 | (from ONE) |
| Annual Costs for Proposed System | $ 30,186 | (from ONE) |
| Years of Annual Services in System Price | 1.0 | Years |

| Baseline $/CFM | | Diversity % |
|---|---|---|
| $9.05 | Cooling System | 100% |
| $0.04 | Heating System | 100% |
| $0.62 | Reheat System | 100% |
| $6.00 | Exhaust Fan | 100% |
| $4.50 | Supply AHU | 100% |
| $0.15 | AHU VFDs | 100% |
| $5.00 | Heat Recovery | 100% |
| $0.45 | Ductwork | 100% |
| $25.81 | Total Base HVAC | |

Copyright 2022

# Occupancy Schedule

May 5, 2023

| | |
|---|---|
| Customer Name | **SUNY Oswego** |
| Project Name | **Shineman** |
| City | **Oswego (Using weather data from Syracuse, New York)** |
| Submitted by | **Walt King** |

| Hour | Sun | Mon | Tue | Wed | Thu | Fri | Sat |
|---|---|---|---|---|---|---|---|
| **12 to 1 AM** | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc |
| **1 to 2 AM** | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc |
| **2 to 3 AM** | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc |
| **3 to 4 AM** | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc |
| **4 to 5 AM** | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc |
| **5 to 6 AM** | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc |
| **6 to 7 AM** | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc |
| **7 to 8 AM** | UnOcc | Occ | Occ | Occ | Occ | Occ | UnOcc |
| **8 to 9 AM** | UnOcc | Occ | Occ | Occ | Occ | Occ | UnOcc |
| **9 to 10 AM** | UnOcc | Occ | Occ | Occ | Occ | Occ | UnOcc |
| **10 to 11 AM** | UnOcc | Occ | Occ | Occ | Occ | Occ | UnOcc |
| **11 to Noon** | UnOcc | Occ | Occ | Occ | Occ | Occ | UnOcc |
| **12 to 1 PM** | UnOcc | Occ | Occ | Occ | Occ | Occ | UnOcc |
| **1 to 2 PM** | UnOcc | Occ | Occ | Occ | Occ | Occ | UnOcc |
| **2 to 3 PM** | UnOcc | Occ | Occ | Occ | Occ | Occ | UnOcc |
| **3 to 4 PM** | UnOcc | Occ | Occ | Occ | Occ | Occ | UnOcc |
| **4 to 5 PM** | UnOcc | Occ | Occ | Occ | Occ | Occ | UnOcc |
| **5 to 6 PM** | UnOcc | Occ | Occ | Occ | Occ | Occ | UnOcc |
| **6 to 7 PM** | UnOcc | Occ | Occ | Occ | Occ | Occ | UnOcc |
| **7 to 8 PM** | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc |
| **8 to 9 PM** | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc |
| **9 to 10 PM** | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc |
| **10 to 11 PM** | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc |
| **11 to Midnight** | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc | UnOcc |

| | Occ Hours | UnOcc Hours | Off Hours | Occ Hours Percent | UnOcc Hours Percent |
|---|---|---|---|---|---|
| **0-6** | 0 | 42 | 0 | 0% | 100% |
| **7-12** | 25 | 17 | 0 | 60% | 40% |
| **13-18** | 30 | 12 | 0 | 71% | 29% |
| **19-24** | 5 | 37 | 0 | 12% | 88% |
| **Total** | 60 | 108 | 0 | **36%** | **64%** |

## Lab Airflow Analysis & Flow Drivers Summary

AIRCUITY®

May 5, 2023

| | |
|---|---|
| Customer Name | **SUNY Oswego** |
| Project Name | **Shineman** |
| City | **Oswego (Using weather data from Syracuse, New York)** |
| Submitted by | **Walt King** |

### Supply CFM Comparisons

| | Base Calculated CFM | Proposed Calculated CFM | CFM Differences | % Differences |
|---|---|---|---|---|
| Total Fume Hood Maximum CFM | 28,000 | 28,000 | 0 | 0% |
| Total Fume Hood Minimum CFM | 28,000 | 28,000 | 0 | 0% |
| Estimated Total Peak FH CFM | 21,000 | 21,000 | 0 | 0% |
| Estimated Total FH Avg CFM - Day | 28,000 | 28,000 | 0 | 0% |
| Estimated Total FH Avg CFM - Night | 28,000 | 28,000 | 0 | 0% |
| Avg Peak Cooling CFM - Day | 32,282 | 33,877 | 1,594 | 5% |
| Avg Cooling CFM - Day | 24,212 | 24,212 | 0 | 0% |
| Avg Peak Cooling CFM - Night | 19,052 | 20,188 | 1,136 | 6% |
| Avg Cooling CFM - Night | 12,701 | 12,701 | 0 | 0% |
| Day Average ACH CFM | 88,689 | 25,381 | (63,309) | -71% |
| Night Average ACH CFM | 88,689 | 24,987 | (63,702) | -72% |
| | | | | |
| | | | | |
| | | | | |
| Avg Peak CFM - Day | 88,689 | 39,903 | (48,786) | -55% |
| Average CFM - Day | 88,689 | 35,575 | **(53,114)** | **-60%** |
| Avg Peak CFM - Night | 88,689 | 35,705 | (52,984) | -60% |
| Average CFM - Night | 88,689 | 33,155 | **(55,535)** | **-63%** |

### Average and Peak Supply Flow Breakdown by Room Type

| Room Type | Base Peak Occ CFM | Base Peak UnOcc CFM | Proposed Peak Occ CFM | Proposed Peak UnOcc CFM |
|---|---|---|---|---|
| Low Load, Non-High Hood Density | 63,919 | 63,919 | 23,605 | 22,931 |
| Low Load, High Hood Density | - | - | - | - |
| Medium Load, Non-High Hood Density | 8,248 | 8,248 | 4,784 | 2,959 |
| Medium Load, High Hood Density | - | - | - | - |
| High Load, Non-High Hood Density | 8,248 | 8,248 | 7,016 | 5,317 |
| High Load, High Hood Density | - | - | - | - |
| Other Areas (Non-Lab, CV Lab, etc.) | - | - | - | - |
| Lab Corridors and Associated Areas | 8,275 | 8,275 | 4,498 | 4,498 |
| Total Peak Supply Flows | 88,689 | 88,689 | 39,903 | 35,705 |

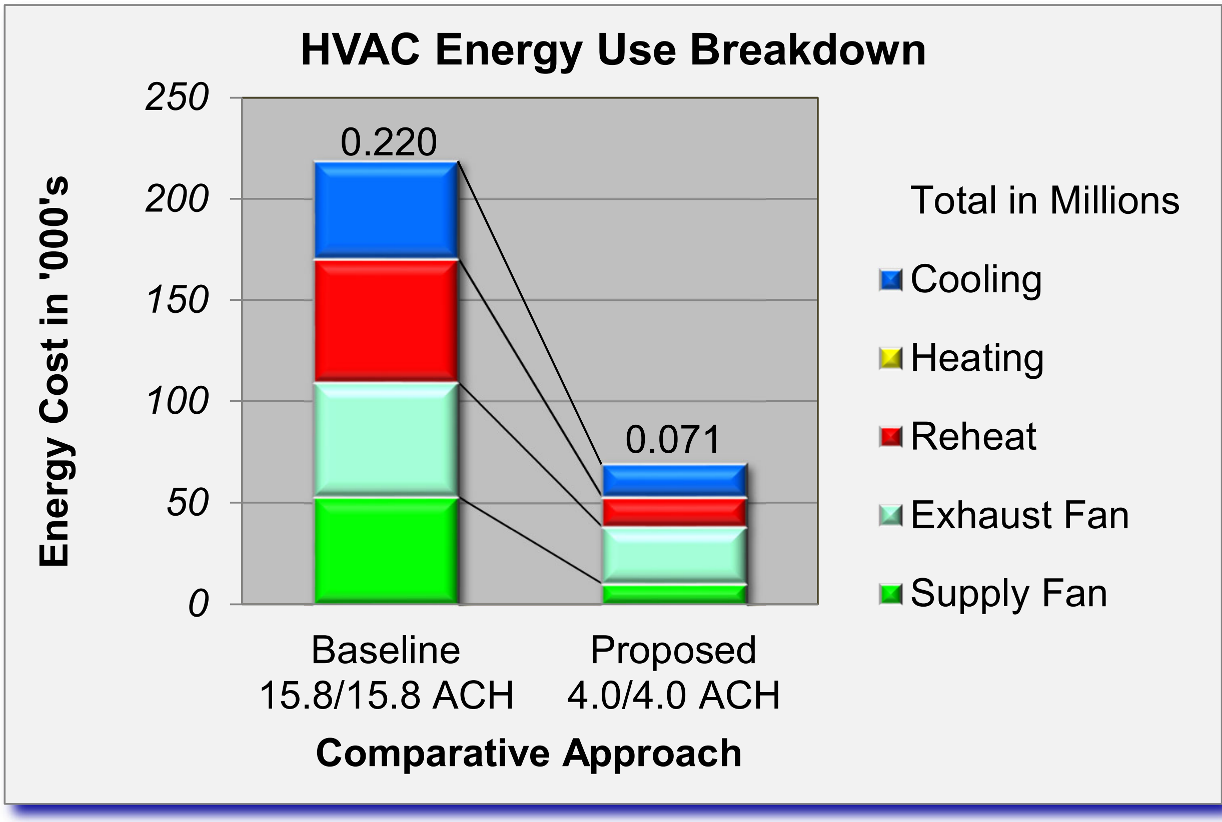
| Room Type | Base Average Occ CFM | Base Average UnOcc CFM | Proposed Average Occ CFM | Proposed Average UnOcc CFM |
|---|---|---|---|---|
| Low Load, Non-High Hood Density | 63,919 | 63,919 | 22,256 | 22,256 |
| Low Load, High Hood Density | - | - | - | - |
| Medium Load, Non-High Hood Density | 8,248 | 8,248 | 3,528 | 2,872 |
| Medium Load, High Hood Density | - | - | - | - |
| High Load, Non-High Hood Density | 8,248 | 8,248 | 5,292 | 3,528 |
| High Load, High Hood Density | - | - | - | - |
| Other Areas (Non-Lab, CV Lab, etc.) | - | - | - | - |
| Lab Corridors and Associated Areas | 8,275 | 8,275 | 4,498 | 4,498 |
| Total Average Supply Flows | 88,689 | 88,689 | 35,575 | 33,155 |

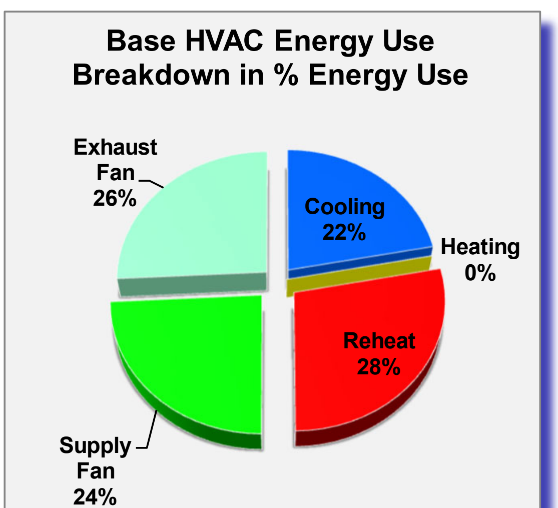
| Color Key for Controlling or Max Flow: | Fume Hood Driven | Cooling Driven | ACH Driven |
|---|---|---|---|

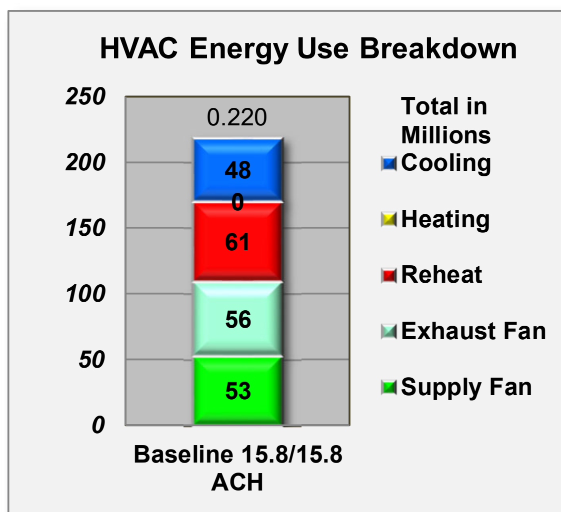
## Base & Proposed HVAC Energy Cost Breakdown

May 5, 2023

| | |
|---|---|
| Customer Name | **SUNY Oswego** |
| Project Name | **Shineman** |
| City | **Oswego (Using weather data from Syracuse, New York)** |
| Submitted by | **Walt King** |



# Proposed System 10 Year Life Cycle Cost Analysis

AIRCUITY

May 5, 2023

| | |
|---|---|
| Customer Name | **SUNY Oswego** |
| Project Name | **Shineman** |
| City | **Oswego (Using weather data from Syracuse, New York)** |
| Submitted by | **Walt King** |

| | Base System Design | Proposed System Design | Proposed System (Aircuity) Savings |
|---|---|---|---|
| **Aircuity First Cost** | **$0** | **$503,100** | **($503,100)** |
| Diversity Savings | $0 | $0 | **$0** |
| Rebate & Incentives | $0 | $0 | **$0** |
| **Adjustments to First Cost** | $0 | $0 | **$0** |
| **Net First Cost** | **$0** | **$503,100** | **($503,100)** |
| Year 1 Energy Cost | $220,106 | $70,986 | **$149,120** |
| Year 2 Energy Cost | $226,709 | $73,116 | **$153,593** |
| Year 3 Energy Cost | $233,510 | $75,309 | **$158,201** |
| Year 4 Energy Cost | $240,515 | $77,569 | **$162,947** |
| Year 5 Energy Cost | $247,731 | $79,896 | **$167,835** |
| Year 6 Energy Cost | $255,163 | $82,292 | **$172,870** |
| Year 7 Energy Cost | $262,818 | $84,761 | **$178,056** |
| Year 8 Energy Cost | $270,702 | $87,304 | **$183,398** |
| Year 9 Energy Cost | $278,823 | $89,923 | **$188,900** |
| Year 10 Energy Cost | $287,188 | $92,621 | **$194,567** |
| **Total 10 Year Energy Cost** | **$2,523,265** | **$813,777** | **$1,709,488** |
| Year 1 Maintenance Cost | | $0 | **$0** |
| Year 2 Maintenance Cost | | $31,092 | **($31,092)** |
| Year 3 Maintenance Cost | | $32,024 | **($32,024)** |
| Year 4 Maintenance Cost | | $32,985 | **($32,985)** |
| Year 5 Maintenance Cost | | $33,975 | **($33,975)** |
| Year 6 Maintenance Cost | | $34,994 | **($34,994)** |
| Year 7 Maintenance Cost | | $36,044 | **($36,044)** |
| Year 8 Maintenance Cost | | $37,125 | **($37,125)** |
| Year 9 Maintenance Cost | | $38,239 | **($38,239)** |
| Year 10 Maintenance Cost | | $39,386 | **($39,386)** |
| **10 Year Maintenance Cost** | **$0** | **$315,863** | **($315,863)** |
| **Total 10 Year Operation Cost** | **$2,523,265** | **$1,129,640** | **$1,393,625** |
| **10 Year Cost of Ownership** | **$2,523,265** | **$1,632,740** | **$890,525** |
| **Avg. Cost of ownership per year** | **$252,326** | **$163,274** | **$89,053** |

## Energy Units and Energy Dollar Savings Detailed Comparison

AIRCUITY®

May 5, 2023

| | |
|---|---|
| Customer | **SUNY Oswego** |
| Project | **Shineman** |
| City | **Oswego (Using weather data from Syracuse, New York)** |
| Submitted by | **Walt King** |

### Occ

#### Base Design

| Annual Occ Energy Units | | Annual Occ Energy Costs | | | Total Annual Costs at Occ Average Flow | | |
|---|---|---|---|---|---|---|---|
| Cooling kWh | 333,724 | Cooling | $ | 20,023 | $ | 2.48 | per CFM |
| Heating Therms | 19 | Heating | $ | 8 | | | |
| Reheat Therms | 48,867 | Reheat | $ | 19,547 | | | |
| Heating kWh | - | | | | | | |
| Reheat kWh | - | | | | **Costs per CFM** | | |
| Supply Fan kWh | 315,060 | Supply Fan | $ | 18,904 | Cooling cost / CFM | $ | 0.63 |
| Exhaust Fan kWh | 335,608 | Exhaust Fan | $ | 20,136 | Heating cost / CFM | $ | 0.00 |
| Total kWh | 984,392 | Total | $ | 78,618 | Reheat cost / CFM extra | $ | 0.85 |
| Total Therms | 48,886 | | | | Fan cost / CFM | $ | 1.23 |
| Peak kW | 791 | | | | | | |

#### Proposed Design

| Annual Occ Energy Units | | Annual Occ Energy Costs | | | Total Annual Costs at Occ Average Flow | | |
|---|---|---|---|---|---|---|---|
| Cooling kWh | 116,742 | Cooling | $ | 7,005 | $ | 1.92 | per CFM |
| Heating Therms | 21 | Heating | $ | 8 | | | |
| Reheat Therms | 8,612 | Reheat | $ | 3,445 | | | |
| Heating kWh | - | | | | | | |
| Reheat kWh | - | | | | **Costs per CFM** | | |
| Supply Fan kWh | 64,280 | Supply Fan | $ | 3,857 | Cooling cost / CFM | $ | 0.55 |
| Exhaust Fan kWh | 167,111 | Exhaust Fan | $ | 10,027 | Heating cost / CFM | $ | 0.00 |
| Total kWh | 348,133 | Total | $ | 24,341 | Reheat cost / CFM extra | $ | 0.85 |
| Total Therms | 8,633 | CV Exh. Fan: | $ | 19,792 | Fan cost / CFM | $ | 1.09 |
| Peak kW | 302 | Staged Exh: | $ | 10,027 | | | |
| | | VFD Exh: | $ | 4,646 | | | |

#### Savings

| Annual Occ Energy Units Saved | | Annual Occ Energy Cost Savings | | |
|---|---|---|---|---|
| Cooling kWh | 216,982 | Cooling | $ | 13,019 |
| Heating Therms | (2) | Heating | $ | (1) |
| Reheat Therms | 40,255 | Reheat | $ | 16,102 |
| Heating kWh | - | | | |
| Reheat kWh | - | | | |
| Supply Fan kWh | 250,780 | Supply Fan | $ | 15,047 |
| Exhaust Fan kWh | 168,497 | Exhaust Fan | $ | 10,110 |
| Total kWh | 636,260 | Total | $ | 54,277 |
| Total Therms | 40,253 | | | |
| Peak kW | 489 | | | |

### UnOcc

#### Base Design

| Annual Unocc Energy Units | | Annual Unocc Energy Costs | | | Total Annual Costs at Unocc Average Flow | | |
|---|---|---|---|---|---|---|---|
| Cooling kWh | 467,015 | Cooling | $ | 28,021 | $ | 2.45 | per CFM |
| Heating Therms | 80 | Heating | $ | 32 | | | |
| Reheat Therms | 103,650 | Reheat | $ | 41,460 | | | |
| Heating kWh | - | | | | | | |
| Reheat kWh | - | | | | **Costs per CFM** | | |
| Supply Fan kWh | 567,041 | Supply Fan | $ | 34,022 | Cooling cost / CFM | $ | 0.49 |
| Exhaust Fan kWh | 604,022 | Exhaust Fan | $ | 36,241 | Heating cost / CFM | $ | 0.00 |
| Total kWh | 1,638,079 | Total | $ | 139,777 | Reheat cost / CFM extra | $ | 0.85 |
| Total Therms | 103,731 | | | | Fan cost / CFM | $ | 1.23 |
| Peak kW | 791 | | | | | | |

#### Proposed Design

| Annual Unocc Energy Units | | Annual Unocc Energy Costs | | | Total Annual Costs at Unocc Average Flow | | |
|---|---|---|---|---|---|---|---|
| Cooling kWh | 152,585 | Cooling | $ | 9,155 | $ | 2.10 | per CFM |
| Heating Therms | 70 | Heating | $ | 28 | | | |
| Reheat Therms | 27,899 | Reheat | $ | 11,160 | | | |
| Heating kWh | - | | | | | | |
| Reheat kWh | - | | | | **Costs per CFM** | | |
| Supply Fan kWh | 106,572 | Supply Fan | $ | 6,394 | Cooling cost / CFM | $ | 0.43 |
| Exhaust Fan kWh | 300,365 | Exhaust Fan | $ | 18,022 | Heating cost / CFM | $ | 0.00 |
| Total kWh | 559,522 | Total | $ | 44,759 | Reheat cost / CFM extra | $ | 0.85 |
| Total Therms | 27,969 | CV Exh. Fan: | $ | 35,574 | Fan cost / CFM | $ | 1.15 |
| Peak kW | 286 | Staged Exh: | $ | 18,022 | | | |
| | | VFD Exh: | $ | 9,686 | | | |

#### Savings

| Annual Unocc Energy Units Saved | | Annual Unocc Energy Cost Savings | | |
|---|---|---|---|---|
| Cooling kWh | 314,430 | Cooling | $ | 18,866 |
| Heating Therms | 10 | Heating | $ | 4 |
| Reheat Therms | 75,751 | Reheat | $ | 30,300 |
| Heating kWh | - | | | |
| Reheat kWh | - | | | |
| Supply Fan kWh | 460,469 | Supply Fan | $ | 27,628 |
| Exhaust Fan kWh | 303,658 | Exhaust Fan | $ | 18,219 |
| Total kWh | 1,078,557 | Total | $ | 95,018 |
| Total Therms | 75,762 | | | |
| Peak kW | 505 | | | |

### Total

#### Base Design

| Annual Total Energy Units | | Annual Total Energy Costs | | | Total Annual Costs at All Average Flows | | |
|---|---|---|---|---|---|---|---|
| Cooling kWh | 800,740 | Cooling | $ | 48,044 | $ | 2.48 | per CFM |
| Heating Therms | 99 | Heating | $ | 40 | | | |
| Reheat Therms | 152,517 | Reheat | $ | 61,007 | | | |
| Heating kWh | - | | | | | | |
| Reheat kWh | - | | | | **Costs per CFM** | | |
| Supply Fan kWh | 882,102 | Supply Fan | $ | 52,926 | Cooling cost / CFM | $ | 0.54 |
| Exhaust Fan kWh | 939,630 | Exhaust Fan | $ | 56,378 | Heating cost / CFM | $ | 0.00 |
| Glycol Pump kWh | - | Glycol Pump | $ | 1,711 | | | |
| Total kWh | 2,622,472 | Total | $ | 220,106 | Reheat cost / CFM extra | $ | 0.85 |
| Total Therms | 152,616 | | | | Fan cost / CFM | $ | 1.23 |
| Peak kW | 791 | | | | | | |

#### Proposed Design

| Annual HVAC Total Energy Units | | Annual Total HVAC Energy Costs | | | Total Annual Costs at All Average Flows | | |
|---|---|---|---|---|---|---|---|
| Cooling kWh | 269,327 | Cooling | $ | 16,160 | $ | 2.09 | per CFM |
| Heating Therms | 91 | Heating | $ | 36 | | | |
| Reheat Therms | 36,511 | Reheat | $ | 14,605 | | | |
| Heating kWh | - | | | | | | |
| Reheat kWh | - | | | | **Costs per CFM** | | |
| Supply Fan kWh | 170,852 | Supply Fan | $ | 10,251 | Cooling cost / CFM | $ | 0.48 |
| Exhaust Fan kWh | 467,475 | Exhaust Fan | $ | 28,049 | Heating cost / CFM | $ | 0.00 |
| Glycol Pump kWh | - | Glycol Pump | $ | 1,886 | | | |
| Total kWh | 907,655 | Total | $ | 70,986 | Reheat cost / CFM extra | $ | 0.85 |
| Total Therms | 36,602 | CV Exh. Fan: | $ | 55,367 | Fan cost / CFM | $ | 1.13 |
| Peak kW | 302 | Staged Exh: | $ | 28,049 | | | |
| | | VFD Exh: | $ | 14,332 | | | |

#### Savings

| Annual Total Energy Units Saved | | Annual Total Energy Cost Savings | | |
|---|---|---|---|---|
| Cooling kWh | 531,412 | Cooling | $ | 31,885 |
| Heating Therms | 8 | Heating | $ | 3 |
| Reheat Therms | 116,006 | Reheat | $ | 46,402 |
| Heating kWh | - | | | |
| Reheat kWh | - | | | |
| Supply Fan kWh | 711,249 | Supply Fan | $ | 42,675 |
| Exhaust Fan kWh | 472,155 | Exhaust Fan | $ | 28,329 |
| Glycol Pump kWh | - | Glycol Pump | $ | (175) |
| Total kWh | 1,714,816 | Total | $ | 149,120 |
| Total Therms | 116,014 | | | 68% |
| Peak kW | 489 | | | |

### Full CV Flow

| Annual Energy Units | | Annual Energy Costs | | | Total Annual Costs at Average Flow | | |
|---|---|---|---|---|---|---|---|
| Cooling kWh | 800,740 | Cooling | $ | 48,044 | $ | 2.42 | per CFM |
| Heating Therms | 99 | Heating | $ | 40 | | | |
| Reheat Therms | 137,738 | Reheat | $ | 55,095 | | | |
| Heating kWh | - | | | | | | |
| Reheat kWh | - | | | | **Costs per CFM** | | |
| Supply Fan kWh | 882,102 | Supply Fan | $ | 52,926 | Cooling cost / CFM | $ | 0.54 |
| Exhaust Fan kWh | 939,630 | Exhaust Fan | $ | 56,378 | Heating cost / CFM | $ | 0.00 |
| Glycol Pump kWh | - | Glycol Pump | $ | 1,711 | Reheat cost / CFM extra | $ | 0.77 |
| Total kWh | 2,622,472 | Total | $ | 214,194 | Fan cost / CFM | $ | 1.23 |
| Total Therms | 137,837 | | | | | | |

| Net Lab & Other Areas Electrical Loads (Plugs, Lights, etc.) | | Net Lab Electrical Load Energy Costs | | |
|---|---|---|---|---|
| Day Clg Load kWh | 374,690 | Day Clg Load | $ | 22,481 |
| Nite Clg Load kWh | 363,670 | Nite Clg Load | $ | 21,820 |
| Total Clg Load kWh | 738,360 | Total Load | $ | 44,302 |
| Peak Clg Load Kw | 160 | | | |

| NSF Lab & Other Energy | Base | Proposed |
|---|---|---|
| HVAC Energy in equiv KBTU | 24,212,115 | 6,758,035 |
| Total energy in equiv. KBTU | 26,732,137 | 9,278,058 |
| Total energy in equiv. BTU/ft2 | 875,402 | 303,830 |
| Total energy in equiv. kWh/ft2 | 256.5 | 89.0 |

| GSF Building Electrical Loads (Plugs, Lights, etc.) | | GSF Building Electrical Load Energy Costs | | |
|---|---|---|---|---|
| Day Clg Load kWh | 430,893 | Day Clg Load | $ | 25,854 |
| Nite Clg Load kWh | 418,221 | Nite Clg Load | $ | 25,093 |
| Total Clg Load kW | 849,114 | Total Load | $ | 50,947 |
| Peak Clg Load Kw | 184 | | | |

| Building GSF Energy | Base | Proposed |
|---|---|---|
| HVAC Energy in equiv KBTU | 27,843,932 | 7,771,741 |
| Total energy in equiv. KBTU | 30,741,958 | 10,669,767 |
| Total energy in equiv. BTU/ft2 | 654,363 | 227,113 |
| Total energy in equiv. kWh/ft2 | 191.7 | 66.5 |

# SUNY OSWEGO | EEM-11 INSTALL VFD ON PUMP MOTORS

*Energy Opportunity Area:* HVAC, Building Automation System (BAS)

*Buildings Affected:* Lanigan Hall, Mahar Hall, Penfield Library, Culkin Hall, Pathfinder Dining Hall, Seneca Hall, Cayuga Hall, Onondaga Hall, Oneida Hall, Cooper Dining Hall

## Overview

Energy efficiency measure EEM-11 analyzes the potential energy savings for installing variable frequency drives (VFD) on eligible campus hot water (HW), chilled water (CHW), and dual temperature pumps. The projected energy savings, energy cost savings, and estimated project cost are summarized below.

**Table 1. EEM-11 Summary Data**

| Description | Values | Units |
|---|---|---|
| Annual Electrical Energy Savings | 294,149 | kWh/year |
| Electrical Peak Demand Savings | 30.7 | kW |
| Annual Electrical Energy Cost Savings | $17,355 | $/year |
| Annual Natural Gas Savings | 0 | Therms/year |
| Annual Natural Gas Cost Savings | $0 | $/year |
| **Total Annual Energy Cost Savings** | **$17,355** | **$/year** |
| **Estimated Implementation Cost** | **$402,611** | **$** |
| **Simple Payback Period** | **23.2** | **years** |
| **Savings to Investment Ratio** | **0.74** | |

## Existing Conditions/Baseline

Pumps considered for this EEM are summarized in Table 2. Hot water (HW) pumps have constant speed motors in a primary flow arrangement serving building terminal heating units, heating coils, or radiation loops. Hot water coils in Mahar and Culkin have two-way control valves. Hot water coils in other buildings generally have three-way control valves. Dual temperature pumps in Culkin serve air handling unit coils.

The chilled water (CHW) pumps listed in Table 2 have constant speed motors in a primary-only loop configuration serving building cooling coils. Flow through air handling unit CHW coils is generally controlled by three-way control valves. CHW coils in Penfield Library have two-way control valves.

**Table 2. EEM-11 Pump Summary**

| Building | Pump Tag | Service | Qty | HP | Fluid |
|---|---|---|---|---|---|
| 0006 - J LANIGAN HALL | P-5 | HW | 1 | 15 | Water |
| 0006 - J LANIGAN HALL | P-6 | HW | 1 | 10 | Water |
| 0006 - J LANIGAN HALL | P-7/P-8 | HW | 2.0 | 7.5 | Water |
| 0013 - M E MAHAR HALL | P-5/P-6 | HW | 2 | 15 | Water |

| Building | Pump Tag | Service | Qty | HP | Fluid |
|---|---|---|---|---|---|
| 0017 - J PENFIELD LIB | P-5 | HW | 1.0 | 7.5 | Water |
| 0017 - J PENFIELD LIB | P-6 | HW | 1.0 | 7.5 | Water |
| 0026 - CULKIN HALL | P-4/P-5 | Dual Temp | 2.0 | 7.5 | Water |
| 0026 - CULKIN HALL | P-6/P-7 | HW | 2.0 | 7.5 | Water |
| 0031 - PATHFINDER DH | P-5/P-6 | HW | 2 | 10 | Water |
| 0032 - SENECA HALL | P-1/P-2 | HW | 2.0 | 7.5 | Water |
| 0033 - CAYUGA HALL | CIR-P1/CIR-P2 | HW | 2 | 10 | Water |
| 0034 - ONONDAGA HALL | P-1/P-2 | HW | 2.0 | 7.5 | Water |
| 0036 - ONEIDA HALL | P-1/P-2 | HW | 2 | 10 | Water |
| 0006 - J LANIGAN HALL | P-1/P-2 | CHW | 2 | 40 | Water |
| 0017 - J PENFIELD LIB | P-1/P-2 | CHW | 2 | 40 | Water |
| 0031 - PATHFINDER DH | P-3/P-4 | CHW | 2 | 15 | Water |
| 0047 - COOPER DH | P-3 | CHW | 1.0 | 7.5 | Water |

### Recommended Action

This measure analyzes the conversion of primary constant speed/constant flow pumping systems to variable flow systems by installing VFDs on eligible pumps, replacing three-way control valves with two-way valves, and installing a differential pressure sensor across HW or CHW loops on each pumping system. The building automation system (BAS) will vary the VFD speed to maintain differential pressure at a determined setpoint. For CHW loops, the measure considers providing controls to prevent CHW flow through the chillers from dropping below the minimum recommended by the manufacturer.

The measure also considers implementing a differential pressure reset control scheme. Differential pressure reset control will poll the position of each valve on the system and dynamically reset the differential pressure setpoint lower until the worst-case valve is near fully open. In this way, the control scheme finds the minimum pressure that will satisfy all zones to minimize pumping energy and maximize energy savings.

Primary CHW pumps in constant speed primary/variable speed secondary pumping arrangements were not analyzed in this measure; Variable primary/variable secondary flow would present issues in meeting CHW loop minimum flow requirements. HW pumps serving the Sheldon Hall heat pump loop were not analyzed in this measure; installation of isolation valves at each heat pump is required to convert the loop to variable flow, increasing the implementation cost.

### Estimated Energy Savings

An hourly analysis was performed using Syracuse- Hancock International Airport TMY3 (Typical Meteorological Year) hourly weather data. Hot water flow was estimated based on assumed load profiles. Performance curves were applied to adjust pump input power for VFD applications.

Lead/standby pumping arrangements were accounted for in the energy savings calculations.

Supporting documents include an example of the assumptions and monthly baseline and post-retrofit conditions used for each pump type; HW, CHW, and Dual Temperature. Table 3 and Table 4 summarize estimated energy savings, implementation cost, and simple payback period for HW and CHW pumps, respectively.

**Table 3. EEM-11 VFD Installation on HW Pumps – Total Savings**

| Building | Annual Electric Energy Savings (kWh/year) | Electrical Peak Demand Savings (kW) | Total Annual Energy Cost Savings ($/year) | Estimated Implementation Cost | Simple Payback Period (years) |
|---|---|---|---|---|---|
| 0006 - J LANIGAN HALL | 32,593 | 2.2 | $1,923 | $66,206 | 34.4 |
| 0013 - M E MAHAR HALL | 16,659 | 1.8 | $983 | $17,050 | 17.3 |
| 0017 - J PENFIELD LIB | 14,410 | 1.0 | $850 | $21,918 | 25.8 |
| 0026 - CULKIN HALL | 46,210 | 2.7 | $2,726 | $43,589 | 16.0 |
| 0031 - PATHFINDER DH | 21,876 | 1.2 | $1,291 | $19,873 | 15.4 |
| 0032 - SENECA HALL | 16,390 | 0.9 | $967 | $22,214 | 23.0 |
| 0033 - CAYUGA HALL | 20,292 | 1.2 | $1,197 | $25,985 | 21.7 |
| 0034 - ONONDAGA HALL | 14,184 | 0.8 | $837 | $19,158 | 22.9 |
| 0036 - ONEIDA HALL | 22,717 | 1.3 | $1,340 | $16,817 | 12.5 |
| **Total** | **205,332** | **13.1** | **$12,115** | **$252,808** | **20.9** |

1. Culkin Hall savings include savings for VFD implementation on the dual temperature pumps
2. Cayuga is currently being used as an isolation dorm. Analysis was done under assumption Cayuga is operating as a residence hall at normal capacity.

**Table 4. EEM-11 VFD Installation on CHW Pumps - Total Savings**

| Building | Annual Electric Energy Savings (kWh/year) | Electrical Peak Demand Savings (kW) | Total Annual Energy Cost Savings ($/year) | Estimated Implementation Cost | Simple Payback Period (years) |
|---|---|---|---|---|---|
| 0006 - J LANIGAN HALL | 37,226 | 6.1 | $2,196 | $50,310 | 22.9 |
| 0017 - J PENFIELD LIB | 42,659 | 7.0 | $2,517 | $50,310 | 20.0 |
| 0031 - PATHFINDER DH | 4,783 | 3.1 | $282 | $23,162 | 82.1 |
| 0047 - COOPER DH | 4,149 | 1.3 | $245 | $26,020 | 106.3 |
| **Total** | **88,817** | **17.6** | **$5,240** | **$149,803** | **28.6** |

Pathfinder and Cooper Dining Halls are closed during the summer. The limited operating hours result in higher simple payback periods for the CHW pumps in these buildings.

### Estimated Project Cost

Costs presented in Table 5 cover the scope of work previously described and are based on costs published in RS Means 2023.

For cost estimation, it was generally assumed that terminal and perimeter radiation heating equipment have ¾" piping and air-handling unit coils have 3" piping for the two-way valve installation.

**Table 5. EEM-11 Estimated Project Costs**

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| Variable Frequency Drive, 7.5 hp | 13 | Ea. | $3,225 | $41,925 |
| Variable Frequency Drive, 10 hp | 7 | Ea. | $3,475 | $24,325 |
| Variable Frequency Drive, 15 hp | 5 | Ea. | $4,625 | $23,125 |
| Variable Frequency Drive, 40 hp | 4 | Ea. | $8,775 | $35,100 |
| Two-way Valve Replacement on Terminal Equip./Radiation Equip. | 18 | Ea. | $1,225 | $22,050 |
| Two-way Valve Replacement on AHU Coils | 42 | Ea. | $1,811 | $76,062 |
| Differential Pressure Sensor | 15.0 | Ea. | $955 | $14,325 |
| BAS I/O Points, Engineering, Calibration, Start-up/Checkout Labor | 1 | Lump Sum | $44,634 | $44,634 |
| **Labor and Materials Subtotal** | | | | **$281,546** |
| General Conditions | 10% | | | $28,155 |
| **Labor and Materials Cost Total** | | | | **$309,701** |
| Architectural & Engineering Fees | 10% | | | $30,970 |
| Construction Management Fees | 10% | | | $30,970 |
| Contingency | 10% | | | $30,970 |
| **Project Cost Subtotal** | | | | **$402,611** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$402,611** |

# EEM-11 – INSTALL VFD ON PUMP MOTORS

# SUPPORTING DOCUMENTS

# SUMMARY INPUTS: ECM-11 INSTALL VFD ON HW PUMP MOTOR - PATHFINDER DINING

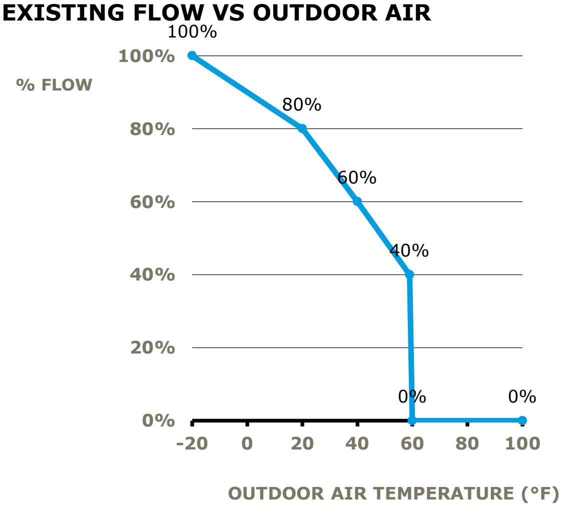
## Existing Conditions

| | |
|---|---|
| Tag | P-5/P-6-HW |
| Service | HW |
| Flow Control | Constant/Bypass |
| GPM | 300 |
| Head (ft) | 85 |
| Motor HP | 10 |
| BHP | 8.6 |
| Motor kW | 7.0 |

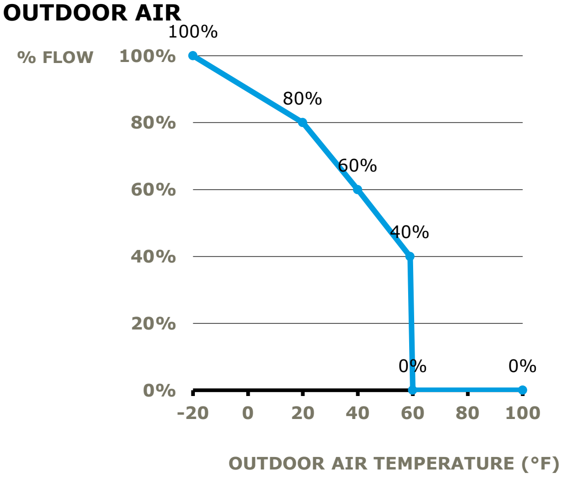
## Post-Retrofit Conditions

| | |
|---|---|
| Tag | P-5/P-6-HW |
| Service | HW |
| Flow Control | VFD with Differential Pressure Reset |
| GPM | 300 |
| Head (ft) | 85 |
| Motor HP | 10 |
| BHP | 8.6 |
| Motor kW | 7.0 |

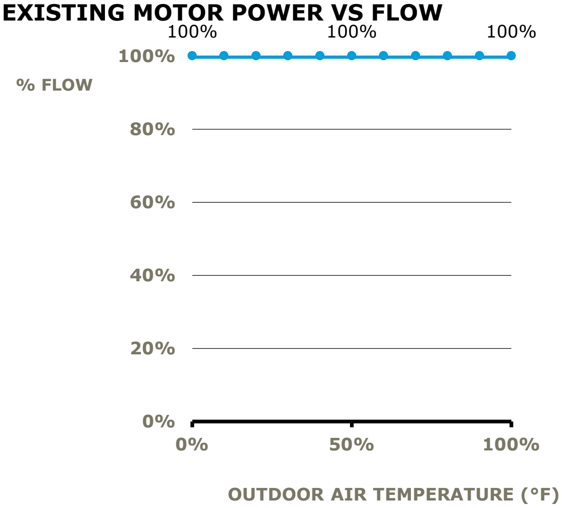
### EXISTING FLOW VS OUTDOOR AIR



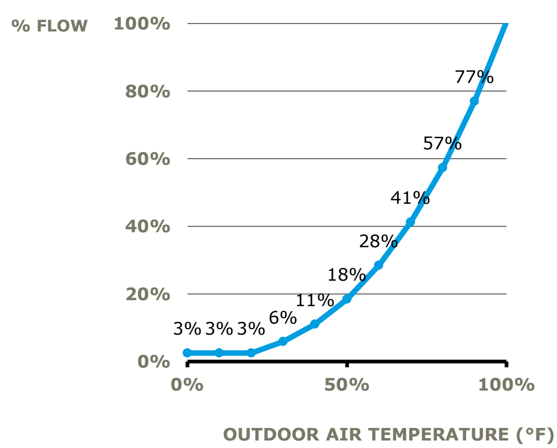

### POST-RETROFIT FLOW VS OUTDOOR AIR




### EXISTING MOTOR POWER VS FLOW




### POST-RETROFIT MOTOR POWER VS FLOW



# RESULTS: ECM-11 INSTALL VFD ON HW PUMP MOTOR - PATHFINDER DINING HALL

## Baseline Monthly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| **Jan** | 26.0 | 744 | 5,197 | 7.0 |
| **Feb** | 25.4 | 672 | 4,694 | 7.0 |
| **Mar** | 37.4 | 672 | 4,694 | 7.0 |
| **Apr** | 47.9 | 591 | 4,128 | 7.0 |
| **May** | 59.9 | 181 | 1,264 | 7.0 |
| **Jun** | 66.4 | 0 | 0 | 0.0 |
| **Jul** | 71.8 | 0 | 0 | 0.0 |
| **Aug** | 68.0 | 0 | 0 | 0.0 |
| **Sep** | 60.7 | 0 | 0 | 0.0 |
| **Oct** | 49.5 | 631 | 4,407 | 7.0 |
| **Nov** | 40.9 | 678 | 4,736 | 7.0 |
| **Dec** | 27.7 | 744 | 5,197 | 7.0 |
| **Annual** | **48.6** | **4,913** | **34,316** | **7.0** |

## Proposed Monthly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| **Jan** | 26.0 | 744 | 2,454 | 5.4 |
| **Feb** | 25.4 | 672 | 2,258 | 4.9 |
| **Mar** | 37.4 | 672 | 1,737 | 4.7 |
| **Apr** | 47.9 | 591 | 1,049 | 3.1 |
| **May** | 59.9 | 181 | 235 | 2.2 |
| **Jun** | 66.4 | 0 | 0 | 0.0 |
| **Jul** | 71.8 | 0 | 0 | 0.0 |
| **Aug** | 68.0 | 0 | 0 | 0.0 |
| **Sep** | 60.7 | 0 | 0 | 0.0 |
| **Oct** | 49.5 | 631 | 951 | 2.9 |
| **Nov** | 40.9 | 678 | 1,437 | 4.7 |
| **Dec** | 27.7 | 744 | 2,319 | 5.7 |
| **Annual** | **48.6** | **4,913** | **12,440** | **5.7** |

## Monthly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| **Jan** | - | 0 | 2,742 | 1.6 |
| **Feb** | - | 0 | 2,435 | 2.1 |
| **Mar** | - | 0 | 2,957 | 2.3 |
| **Apr** | - | 0 | 3,079 | 3.9 |
| **May** | - | 0 | 1,030 | 4.8 |
| **Jun** | - | 0 | 0 | 0.0 |
| **Jul** | - | 0 | 0 | 0.0 |
| **Aug** | - | 0 | 0 | 0.0 |
| **Sep** | - | 0 | 0 | 0.0 |
| **Oct** | - | 0 | 3,456 | 4.1 |
| **Nov** | - | 0 | 3,298 | 2.3 |
| **Dec** | - | 0 | 2,877 | 1.2 |
| **Annual** | **-** | **0** | **21,876** | **4.8** |

# SUMMARY INPUTS: ECM-11 INSTALL VFD ON CHW PUMP MOTOR - PENFIELD LIBRARY

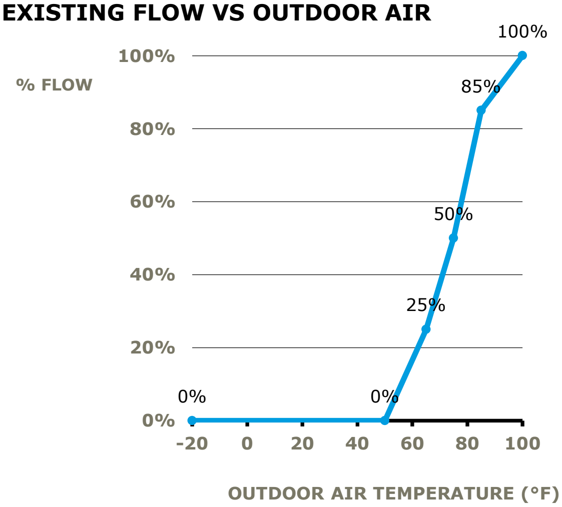
## Existing Conditions

| | |
|---|---|
| Tag | P-1/P-2 |
| Service | Primary CHW |
| Flow Control | Constant/Bypass |
| GPM | 1510 |
| Head (ft) | 80 |
| Motor HP | 40 |
| BHP | 35.5 |
| Motor kW | 28.1 |

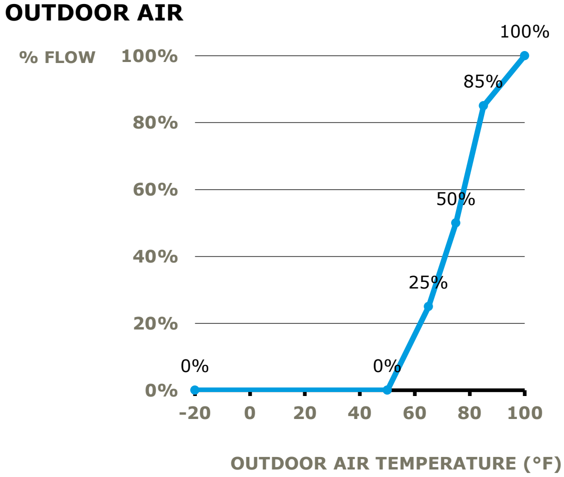
## Post-Retrofit Conditions

| | |
|---|---|
| Tag | P-1/P-2 |
| Service | Primary CHW |
| Flow Control | VFD with Differential Pressure Reset |
| GPM | 1510 |
| Head (ft) | 80 |
| Motor HP | 40 |
| BHP | 35.5 |
| Motor kW | 28.1 |

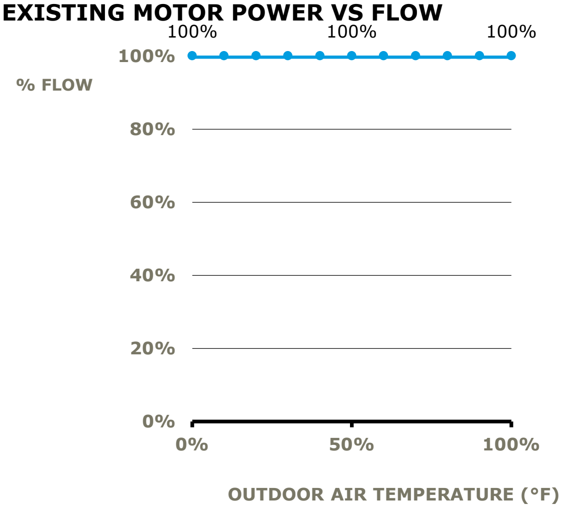
**EXISTING FLOW VS OUTDOOR AIR**



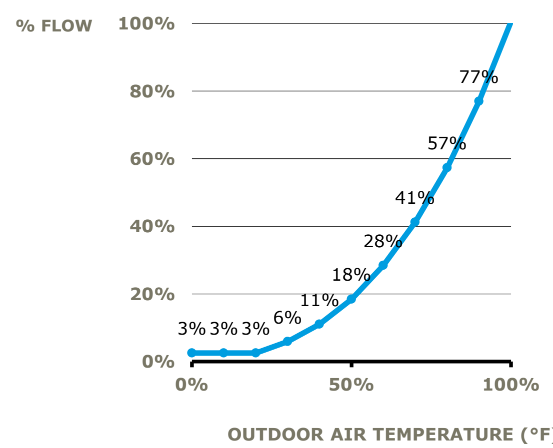

**POST-RETROFIT FLOW VS OUTDOOR AIR**




**EXISTING MOTOR POWER VS FLOW**




**POST-RETROFIT MOTOR POWER VS FLOW**



# RESULTS: ECM-11 INSTALL VFD ON HW PUMP MOTOR - PENFIELD LIBRARY

## Baseline Monthly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| **Jan** | 26.0 | 0 | 0 | 0.0 |
| **Feb** | 25.4 | 0 | 0 | 0.0 |
| **Mar** | 37.4 | 0 | 0 | 0.0 |
| **Apr** | 47.9 | 0 | 0 | 0.0 |
| **May** | 59.9 | 143 | 4,021 | 28.1 |
| **Jun** | 66.4 | 527 | 14,819 | 28.1 |
| **Jul** | 71.8 | 670 | 18,841 | 28.1 |
| **Aug** | 68.0 | 521 | 14,651 | 28.1 |
| **Sep** | 60.7 | 368 | 10,341 | 28.1 |
| **Oct** | 49.5 | 0 | 0 | 0.0 |
| **Nov** | 40.9 | 0 | 0 | 0.0 |
| **Dec** | 27.7 | 0 | 0 | 0.0 |
| **Annual** | **48.6** | **2,229** | **62,673** | **28.1** |

## Proposed Monthly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| **Jan** | 26.0 | 0 | 0 | 0.0 |
| **Feb** | 25.4 | 0 | 0 | 0.0 |
| **Mar** | 37.4 | 0 | 0 | 0.0 |
| **Apr** | 47.9 | 0 | 0 | 0.0 |
| **May** | 59.9 | 143 | 1,154 | 8.0 |
| **Jun** | 66.4 | 527 | 4,738 | 21.1 |
| **Jul** | 71.8 | 670 | 6,430 | 21.1 |
| **Aug** | 68.0 | 521 | 4,555 | 19.3 |
| **Sep** | 60.7 | 368 | 3,136 | 19.3 |
| **Oct** | 49.5 | 0 | 0 | 0.0 |
| **Nov** | 40.9 | 0 | 0 | 0.0 |
| **Dec** | 27.7 | 0 | 0 | 0.0 |
| **Annual** | **48.6** | **2,229** | **20,014** | **21.1** |

## Monthly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| **Jan** | - | 0 | 0 | 0.0 |
| **Feb** | - | 0 | 0 | 0.0 |
| **Mar** | - | 0 | 0 | 0.0 |
| **Apr** | - | 0 | 0 | 0.0 |
| **May** | - | 0 | 2,867 | 20.1 |
| **Jun** | - | 0 | 10,081 | 7.0 |
| **Jul** | - | 0 | 12,410 | 7.0 |
| **Aug** | - | 0 | 10,095 | 8.8 |
| **Sep** | - | 0 | 7,205 | 8.8 |
| **Oct** | - | 0 | 0 | 0.0 |
| **Nov** | - | 0 | 0 | 0.0 |
| **Dec** | - | 0 | 0 | 0.0 |
| **Annual** | **-** | **0** | **42,659** | **20.1** |

## SUMMARY INPUTS: ECM-11 INSTALL VFD ON DUAL TEMPERATURE PUMP MOTOR - CULKI

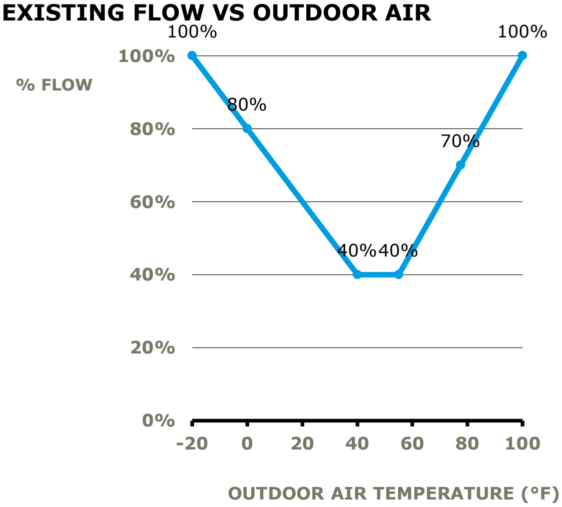
### Existing Conditions

| | |
|---|---|
| Tag | P-4/P-5 |
| Service | Dual Temperature |
| Flow Control | Constant/Bypass |
| GPM | 316 |
| Head (ft) | 60 |
| Motor HP | 7.5 |
| BHP | 6.4 |
| Motor kW | 5.4 |

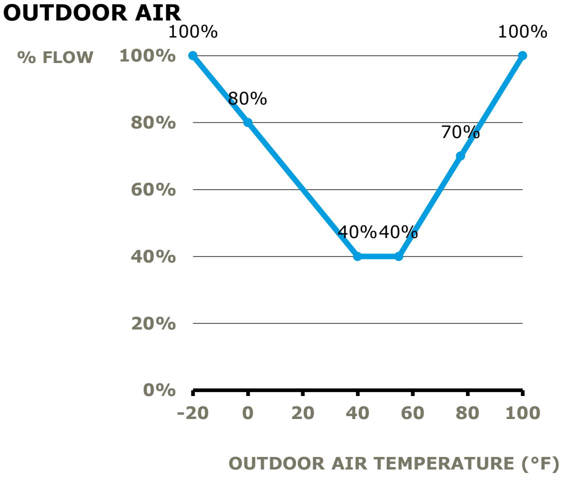
### Post-Retrofit Conditions

| | |
|---|---|
| Tag | P-4/P-5 |
| Service | Dual Temperature |
| Flow Control | VFD with Differential Pressure Reset |
| GPM | 316 |
| Head (ft) | 60 |
| Motor HP | 7.5 |
| BHP | 6.4 |
| Motor kW | 5.4 |

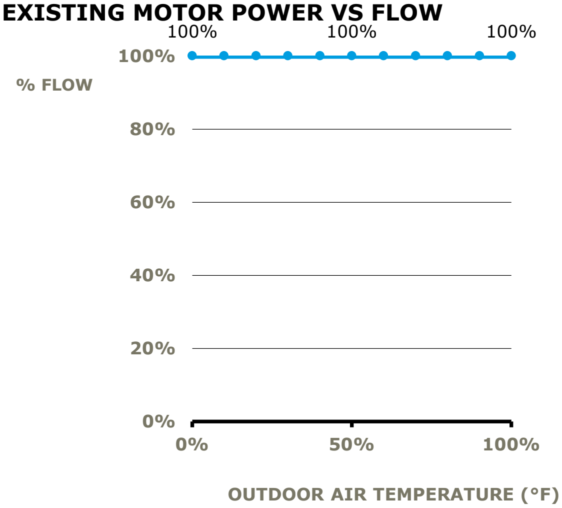
**EXISTING FLOW VS OUTDOOR AIR**



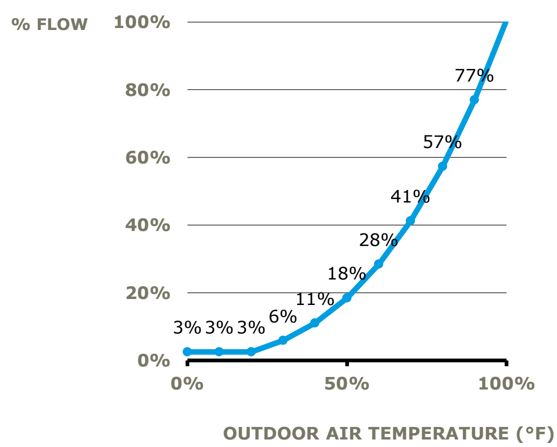

**POST-RETROFIT FLOW VS OUTDOOR AIR**




**EXISTING MOTOR POWER VS FLOW**




**POST-RETROFIT MOTOR POWER VS FLOW**



# RESULTS: ECM-11 INSTALL VFD ON DUAL TEMPERATURE PUMP MOTOR - CULKIN HALL

## Baseline Monthly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| Jan | 26.0 | 618 | 3,326 | 5.4 |
| Feb | 25.4 | 672 | 3,616 | 5.4 |
| Mar | 37.4 | 600 | 3,229 | 5.4 |
| Apr | 47.9 | 648 | 3,487 | 5.4 |
| May | 59.9 | 582 | 3,132 | 5.4 |
| Jun | 66.4 | 720 | 3,874 | 5.4 |
| Jul | 71.8 | 726 | 3,907 | 5.4 |
| Aug | 68.0 | 582 | 3,132 | 5.4 |
| Sep | 60.7 | 684 | 3,681 | 5.4 |
| Oct | 49.5 | 708 | 3,810 | 5.4 |
| Nov | 40.9 | 648 | 3,487 | 5.4 |
| Dec | 27.7 | 420 | 2,260 | 5.4 |
| **Annual** | **48.6** | **7,608** | **40,940** | **5.4** |

## Proposed Monthly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| Jan | 26.0 | 618 | 769 | 3.1 |
| Feb | 25.4 | 672 | 861 | 2.5 |
| Mar | 37.4 | 600 | 636 | 2.7 |
| Apr | 47.9 | 648 | 538 | 3.0 |
| May | 59.9 | 582 | 604 | 2.6 |
| Jun | 66.4 | 720 | 1,024 | 3.2 |
| Jul | 71.8 | 726 | 1,269 | 3.6 |
| Aug | 68.0 | 582 | 914 | 3.1 |
| Sep | 60.7 | 684 | 754 | 3.2 |
| Oct | 49.5 | 708 | 500 | 1.5 |
| Nov | 40.9 | 648 | 544 | 2.3 |
| Dec | 27.7 | 420 | 540 | 3.6 |
| **Annual** | **48.6** | **7,608** | **8,953** | **3.6** |

## Monthly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| Jan | - | 0 | 2,556 | 2.3 |
| Feb | - | 0 | 2,756 | 2.9 |
| Mar | - | 0 | 2,592 | 2.7 |
| Apr | - | 0 | 2,949 | 2.4 |
| May | - | 0 | 2,528 | 2.8 |
| Jun | - | 0 | 2,850 | 2.2 |
| Jul | - | 0 | 2,638 | 1.7 |
| Aug | - | 0 | 2,217 | 2.3 |
| Sep | - | 0 | 2,926 | 2.2 |
| Oct | - | 0 | 3,310 | 3.9 |
| Nov | - | 0 | 2,943 | 3.1 |
| Dec | - | 0 | 1,721 | 1.8 |
| **Annual** | **-** | **0** | **31,987** | **3.9** |

## LIFE CYCLE COST ANALYSIS

ECM No.: EEM-11

ECM Title: Install VFD on Pump Motors

**General Parameters**

| | |
|---|---|
| Base Date: | 1/1/2023 |
| Service Date: | 1/1/2023 |
| Study Period (Years): | 15 |
| Discount Rate: | 3% |
| Cost Escalation: | 0% |
| FEMP UPV Discount Factor (Elect.): | 14.96 |
| FEMP UPV Discount Factor (NG): | 13.70 |

| Cost Data | Baseline | Proposed | Savings |
|---|---|---|---|
| Initial Capital Cost: | | $402,611 | ($402,611) |
| Annual Electricity Costs: | $29,788 | $10,003 | $19,785 |
| Annual Natural Gas Costs: | $0 | $0 | $0 |
| Annual Water Costs: | $0 | $0 | $0 |
| Annual OM&R Costs: | $8,446 | $8,446 | $0 |
| Other Recurring Annual Costs: | $0 | $0 | $0 |

| Life Cycle Cost Calculations | Baseline | Proposed | Savings |
|---|---|---|---|
| Present Value Investment Costs, I: | $0 | $402,611 | ($402,611) |
| Present-Value Capital Replacement Cost, Repl: | $0 | $0 | $0 |
| Present Value Residual Cost, Res: | $0 | $0 | $0 |
| Present Value Energy Costs, E: | $445,595 | $149,635 | $295,960 |
| Present Value Water Cost, W: | $0 | $0 | $0 |
| Present Value O&M and Other Recurring Costs, OM&R: | $100,832 | $100,832 | $0 |
| **LCC:** | **$546,427** | **$653,078** | **($106,650)** |

**Savings to Investment Ratio Calculations**

| | |
|---|---|
| Present Value Energy Cost Savings, DE: | $295,960 |
| Present Value Water Cost Savings, DW: | $0 |
| Present Value OM&R Cost Savings, DOM&R: | $0 |
| **SIR:** | **0.74** |

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

# SUNY OSWEGO | EEM-12 CONVERT CONSTANT VOLUME SINGLE ZONE SYSTEM TO SINGLE ZONE VAV SYSTEM

*Energy Opportunity Area:* HVAC, Building Automation System (BAS)

*Buildings Affected:* Marano Campus Center, Cooper Dining Hall, Laker Hall, Lakeside Dining Hall, Lanigan Hall, Lee Hall, Pathfinder Dining Hall, Romney Field House

**Table 1. EEM-12 Summary Data**

| Description | Values | Units |
|---|---|---|
| Annual Electrical Energy Savings | 376,296 | kWh/year |
| Electrical Peak Demand Savings | 96.7 | kW |
| Annual Electrical Energy Cost Savings | $22,201 | $/year |
| Annual Natural Gas Savings | 0 | Therms/year |
| Annual Natural Gas Cost Savings | $0 | $/year |
| **Total Annual Energy Cost Savings** | **$22,201** | **$/year** |
| **Total Project Cost** | **$142,040** | **$** |
| **Simple Payback Period** | **6.4** | **Years** |
| **Savings to Investment Ratio** | **2.3** | - |

## Existing Conditions/Baseline

Table 2 lists constant volume single zone (CVSZ) units that are potential candidates for conversion to single zone variable air volume (SZVAV) units. All units provide heating and ventilation. Four of the units listed (in Cooper, Lakeside, Lanigan, and Pathfinder) also provide cooling. Air handling unit (AHU) heating and cooling coils are controlled through the building automation system (BAS) to maintain space temperature at setpoint, while the supply and return fans deliver a constant quantity of air when the system is operating. The BAS enables the Romney Field House packaged outdoor AHU, but the furnace is controlled through internal AHU controls.

**Table 2. Constant Volume Single Zone Units**

| Building | Unit | Serves | Supply Fan HP | Return Fan HP |
|---|---|---|---|---|
| 0003 – CAMPUS CENTER | S-3 | Swetman Gym (North) | 3 | 1 |
| 0003 – CAMPUS CENTER | S-4 | Swetman Gym (South) | 3 | 1 |
| 0047 – COOPER DINING HALL | AC-2 | Dining Area | 10 | - |
| 0019 – LAKER HALL | AHU-1 | Weight Room | 5 | - |
| 0019 – LAKER HALL | HV-4 | Main Gym (East) | 15 | - |
| 0019 – LAKER HALL | HV-5 | Main Gym (Center) | 15 | - |

| Building | Unit | Serves | Supply Fan HP | Return Fan HP |
|---|---|---|---|---|
| 0019 – LAKER HALL | HV-6 | Main Gym (West) | 15 | - |
| 0019 – LAKER HALL | HV-7 | Auxiliary Gym | 15 | - |
| 0042 – LAKESIDE DINING HALL | AHU-1 | Dining Area | 10 | - |
| 0006 – J LANIGAN HALL | AC-3 | Lecture Hall 101 | 10 | 3 |
| 0004 – M V LEE HALL | HV-2 | Main Gym | 7.5 | 3 |
| 0031 – PATHFINDER DINING HALL | SF-1 | Dining Area | 20 | - |
| 0021 – ROMNEY FIELD HOUSE | AHU-1 | Field House | 50 (est.) | - |

### Recommended Action

Constant volume single zone systems can be converted to single zone VAV by installing variable frequency drives (VFDs) on the air handling unit fans and applying a temperature-based control scheme to modulate airflow as heating and cooling loads change. A typical SZVAV control scheme is shown in Figure 1. Ultimately, fan speed and heating and cooling coil valves are controlled to maintain space temperature at setpoint. Additionally, retrofit kits can be installed to convert constant volume single zone packaged units to SZVAV packaged units. Variable frequency drives, sensors, hardware, and internal control logic control fan speed and discharge temperature, while maintaining a minimum flow through the unit’s furnace and across the evaporator coil.

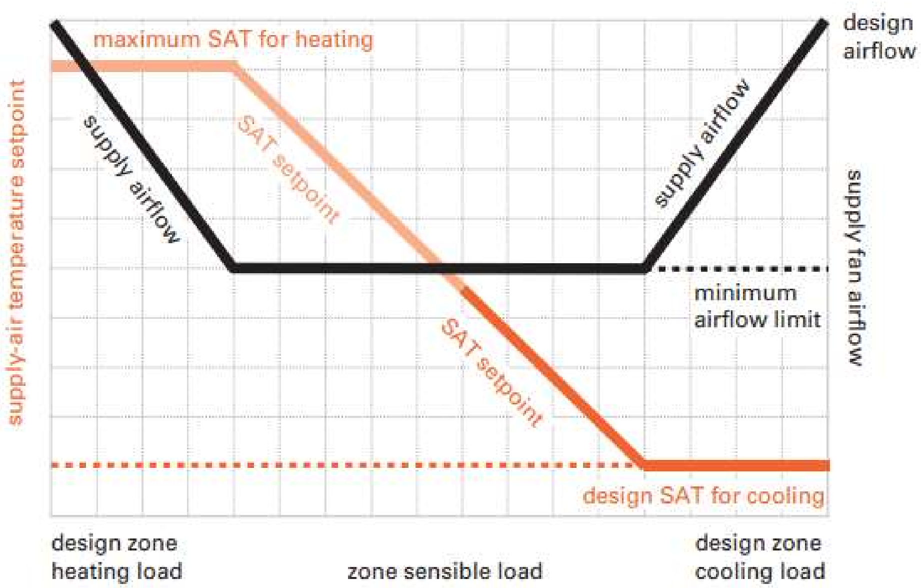



**Figure 1. Single Zone VAV Control Scheme**[1]

[1] Trane Engineers Newsletter volume 42-2, 2013

## Estimated Energy Savings

An hourly analysis was performed using Syracuse Hancock International Airport TMY3 (Typical Meteorological Year) hourly weather data. Airflows were estimated based on assumed load profiles. Performance curves obtained from the Pacific Northwest National Laboratory PNNL-26917 reference manual document ("Single Zone VAV Fan") were applied to adjust fan input power for off-design conditions. Single zone VAV systems provide the following benefits:

- Reduced energy consumption at part load conditions
- Better dehumidification at part load conditions
- Reduced noise due to slower fan speeds and lower airflow in the ductwork

Supporting documents include a summary of the assumptions and monthly baseline and post-retrofit conditions for one of each representative space type analyzed – lecture hall (Lanigan), gymnasium (Lee), and dining hall (Pathfinder).

Table 3 summarizes estimated energy savings, implementation cost, and simple payback period.

**Table 3. EEM-12 Savings**

| Building | Annual Electric Energy Savings (kWh/year) | Electrical Peak Demand Savings (kW) | Total Annual Energy Cost Savings ($/year) | Estimated Implementation Cost | Simple Payback Period (years) |
|---|---|---|---|---|---|
| 0003 – CAMPUS CENTER | 16,356 | 4.2 | $965 | $21,485 | 22.3 |
| 0047 – COOPER DINING HALL | 23,557 | 5.5 | $1,390 | $7,889 | 5.7 |
| 0019 – LAKER HALL | 109,364 | 28.2 | $6,452 | $46,418 | 7.2 |
| 0042 – LAKESIDE DINING HALL | 21,581 | 5.0 | $1,273 | $7,889 | 6.2 |
| 0006 – J LANIGAN HALL | 19,993 | 7.3 | $1,180 | $13,103 | 11.1 |
| 0004 – M V LEE HALL | 25,263 | 6.5 | $1,491 | $12,746 | 8.6 |
| 0031 – PATHFINDER DINING HALL | 51,144 | 11.9 | $3,018 | $11,357 | 3.8 |
| 0021 – ROMNEY FIELD HOUSE | 109,038 | 28.1 | $6,433 | $21,153 | 3.3 |
| **Total** | **376,296** | **96.7** | **$22,201** | **$142,040** | **6.4** |

## Estimated Project Cost

Costs presented in Table 4 represent the scope of work described previously and are based on costs published in RS Means 2023.

**Table 4. EEM-12 Estimated Project Costs**

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| Variable Frequency Drive, 1 HP | 2 | Ea. | $2,474 | $4,948 |
| Variable Frequency Drive, 3 HP | 4 | Ea. | $2,950 | $11,800 |
| Variable Frequency Drive, 5 HP | 1 | Ea. | $3,200 | $3,200 |

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| Variable Frequency Drive, 7.5 HP | 1 | Ea. | $3,875 | $3,875 |
| Variable Frequency Drive, 10 HP | 3 | Ea. | $4,125 | $12,375 |
| Variable Frequency Drive, 15 HP | 4 | Ea. | $5,575 | $22,300 |
| Variable Frequency Drive, 20 HP | 1 | Ea. | $6,550 | $6,550 |
| Variable Frequency Drive, 50 HP | 1 | Ea. | $13,400 | $13,400 |
| BAS I/O Points, Engineering, Calibration, Start-up/Checkout Labor | 1 | Lump Sum | $20,880 | $20,880 |
| **Labor and Materials Subtotal** | | | | **$99,328** |
| General Conditions | 10% | | | $9,933 |
| **Labor and Materials Cost Total** | | | | **$109,261** |
| Architectural & Engineering Fees | 10% | | | $10,926 |
| Construction Management Fees | 10% | | | $10,926 |
| Contingency | 10% | | | $10,926 |
| **Project Cost Subtotal** | | | | **$142,040** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$142,040** |

# EEM-12 – CONVERT CONSTANT VOLUME SINGLE ZONE SYSTEM TO SINGLE ZONE VAV SYSTEM

## SUPPORTING DOCUMENTS

# SUMMARY INPUTS: EEM-12 CONVERT CVSZ TO SZVAV - LANIGAN HALL

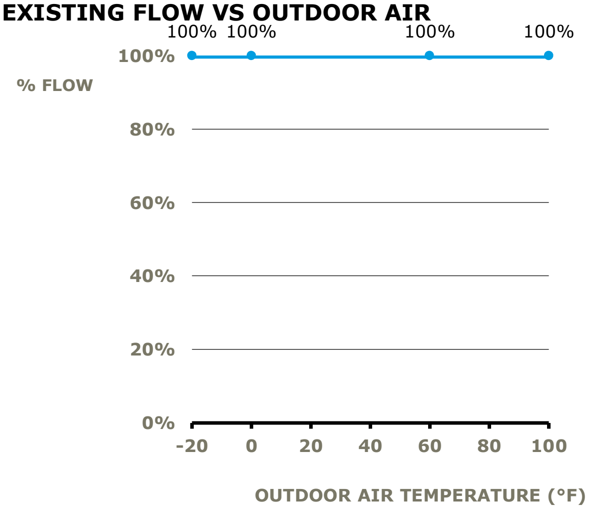
## Existing Conditions

| | |
|---|---|
| Tag | Fan |
| Service | Lecture Hall 101 SF |
| Flow Control | Constant |
| CFM | 12,350 |
| Total SP (in w | 3 |
| Motor HP | 10 |
| BHP | 7.5 |
| Motor kW | 6.1 |

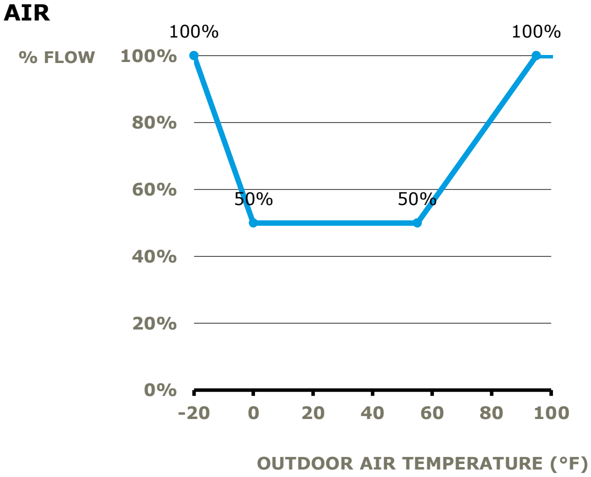
## Post-Retrofit Conditions

| | |
|---|---|
| Tag | Fan |
| Service | Lecture Hall 101 SF |
| Flow Control | Single Zone VAV Fan |
| CFM | 12,350 |
| Total SP (in w | 3 |
| Motor HP | 10 |
| BHP | 7.5 |
| Motor kW | 6.1 |

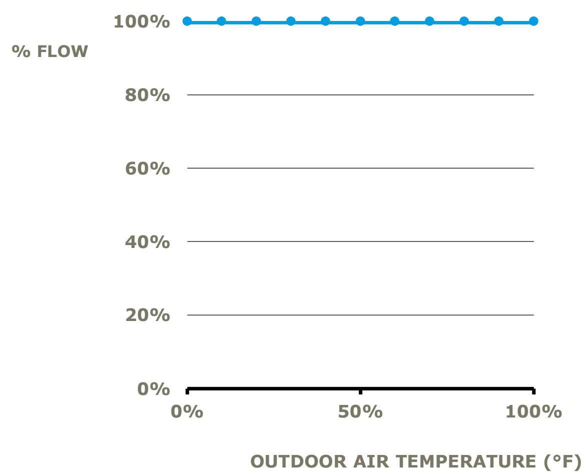
### EXISTING FLOW VS OUTDOOR AIR



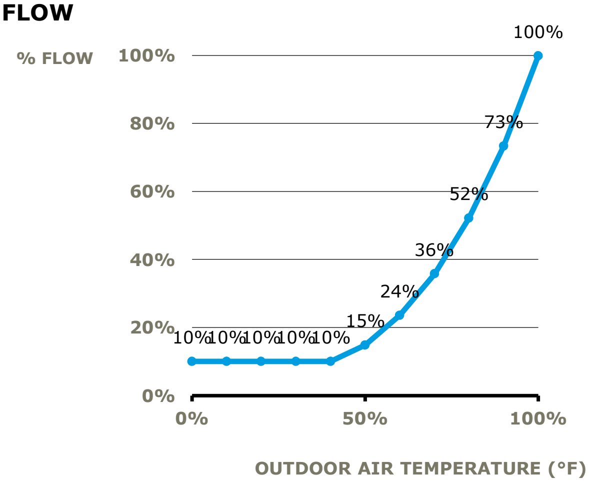

### POST-RETROFIT FLOW VS OUTDOOR AIR




### EXISTING MOTOR POWER VS FLOW




### POST-RETROFIT MOTOR POWER VS FLOW



# RESULTS: EEM-12 CONVERT CVSZ TO SZVAV - LANIGAN HALL

## Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| **Jan** | 26.0 | 270 | 2,319 | 8.6 |
| **Feb** | 25.4 | 300 | 2,577 | 8.6 |
| **Mar** | 37.4 | 240 | 2,061 | 8.6 |
| **Apr** | 47.9 | 300 | 2,577 | 8.6 |
| **May** | 59.9 | 243 | 2,087 | 8.6 |
| **Jun** | 66.4 | 240 | 2,061 | 8.6 |
| **Jul** | 71.8 | 264 | 2,267 | 8.6 |
| **Aug** | 68.0 | 219 | 1,881 | 8.6 |
| **Sep** | 60.7 | 285 | 2,448 | 8.6 |
| **Oct** | 49.5 | 315 | 2,705 | 8.6 |
| **Nov** | 40.9 | 270 | 2,319 | 8.6 |
| **Dec** | 27.7 | 150 | 1,288 | 8.6 |
| **Annual** | **48.6** | **3,096** | **26,590** | **8.6** |

## Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| **Jan** | 26.0 | 270 | 344 | 1.3 |
| **Feb** | 25.4 | 300 | 382 | 1.3 |
| **Mar** | 37.4 | 240 | 373 | 5.1 |
| **Apr** | 47.9 | 300 | 544 | 5.6 |
| **May** | 59.9 | 243 | 557 | 4.9 |
| **Jun** | 66.4 | 240 | 764 | 6.0 |
| **Jul** | 71.8 | 264 | 1,094 | 6.8 |
| **Aug** | 68.0 | 219 | 831 | 5.8 |
| **Sep** | 60.7 | 285 | 689 | 6.0 |
| **Oct** | 49.5 | 315 | 459 | 2.8 |
| **Nov** | 40.9 | 270 | 368 | 3.4 |
| **Dec** | 27.7 | 150 | 192 | 2.2 |
| **Annual** | **48.6** | **3,096** | **6,597** | **6.8** |

## Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| **Jan** | - | 0 | 1,975 | 7.2 |
| **Feb** | - | 0 | 2,195 | 7.3 |
| **Mar** | - | 0 | 1,688 | 3.5 |
| **Apr** | - | 0 | 2,033 | 3.0 |
| **May** | - | 0 | 1,530 | 3.7 |
| **Jun** | - | 0 | 1,297 | 2.5 |
| **Jul** | - | 0 | 1,174 | 1.8 |
| **Aug** | - | 0 | 1,050 | 2.8 |
| **Sep** | - | 0 | 1,759 | 2.5 |
| **Oct** | - | 0 | 2,246 | 5.8 |
| **Nov** | - | 0 | 1,951 | 5.2 |
| **Dec** | - | 0 | 1,096 | 6.4 |
| **Annual** | **-** | **0** | **19,993** | **7.3** |

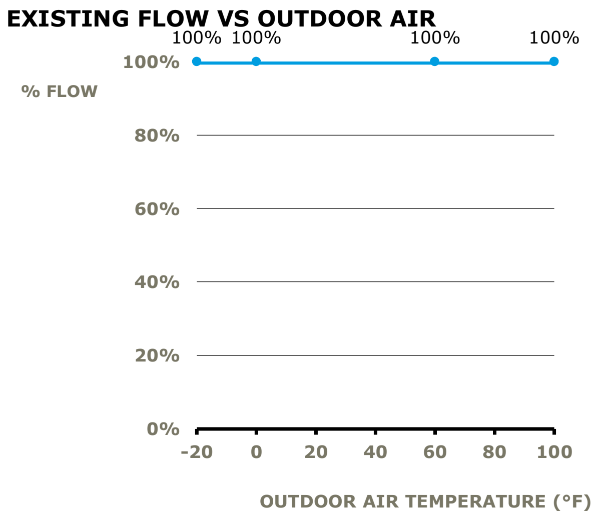
# SUMMARY INPUTS: EEM-12 CONVERT CVSZ TO SZVAV - LEE HALL

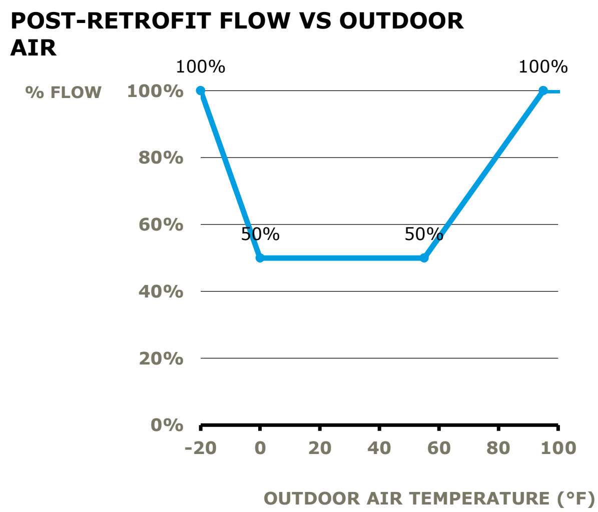
## Existing Conditions

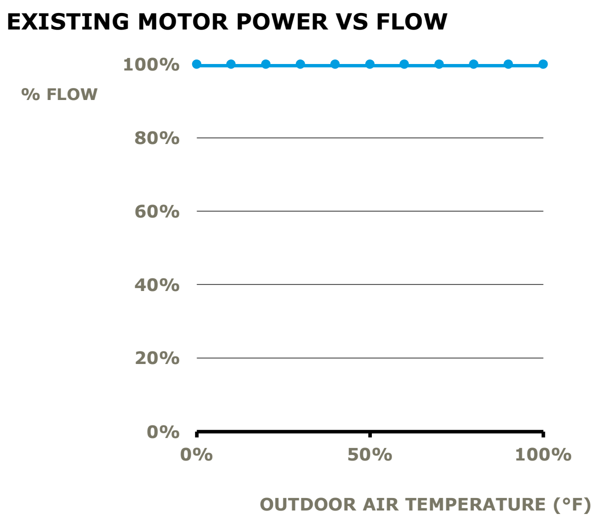
| | |
|---|---|
| Tag | Fan |
| Service | Main Gym SF |
| Flow Control | Constant |
| CFM | 18000 |
| Total SP (in w | 0 |
| Motor HP | 7.5 |
| BHP | 6.0 |
| Motor kW | 4.9 |

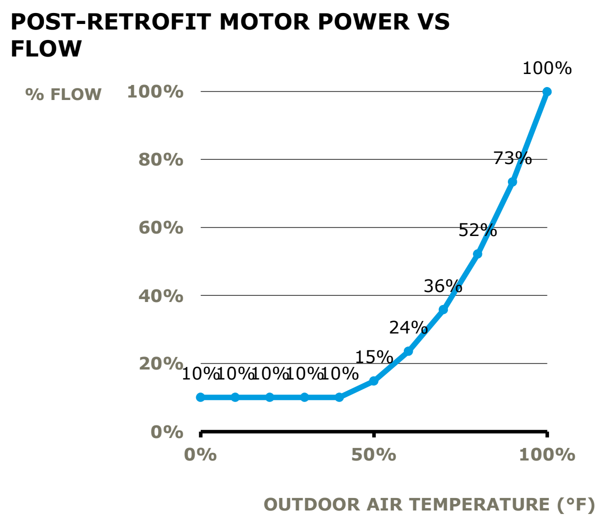
## Post-Retrofit Conditions

| | |
|---|---|
| Tag | Fan |
| Service | Main Gym SF |
| Flow Control | Single Zone VAV Fan |
| CFM | 18000 |
| Total SP (in w | 0 |
| Motor HP | 7.5 |
| BHP | 6.0 |
| Motor kW | 4.9 |



# RESULTS: EEM-12 CONVERT CVSZ TO SZVAV - LEE HALL

## Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| **Jan** | 26.0 | 457 | 3,493 | 7.6 |
| **Feb** | 25.4 | 424 | 3,240 | 7.6 |
| **Mar** | 37.4 | 451 | 3,447 | 7.6 |
| **Apr** | 47.9 | 450 | 3,439 | 7.6 |
| **May** | 59.9 | 158 | 1,207 | 3.8 |
| **Jun** | 66.4 | 160 | 1,223 | 3.8 |
| **Jul** | 71.8 | 168 | 1,284 | 3.8 |
| **Aug** | 68.0 | 158 | 1,207 | 3.8 |
| **Sep** | 60.7 | 429 | 3,279 | 7.6 |
| **Oct** | 49.5 | 466 | 3,561 | 7.6 |
| **Nov** | 40.9 | 444 | 3,393 | 7.6 |
| **Dec** | 27.7 | 433 | 3,309 | 7.6 |
| **Annual** | **48.6** | **4,198** | **32,083** | **7.6** |

## Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| **Jan** | 26.0 | 457 | 518 | 1.2 |
| **Feb** | 25.4 | 424 | 480 | 1.1 |
| **Mar** | 37.4 | 451 | 603 | 4.6 |
| **Apr** | 47.9 | 450 | 685 | 5.0 |
| **May** | 59.9 | 158 | 364 | 2.2 |
| **Jun** | 66.4 | 160 | 482 | 2.7 |
| **Jul** | 71.8 | 168 | 635 | 3.0 |
| **Aug** | 68.0 | 158 | 514 | 2.6 |
| **Sep** | 60.7 | 429 | 899 | 5.4 |
| **Oct** | 49.5 | 466 | 604 | 2.5 |
| **Nov** | 40.9 | 444 | 542 | 3.0 |
| **Dec** | 27.7 | 433 | 492 | 1.9 |
| **Annual** | **48.6** | **4,198** | **6,819** | **5.4** |

## Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| **Jan** | - | 0 | 2,975 | 6.4 |
| **Feb** | - | 0 | 2,760 | 6.5 |
| **Mar** | - | 0 | 2,843 | 3.1 |
| **Apr** | - | 0 | 2,754 | 2.7 |
| **May** | - | 0 | 843 | 1.6 |
| **Jun** | - | 0 | 741 | 1.1 |
| **Jul** | - | 0 | 649 | 0.8 |
| **Aug** | - | 0 | 694 | 1.3 |
| **Sep** | - | 0 | 2,379 | 2.3 |
| **Oct** | - | 0 | 2,957 | 5.2 |
| **Nov** | - | 0 | 2,851 | 4.6 |
| **Dec** | - | 0 | 2,817 | 5.7 |
| **Annual** | **-** | **0** | **25,263** | **6.5** |

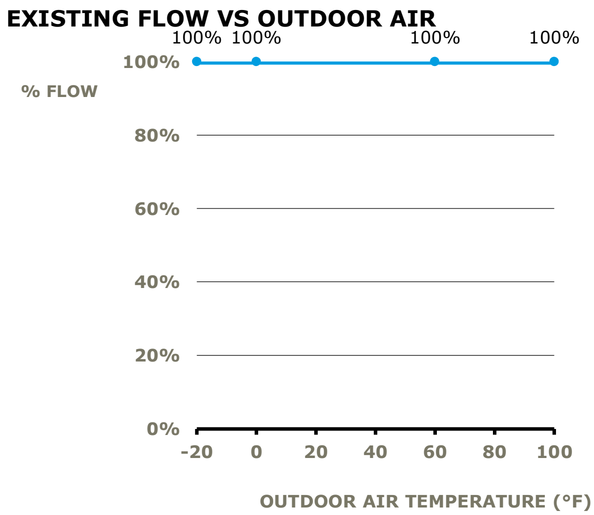
# SUMMARY INPUTS: EEM-12 CONVERT CVSZ TO SZVAV - PATHFINDER DINING HALL

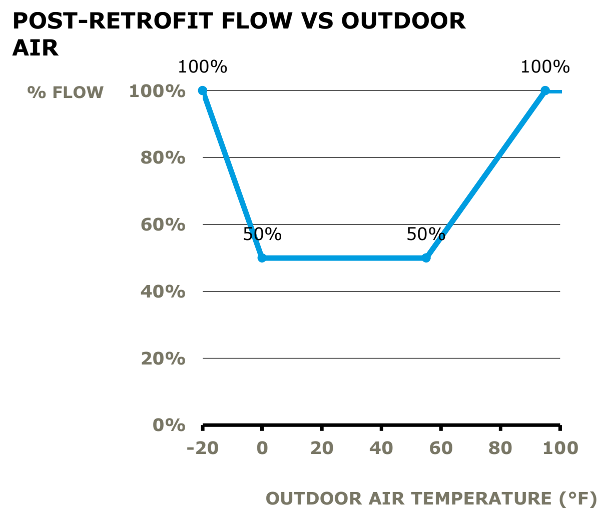
## Existing Conditions

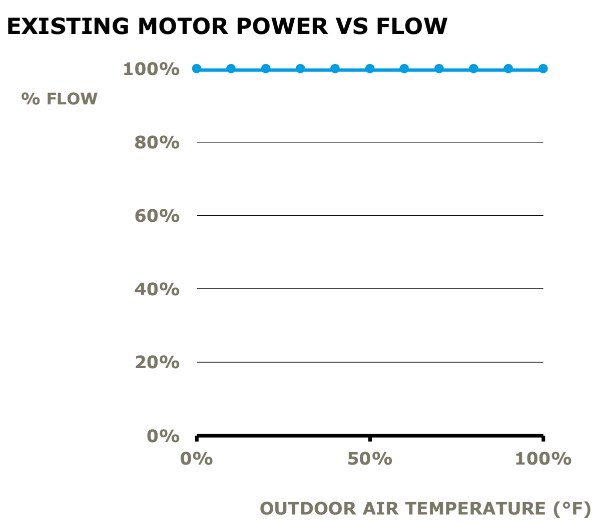
| | |
|---|---|
| Tag | Fan |
| Service | Dining Area |
| Flow Control | Constant |
| CFM | 31892 |
| Total SP (in v | 2 |
| Motor HP | 20 |
| BHP | 17.4 |
| Motor kW | 13.9 |

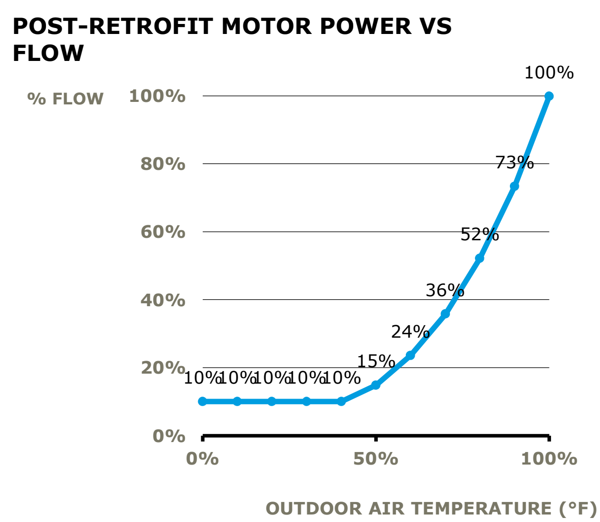
## Post-Retrofit Conditions

| | |
|---|---|
| Tag | Fan |
| Service | Dining Area |
| Flow Control | Single Zone VAV Fan |
| CFM | 31892 |
| Total SP (in v | 2 |
| Motor HP | 20 |
| BHP | 17.4 |
| Motor kW | 13.9 |



# RESULTS: EEM-12 CONVERT CVSZ TO SZVAV - PATHFINDER DINING HALL

## Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| **Jan** | 26.0 | 483 | 6,729 | 13.9 |
| **Feb** | 25.4 | 492 | 6,855 | 13.9 |
| **Mar** | 37.4 | 497 | 6,924 | 13.9 |
| **Apr** | 47.9 | 522 | 7,273 | 13.9 |
| **May** | 59.9 | 294 | 4,096 | 13.9 |
| **Jun** | 66.4 | 0 | 0 | 0.0 |
| **Jul** | 71.8 | 0 | 0 | 0.0 |
| **Aug** | 68.0 | 104 | 1,449 | 13.9 |
| **Sep** | 60.7 | 528 | 7,356 | 13.9 |
| **Oct** | 49.5 | 543 | 7,565 | 13.9 |
| **Nov** | 40.9 | 526 | 7,328 | 13.9 |
| **Dec** | 27.7 | 533 | 7,426 | 13.9 |
| **Annual** | **48.6** | **4,522** | **63,002** | **13.9** |

## Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| **Jan** | 26.0 | 483 | 998 | 2.2 |
| **Feb** | 25.4 | 492 | 1,016 | 2.1 |
| **Mar** | 37.4 | 497 | 1,206 | 8.3 |
| **Apr** | 47.9 | 522 | 1,405 | 9.0 |
| **May** | 59.9 | 294 | 1,065 | 7.9 |
| **Jun** | 66.4 | 0 | 0 | 0.0 |
| **Jul** | 71.8 | 0 | 0 | 0.0 |
| **Aug** | 68.0 | 104 | 627 | 8.3 |
| **Sep** | 60.7 | 528 | 2,007 | 9.8 |
| **Oct** | 49.5 | 543 | 1,266 | 4.5 |
| **Nov** | 40.9 | 526 | 1,164 | 5.5 |
| **Dec** | 27.7 | 533 | 1,103 | 3.5 |
| **Annual** | **48.6** | **4,522** | **11,858** | **9.8** |

## Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) |
|---|---|---|---|---|
| **Jan** | - | 0 | 5,732 | 11.7 |
| **Feb** | - | 0 | 5,839 | 11.9 |
| **Mar** | - | 0 | 5,718 | 5.6 |
| **Apr** | - | 0 | 5,868 | 4.9 |
| **May** | - | 0 | 3,031 | 6.0 |
| **Jun** | - | 0 | 0 | 0.0 |
| **Jul** | - | 0 | 0 | 0.0 |
| **Aug** | - | 0 | 822 | 5.6 |
| **Sep** | - | 0 | 5,350 | 4.1 |
| **Oct** | - | 0 | 6,299 | 9.4 |
| **Nov** | - | 0 | 6,164 | 8.4 |
| **Dec** | - | 0 | 6,323 | 10.4 |
| **Annual** | **-** | **0** | **51,144** | **11.9** |

## LIFE CYCLE COST ANALYSIS

| | | | |
|---|---|---|---|
| ECM No.: | EEM-12 | | |
| ECM Title: | Convert CVSZ to SZVAV | | |
| **General Parameters** | | | |
| Base Date: | 1/1/2023 | | |
| Service Date: | 1/1/2023 | | |
| Study Period (Years): | 15 | | |
| Discount Rate: | 3% | | |
| Cost Escalation: | 0% | | |
| FEMP UPV Discount Factor (Elect.): | 14.96 | | |
| FEMP UPV Discount Factor (NG): | 13.70 | | |
| **Cost Data** | **Baseline** | **Proposed** | **Savings** |
| Initial Capital Cost: | | $142,040 | ($142,040) |
| Annual Electricity Costs: | $516,317 | $494,116 | $22,201 |
| Annual Natural Gas Costs: | $303,569 | $303,569 | $0 |
| Annual Water Costs: | $0 | $0 | $0 |
| Annual OM&R Costs: | $2,980 | $2,980 | $0 |
| Other Recurring Annual Costs: | $0 | $0 | $0 |
| **Life Cycle Cost Calculations** | **Baseline** | **Proposed** | **Savings** |
| Present Value Investment Costs, I: | $0 | $142,040 | ($142,040) |
| Present-Value Capital Replacement Cost, Repl: | $0 | $0 | $0 |
| Present Value Residual Cost, Res: | $0 | $0 | $0 |
| Present Value Energy Costs, E: | $11,882,795 | $11,550,691 | $332,104 |
| Present Value Water Cost, W: | $0 | $0 | $0 |
| Present Value O&M and Other Recurring Costs, OM&R: | $35,573 | $35,573 | $0 |
| **LCC:** | **$11,918,368** | **$11,728,304** | **$190,064** |
| **Savings to Investment Ratio Calculations** | | | |
| Present Value Energy Cost Savings, DE: | $332,104 | | |
| Present Value Water Cost Savings, DW: | $0 | | |
| Present Value OM&R Cost Savings, DOM&R: | $0 | | |
| **SIR:** | **2.34** | | |

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

# SUNY OSWEGO | EEM-13 INSTALL POOL DEHUMIDIFICATION SYSTEM

*Energy Opportunity Area:* HVAC, Building Automation System (BAS)

*Buildings Affected:* Laker Hall, Lee Hall

**Table 1. EEM-13 Summary Data**

| Description | Values | Units |
|---|---|---|
| Annual Electrical Energy Savings | 4,830 | kWh/year |
| Electrical Peak Demand Savings | -48.3 | kW |
| Annual Electrical Energy Cost Savings | $285 | $/year |
| Annual Natural Gas Savings | 38,215 | Therms/year |
| Annual Natural Gas Cost Savings | $15,439 | $/year |
| **Total Annual Energy Cost Savings** | **$15,724** | **$/year** |
| **Estimated Implementation Cost** | **$1,099,423** | **$** |
| **Simple Payback Period** | **69.9** | **years** |
| **Savings to Investment Ratio** | **0.2** | |

## Existing Conditions/Baseline

Laker Hall and Lee Hall are campus athletic buildings which house natatoriums. Laker Hall natatorium includes a six-lane pool and a diving well which are primarily used for the University's swim team practice and swim meets. Lee Hall houses a single pool which is used for practice, intramural sports, and open swim. Table 2 summarizes existing systems serving the natatoriums. Existing units have steam heating coils and no capability for mechanical cooling and dehumidification. Laker heating & ventilating (HV) unit has a glycol runaround loop for heat recovery.

**Table 2. Existing Conditions Summary**

| Building | Unit | Unit Type | Supply Fan HP | Return Fan HP | Energy Recovery |
|---|---|---|---|---|---|
| 0019 – LAKER HALL | HV-8 | Single Zone Variable Air Volume | 7.5 | 3 | Yes |
| 0004 – M V LEE HALL | HV-1 | Single Zone Constant Volume | 5 | 2 | No |

## Recommended Action

This measure assesses the impact of replacing existing pool heating & ventilating (HV) units with units that can provide dehumidification via mechanical cooling. The proposed system includes hot water heating coils and a direct expansion (DX) cooling unit for dehumidification and space cooling. A single zone variable air volume system should be considered with a temperature-based control scheme to modulate air flow. Fan speed and heating and cooling equipment are controlled to maintain space temperature setpoints. The system would also include a sensible-only device to recovery heat from the exhaust air stream to precondition outdoor air.

This measure also considers utilizing heat recovery on the DX unit by capturing heat from the compressor hot gas waste heat to provide dehumidification reheat and pool water heating.

The estimated dehumidification unit sizes are presented in Table 3. Ventilation rates were sized according to ASHRAE 62.1 ventilation requirements for natatoriums.

**Table 3. Proposed Dehumidification Unit Size**

| Building | Estimated Pool Evaporation (lb/hr) | Estimated Natatorium Outdoor Air Requirement (cfm) | Estimated Dehumidification Unit Total Supply Air Flow (cfm) | Estimated Supply/Return Fan HP |
|---|---|---|---|---|
| 0019 – LAKER HALL | 175 | 6,868 | 14,400 | 15 / 7.5 |
| 0004 – M V LEE HALL | 93 | 1,748 | 7,000 | 7.5 / 5 |

## Estimated Energy Savings

An hourly analysis was performed using Syracuse-Hancock International Airport TMY3 (Typical Meteorological Year) hourly weather data to assess energy use of baseline and proposed systems. Heating and cooling loads were estimated based on outdoor air conditions, space temperature and relative humidity setpoints, and pool sensible and latent loads (which are influenced by pool and natatorium characteristics and activity level).

The addition of cooling in the proposed system results in increased fan and cooling energy use. Incorporation of energy recovery through an enthalpy wheel and hot gas reheat can decrease energy use for space heating and pool heating. Pool water evaporation can be reduced by utilizing pool covers when the space is not in use. This would reduce pool water heating and space dehumidification loads. However, the analysis does not consider this since it is not the current practice. Table 4 summarizes energy use and costs associated with this measure.

**Table 4. EEM-13 Savings**

| Building | Annual Electrical Energy Savings (kWh/year) | Annual Natural Gas Savings (Therms/year) | Total Annual Energy Cost Savings ($/year) | Estimated Implementation Cost | Simple Payback Period |
|---|---|---|---|---|---|
| 0019 – LAKER HALL | 17,409 | 12,810 | $6,202 | $647,023 | 104.3 |
| 0004 – M V LEE HALL | -12,579 | 25,405 | $9,521 | $452,399 | 47.5 |
| **Total** | **4,830** | **38,215** | **$15,724** | **$1,099,423** | **69.9** |

## Estimated Project Cost

Costs presented in Table 5 represent the scope of work described previously and were developed based on RS Means 2023 values and estimates from similar projects. Although the simple payback and SIR economics do not indicate cost-effectiveness, the project could be justified from an infrastructure renewal perspective since the existing units do not provide dehumidification.

**Table 5. EEM-13 Estimated Project Costs**

| Item Description | Qty | Unit | Unit Cost | Subtotal |
|---|---|---|---|---|
| Demolition and removal of existing equipment | 1 | Lump Sum | $24,037 | $24,037 |
| Dehumidification Unit, 14,000 nominal cfm, 188 lbs/hr of moisture removal (includes sensible energy recovery and VFDs) | 1 | Lump Sum | $362,325 | $362,325 |
| Piping/Insulation | 1 | Lump Sum | $68,502 | $68,502 |
| Ductwork | 1 | Lump Sum | $127,377 | $127,377 |
| Testing, Adjusting, and Balancing | 1 | Lump Sum | $4,442 | $4,442 |
| BAS I/O Points, Engineering, Calibration, Start-up/Checkout Labor | 1 | Lump Sum | $53,374 | $53,374 |
| Electrical | 1 | Lump Sum | $82,721 | $82,721 |
| Misc. (including cleaning, rigging, patchwork, etc.) | 1 | Lump Sum | $46,049 | $46,049 |
| **Labor and Materials Subtotal** | | | | **$768,827** |
| General Conditions | 10% | | | $76,883 |
| **Labor and Materials Cost Total** | | | | **$845,710** |
| Architectural & Engineering Fees | 10% | | | $84,571 |
| Construction Management Fees | 10% | | | $84,571 |
| Contingency | 10% | | | $84,571 |
| **Project Cost Subtotal** | | | | **$1,099,423** |
| Agency Administrative Fee | 0% | | | $0 |
| **Total Project Cost** | | | | **$1,099,423** |

## EEM-13 – INSTALL POOL DEHUMIDIFICATION SYSTEM

## SUPPORTING DOCUMENTS

# SUMMARY INPUTS: EEM-13 INSTALL POOL DEHUMIDIFICAITON SYSTEM

## Existing System

| Building | Unit | Supply CFM | Outdoor Air CFM | Supply Fan HP | Return Fan HP | Motor Control |
|---|---|---|---|---|---|---|
| 0019 - LAKER HALL | HV-8 | 10,000 | 10,000 | 7.5 | 3 | VFD |
| 0004 - M V LEE HALL | HV-1 | 10,000 | 10,000 | 5 | 2 | None |

## Existing Natatorium Conditions

| Building | Natatorium Area (GSF) | Pool Surface Area (GSF) | Natatorium Air Temp (F) | Natatorium Air RH | Pool Water Temp (F) | Pool Water Evaporation Rate (lb/h) |
|---|---|---|---|---|---|---|
| 0019 - LAKER HALL | 10,861 | 4,995 | 81 | 60% | 79 | 175 |
| 0004 - M V LEE HALL | 3,642 | 2,100 | 88 | 60% | 86 | 93 |

## Proposed System

| Building | Unit | Supply CFM | Outdoor Air CFM | Supply Fan HP | Return Fan HP | Motor Control |
|---|---|---|---|---|---|---|
| 0019 - LAKER HALL | DH-1 | 14,400 | 6,868 | 15 | 7.5 | VFD |
| 0004 - M V LEE HALL | DH-1 | 7,000 | 1,748 | 7.5 | 5 | VFD |

## Existing Natatorium Conditions

| Building | Natatorium Area (GSF) | Pool Surface Area (GSF) | Natatorium Air Temp (F) | Natatorium Air RH | Pool Water Temp (F) | Pool Water Evaporation Rate (lb/h) |
|---|---|---|---|---|---|---|
| 0019 - LAKER HALL | 10,861 | 4,995 | 81 | 1 | 79 | 175 |
| 0004 - M V LEE HALL | 3,642 | 2,100 | 88 | 1 | 86 | 93 |

# RESULTS: EEM-13 INSTALL POOL DEHUMIDIFICAITON SYSTEM

## Baseline Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) | Natural Gas Consumption |
|---|---|---|---|---|---|
| **Jan** | 26.0 | 744 | 4,433 | 6.0 | 4,497 |
| **Feb** | 25.4 | 672 | 4,004 | 6.0 | 4,263 |
| **Mar** | 37.4 | 744 | 4,433 | 6.0 | 3,760 |
| **Apr** | 47.9 | 720 | 4,290 | 6.0 | 2,887 |
| **May** | 59.9 | 744 | 4,433 | 6.0 | 2,125 |
| **Jun** | 66.4 | 720 | 4,290 | 6.0 | 1,772 |
| **Jul** | 71.8 | 744 | 4,433 | 6.0 | 1,634 |
| **Aug** | 68.0 | 744 | 4,433 | 6.0 | 1,879 |
| **Sep** | 60.7 | 720 | 4,290 | 6.0 | 2,066 |
| **Oct** | 49.5 | 744 | 4,433 | 6.0 | 2,816 |
| **Nov** | 40.9 | 720 | 4,290 | 6.0 | 3,367 |
| **Dec** | 27.7 | 744 | 4,433 | 6.0 | 4,336 |
| **Annual** | **48.6** | **8,760** | **52,197** | **6.0** | **35,401** |

## Proposed Montly Operational Data

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) | Natural Gas Consumption |
|---|---|---|---|---|---|
| **Jan** | 26.0 | 744 | 1,474 | 2.8 | 2,945 |
| **Feb** | 25.4 | 672 | 1,335 | 2.8 | 2,847 |
| **Mar** | 37.4 | 744 | 1,776 | 19.0 | 2,478 |
| **Apr** | 47.9 | 720 | 2,081 | 26.6 | 1,893 |
| **May** | 59.9 | 744 | 3,175 | 29.0 | 1,365 |
| **Jun** | 66.4 | 720 | 4,461 | 37.2 | 1,044 |
| **Jul** | 71.8 | 744 | 6,778 | 36.0 | 767 |
| **Aug** | 68.0 | 744 | 5,528 | 38.4 | 1,033 |
| **Sep** | 60.7 | 720 | 3,412 | 39.3 | 1,307 |
| **Oct** | 49.5 | 744 | 1,768 | 14.3 | 1,873 |
| **Nov** | 40.9 | 720 | 1,528 | 9.4 | 2,220 |
| **Dec** | 27.7 | 744 | 1,471 | 2.6 | 2,820 |
| **Annual** | **48.6** | **8,760** | **34,788** | **39.3** | **22,591** |

## Montly Operational Savings

| Month | Average $OAT_{DB}$ (F) | Operating Hours | Electric Consumption (kWh) | Electric Peak Demand (kW) | Natural Gas Consumption |
|---|---|---|---|---|---|
| **Jan** | - | 0 | 2,959 | 3.2 | 1,552 |
| **Feb** | - | 0 | 2,669 | 3.1 | 1,415 |
| **Mar** | - | 0 | 2,657 | -13.1 | 1,282 |
| **Apr** | - | 0 | 2,209 | -20.7 | 994 |
| **May** | - | 0 | 1,258 | -23.1 | 760 |
| **Jun** | - | 0 | -171 | -31.3 | 729 |
| **Jul** | - | 0 | -2,345 | -30.1 | 867 |
| **Aug** | - | 0 | -1,095 | -32.5 | 847 |
| **Sep** | - | 0 | 878 | -33.3 | 759 |
| **Oct** | - | 0 | 2,665 | -8.4 | 943 |
| **Nov** | - | 0 | 2,762 | -3.5 | 1,147 |
| **Dec** | - | 0 | 2,962 | 3.3 | 1,515 |
| **Annual** | **-** | **0** | **17,409** | **3.3** | **12,810** |

## LIFE CYCLE COST ANALYSIS

ECM No.: EEM-13

ECM Title: Install Pool Dehumidificaiton System

| General Parameters | |
|---|---|
| Base Date: | 1/1/2023 |
| Service Date: | 1/1/2023 |
| Study Period (Years): | 15 |
| Discount Rate: | 3% |
| Cost Escalation: | 0% |
| FEMP UPV Discount Factor (Elect.): | 14.96 |
| FEMP UPV Discount Factor (NG): | 13.70 |

| Cost Data | Baseline | Proposed | Savings |
|---|---|---|---|
| Initial Capital Cost: | | $1,099,423 | ($1,099,423) |
| Annual Electricity Costs: | $5,878 | $5,593 | $285 |
| Annual Natural Gas Costs: | $28,508 | $13,070 | $15,439 |
| Annual CHP Natural Gas Costs: | $0 | $0 | $0 |
| Annual CHW Costs: | $0 | $0 | $0 |
| Annual HTHW Costs: | $0 | $0 | $0 |
| Annual Water Costs: | $0 | $0 | $0 |
| Annual OM&R Costs: | $23,065 | $23,065 | $0 |
| Other Recurring Annual Costs: | $0 | $0 | $0 |

| Life Cycle Cost Calculations | Baseline | Proposed | Savings |
|---|---|---|---|
| Present Value Investment Costs, I: | $0 | $1,099,423 | ($1,099,423) |
| Present-Value Capital Replacement Cost, Repl: | $0 | $0 | $0 |
| Present Value Residual Cost, Res: | $0 | $0 | $0 |
| Present Value Energy Costs, E: | $478,539 | $262,742 | $215,798 |
| Present Value Water Cost, W: | $0 | $0 | $0 |
| Present Value O&M and Other Recurring Costs, OM&R: | $275,346 | $275,346 | $0 |
| **LCC:** | **$753,886** | **$1,637,511** | **($883,625)** |

| Savings to Investment Ratio Calculations | |
|---|---|
| Present Value Energy Cost Savings, DE: | $215,798 |
| Present Value Water Cost Savings, DW: | $0 |
| Present Value OM&R Cost Savings, DOM&R: | $0 |
| **SIR:** | **0.20** |

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

# Appendix D
## Building Upgrades Budgetary Cost Estimate

| Building | Building Type | GSF | Location | Building Vintage | Building Upgrades for LTHW: Replace Finned Tube Radiation | Replace AHU Coils | Replace Terminal Equipment | Complete HVAC Removal and Replacement | Timeframe (approx. year) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| 0001 - SHELDON HALL | ACADEMIC | 119,211 | MAIN | 1912 | | ● | ● | | 2038 | |
| 0002 - J C PARK HALL | ACADEMIC | 66,979 | MAIN | 1933 | ◑ | ● | ● | | 2030 | |
| 0003 - CAMPUS CENTER | ACADEMIC | 185,524 | MAIN | 1963 | ● | ● | ◕ | | 2030 | |
| 003A - I POUCHER HALL | ACADEMIC | 40,080 | MAIN | 1963 | ● | ● | ◑ | | 2030 | |
| 003B - REC & CONVOCATION CTR | ACADEMIC | 115,421 | MAIN | 2006 | ● | ● | ◕ | | 2030 | |
| 0004 - M V LEE HALL | ACADEMIC | 65,000 | MAIN | 1958 | ● | ● | | | 2030 | |
| 004A - CENTRAL HEATING PLANT | MAINTENANCE | 21,980 | MAIN | 1958 | | ● | | | 2030 | |
| 0005 - SHADY SHORE | ADMINISTRATION | 8,754 | MAIN | 1909 | ● | | | | 2040 | |
| 0006 - J LANIGAN HALL | ACADEMIC | 88,200 | MAIN | 1967 | ● | ● | | | 2034 | |
| 0007 - J TYLER HALL | ACADEMIC | 115,430 | MAIN | 1968 | ● | ● | ● | | 2034 | |
| 0008 - RICHARD S SHINEMAN CENTER | ACADEMIC | 235,860 | MAIN | 2013 | ● | | | | 2034 | |
| 0009 - WILBER HALL | ACADEMIC | 108,933 | MAIN | 1964 | ◔ | ● | | | 2034 | |
| 0010 - MARY WALKER HEALTH CENTER | ADMINISTRATION | 33,260 | MAIN | 1965 | | ● | | | 2040 | |
| 0013 - M E MAHAR HALL | ACADEMIC | 91,530 | MAIN | 1966 | | | | ● | 2032 | |
| 0014 - RICH HALL | ACADEMIC | 53,742 | MAIN | 1961 | | ● | | | 2038 | |
| 0015 - MACKIN HALL | RESIDENTIAL | 41,984 | MAIN | 1951 | | | | ● | 2038 | |
| 015A - MORELAND HALL | RESIDENTIAL | 29,400 | MAIN | 1951 | | | | ● | 2038 | |
| 015B - LONIS HALL | RESIDENTIAL | 32,285 | MAIN | 1951 | | | | ● | 2038 | |
| 0017 - J PENFIELD LIB | ACADEMIC | 192,298 | MAIN | 1968 | | | | ● | 2028 | |
| 0020 - GAR-20 | MAINTENANCE | 14,850 | MAIN | 1971 | ● | | | | 2038 | |
| 0022 - KING HALL | ADMINISTRATION | 7,200 | MAIN | 1935 | ● | | | | | |
| 0026 - CULKIN HALL | ADMINISTRATION | 63,591 | MAIN | 1967 | ● | ● | ◔ | | 2034 | |
| 0029 - HEWITT HALL | ACADEMIC | 135,010 | MAIN | 1967 | | | | ● | 2024 | |
| 0031 - PATHFINDER DH | RESIDENTIAL | 33,827 | MAIN | 1967 | ● | ● | | | 2042 | |
| 0032 - SENECA HALL | RESIDENTIAL | 152,548 | MAIN | 1967 | | | | ● | 2030 | |
| 0033 - CAYUGA HALL | RESIDENTIAL | 105,072 | MAIN | 1967 | | | | ● | 2032 | |
| 0034 - ONONDAGA HALL | RESIDENTIAL | 152,548 | MAIN | 1968 | | | | ● | 2034 | |
| 0035 - LITTLEPAGE DH | RESIDENTIAL | 33,827 | MAIN | | | | | ● | 2025 | |
| 0036 - ONEIDA HALL | RESIDENTIAL | 105,000 | MAIN | 1970 | | | | ● | 2036 | |
| 0037A - TOWNHOUSE A | RESIDENTIAL | 10,260 | MAIN | 2010 | | | ● | | 2042 | |
| 0037B - TOWNHOUSE B | RESIDENTIAL | 8,082 | MAIN | 2010 | | | ● | | 2042 | |
| 0037C - TOWNHOUSE C | RESIDENTIAL | 12,599 | MAIN | 2010 | | | ● | | 2042 | |
| 0037D - TOWNHOUSE D | RESIDENTIAL | 12,599 | MAIN | 2010 | | | ● | | 2042 | |
| 0037E - TOWNHOUSE E | RESIDENTIAL | 15,880 | MAIN | 2010 | | | ● | | 2042 | |
| 0037F - TOWNHOUSE F | RESIDENTIAL | 18,295 | MAIN | 2010 | | ◔ | ● | | 2042 | |
| 0037G - TOWNHOUSE G | RESIDENTIAL | 8,082 | MAIN | 2010 | | | ● | | 2042 | |
| 0037H - TOWNHOUSE H | RESIDENTIAL | 10,260 | MAIN | 2010 | | | ● | | 2042 | |
| 0037I - TOWNHOUSE I | RESIDENTIAL | 12,599 | MAIN | 2010 | | | ● | | 2042 | |
| 0037J - TOWNHOUSE J | RESIDENTIAL | 12,599 | MAIN | 2010 | | | ● | | 2042 | |
| 0037K - TOWNHOUSE K | RESIDENTIAL | 16,729 | MAIN | 2010 | | | ● | | 2042 | |
| 0037L - TOWNHOUSE L | RESIDENTIAL | 12,567 | MAIN | 2010 | | | ● | | 2042 | |
| 0041 - JOHNSON HALL | RESIDENTIAL | 79,097 | MAIN | 1958 | ◔ | ● | ● | | 2040 | |
| 0042 - LAKESIDE DH | RESIDENTIAL | 27,870 | MAIN | 1959 | | ● | | | 2040 | |
| 0043 - RIGGS HALL | RESIDENTIAL | 58,201 | MAIN | 1960 | ◔ | ● | | | 2040 | |
| 0044 - WATERBURY HALL | RESIDENTIAL | 57,464 | MAIN | 1960 | ● | ◔ | | | 2040 | |
| 0045 - SCALES HALL | RESIDENTIAL | 57,464 | MAIN | 1961 | ● | ◔ | | | 2040 | |
| 0046 - HART HALL | RESIDENTIAL | 114,365 | MAIN | 1963 | ● | | | | 2036 | |
| 0047 - COOPER DH | RESIDENTIAL | 33,546 | MAIN | 1967 | ◔ | ● | ◔ | | 2036 | |

| Building | Building Type | GSF | Location | Building Vintage | Building Upgrades for LTHW: Replace Finned Tube Radiation | Replace AHU Coils | Replace Terminal Equipment | Complete HVAC Removal and Replacement | Timeframe (approx. year) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| 0048 - FUNNELLE HALL | RESIDENTIAL | 114,365 | MAIN | 1965 | ● | | | | 2036 | |
| 0011 - COMMISSARY BLDG | ADMINISTRATION | 30,836 | MAIN-SOUTH | 1966 | | ● | | | 2035 | |
| 0012 - MAINTENANCE BLDG | MAINTENANCE | 20,664 | MAIN-SOUTH | 1965 | ● | | | | 2035 | |
| 0019 - LAKER HALL | ACADEMIC | 196,608 | MAIN-SOUTH | 1968 | ● | ● | | | 2035 | |
| 0021 - ROMNEY FIELD HOUSE | ACADEMIC | 55,000 | MAIN-SOUTH | 1962 | | ● | | | 2035 | |
| CAMPUS GROUNDS | | 0 | MAIN | | | | | | | |
| | Total | 3,445,375 | - | - | 23 | 24 | 21 | 11 | - | |

## SUNY Oswego

| Building | Building Type | GSF | Location | Building Vintage | Interior LED Lighting Retrofit | Parking Lot and Roadway LED Retrofit | Retro-Commissioning | HVAC Scheduling | Occupancy Based HVAC Controls | Pump Differential Pressure Reset Control | Multizone VAV Static Pressure Reset Controls | Implement Demand Controlled Ventilation | Implement Kitchen Demand Controlled Ventilation | Implement Laboratory Demand Controlled Ventilation | Install VFD on Pump Motor | Convert CVSZ to SZVAV | Install Pool Dehumidification System | Replace Finned Tube Radiation | Replace AHU Coils | Replace Terminal Equipment | Complete HVAC Removal and Replacement | Building Cost Total | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Energy Efficiency Measures | | | | | | | | | | | | | Building Upgrades for LTHW | | | | | |
| 0001 - SHELDON HALL | ACADEMIC | 119,211 | MAIN | 1912 | $19.5 k | | | | $242.8 k | $1.6 k | $6.4 k | | | | | | | | $0.2 M | $4.5 M | | $5.0 M | E |
| 0002 - J C PARK HALL | ACADEMIC | 66,979 | MAIN | 1933 | $1.5 k | | | | $13.6 k | $1.6 k | $1.6 k | | | | | | | $0.6 M | $0.1 M | $2.5 M | | $3.2 M | C |
| 0003 - CAMPUS CENTER | ACADEMIC | 185,524 | MAIN | 1963 | $100.7 k | | $93.2 k | $0.5 k | $1,389.4 k | $4.8 k | $11.3 k | $7.0 k | | | | $31.4 k | | $2.5 M | $0.3 M | $5.2 M | | $9.7 M | C |
| 003A - I POUCHER HALL | ACADEMIC | 40,080 | MAIN | 1963 | | | $17.0 k | | | $3.2 k | $1.1 k | | | | | | | $0.7 M | $0.1 M | $0.7 M | | $1.5 M | C |
| 003B - REC & CONVOCATION CTR | ACADEMIC | 115,421 | MAIN | 2006 | $43.3 k | | $48.9 k | | | $6.4 k | $1.6 k | | $81.8 k | | | | | $1.2 M | $0.3 M | $1.2 M | | $2.8 M | C |
| 0004 - M V LEE HALL | ACADEMIC | 65,000 | MAIN | 1958 | | | | $0.5 k | $89.4 k | | | $3.5 k | | | | $18.6 k | $661.0 k | $1.1 M | $0.1 M | | | $2.0 M | C |
| 004A - CENTRAL HEATING PLANT | MAINTENANCE | 21,980 | MAIN | 1958 | | | | | | | | | | | | | | | $0.0 M | | | $0.0 M | C |
| 0005 - SHADY SHORE | ADMINISTRATION | 8,754 | MAIN | 1909 | | | | | | | | | | | | | | $0.1 M | | | | $0.1 M | N |
| 0006 - J LANIGAN HALL | ACADEMIC | 88,200 | MAIN | 1967 | $440.1 k | | | | $359.3 k | | | $3.5 k | | | $170.2 k | $19.1 k | | $1.5 M | $0.2 M | | | $2.7 M | C |
| 0007 - J TYLER HALL | ACADEMIC | 115,430 | MAIN | 1968 | | | $48.9 k | | $470.3 k | $1.6 k | $4.8 k | | | | | | | $1.9 M | $0.2 M | $4.3 M | | $7.0 M | C |
| 0008 - RICHARD S SHINEMAN CENTER | ACADEMIC | 235,860 | MAIN | 2013 | | | | | $960.9 k | $8.1 k | | | | | | | | $1.6 M | | | | $2.6 M | C |
| 0009 - WILBER HALL | ACADEMIC | 108,933 | MAIN | 1964 | | | | | $146.5 k | $6.4 k | $1.6 k | | | | | | | $0.2 M | $0.2 M | | | $0.6 M | C |
| 0010 - MARY WALKER HEALTH CENTER | ADMINISTRATION | 33,260 | MAIN | 1965 | | | | | $115.2 k | $1.6 k | | | | | | | | | $0.1 M | | | $0.2 M | N |
| 0013 - M E MAHAR HALL | ACADEMIC | 91,530 | MAIN | 1966 | | | | | $335.6 k | $1.6 k | $1.1 k | | | | $24.9 k | | | | | | $11.8 M | $12.2 M | C |
| 0014 - RICH HALL | ACADEMIC | 53,742 | MAIN | 1961 | | | $22.8 k | $0.5 k | $197.1 k | | $3.2 k | | | | | | | | $0.1 M | | | $0.3 M | E |
| 0015 - MACKIN HALL | RESIDENTIAL | 41,984 | MAIN | 1951 | | | | $0.5 k | | | | | | | | | | | | | $4.1 M | $4.1 M | E |
| 015A - MORELAND HALL | RESIDENTIAL | 29,400 | MAIN | 1951 | | | | | | | | | | | | | | | | | $2.8 M | $2.8 M | E |
| 015B - LONIS HALL | RESIDENTIAL | 32,285 | MAIN | 1951 | | | | | | | | | | | | | | | | | $3.1 M | $3.1 M | E |
| 0017 - J PENFIELD LIB | ACADEMIC | 192,298 | MAIN | 1968 | | | | | $665.9 k | | | | | | $105.5 k | | | | | | $24.8 M | $25.6 M | C |
| 0020 - GAR-20 | MAINTENANCE | 14,850 | MAIN | 1971 | | | | | | | | | | | | | | $0.2 M | | | | $0.2 M | E |
| 0022 - KING HALL | ADMINISTRATION | 7,200 | MAIN | 1935 | | | | | | | | | | | | | | | | | | $0.0 M | |
| 0026 - CULKIN HALL | ADMINISTRATION | 63,591 | MAIN | 1967 | | | | $0.5 k | $246.1 k | | | | | | $63.7 k | | | $0.9 M | $0.1 M | $0.5 M | | $1.8 M | C |
| 0029 - HEWITT HALL | ACADEMIC | 135,010 | MAIN | 1967 | | | | | | | | | | | | | | | | | $17.4 M | $17.4 M | C |
| 0031 - PATHFINDER DH | RESIDENTIAL | 33,827 | MAIN | 1967 | | | | $0.5 k | | | | $3.5 k | $53.1 k | | $62.9 k | $16.6 k | | $0.5 M | $0.1 M | | | $0.7 M | W |
| 0032 - SENECA HALL | RESIDENTIAL | 152,548 | MAIN | 1967 | | | | | | | | | | | $32.5 k | | | | | | $16.2 M | $16.3 M | W |
| 0033 - CAYUGA HALL | RESIDENTIAL | 105,072 | MAIN | 1967 | | | | | | | | $13.9 k | | | $38.0 k | | | | | | $10.1 M | $10.2 M | W |
| 0034 - ONONDAGA HALL | RESIDENTIAL | 152,548 | MAIN | 1968 | | | | | | | | | | | $28.0 k | | | | | | $16.2 M | $16.3 M | W |
| 0035 - LITTLEPAGE DH | RESIDENTIAL | 33,827 | MAIN | 0 | | | | | | | | | | | | | | | | | $4.3 M | $4.3 M | W |
| 0036 - ONEIDA HALL | RESIDENTIAL | 105,000 | MAIN | 1970 | | | | | | | | | | | $24.6 k | | | | | | $10.1 M | $10.2 M | W |
| 0037A - TOWNHOUSE A | RESIDENTIAL | 10,260 | MAIN | 2010 | | | $4.0 k | | | $0.5 k | | | | | | | | | | $0.1 M | | $0.1 M | W |
| 0037B - TOWNHOUSE B | RESIDENTIAL | 8,082 | MAIN | 2010 | | | $4.0 k | | | $0.5 k | | | | | | | | | | $0.1 M | | $0.1 M | W |
| 0037C - TOWNHOUSE C | RESIDENTIAL | 12,599 | MAIN | 2010 | | | $4.0 k | | | $0.5 k | | | | | | | | | | $0.2 M | | $0.2 M | W |
| 0037D - TOWNHOUSE D | RESIDENTIAL | 12,599 | MAIN | 2010 | | | $4.0 k | | | $0.5 k | | | | | | | | | | $0.2 M | | $0.2 M | W |
| 0037E - TOWNHOUSE E | RESIDENTIAL | 15,880 | MAIN | 2010 | | | $4.0 k | | | $0.5 k | | | | | | | | | | $0.2 M | | $0.2 M | W |
| 0037F - TOWNHOUSE F | RESIDENTIAL | 18,295 | MAIN | 2010 | | | $4.0 k | | | $0.5 k | | | | | | | | | $0.0 M | $0.2 M | | $0.2 M | W |
| 0037G - TOWNHOUSE G | RESIDENTIAL | 8,082 | MAIN | 2010 | | | $4.0 k | | | $0.5 k | | | | | | | | | | $0.1 M | | $0.1 M | W |
| 0037H - TOWNHOUSE H | RESIDENTIAL | 10,260 | MAIN | 2010 | | | $4.0 k | | | $0.5 k | | | | | | | | | | $0.1 M | | $0.1 M | W |
| 0037I - TOWNHOUSE I | RESIDENTIAL | 12,599 | MAIN | 2010 | | | $4.0 k | | | $0.5 k | | | | | | | | | | $0.2 M | | $0.2 M | W |
| 0037J - TOWNHOUSE J | RESIDENTIAL | 12,599 | MAIN | 2010 | | | $4.0 k | | | $0.5 k | | | | | | | | | | $0.2 M | | $0.2 M | W |
| 0037K - TOWNHOUSE K | RESIDENTIAL | 16,729 | MAIN | 2010 | | | $4.0 k | | | $0.5 k | | | | | | | | | | $0.2 M | | $0.2 M | W |
| 0037L - TOWNHOUSE L | RESIDENTIAL | 12,567 | MAIN | 2010 | | | $4.0 k | | | $0.5 k | | | | | | | | | | $0.2 M | | $0.2 M | W |
| 0041 - JOHNSON HALL | RESIDENTIAL | 79,097 | MAIN | 1958 | | | $25.4 k | | | $1.6 k | | | | | | | | $0.1 M | $0.1 M | $0.9 M | | $1.2 M | N |
| 0042 - LAKESIDE DH | RESIDENTIAL | 27,870 | MAIN | 1959 | | | | $0.5 k | | | $1.1 k | $13.0 k | $90.2 k | | | $11.5 k | | | $0.0 M | | | $0.2 M | N |
| 0043 - RIGGS HALL | RESIDENTIAL | 58,201 | MAIN | 1960 | | | $18.7 k | | | $3.2 k | $1.6 k | | | | | | | $0.1 M | $0.1 M | | | $0.2 M | N |
| 0044 - WATERBURY HALL | RESIDENTIAL | 57,464 | MAIN | 1960 | | | $18.5 k | | | | | | | | | | | $0.8 M | $0.0 M | | | $0.8 M | N |
| 0045 - SCALES HALL | RESIDENTIAL | 57,464 | MAIN | 1961 | | | $18.5 k | | | $1.6 k | | | | | | | | $0.8 M | $0.0 M | | | $0.8 M | N |
| 0046 - HART HALL | RESIDENTIAL | 114,365 | MAIN | 1963 | | | | | | | | | | | | | | $1.5 M | | | | $1.5 M | C |
| 0047 - COOPER DH | RESIDENTIAL | 33,546 | MAIN | 1967 | | | | $0.5 k | | | | | $56.7 k | | $38.0 k | $11.5 k | | $0.1 M | $0.1 M | $0.3 M | | $0.6 M | C |
| 0048 - FUNNELLE HALL | RESIDENTIAL | 114,365 | MAIN | 1965 | | | | | | $4.3 k | | | | | | | | $1.5 M | | | | $1.5 M | C |

| Building | Building Type | GSF | Location | Building Vintage | Interior LED Lighting Retrofit | Parking Lot and Roadway LED Retrofit | Retro-Commissioning | HVAC Scheduling | Occupancy Based HVAC Controls | Pump Differential Pressure Reset Control | Multizone VAV Static Pressure Reset Controls | Implement Demand Controlled Ventilation | Implement Kitchen Demand Controlled Ventilation | Implement Laboratory Demand Controlled Ventilation | Install VFD on Pump Motor | Convert CVSZ to SZVAV | Install Pool Dehumidification System | Replace Finned Tube Radiation | Replace AHU Coils | Replace Terminal Equipment | Complete HVAC Removal and Replacement | Building Cost Total | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Energy Efficiency Measures | | | | | | | | | | | | | Building Upgrades for LTHW | | | | | |
| 0011 - COMMISSARY BLDG | ADMINISTRATION | 30,836 | MAIN-SOUTH | 1966 | | | | | | | | | | | | | | | $0.1 M | | | $0.1 M | S |
| 0012 - MAINTENANCE BLDG | MAINTENANCE | 20,664 | MAIN-SOUTH | 1965 | | | | | | | | | | | | | | $0.3 M | | | | $0.3 M | S |
| 0019 - LAKER HALL | ACADEMIC | 196,608 | MAIN-SOUTH | 1968 | | | | $0.5 k | $5.7 k | | | $13.9 k | | | | $67.8 k | $945.3 k | $2.0 M | $0.5 M | | | $3.6 M | S |
| 0021 - ROMNEY FIELD HOUSE | ACADEMIC | 55,000 | MAIN-SOUTH | 1962 | | | | $0.5 k | $212.9 k | | | $1.1 k | | | | $30.9 k | | | $0.1 M | | | $0.4 M | S |
| CAMPUS GROUNDS | 0 | 0 | MAIN | 0 | | $2,919.9 k | | | | | | | | | | | | | | | | $2.9 M | |
| TOTAL | Total | 3,445,375 | - | - | $605.1 k | $2,919.9 k | $360.3 k | $5.5 k | $5,450.8 k | $54.2 k | $35.4 k | $59.4 k | $281.8 k | $0.0 k | $588.2 k | $207.5 k | $1,606.3 k | $20.0 M | $3.4 M | $22.0 M | $121.0 M | $178.6 M | |

**Notes:**

C. Cluster C
N. Cluster N
E. Cluster E
W. Cluster W
S. Cluster S

| | |
|---|---|
| Energy Efficiency Measure Cost Subtotal: | $12.2 M |
| HVAC Renovations Subtotal: | $121.0 M |
| HVAC Coil Replacements for 130°F Supply Subtotal: | $45.4 M |
| Total Building Upgrade Costs: | $178.6 M |

# Appendix E
# Hydraulic Modeling

# SUNY Oswego
# Distribution System

Bright ideas.
Sustainable change.

# Scenarios

1. **Centralized scenario:** Sizing the network for the centralized scenario (all buildings are connected except for cluster S and the 2 individual buildings in the grey area north of the road 104). The heating plant can be assume to be located in building 0004A

2. **Clustered scenario:** in this scenario the buildings are divided into independent clusters (N, C, E, W, S; blue boxes image below). Each cluster has its own distribution network. For the location of the energy centers in each cluster, please assume the following:

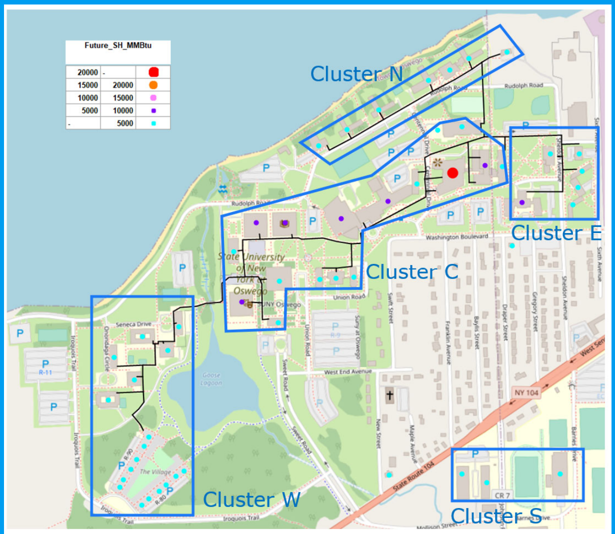
   Cluster C – energy center in building 004A Central Heating Plant
   (close to the WWTP, and easy peaking/backup from the existing steam plant)

   Cluster E – energy center in building 0015 Mackin
   (building likely to be repurposed, so provides a good opportunity for carving out mechanical space)

   Cluster N – energy center in building 0043 Riggs
   (centrally located in the cluster) and adjacent to potential geo field locations

   Cluster W – energy center in building 0032 Seneca
   (next building to be rehabbed, and their plan was to start a geo plant for this building)

   Cluster S – energy center in building 0019 Laker
   (plans of enclose a courtyard to create more mechanical/building space)



# Scenarios

**Additional info:**

- use insulated pipes
- Design DT for the heating is 20 K.
- Design DT for the cooling is 5-6 K.
- The same network will be used to supply heating in winter and cooling in summer, so each pipe should have the larger diameter from the two sizings (for heating and cooling)

# Demand, Peak

| BLDG NUMBER AND NAME | BUILDING NAME | BLDG NUMBER | Peak demand heat, [mmbtu/h] | Peak demand cooling, [mmbtu/h] |
|---|---|---|---|---|
| 0001 - SHELDON HALL | SHELDON HALL | 0001 | 3.840 | 1.982 |
| 0002 - J C PARK HALL | J C PARK HALL | 0002 | 1.921 | 1.739 |
| 0003 - CAMPUS CENTER | CAMPUS CENTER | 0003 | 5.619 | 4.758 |
| 003A - I POUCHER HALL | I POUCHER HALL | 003A | 1.269 | 1.016 |
| 003B - REC & CONVOCATION CTR | REC & CONVOCATION CTR | 003B | 3.904 | 1.694 |
| 003C - CC STORAGE BLDG | CC STORAGE BLDG | 003C | - | - |
| 0004 - M V LEE HALL | M V LEE HALL | 0004 | 1.303 | - |
| 004A - CENTRAL HEATING PLANT | CENTRAL HEATING PLANT | 004A | 0.284 | - |
| 0005 - SHADY SHORE | SHADY SHORE | 0005 | 0.161 | 0.113 |
| 0005A - PRESIDENT GARAGE | PRESIDENT GARAGE | 0005A | - | - |
| 0006 - J LANIGAN HALL | J LANIGAN HALL | 0006 | 3.074 | 1.668 |
| 0007 - J TYLER HALL | J TYLER HALL | 0007 | 3.084 | 2.563 |
| 0008 - RICHARD S SHINEMAN CENTER | RICHARD S SHINEMAN CENTER | 0008 | 17.659 | 5.385 |
| 0009 - WILBER HALL | WILBER HALL | 0009 | 2.531 | 2.805 |
| 0010 - MARY WALKER HEALTH CENTER | MARY WALKER HEALTH CENTER | 0010 | 0.461 | 0.770 |
| 0011 - COMMISSARY BLDG | COMMISSARY BLDG | 0011 | 0.743 | - |
| 0012 - MAINTENANCE BLDG | MAINTENANCE BLDG | 0012 | 0.161 | - |
| 0013 - M E MAHAR HALL | M E MAHAR HALL | 0013 | 1.857 | 1.790 |
| 0014 - RICH HALL | RICH HALL | 0014 | 1.513 | 1.207 |
| 0015 - MACKIN HALL | MACKIN HALL | 0015 | 0.740 | 0.121 |
| 015A - MORELAND HALL | MORELAND HALL | 015A | 0.448 | 0.085 |
| 015B - LONIS HALL | LONIS HALL | 015B | 0.509 | 0.093 |
| 0016 - OBSERVATORY | OBSERVATORY | 0016 | 0.001 | - |
| 0017 - J PENFIELD LIB | J PENFIELD LIB | 0017 | 3.365 | 4.337 |
| 0019 - LAKER HALL | LAKER HALL | 0019 | 4.878 | 0.394 |
| 0020 - GAR-20 | GAR-20 | 0020 | 0.333 | 0.344 |
| 0021 - ROMNEY FIELD HOUSE | ROMNEY FIELD HOUSE | 0021 | 1.956 | - |
| 0022 - KING HALL | KING HALL | 0022 | 0.144 | - |
| 0023A - RICE CREEK FIELD STATION | RICE CREEK FIELD STATION | 0023A | 0.419 | 0.270 |

# Demand, Peak

| BLDG NUMBER AND NAME | BUILDING NAME | BLDG NUMBER | Peak demand heat, [mmbtu/h] | Peak demand cooling, [mmbtu/h] |
|---|---|---|---|---|
| 0024A - BIO FIELD GARAGE | BIO FIELD GARAGE | 0024A | - | - |
| 0026 - CULKIN HALL | CULKIN HALL | 0026 | 0.399 | 0.563 |
| 0028 - SEWAGE PUMP STATION | SEWAGE PUMP STATION | 0028 | 0.005 | - |
| 0028A - SEWAGE PUMP STATION - SENECA | SEWAGE PUMP STATION - SENECA | 0028A | 0.001 | - |
| 0028B - SEWAGE PUMP STATION - BLG 12 | SEWAGE PUMP STATION - BLG 12 | 0028B | 0.001 | - |
| 0029 - HEWITT HALL | HEWITT HALL | 0029 | 2.454 | 2.290 |
| 0031 - PATHFINDER DH | PATHFINDER DH | 0031 | 0.779 | 0.728 |
| 0032 - SENECA HALL | SENECA HALL | 0032 | 2.559 | 0.232 |
| 0033 - CAYUGA HALL | CAYUGA HALL | 0033 | 1.786 | 0.160 |
| 0034 - ONONDAGA HALL | ONONDAGA HALL | 0034 | 2.569 | 0.232 |
| 0035 - LITTLEPAGE DH | LITTLEPAGE DH | 0035 | 0.583 | 0.605 |
| 0036 - ONEIDA HALL | ONEIDA HALL | 0036 | 1.723 | 0.160 |
| 0037A - TOWNHOUSE A | TOWNHOUSE A | 0037A | 0.119 | 0.180 |
| 0037B - TOWNHOUSE B | TOWNHOUSE B | 0037B | 0.094 | 0.142 |
| 0037C - TOWNHOUSE C | TOWNHOUSE C | 0037C | 0.147 | 0.221 |
| 0037D - TOWNHOUSE D | TOWNHOUSE D | 0037D | 0.147 | 0.221 |
| 0037E - TOWNHOUSE E | TOWNHOUSE E | 0037E | 0.185 | 0.279 |
| 0037F - TOWNHOUSE F | TOWNHOUSE F | 0037F | 0.213 | 0.320 |
| 0037G - TOWNHOUSE G | TOWNHOUSE G | 0037G | 0.111 | 0.146 |
| 0037H - TOWNHOUSE H | TOWNHOUSE H | 0037H | 0.140 | 0.185 |
| 0037I - TOWNHOUSE I | TOWNHOUSE I | 0037I | 0.172 | 0.227 |
| 0037J - TOWNHOUSE J | TOWNHOUSE J | 0037J | 0.172 | 0.228 |
| 0037K - TOWNHOUSE K | TOWNHOUSE K | 0037K | 0.228 | 0.301 |
| 0037L - TOWNHOUSE L | TOWNHOUSE L | 0037L | 0.172 | 0.227 |
| 0041 - JOHNSON HALL | JOHNSON HALL | 0041 | 1.578 | 1.432 |
| 0042 - LAKESIDE DH | LAKESIDE DH | 0042 | 0.606 | 0.599 |
| 0043 - RIGGS HALL | RIGGS HALL | 0043 | 1.238 | 1.054 |
| 0044 - WATERBURY HALL | WATERBURY HALL | 0044 | 1.195 | - |
| 0045 - SCALES HALL | SCALES HALL | 0045 | 1.195 | - |
| 0046 - HART HALL | HART HALL | 0046 | 2.844 | - |

# Demand, Peak

| BLDG NUMBER AND NAME | BUILDING NAME | BLDG NUMBER | Peak demand heat, [mmbtu/h] | Peak demand cooling, [mmbtu/h] |
|---|---|---|---|---|
| 0047 - COOPER DH | COOPER DH | 0047 | 0.786 | 0.508 |
| 0048 - FUNNELLE HALL | FUNNELLE HALL | 0048 | 2.798 | - |
| 0049 - PUBLIC RESTROOM | PUBLIC RESTROOM | 0049 | - | - |
| 0051 - FM RADIO TRANSMISSION FAC | FM RADIO TRANSMISSION FAC | 0051 | 0.124 | - |
| 0061 - MAINTENANCE STORAGE | MAINTENANCE STORAGE | 0061 | - | - |
| 0071 - POLE BARN (FALLBROOK) | POLE BARN (FALLBROOK) | 0071 | 0.007 | - |
| 0080 - FT DRM ED SVC CONSORTIUM | FT DRM ED SVC CONSORTIUM | 0080 | - | - |
| 0081 - RICE CREEK OBSERVATORY | RICE CREEK OBSERVATORY | 0081 | 0.002 | - |
| 0082 - PRESS BOX | PRESS BOX | 0082 | 0.001 | - |
| 0083 - RICE CREEK PAVILION | RICE CREEK PAVILION | 0083 | 0.003 | - |
| 0104 - SECURITY PARKING OFFICE | SECURITY PARKING OFFICE | 0104 | 0.050 | 0.043 |
| 0106 - VOLATILE STO | VOLATILE STO | 0106 | - | - |
| 0107 - 1 ROOM SCHOOL HSE | 1 ROOM SCHOOL HSE | 0107 | 0.001 | 0.011 |
| 0108 - POWER STATION 1 | POWER STATION 1 | 0108 | 0.001 | - |
| 0109 - POWER STATION 1A | POWER STATION 1A | 0109 | - | - |
| 0110 - POWER STATION 2 | POWER STATION 2 | 0110 | - | - |
| PARKING LOT | PARKING LOT | | - | - |
| FALLBROOK REC CENTER | FALLBROOK REC CENTER | | 0.173 | 0.077 |
| **SUM** | | | **89.536** | **44.505** |

## Pipe Catalogue:

Based on ASTM A53 - Standard Specification for Pipe

| Nom. Dia [”] | ex. Dia [”] | Int. Dia [”] | Heatloss Coefficient | |
|---|---|---|---|---|
| | | | Series 1 [W/m/K] | Series 2 [W/m/K] |
| 1" | 1.315 | 1.05 | 0.18 | 0.14 |
| 1.25" | 1.66 | 1.38 | 0.18 | 0.16 |
| 1.5" | 1.9 | 1.61 | 0.21 | 0.18 |
| 2" | 2.375 | 2.07 | 0.24 | 0.20 |
| 2.5" | 2.875 | 2.47 | 0.27 | 0.22 |
| 3" | 3.5 | 3.07 | 0.30 | 0.24 |
| 4" | 4.5 | 4.03 | 0.31 | 0.25 |
| 5" | 5.563 | 5.05 | 0.37 | 0.30 |
| 6" | 6.625 | 6.07 | 0.44 | 0.34 |
| 8" | 8.625 | 7.98 | 0.48 | 0.36 |
| 10" | 10.75 | 10.02 | 0.45 | 0.34 |
| 12" | 12.75 | 11.94 | 0.53 | 0.40 |
| 14" | 14 | 13.13 | 0.51 | 0.38 |
| 16" | 16 | 15 | 0.54 | 0.39 |

## Theoretical Capacity, CHW:

### Assumptions:

- Supply Temp.: 40 ºF (277.6 K)
- Return Temp.: 52 ºF (284.3 K)

- ANSI Schedule 40 (pipedimensions)
- Roughness: 0.0039” (0.1 mm)
- Max. Pressure gradient: 0.0133 psi/ft (300 Pa/m)
- Max. Velocities:

| Slsh Vl}h ^|` | Yhorflw| ^Iw2v` |
|---|---|
| 2” - 6” | 8.2 |
| 8” - 10” | 9.8 |
| 12” - 14” | 11.5 |
| 16” < | 13.1 |

For CHW system Ramboll normally recommends to accept a higher pressure gradient to reduce the pipe size. The consequence is higher operational cost for pumping.

| Nom. Dia [”] | ex. Dia [”] | Int. Dia [”] | Flow | ΔT 12 ºF | |
|---|---|---|---|---|---|
| | | | [GPM] | Capacity [Tons] | Capacity [MMBtu/h] |
| 1" | 1.315 | 1.05 | 6 | 3 | 0.036 |
| 1.25" | 1.66 | 1.38 | 12 | 6 | 0.075 |
| 1.5" | 1.9 | 1.61 | 18 | 9 | 0.111 |
| 2" | 2.375 | 2.07 | 37 | 19 | 0.223 |
| 2.5" | 2.875 | 2.47 | 59 | 30 | 0.357 |
| 3" | 3.5 | 3.07 | 104 | 52 | 0.629 |
| 4" | 4.500 | 4.03 | 214 | 107 | 1.290 |
| 5" | 5.563 | 5.05 | 391 | 196 | 2.358 |
| 6" | 6.625 | 6.07 | 638 | 321 | 3.850 |
| 8" | 8.625 | 7.98 | 1,322 | 665 | 7.983 |
| 10" | 10.750 | 10.02 | 2,400 | 1,207 | 14.488 |
| 12" | 12.750 | 11.94 | 3,813 | 1,918 | 23.020 |

## Theoretical Capacity, HW:

### Assumptions:

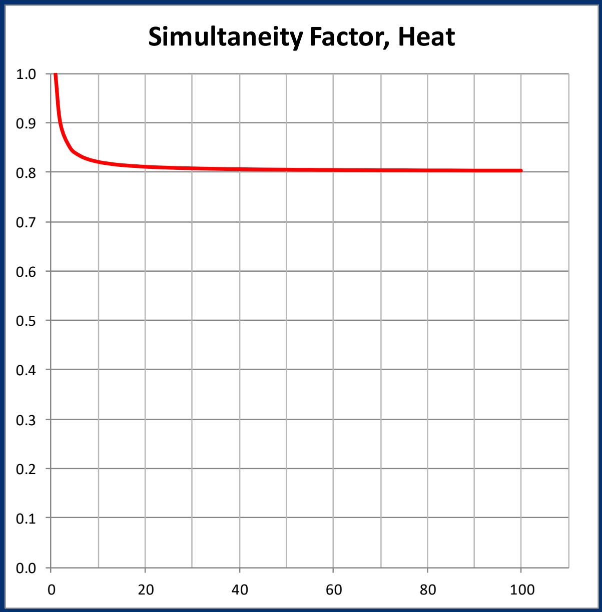
- Supply Temp.: 149 °F (338.2 K)
- Return Temp.: 113 °F (318.2 K)

- ANSI Schedule 40 (pipedimensions)
- Roughness: 0.0039” (0.1 mm)
- Max. Pressure gradient: 0.0066 psi/ft (150 Pa/m)
- Max. Velocities:

| Slsh Vl}h ^|` | Yhorflw| ^iw2v` |
|---|---|
| 1”- 2” | 3.3 |
| 2” - 6” | 6.6 |
| 8” - 10” | 8.2 |
| 12” - 14” | 9.8 |

| Nom. Dia [”] | ex. Dia [”] | Int. Dia [”] | Flow [GPM] | Capacity [MMBtu/h] ΔT 36 °F |
|---|---|---|---|---|
| 1" | 1.315 | 1.05 | 4.5 | 0.080 |
| 1.25" | 1.66 | 1.38 | 9.2 | 0.163 |
| 1.5" | 1.9 | 1.61 | 14 | 0.243 |
| 2" | 2.375 | 2.07 | 27 | 0.482 |
| 2.5" | 2.875 | 2.47 | 44 | 0.770 |
| 3" | 3.5 | 3.07 | 76 | 1.35 |
| 4" | 4.5 | 4.03 | 156 | 2.75 |
| 5" | 5.563 | 5.05 | 283 | 5.01 |
| 6" | 6.625 | 6.07 | 462 | 8.16 |
| 8" | 8.625 | 7.98 | 953 | 16.84 |
| 10" | 10.75 | 10.02 | 1,724 | 30.48 |
| 12" | 12.75 | 11.94 | 2,732 | 48.29 |
| 14" | 14 | 13.13 | 3,507 | 61.98 |
| 16" | 16 | 15 | 4,953 | 87.54 |

# Simultaneity



# Design, Centralized CHW:

Simultaneity: 0.9 ~ 39 MMBtu/h

## Assumptions:

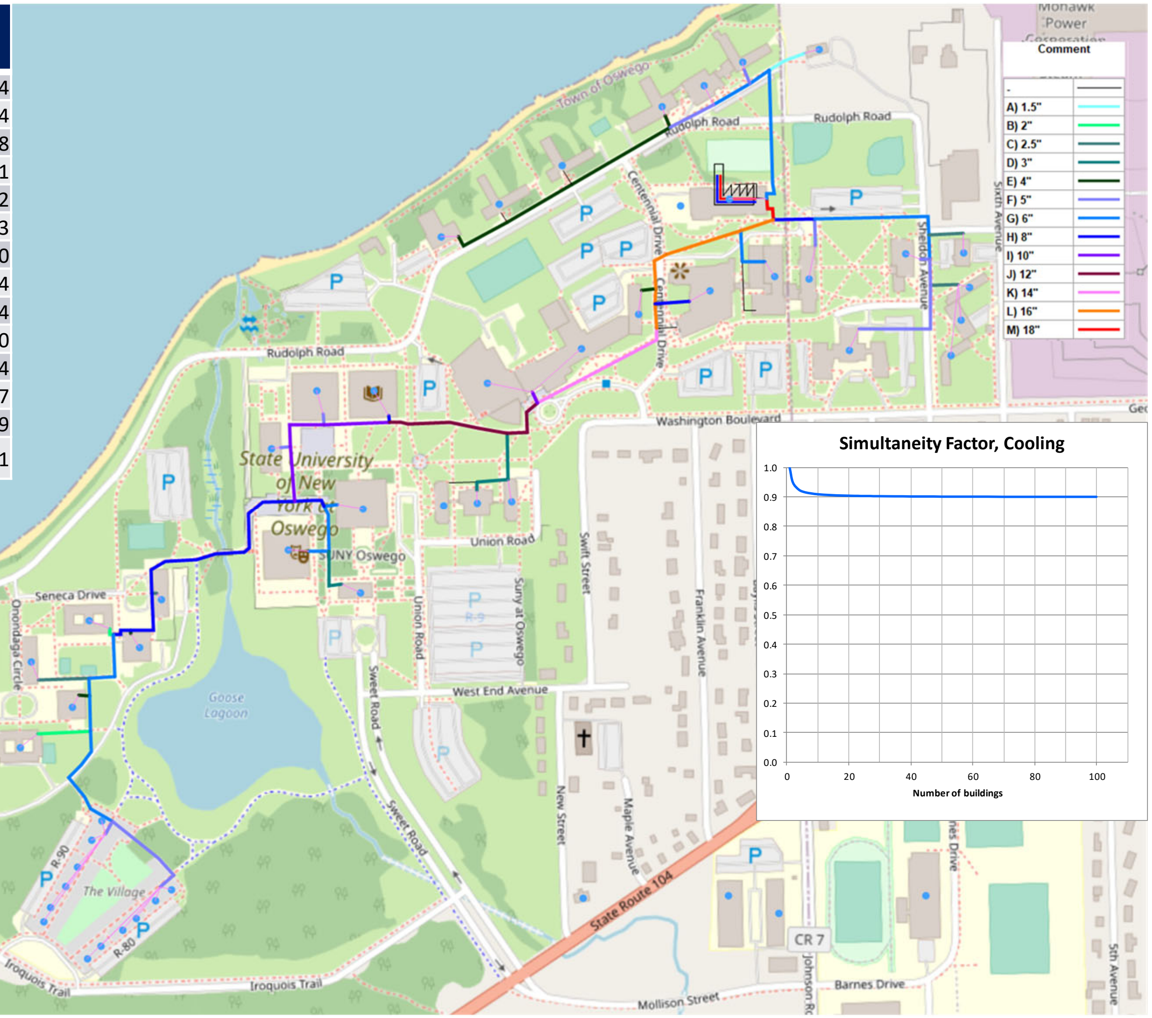
- Supply Temp.: 40 ºF
- Return Temp.: 52 ºF
- Min. dP: 14.5 PSI
- ANSI Schedule 40 (pipedimensions)

## Calculated Results:

| Production | | |
|---|---|---|
| Load | [MMbtu/h] | 39.2 |
| Flow | [GPM] | 6,472 |
| Temp. Supply | [F] | 40 |
| Temp. Return | [F] | 52 |
| Pressure, Supply | [psig] | 128 |
| Pressure, Return | [psig] | 22 |
| ΔP | [psi] | 106* |

Note:
* The model has not been configured to account for internal losses. An additional 14.5-21 psi should be added when specifying the main pumps.

| Type ["] | Trench [ft] |
|---|---|
| A) 1.5" | 174 |
| B) 2" | 274 |
| C) 2.5" | 518 |
| D) 3" | 581 |
| E) 4" | 1272 |
| F) 5" | 1643 |
| G) 6" | 3200 |
| H) 8" | 1784 |
| I) 10" | 824 |
| J) 12" | 760 |
| K) 14" | 644 |
| L) 16" | 847 |
| M) 18" | 119 |
| SUM | 12641 |




The difference of approx. 240 ft of trench, compared to the heating model, is due to three building does not have a cooling demand and therefore not being supplied

## Design, Centralized HW:
## Simultaneity: 0.8 ~ 65 MMBtu/h

### Assumptions:

- Supply Temp.: 149 ºF
- Return Temp.: 113 ºF
- Min. dP: 14.5 PSI

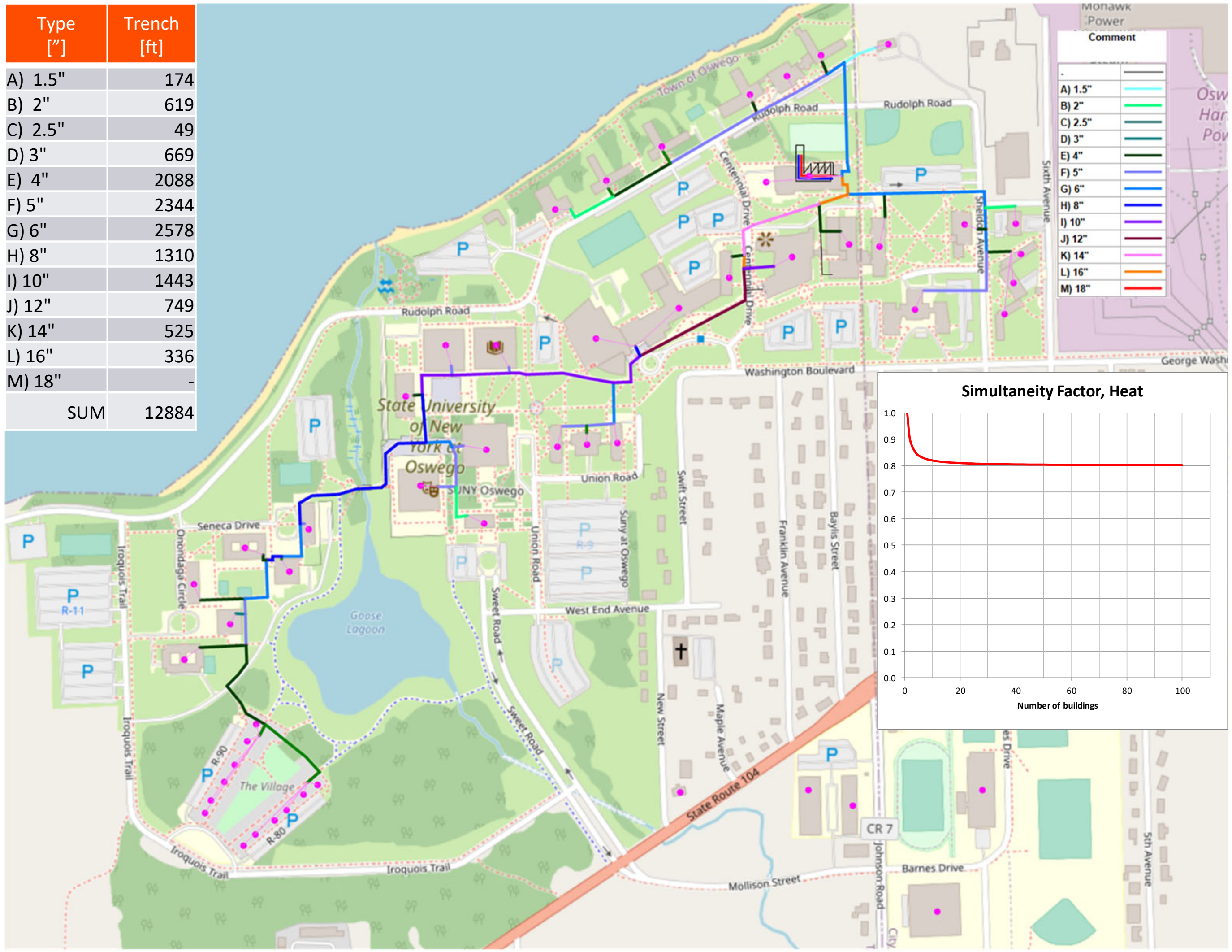
- ANSI Schedule 40 (pipedimensions)

## Calculated Results:

| Production | | |
|---|---|---|
| Load | [MMbtu/h] | 65.3 |
| Flow | [GPM] | 3,638 |
| Temp. Supply | [F] | 149 |
| Temp. Return | [F] | 113 |
| Pressure, Supply | [psig] | 74 |
| Pressure, Return | [psig] | 22 |
| ΔP | [psi] | 54* |

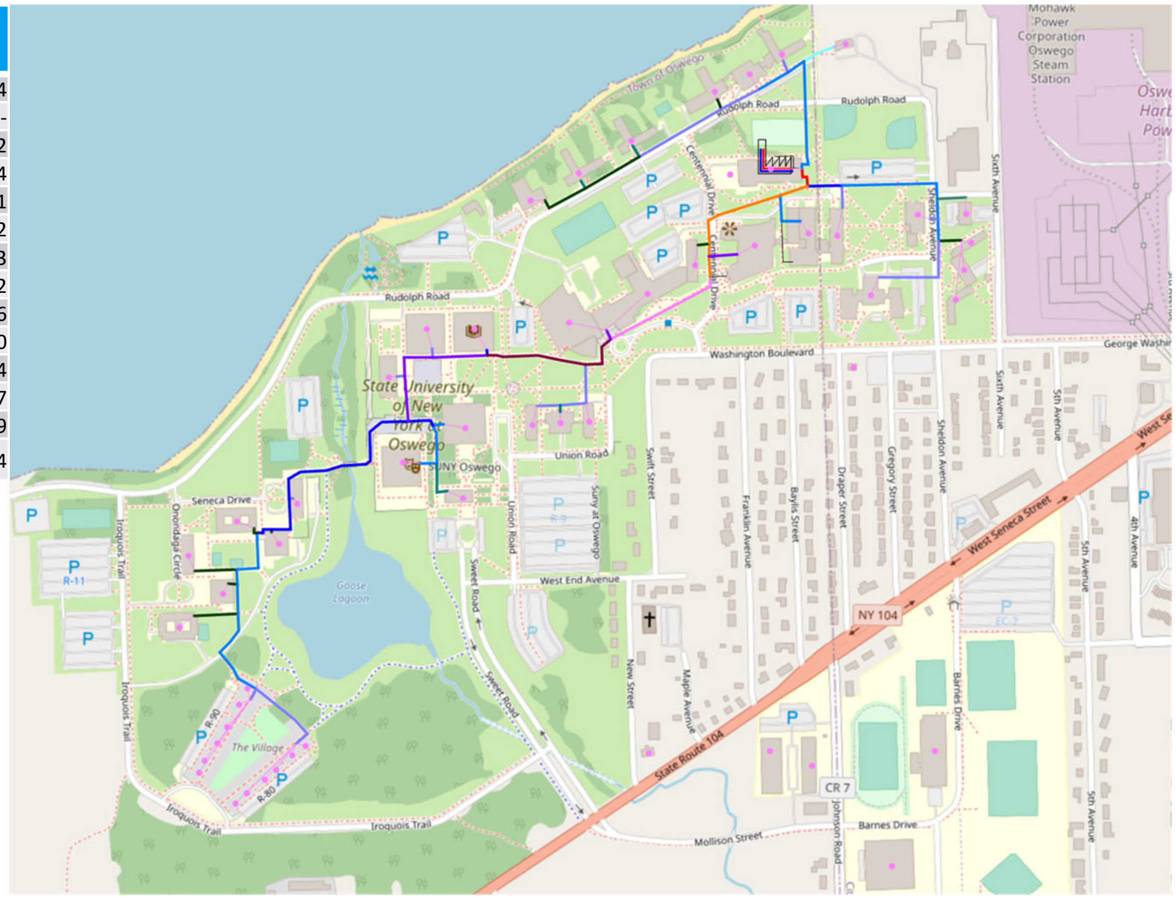
Note:
* The model has not been configured to account for internal losses. An additional 14.5-21 psi should be added when specifying the main pumps.

| Type ["] | Trench [ft] |
|---|---|
| A) 1.5" | 174 |
| B) 2" | 619 |
| C) 2.5" | 49 |
| D) 3" | 669 |
| E) 4" | 2088 |
| F) 5" | 2344 |
| G) 6" | 2578 |
| H) 8" | 1310 |
| I) 10" | 1443 |
| J) 12" | 749 |
| K) 14" | 525 |
| L) 16" | 336 |
| M) 18" | - |
| SUM | 12884 |



# Distribution System, Centralized

| Type ["] | Trench [ft] |
|---|---|
| A) 1.5" | 174 |
| B) 2" | - |
| C) 2.5" | 152 |
| D) 3" | 364 |
| E) 4" | 1391 |
| F) 5" | 2512 |
| G) 6" | 3313 |
| H) 8" | 1632 |
| I) 10" | 976 |
| J) 12" | 760 |
| K) 14" | 644 |
| L) 16" | 847 |
| M) 18" | 119 |
| SUM | 12884 |



## Design, Cluster CHW:
## Simultaneity: 0.92 ~ 40 MMBtu/h

## Assumptions:

- Supply Temp.: 40 ºF
- Return Temp.: 52 ºF
- Min. dP: 14.5 PSI

- ANSI Schedule 40 (pipedimensions)

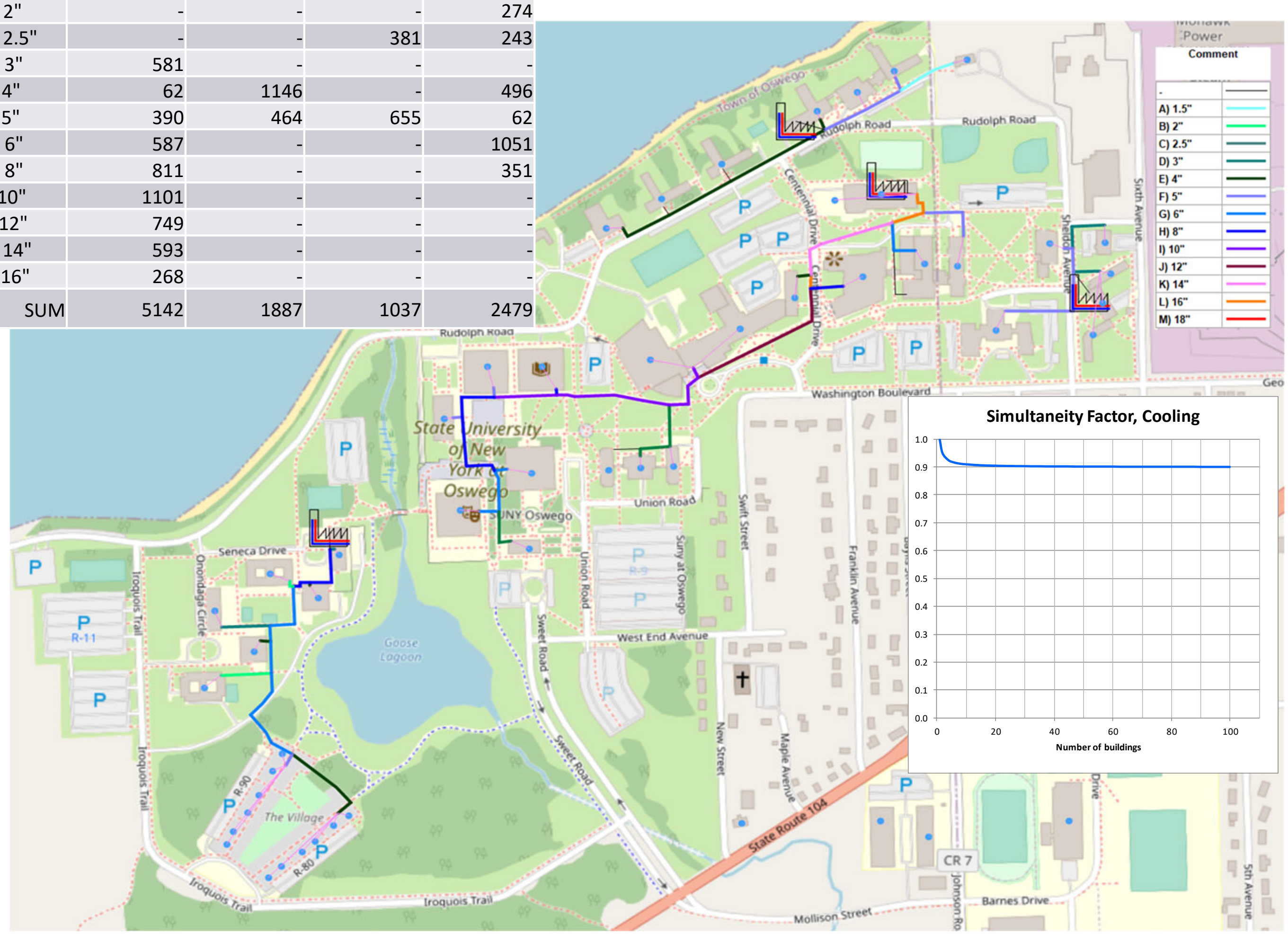
## Calculated Results:

| Production | | C | N | E | W |
|---|---|---|---|---|---|
| Load | [MMbtu/h] | 28.6 | 3.6 | 3.5 | 4.4 |
| Flow | [GPM] | 4,711 | 600 | 580 | 725 |
| Temp. Supply | [F] | 40 | 40 | 40 | 40 |
| Temp. Return | [F] | 52 | 52 | 52 | 52 |
| Pressure, Supply | [psig] | 108 | 46 | 45 | 63 |
| Pressure, Return | [psig] | 22 | 22 | 22 | 22 |
| ΔP | [psi] | 86* | 24* | 23* | 41* |

Note:
* The model has not been configured to account for internal losses. An additional 14.5-21 psi should be added when specifying the main pumps.

| Type ["] | Cluster C [ft] | Cluster N [ft] | Cluster E [ft] | Cluster W [ft] |
|---|---|---|---|---|
| A) 1.5" | - | 277 | - | - |
| B) 2" | - | - | - | 274 |
| C) 2.5" | - | - | 381 | 243 |
| D) 3" | 581 | - | - | - |
| E) 4" | 62 | 1146 | - | 496 |
| F) 5" | 390 | 464 | 655 | 62 |
| G) 6" | 587 | - | - | 1051 |
| H) 8" | 811 | - | - | 351 |
| I) 10" | 1101 | - | - | - |
| J) 12" | 749 | - | - | - |
| K) 14" | 593 | - | - | - |
| L) 16" | 268 | - | - | - |
| SUM | 5142 | 1887 | 1037 | 2479 |

Cluster S:
Only 0019 - LAKER HALL has a chilled water demand therefore no network

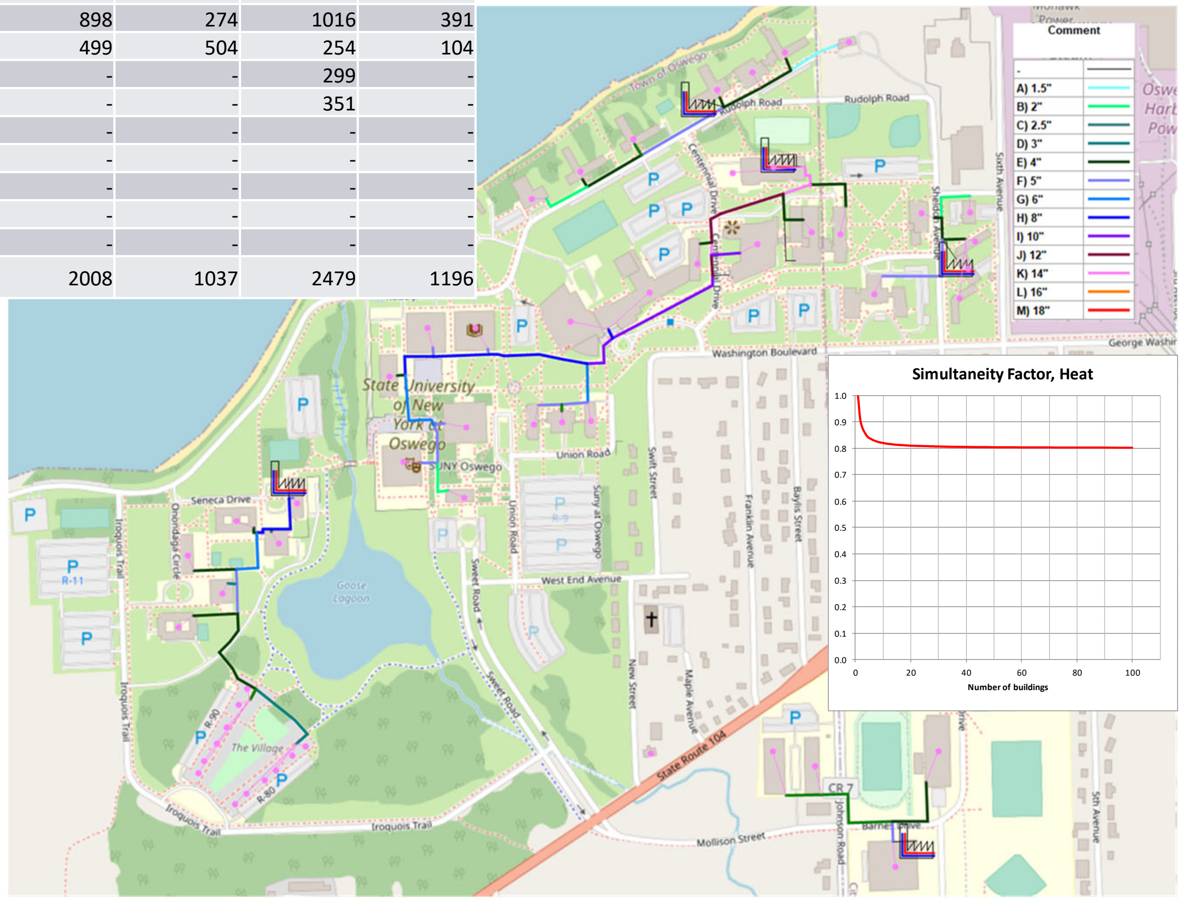


## Design, Cluster HW:
Simultaneity: 0.83 ~ 74 MMBtu/h

### Assumptions:
- Supply Temp.: 149 ºF
- Return Temp.: 113 ºF
- Min. dP: 14.5 PSI

- ANSI Schedule 40 (pipedimensions)

| Type ["] | Cluster C [ft] | Cluster N [ft] | Cluster E [ft] | Cluster W [ft] | Cluster S [ft] |
|---|---|---|---|---|---|
| A) 1.5" | - | 277 | - | - | - |
| B) 2" | 204 | 263 | 259 | - | - |
| C) 2.5" | - | - | - | 481 | - |
| D) 3" | 39 | 71 | - | 78 | 701 |
| E) 4" | 641 | 898 | 274 | 1016 | 391 |
| F) 5" | 689 | 499 | 504 | 254 | 104 |
| G) 6" | 583 | - | - | 299 | - |
| H) 8" | 1105 | - | - | 351 | - |
| I) 10" | 1036 | - | - | - | - |
| J) 12" | 630 | - | - | - | - |
| K) 14" | 336 | - | - | - | - |
| L) 16" | - | - | - | - | - |
| M) 18" | - | - | - | - | - |
| SUM | 5264 | 2008 | 1037 | 2479 | 1196 |



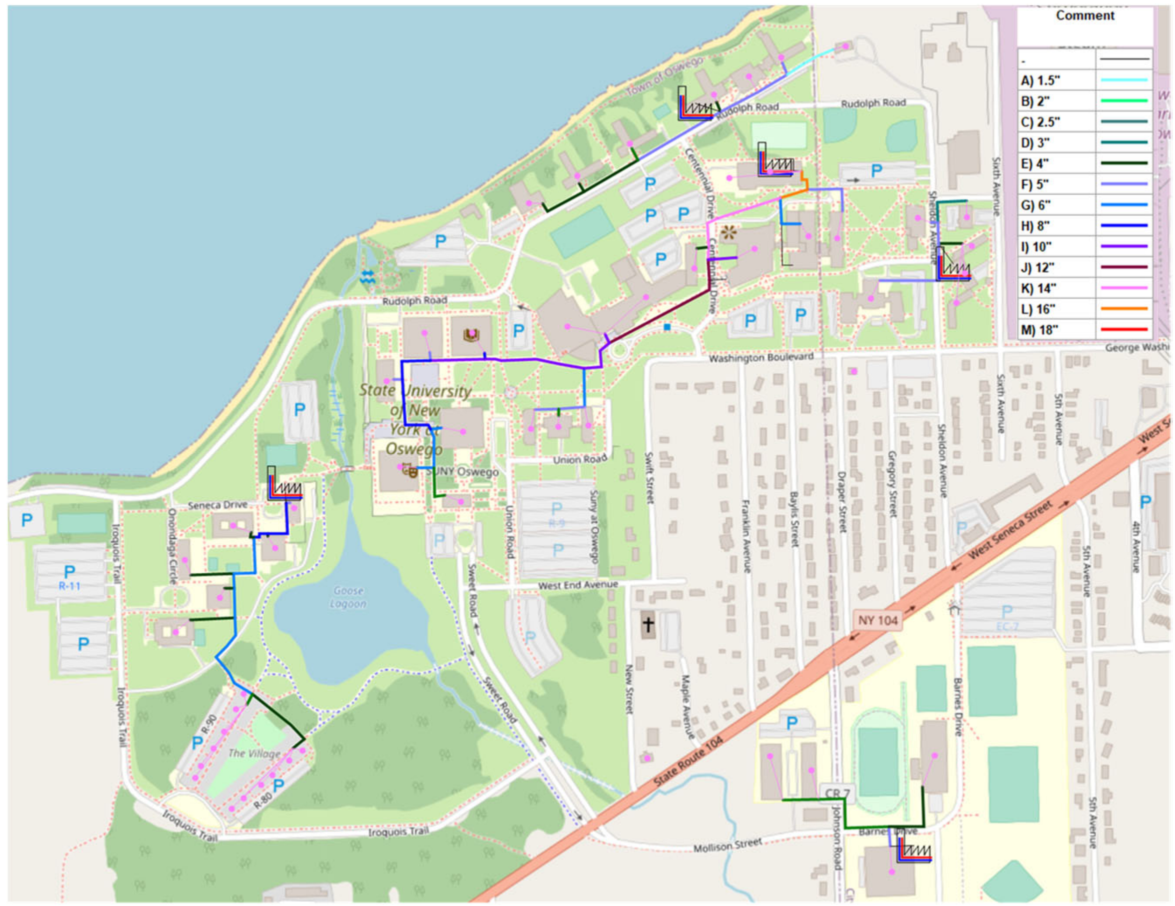

## Calculated Results:

| Production | | C | N | E | W | S |
|---|---|---|---|---|---|---|
| Load | [MMbtu/h] | 46.0 | 5.4 | 6.2 | 10.0 | 6.5 |
| Flow | [GPM] | 2,569 | 301 | 344 | 556 | 361 |
| Temp. Supply | [F] | 149 | 149 | 149 | 149 | 149 |
| Temp. Return | [F] | 113 | 113 | 113 | 113 | 113 |
| Pressure, Supply | [psig] | 61 | 42 | 39 | 48 | 40 |
| Pressure, Return | [psig] | 22 | 22 | 22 | 22 | 22 |
| ΔP | [psi] | 39* | 20* | 17* | 26* | 18* |

Note:
* The model has not been configured to account for internal losses. An additional 14.5-21 psi should be added when specifying the main pumps.

# Distribution System, Cluster

| Type ["] | Cluster C [ft] | Cluster N [ft] | Cluster E [ft] | Cluster W [ft] | Cluster S [ft] |
|---|---|---|---|---|---|
| A) 1.5" | - | 277 | - | - | - |
| B) 2" | - | - | - | - | - |
| C) 2.5" | - | - | 259 | - | - |
| D) 3" | 243 | 71 | - | 62 | 701 |
| E) 4" | 62 | 696 | 122 | 992 | 391 |
| F) 5" | 650 | 963 | 655 | 22 | 104 |
| G) 6" | 787 | - | - | 1051 | - |
| H) 8" | 659 | - | - | 351 | - |
| I) 10" | 1252 | - | - | - | - |
| J) 12" | 749 | - | - | - | - |
| K) 14" | 593 | - | - | - | - |
| L) 16" | 268 | - | - | - | - |
| M) 18" | - | - | - | - | - |
| SUM | 5264 | 2008 | 1037 | 2479 | 1196 |



# Appendix F
# EnergyPro Techno-Economic Analysis

| TECHNICAL DATA | Units | Scenario 0<br>BaU | Scenario 2a<br>Cluster + NG Peaking | Scenario 2b<br>Cluster + Electric Peaking | Scenario 4a<br>Centralized + NG Peaking | Scenario 4b<br>Centralized + Electric Peaking | Scenario 5b<br>Centralized + WWHP + Electric Peaking | Scenario 6a<br>Centralized Cascade + NG Peaking | Scenario 6b<br>Centralized Cascade + Electric Peaking |
|---|---|---|---|---|---|---|---|---|---|
| Space Heating (SH) Demand | MWh-h | 43,107 | 36,036 | 36,036 | 36,036 | 36,036 | 36,036 | 36,036 | 36,036 |
| Domestic Hot Water (DHW) Demand | MWh-h | 13,613 | 13,613 | 13,613 | 13,613 | 13,613 | 13,613 | 13,613 | 13,613 |
| Network Losses | MWh-h | 9,222 | 811 | 811 | 811 | 811 | 811 | 811 | 811 |
| ***Total Heat Demand*** | MWh-h | ***65,941*** | ***50,460*** | ***50,460*** | ***50,460*** | ***50,460*** | ***50,460*** | ***50,460*** | ***50,460*** |
| ***Total Cooling Demand*** | MWh-c | ***12,984*** | ***8,887*** | ***8,887*** | ***8,887*** | ***8,887*** | ***8,887*** | ***8,887*** | ***8,887*** |
| **Heating Production** | | | | | | | | | |
| Central Steam | MWh-h | 46,108 | - | - | - | - | - | - | - |
| Natural Gas Boiler | MWh-h | 7,375 | 4,725 | 223 | 4,713 | 223 | 223 | 3,558 | 223 |
| GSHP | MWh-h | 12,059 | 39,227 | 39,227 | 39,228 | 39,228 | 15,535 | 17,259 | 17,276 |
| WWHP | MWh-h | - | - | - | - | - | 26,026 | - | - |
| Cascade HP | MWh-h | - | - | - | - | - | - | 23,125 | 24,236 |
| Electric Boiler | MWh-h | - | - | 4,440 | - | 4,428 | 2,095 | - | 2,143 |
| Local Electric Boiler | MWh-h | 399 | 6,548 | 6,611 | 6,547 | 6,611 | 6,611 | 6,547 | 6,611 |
| TES Heat Loss | MWh-h | - | (39) | (41) | (29) | (30) | (30) | (29) | (30) |
| ***Total Heating Production*** | MWh-h | ***65,941*** | ***50,460*** | ***50,460*** | ***50,460*** | ***50,460*** | ***50,460*** | ***50,460*** | ***50,460*** |
| **Cooling Production** | | | | | | | | | |
| GSHP | MWh-c | 1,697 | 3,389 | 3,389 | 3,617 | 3,617 | 3,617 | 3,617 | 3,617 |
| Central Chillers | MWh-c | - | 5,409 | 5,409 | 5,182 | 5,182 | 5,182 | 5,182 | 5,182 |
| Local Cooling | MWh-c | 11,287 | 88 | 88 | 88 | 88 | 88 | 88 | 88 |
| TES Heat Loss | MWh-c | - | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| ***Total Cooling Production*** | MWh-c | ***12,984*** | ***8,886*** | ***8,886*** | ***8,887*** | ***8,887*** | ***8,887*** | ***8,887*** | ***8,887*** |
| **Fuel Consumption** | | | | | | | | | |
| District Steam | MWh-f | 65,820 | - | - | - | - | - | - | - |
| Natural Gas Boiler | MWh-f | 9,219 | 5,769 | 279 | 5,601 | 279 | 279 | 4,235 | 279 |
| GSHP | MWh-el | 3,636 | 11,355 | 11,355 | 11,406 | 11,406 | 5,003 | 5,469 | 5,473 |
| WWHP | MWh-el | - | - | - | - | - | 6,889 | - | - |
| Cascade HP | MWh-el | - | - | - | - | - | - | 8,766 | 9,305 |
| Electric Boiler | MWh-el | - | - | 4,530 | - | 4,518 | 2,138 | - | 2,187 |
| Local Electric Boiler | MWh-el | 274 | 6,548 | 6,613 | 6,547 | 6,612 | 6,612 | 6,547 | 6,612 |
| Central Chillers | MWh-el | - | 1,202 | 1,202 | 1,152 | 1,152 | 1,152 | 1,152 | 1,152 |
| Local Cooling | MWh-el | 2,609 | 29 | 29 | 29 | 29 | 29 | 29 | 29 |
| Dry-Cooler or Pumping Operation | MWh-el | - | 894 | 894 | 894 | 894 | 102 | - | - |
| Electricity for uses other than heating/cooling | MWh-el | 31,506 | 25,369 | 25,369 | 25,369 | 25,369 | 25,369 | 25,369 | 25,369 |
| ***Total Fuel Consumption*** | MWh | ***113,064*** | ***51,165*** | ***50,271*** | ***50,998*** | ***50,258*** | ***47,573*** | ***51,567*** | ***50,406*** |
| **CO2e Emissions** | | | | | | | | | |
| District Steam | MT CO2e | 11,927 | - | - | - | - | - | - | - |
| Natural Gas Boiler | MT CO2e | 1,670 | 1,045 | 51 | 1,015 | 51 | 51 | 767 | 51 |
| GSHP | MT CO2e | - | - | - | - | - | - | - | - |
| Central Chillers | MT CO2e | - | - | - | - | - | - | - | - |
| WWHP | MT CO2e | - | - | - | - | - | - | - | - |
| Electric Boiler | MT CO2e | - | - | - | - | - | - | - | - |
| Local Electric Boiler | MT CO2e | - | - | - | - | - | - | - | - |
| Local Cooling | MT CO2e | - | - | - | - | - | - | - | - |
| Cascade HP | MT CO2e | - | - | - | - | - | - | - | - |
| Dry-Cooler or Pumping Operation | MT CO2e | - | - | - | - | - | - | - | - |
| Electricity for uses other than heating/cooling | MT CO2e | - | - | - | - | - | - | - | - |
| ***Total CO2e Emissions*** | MT CO2e | ***13,597*** | ***1,045*** | ***51*** | ***1,015*** | ***51*** | ***51*** | ***767*** | ***51*** |

Legend:
MWh-h Megawatt hours of heating production
MWh-c Megawatt hours of cooling production
MWh-el Megawatt hours of electric consumption
MWh-f Megawatt hours of feul consumption
MT $CO_2e$ Metric tons of equivalent carbon emissions

| CAPEX | Scenario 0<br>BaU | Scenario 2a<br>Cluster + NG Peaking | Scenario 2b<br>Cluster + Electric Peaking | Scenario 4a<br>Centralized + NG Peaking | Scenario 4b<br>Centralized + Electric Peaking | Scenario 5b<br>Centralized + WWHP + Electric Peaking | Scenario 6a<br>Centralized Cascade + NG Peaking | Scenario 6b<br>Centralized Cascade + Electric Peaking |
|---|---|---|---|---|---|---|---|---|
| Domestic Water Heating Equipment | $ 3,101,237 | $ 3,101,237 | $ 3,101,237 | $ 3,101,237 | $ 3,101,237 | $ 3,101,237 | $ 3,101,237 | $ 3,101,237 |
| Thermal Distribution | $ 24,700,000 | $ 11,561,372 | $ 11,561,372 | $ 13,656,780 | $ 13,656,780 | $ 13,656,780 | $ 13,656,780 | $ 13,656,780 |
| Hot Water Heat Exchangers | $ 6,963,745 | $ 6,963,745 | $ 6,963,745 | $ 6,963,745 | $ 6,963,745 | $ 6,963,745 | $ 6,963,745 | $ 6,963,745 |
| Chilled Water Heat Exchangers | $ - | $ 4,838,244 | $ 4,838,244 | $ 4,838,244 | $ 4,838,244 | $ 4,838,244 | $ 4,838,244 | $ 4,838,244 |
| Geothermal Wellfield | $ - | $ 57,944,113 | $ 57,944,113 | $ 49,143,608 | $ 49,143,608 | $ 40,475,416 | $ 49,143,608 | $ 49,143,608 |
| Heat Pumps | $ - | $ 17,323,247 | $ 17,323,247 | $ 16,397,424 | $ 16,397,424 | $ 15,254,034 | $ 25,114,425 | $ 25,114,425 |
| Heating Thermal Energy Tanks | $ - | $ 8,458,582 | $ 8,458,582 | $ 8,141,671 | $ 8,141,671 | $ 8,141,671 | $ 8,141,671 | $ 8,141,671 |
| Waste Water Energy Recovery | $ - | $ - | $ - | $ - | $ - | $ 8,165,365 | $ - | $ - |
| Dry Cooler Borefield Balancing | $ - | $ 3,292,910 | $ 3,292,910 | $ 2,081,294 | $ 2,081,294 | $ 494,886 | $ 494,886 | $ 494,886 |
| Peaking Gas Boilers | $ 2,725,549 | $ 3,390,858 | $ - | $ 2,725,549 | $ - | $ - | $ 2,725,549 | $ - |
| Peaking Electric Boilers | $ - | $ - | $ 4,216,135 | $ - | $ 3,820,287 | $ 3,748,893 | $ - | $ 3,820,287 |
| Campus Electrical Infrastructure Upgrades | $ - | $ 16,133,775 | $ 22,017,640 | $ 15,011,595 | $ 19,231,844 | $ 19,231,844 | $ 15,011,595 | $ 19,231,844 |
| **Total** | **$ 37,490,531** | **$ 133,008,083** | **$ 139,717,226** | **$ 122,061,148** | **$ 127,376,135** | **$ 124,072,115** | **$ 129,191,741** | **$ 134,506,728** |

| NPV COSTS | Scenario 0 | Scenario 2a | Scenario 2b | Scenario 4a | Scenario 4b | Scenario 5b | Scenario 6a | Scenario 6b |
|---|---|---|---|---|---|---|---|---|
| | BaU | GSHP + Natural Gas Peaking | GSHP + Electric Peaking | AS+GS HP + NG Peaking | AS+GS HP + Electric Peaking | ASHP Cascade + NG Peaking | ASHP Cascade + Electric Peaking | Decentralized + NG Peaking |
| **Fuel Cost** | | | | | | | | |
| District Steam | $ 13,336,957 | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| District LTHW | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| Natural Gas Boiler | $ 1,867,958 | $ 1,168,869 | $ 56,484 | $ 1,136,015 | $ 56,484 | $ 56,484 | $ 975,299 | $ 56,484 |
| GSHP | $ 3,178,277 | $ 9,924,950 | $ 9,500,311 | $ 9,965,957 | $ 9,545,254 | $ 4,295,153 | $ 4,696,242 | $ 4,700,712 |
| Central Chillers | $ - | $ 1,050,698 | $ 1,005,744 | $ 1,006,111 | $ 963,639 | $ 988,660 | $ 988,886 | $ 988,995 |
| WWHP | $ - | $ - | $ - | $ - | $ - | $ 5,915,129 | $ - | $ - |
| Electric Boiler | $ - | $ - | $ 3,790,135 | $ - | $ 3,780,912 | $ 1,835,223 | $ - | $ 1,878,361 |
| Local Electric Boiler | $ 239,485 | $ 5,723,114 | $ 5,542,962 | $ 5,720,626 | $ 5,543,724 | $ 5,681,448 | $ 5,626,788 | $ 5,683,296 |
| Local Cooling | $ 2,280,473 | $ 25,637 | $ 25,637 | $ 25,637 | $ 25,637 | $ 25,637 | $ 25,637 | $ 25,637 |
| Cascade HP | $ - | $ - | $ - | $ - | $ - | $ - | $ 7,528,071 | $ 7,991,665 |
| Dry-Cooler or Pumping Operation | $ - | $ 781,011 | $ 781,011 | $ 781,055 | $ 781,055 | $ 89,535 | $ - | $ - |
| Electricity for uses other than heating/cooling | $ 27,537,740 | $ 22,173,735 | $ 22,173,735 | $ 22,173,735 | $ 22,173,735 | $ 22,173,735 | $ 22,173,735 | $ 22,173,735 |
| ***Total Fuel Cost*** | ***$ 48,440,891*** | ***$ 40,848,014*** | ***$ 42,876,018*** | ***$ 40,809,135*** | ***$ 42,870,438*** | ***$ 41,061,004*** | ***$ 42,014,658*** | ***$ 43,498,884*** |
| **O&M Cost** | | | | | | | | |
| District Steam | $ 2,337,360 | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| District LTHW | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| Natural Gas Boiler | $ 277,170 | $ 684,128 | $ 8,594 | $ 683,898 | $ 8,594 | $ 8,594 | $ 660,882 | $ 8,594 |
| GSHP | $ 632,926 | $ 1,656,886 | $ 1,656,886 | $ 1,663,889 | $ 1,663,889 | $ 937,771 | $ 990,607 | $ 991,128 |
| Central Chillers | $ - | $ 262,895 | $ 262,895 | $ 262,267 | $ 262,267 | $ 262,267 | $ 142,925 | $ 142,925 |
| WWHP | $ - | $ - | $ - | $ - | $ - | $ 797,634 | $ - | $ - |
| Electric Boiler | $ - | $ - | $ 386,169 | $ - | $ 386,000 | $ 352,395 | $ - | $ 353,100 |
| Local Electric Boiler | $ 10,777 | $ 300,737 | $ 301,626 | $ 300,722 | $ 301,626 | $ 301,626 | $ 300,722 | $ 301,626 |
| Local Cooling | $ 636,627 | $ 8,400 | $ 8,400 | $ 8,400 | $ 8,400 | $ 8,400 | $ 8,400 | $ 8,400 |
| Cascade HP | $ - | $ - | $ - | $ - | $ - | $ - | $ 263,094 | $ 263,094 |
| Dry-Cooler or Pumping Operation | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| ***Total O&M Cost*** | ***$ 3,894,859*** | ***$ 2,913,046*** | ***$ 2,624,569*** | ***$ 2,919,176*** | ***$ 2,630,776*** | ***$ 2,668,687*** | ***$ 2,366,630*** | ***$ 2,068,867*** |
| **CO2e Cost** | | | | | | | | |
| Imported Electricity | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| Natural Gas | $ 35,795,184 | $ 2,751,720 | $ 132,973 | $ 2,671,962 | $ 132,973 | $ 132,973 | $ 2,020,400 | $ 132,973 |
| ***Total CO2e Cost*** | ***$ 35,795,184*** | ***$ 2,751,720*** | ***$ 132,973*** | ***$ 2,671,962*** | ***$ 132,973*** | ***$ 132,973*** | ***$ 2,020,400*** | ***$ 132,973*** |
| **CAPEX** | | | | | | | | |
| Domestic Water Heating Equipment | $ 4,803,707 | $ 5,091,803 | $ 5,091,803 | $ 5,091,803 | $ 5,091,803 | $ 5,091,803 | $ 5,091,803 | $ 5,091,803 |
| Thermal Distribution | $ 23,302,466 | $ 11,561,372 | $ 11,561,372 | $ 13,656,780 | $ 13,656,780 | $ 13,656,780 | $ 13,656,780 | $ 13,656,780 |
| Hot Water Heat Exchangers | $ 6,569,734 | $ 6,963,745 | $ 6,963,745 | $ 6,963,745 | $ 6,963,745 | $ 6,963,745 | $ 6,963,745 | $ 6,963,745 |
| Chilled Water Heat Exchangers | $ - | $ 4,838,244 | $ 4,838,244 | $ 4,838,244 | $ 4,838,244 | $ 4,838,244 | $ 4,838,244 | $ 4,838,244 |
| Geothermal Wellfield | $ - | $ 57,944,113 | $ 57,944,113 | $ 49,143,608 | $ 49,143,608 | $ 40,475,416 | $ 49,143,608 | $ 49,143,608 |
| Heat Pumps | $ - | $ 17,323,247 | $ 17,323,247 | $ 16,397,424 | $ 16,397,424 | $ 15,254,034 | $ 25,114,425 | $ 25,114,425 |
| Heating Thermal Energy Tanks | $ - | $ 8,458,582 | $ 8,458,582 | $ 8,141,671 | $ 8,141,671 | $ 8,141,671 | $ 8,141,671 | $ 8,141,671 |
| Waste Water Energy Recovery | $ - | $ - | $ - | $ - | $ - | $ 8,165,365 | $ - | $ - |
| Dry Cooler Borefield Balancing | $ - | $ 3,292,910 | $ 3,292,910 | $ 2,081,294 | $ 2,081,294 | $ 494,886 | $ 494,886 | $ 494,886 |
| Peaking Gas Boilers | $ 2,725,549 | $ 3,390,858 | $ - | $ 2,725,549 | $ - | $ - | $ 2,725,549 | $ - |
| Peaking Electric Boilers | $ - | $ - | $ 4,216,135 | $ - | $ 3,820,287 | $ 3,748,893 | $ - | $ 3,820,287 |
| Campus Electrical Infrastructure Upgrades | $ - | $ 16,133,775 | $ 22,017,640 | $ 15,011,595 | $ 19,231,844 | $ 19,231,844 | $ 15,011,595 | $ 19,231,844 |
| ***Total CAPEX Cost*** | ***$ 37,401,456*** | ***$ 134,998,649*** | ***$ 141,707,792*** | ***$ 124,051,714*** | ***$ 129,366,700*** | ***$ 126,062,681*** | ***$ 131,182,307*** | ***$ 136,497,294*** |
| **Residual Value** | | | | | | | | |
| Domestic Water Heating Equipment | $ (1,494,953) | $ (1,327,044) | $ (1,327,044) | $ (1,327,044) | $ (1,327,044) | $ (1,327,044) | $ (1,327,044) | $ (1,327,044) |
| Thermal Distribution | $ (14,886,037) | $ (6,936,823) | $ (6,936,823) | $ (8,194,068) | $ (8,194,068) | $ (8,194,068) | $ (8,194,068) | $ (8,194,068) |
| Hot Water Heat Exchangers | $ (1,823,996) | $ (1,392,749) | $ (1,392,749) | $ (1,392,749) | $ (1,392,749) | $ (1,392,749) | $ (1,392,749) | $ (1,392,749) |
| Chilled Water Heat Exchangers | $ - | $ (967,649) | $ (967,649) | $ (967,649) | $ (967,649) | $ (967,649) | $ (967,649) | $ (967,649) |
| Geothermal Wellfield | $ - | $ (28,972,057) | $ (28,972,057) | $ (24,571,804) | $ (24,571,804) | $ (20,237,708) | $ (24,571,804) | $ (24,571,804) |
| Heat Pumps | $ - | $ (3,464,649) | $ (3,464,649) | $ (3,279,485) | $ (3,279,485) | $ (3,050,807) | $ (5,022,885) | $ (5,022,885) |
| Heating Thermal Energy Tanks | $ - | $ (2,819,527) | $ (2,819,527) | $ (2,713,890) | $ (2,713,890) | $ (2,713,890) | $ (2,713,890) | $ (2,713,890) |
| Waste Water Energy Recovery | $ - | $ - | $ - | $ - | $ - | $ (1,633,073) | $ - | $ - |
| Dry Cooler Borefield Balancing | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| Peaking Gas Boilers | $ (545,110) | $ (678,172) | $ - | $ (545,110) | $ - | $ - | $ (545,110) | $ - |
| Peaking Electric Boilers | $ - | $ - | $ (843,227) | $ - | $ (764,057) | $ (749,779) | $ - | $ (764,057) |
| Campus Electrical Infrastructure Upgrades | $ - | $ (9,680,265) | $ (13,210,584) | $ (9,006,957) | $ (11,539,107) | $ (11,539,107) | $ (9,006,957) | $ (11,539,107) |
| ***Total Residual Value*** | ***$ (18,750,096)*** | ***$ (56,238,935)*** | ***$ (59,934,310)*** | ***$ (51,998,756)*** | ***$ (54,749,853)*** | ***$ (51,805,873)*** | ***$ (53,742,156)*** | ***$ (56,493,253)*** |
| **Total Net Present Value** | **$ 106,782,295** | **$ 125,272,494** | **$ 127,407,043** | **$ 118,453,230** | **$ 120,251,034** | **$ 118,119,471** | **$ 123,841,838** | **$ 125,704,764** |

| Annual Cash Flow (2022 USD) | | NPV | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Scenario 0** | **BaU** | | | | | | | | | | |
| | Fuel Costs | $ 48,440,891 | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 |
| | O&M Costs | $ 3,894,859 | $ 254,171 | $ 254,171 | $ 254,171 | $ 254,171 | $ 254,171 | $ 254,171 | $ 254,171 | $ 254,171 | $ 254,171 |
| | $CO_2e$ Costs | $ 35,795,184 | $ 2,107,548 | $ 2,134,742 | $ 2,161,936 | $ 2,189,130 | $ 2,216,325 | $ 2,243,519 | $ 2,257,116 | $ 2,284,310 | $ 2,325,101 |
| | CAPEX | $ 37,401,456 | $ 9,678,545 | $ 6,952,996 | $ 6,952,996 | $ 6,952,996 | $ 6,952,996 | $ - | $ - | $ - | $ - |
| | Residual Value | $ (18,750,096) | $ (3,787,660) | $ (3,397,060) | $ (3,551,570) | $ (3,706,080) | $ (3,860,590) | $ - | $ - | $ - | $ - |
| | **Total** | **$ 106,782,295** | **$ 11,413,758** | **$ 9,106,003** | **$ 8,978,688** | **$ 8,851,372** | **$ 8,724,056** | **$ 5,658,843** | **$ 5,672,440** | **$ 5,699,635** | **$ 5,740,426** |
| **Scenario 2a** | **Cluster + NG Peaking** | | | | | | | | | | |
| | Fuel Costs | $ 40,848,014 | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 |
| | O&M Costs | $ 2,913,046 | $ 190,099 | $ 190,099 | $ 190,099 | $ 190,099 | $ 190,099 | $ 190,099 | $ 190,099 | $ 190,099 | $ 190,099 |
| | $CO_2e$ Costs | $ 2,751,720 | $ 162,016 | $ 164,106 | $ 166,197 | $ 168,287 | $ 170,378 | $ 172,468 | $ 173,514 | $ 175,604 | $ 178,740 |
| | CAPEX | $ 134,998,649 | $ 133,008,083 | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| | Residual Value | $ (56,238,935) | $ (54,911,891) | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| | **Total** | **$ 125,272,494** | **$ 81,113,966** | **$ 3,019,864** | **$ 3,021,955** | **$ 3,024,045** | **$ 3,026,136** | **$ 3,028,226** | **$ 3,029,271** | **$ 3,031,362** | **$ 3,034,498** |
| **Scenario 2b** | **Cluster + Electric Peaking** | | | | | | | | | | |
| | Fuel Costs | $ 42,876,018 | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 |
| | O&M Costs | $ 2,624,569 | $ 171,274 | $ 171,274 | $ 171,274 | $ 171,274 | $ 171,274 | $ 171,274 | $ 171,274 | $ 171,274 | $ 171,274 |
| | $CO_2e$ Costs | $ 132,973 | $ 7,829 | $ 7,930 | $ 8,031 | $ 8,132 | $ 8,233 | $ 8,334 | $ 8,385 | $ 8,486 | $ 8,637 |
| | CAPEX | $ 141,707,792 | $ 139,717,226 | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| | Residual Value | $ (59,934,310) | $ (58,607,266) | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| | **Total** | **$ 127,407,043** | **$ 84,087,065** | **$ 2,977,206** | **$ 2,977,307** | **$ 2,977,408** | **$ 2,977,509** | **$ 2,977,610** | **$ 2,977,661** | **$ 2,977,762** | **$ 2,977,913** |
| **Scenario 4a** | **Centralized + NG Peaking** | | | | | | | | | | |
| | Fuel Costs | $ 40,809,135 | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 |
| | O&M Costs | $ 2,919,176 | $ 190,499 | $ 190,499 | $ 190,499 | $ 190,499 | $ 190,499 | $ 190,499 | $ 190,499 | $ 190,499 | $ 190,499 |
| | $CO_2e$ Costs | $ 2,671,962 | $ 157,320 | $ 159,350 | $ 161,380 | $ 163,410 | $ 165,439 | $ 167,469 | $ 168,484 | $ 170,514 | $ 173,559 |
| | CAPEX | $ 124,051,714 | $ 122,061,148 | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| | Residual Value | $ (51,998,756) | $ (50,671,712) | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| | **Total** | **$ 118,453,230** | **$ 74,400,376** | **$ 3,012,970** | **$ 3,015,000** | **$ 3,017,030** | **$ 3,019,060** | **$ 3,021,090** | **$ 3,022,105** | **$ 3,024,135** | **$ 3,027,180** |
| **Scenario 4b** | **Centralized + Electric Peaking** | | | | | | | | | | |
| | Fuel Costs | $ 42,870,438 | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 |
| | O&M Costs | $ 2,630,776 | $ 171,679 | $ 171,679 | $ 171,679 | $ 171,679 | $ 171,679 | $ 171,679 | $ 171,679 | $ 171,679 | $ 171,679 |
| | $CO_2e$ Costs | $ 132,973 | $ 7,829 | $ 7,930 | $ 8,031 | $ 8,132 | $ 8,233 | $ 8,334 | $ 8,385 | $ 8,486 | $ 8,637 |
| | CAPEX | $ 129,366,700 | $ 127,376,135 | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| | Residual Value | $ (54,749,853) | $ (53,422,809) | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| | **Total** | **$ 120,251,034** | **$ 76,930,472** | **$ 2,977,247** | **$ 2,977,348** | **$ 2,977,449** | **$ 2,977,550** | **$ 2,977,651** | **$ 2,977,702** | **$ 2,977,803** | **$ 2,977,954** |
| **Scenario 5b** | **Centralized + WWHP + Electric Peaking** | | | | | | | | | | |
| | Fuel Costs | $ 41,061,004 | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 |
| | O&M Costs | $ 2,668,687 | $ 174,153 | $ 174,153 | $ 174,153 | $ 174,153 | $ 174,153 | $ 174,153 | $ 174,153 | $ 174,153 | $ 174,153 |
| | $CO_2e$ Costs | $ 132,973 | $ 7,829 | $ 7,930 | $ 8,031 | $ 8,132 | $ 8,233 | $ 8,334 | $ 8,385 | $ 8,486 | $ 8,637 |
| | CAPEX | $ 126,062,681 | $ 124,072,115 | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| | Residual Value | $ (51,805,873) | $ (50,478,829) | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| | **Total** | **$ 118,119,471** | **$ 76,454,826** | **$ 2,861,641** | **$ 2,861,742** | **$ 2,861,843** | **$ 2,861,944** | **$ 2,862,045** | **$ 2,862,096** | **$ 2,862,197** | **$ 2,862,348** |
| **Scenario 6a** | **Centralized Cascade + NG Peaking** | | | | | | | | | | |
| | Fuel Costs | $ 42,014,658 | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 |
| | O&M Costs | $ 2,366,630 | $ 154,441 | $ 154,441 | $ 154,441 | $ 154,441 | $ 154,441 | $ 154,441 | $ 154,441 | $ 154,441 | $ 154,441 |
| | $CO_2e$ Costs | $ 2,020,400 | $ 118,957 | $ 120,492 | $ 122,027 | $ 123,562 | $ 125,097 | $ 126,632 | $ 127,399 | $ 128,934 | $ 131,236 |
| | CAPEX | $ 131,182,307 | $ 129,191,741 | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| | Residual Value | $ (53,742,156) | $ (52,415,112) | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| | **Total** | **$ 123,841,838** | **$ 79,791,818** | **$ 3,016,725** | **$ 3,018,260** | **$ 3,019,795** | **$ 3,021,329** | **$ 3,022,864** | **$ 3,023,632** | **$ 3,025,167** | **$ 3,027,469** |
| **Scenario 6b** | **Centralized Cascade + Electric Peaking** | | | | | | | | | | |
| | Fuel Costs | $ 43,498,884 | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 |
| | O&M Costs | $ 2,068,867 | $ 135,010 | $ 135,010 | $ 135,010 | $ 135,010 | $ 135,010 | $ 135,010 | $ 135,010 | $ 135,010 | $ 135,010 |
| | $CO_2e$ Costs | $ 132,973 | $ 7,829 | $ 7,930 | $ 8,031 | $ 8,132 | $ 8,233 | $ 8,334 | $ 8,385 | $ 8,486 | $ 8,637 |
| | CAPEX | $ 136,497,294 | $ 134,506,728 | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| | Residual Value | $ (56,493,253) | $ (55,166,209) | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| | **Total** | **$ 125,704,764** | **$ 82,322,006** | **$ 2,981,589** | **$ 2,981,690** | **$ 2,981,791** | **$ 2,981,892** | **$ 2,981,993** | **$ 2,982,044** | **$ 2,982,145** | **$ 2,982,296** |

| Annual Cash Flow (2022 USD) | | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Scenario 0** | **BaU** | | | | | | | | | | | |
| | Fuel Costs | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 | $ 3,161,154 |
| | O&M Costs | $ 254,171 | $ 254,171 | $ 254,171 | $ 254,171 | $ 254,171 | $ 254,171 | $ 254,171 | $ 254,171 | $ 254,171 | $ 254,171 | $ 254,171 |
| | $CO_2e$ Costs | $ 2,338,698 | $ 2,365,892 | $ 2,393,087 | $ 2,433,878 | $ 2,461,072 | $ 2,488,266 | $ 2,515,460 | $ 2,556,252 | $ 2,569,849 | $ 2,597,043 | $ 2,610,640 |
| | CAPEX | $ - | $ - | $ - | $ - | $ - | $ - | $ 620,247 | $ 620,247 | $ 620,247 | $ 620,247 | $ 620,247 |
| | Residual Value | $ - | $ - | $ - | $ - | $ - | $ - | $ (413,498) | $ (454,848) | $ (496,198) | $ (537,548) | $ (578,898) |
| | **Total** | **$ 5,754,023** | **$ 5,781,217** | **$ 5,808,411** | **$ 5,849,203** | **$ 5,876,397** | **$ 5,903,591** | **$ 6,137,534** | **$ 6,136,976** | **$ 6,109,223** | **$ 6,095,067** | **$ 6,067,314** |
| **Scenario 2a** | **Cluster + NG Peaking** | | | | | | | | | | | |
| | Fuel Costs | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 | $ 2,665,658 |
| | O&M Costs | $ 190,099 | $ 190,099 | $ 190,099 | $ 190,099 | $ 190,099 | $ 190,099 | $ 190,099 | $ 190,099 | $ 190,099 | $ 190,099 | $ 190,099 |
| | $CO_2e$ Costs | $ 179,785 | $ 181,876 | $ 183,966 | $ 187,102 | $ 189,193 | $ 191,283 | $ 193,374 | $ 196,509 | $ 197,555 | $ 199,645 | $ 200,690 |
| | CAPEX | $ - | $ - | $ - | $ - | $ - | $ - | $ 3,101,237 | $ - | $ - | $ - | $ - |
| | Residual Value | $ - | $ - | $ - | $ - | $ - | $ - | $ (2,067,491) | $ - | $ - | $ - | $ - |
| | **Total** | **$ 3,035,543** | **$ 3,037,634** | **$ 3,039,724** | **$ 3,042,860** | **$ 3,044,950** | **$ 3,047,041** | **$ 4,082,877** | **$ 3,052,267** | **$ 3,053,312** | **$ 3,055,403** | **$ 3,056,448** |
| **Scenario 2b** | **Cluster + Electric Peaking** | | | | | | | | | | | |
| | Fuel Costs | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 | $ 2,798,002 |
| | O&M Costs | $ 171,274 | $ 171,274 | $ 171,274 | $ 171,274 | $ 171,274 | $ 171,274 | $ 171,274 | $ 171,274 | $ 171,274 | $ 171,274 | $ 171,274 |
| | $CO_2e$ Costs | $ 8,688 | $ 8,789 | $ 8,890 | $ 9,041 | $ 9,142 | $ 9,243 | $ 9,344 | $ 9,496 | $ 9,547 | $ 9,648 | $ 9,698 |
| | CAPEX | $ - | $ - | $ - | $ - | $ - | $ - | $ 3,101,237 | $ - | $ - | $ - | $ - |
| | Residual Value | $ - | $ - | $ - | $ - | $ - | $ - | $ (2,067,491) | $ - | $ - | $ - | $ - |
| | **Total** | **$ 2,977,964** | **$ 2,978,065** | **$ 2,978,166** | **$ 2,978,317** | **$ 2,978,418** | **$ 2,978,519** | **$ 4,012,366** | **$ 2,978,772** | **$ 2,978,822** | **$ 2,978,923** | **$ 2,978,974** |
| **Scenario 4a** | **Centralized + NG Peaking** | | | | | | | | | | | |
| | Fuel Costs | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 | $ 2,663,121 |
| | O&M Costs | $ 190,499 | $ 190,499 | $ 190,499 | $ 190,499 | $ 190,499 | $ 190,499 | $ 190,499 | $ 190,499 | $ 190,499 | $ 190,499 | $ 190,499 |
| | $CO_2e$ Costs | $ 174,574 | $ 176,604 | $ 178,634 | $ 181,679 | $ 183,709 | $ 185,739 | $ 187,769 | $ 190,814 | $ 191,829 | $ 193,858 | $ 194,873 |
| | CAPEX | $ - | $ - | $ - | $ - | $ - | $ - | $ 3,101,237 | $ - | $ - | $ - | $ - |
| | Residual Value | $ - | $ - | $ - | $ - | $ - | $ - | $ (2,067,491) | $ - | $ - | $ - | $ - |
| | **Total** | **$ 3,028,195** | **$ 3,030,225** | **$ 3,032,255** | **$ 3,035,300** | **$ 3,037,330** | **$ 3,039,359** | **$ 4,075,135** | **$ 3,044,434** | **$ 3,045,449** | **$ 3,047,479** | **$ 3,048,494** |
| **Scenario 4b** | **Centralized + Electric Peaking** | | | | | | | | | | | |
| | Fuel Costs | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 | $ 2,797,638 |
| | O&M Costs | $ 171,679 | $ 171,679 | $ 171,679 | $ 171,679 | $ 171,679 | $ 171,679 | $ 171,679 | $ 171,679 | $ 171,679 | $ 171,679 | $ 171,679 |
| | $CO_2e$ Costs | $ 8,688 | $ 8,789 | $ 8,890 | $ 9,041 | $ 9,142 | $ 9,243 | $ 9,344 | $ 9,496 | $ 9,547 | $ 9,648 | $ 9,698 |
| | CAPEX | $ - | $ - | $ - | $ - | $ - | $ - | $ 3,101,237 | $ - | $ - | $ - | $ - |
| | Residual Value | $ - | $ - | $ - | $ - | $ - | $ - | $ (2,067,491) | $ - | $ - | $ - | $ - |
| | **Total** | **$ 2,978,005** | **$ 2,978,106** | **$ 2,978,207** | **$ 2,978,358** | **$ 2,978,459** | **$ 2,978,560** | **$ 4,012,407** | **$ 2,978,813** | **$ 2,978,863** | **$ 2,978,964** | **$ 2,979,015** |
| **Scenario 5b** | **Centralized + WWHP + Electric Peaking** | | | | | | | | | | | |
| | Fuel Costs | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 | $ 2,679,558 |
| | O&M Costs | $ 174,153 | $ 174,153 | $ 174,153 | $ 174,153 | $ 174,153 | $ 174,153 | $ 174,153 | $ 174,153 | $ 174,153 | $ 174,153 | $ 174,153 |
| | $CO_2e$ Costs | $ 8,688 | $ 8,789 | $ 8,890 | $ 9,041 | $ 9,142 | $ 9,243 | $ 9,344 | $ 9,496 | $ 9,547 | $ 9,648 | $ 9,698 |
| | CAPEX | $ - | $ - | $ - | $ - | $ - | $ - | $ 3,101,237 | $ - | $ - | $ - | $ - |
| | Residual Value | $ - | $ - | $ - | $ - | $ - | $ - | $ (2,067,491) | $ - | $ - | $ - | $ - |
| | **Total** | **$ 2,862,399** | **$ 2,862,500** | **$ 2,862,601** | **$ 2,862,752** | **$ 2,862,853** | **$ 2,862,954** | **$ 3,896,801** | **$ 2,863,207** | **$ 2,863,257** | **$ 2,863,358** | **$ 2,863,409** |
| **Scenario 6a** | **Centralized Cascade + NG Peaking** | | | | | | | | | | | |
| | Fuel Costs | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 | $ 2,741,791 |
| | O&M Costs | $ 154,441 | $ 154,441 | $ 154,441 | $ 154,441 | $ 154,441 | $ 154,441 | $ 154,441 | $ 154,441 | $ 154,441 | $ 154,441 | $ 154,441 |
| | $CO_2e$ Costs | $ 132,004 | $ 133,539 | $ 135,074 | $ 137,376 | $ 138,911 | $ 140,446 | $ 141,981 | $ 144,283 | $ 145,051 | $ 146,586 | $ 147,353 |
| | CAPEX | $ - | $ - | $ - | $ - | $ - | $ - | $ 3,101,237 | $ - | $ - | $ - | $ - |
| | Residual Value | $ - | $ - | $ - | $ - | $ - | $ - | $ (2,067,491) | $ - | $ - | $ - | $ - |
| | **Total** | **$ 3,028,237** | **$ 3,029,772** | **$ 3,031,306** | **$ 3,033,609** | **$ 3,035,144** | **$ 3,036,679** | **$ 4,071,959** | **$ 3,040,516** | **$ 3,041,284** | **$ 3,042,818** | **$ 3,043,586** |
| **Scenario 6b** | **Centralized Cascade + Electric Peaking** | | | | | | | | | | | |
| | Fuel Costs | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 | $ 2,838,649 |
| | O&M Costs | $ 135,010 | $ 135,010 | $ 135,010 | $ 135,010 | $ 135,010 | $ 135,010 | $ 135,010 | $ 135,010 | $ 135,010 | $ 135,010 | $ 135,010 |
| | $CO_2e$ Costs | $ 8,688 | $ 8,789 | $ 8,890 | $ 9,041 | $ 9,142 | $ 9,243 | $ 9,344 | $ 9,496 | $ 9,547 | $ 9,648 | $ 9,698 |
| | CAPEX | $ - | $ - | $ - | $ - | $ - | $ - | $ 3,101,237 | $ - | $ - | $ - | $ - |
| | Residual Value | $ - | $ - | $ - | $ - | $ - | $ - | $ (2,067,491) | $ - | $ - | $ - | $ - |
| | **Total** | **$ 2,982,347** | **$ 2,982,448** | **$ 2,982,549** | **$ 2,982,700** | **$ 2,982,801** | **$ 2,982,902** | **$ 4,016,749** | **$ 2,983,155** | **$ 2,983,205** | **$ 2,983,306** | **$ 2,983,357** |

# Appendix G
# Trophy Point Cost Estimates

SCENARIO SUMMARY

| | Sc.2a | Sc.2b | Sc.4a | Sc.4b | Sc.5b | Sc.6a | Sc.6b |
|---|---|---|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | $3,101,237 | $3,101,237 | $3,101,237 | $3,101,237 | $3,101,237 | $3,101,237 | $3,101,237 |
| **THERMAL DISTRIBUTION** | $11,561,372 | $11,561,372 | $13,656,780 | $13,656,780 | $13,656,780 | $13,656,780 | $13,656,780 |
| **HOT WATER HEAT EXCHANGERS** | $6,963,745 | $6,963,745 | $6,963,745 | $6,963,745 | $6,963,745 | $6,963,745 | $6,963,745 |
| **CHILLED WATER HEAT EXCHANGERS** | $4,838,244 | $4,838,244 | $4,838,244 | $4,838,244 | $4,838,244 | $4,838,244 | $4,838,244 |
| **GEOTHERMAL WELLFIELD** | $57,944,113 | $57,944,113 | $49,143,608 | $49,143,608 | $40,475,416 | $49,143,608 | $49,143,608 |
| **GEOTHERMAL HEAT PUMPS** | $17,323,247 | $17,323,247 | $16,397,424 | $16,397,424 | $15,254,034 | $25,114,425 | $25,114,425 |
| **HEATING THERMAL ENERGY TANKS** | $8,458,582 | $8,458,582 | $8,141,671 | $8,141,671 | $8,141,671 | $8,141,671 | $8,141,671 |
| **WASTE WATER ENERGY RECOVERY** | $0 | $0 | $0 | $0 | $8,165,365 | $0 | $0 |
| **DRY COOLER BOREFIELD BALANCING** | $3,292,910 | $3,292,910 | $2,081,294 | $2,081,294 | $494,886 | $494,886 | $494,886 |
| **PEAKING GAS BOILERS** | $3,390,858 | $0 | $2,725,549 | $0 | $0 | $2,725,549 | $0 |
| **PEAKING ELECTRIC BOILERS** | $0 | $4,216,135 | $0 | $3,820,287 | $3,748,893 | $0 | $3,820,287 |
| **CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES** | $16,133,775 | $22,017,640 | $15,011,595 | $19,231,844 | $19,231,844 | $15,011,595 | $19,231,844 |
| **TOTAL** | **$133,008,083** | **$139,717,226** | **$122,061,148** | **$127,376,135** | **$124,072,115** | **$129,191,741** | **$134,506,728** |

SCENARIO DETAIL

## Sc.2a

| | Cluster C | Cluster N | Cluster E | Cluster W | Cluster S | Subtotal | Total with Markups |
|---|---|---|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | | | | | | |
| DHW | $996,575 | $194,175 | $168,750 | $340,250 | $69,060 | $1,768,810 | $3,101,237 |
| **THERMAL DISTRIBUTION** | | | | | | | |
| 2-Pipe Distribution | $3,414,650 | $684,569 | $364,042 | $977,597 | $389,449 | $5,830,307 | $10,222,218 |
| Distribution Pumps/VFDs | $371,620 | $96,785 | $96,785 | $126,680 | $71,925 | $763,795 | $1,339,154 |
| **HOT WATER HEAT EXCHANGERS** | | | | | | | |
| HW HX | $2,200,470 | $282,371 | $342,707 | $859,181 | $287,087 | $3,971,816 | $6,963,745 |
| **CHILLED WATER HEAT EXCHANGERS** | | | | | | | |
| CHW HX | $1,500,465 | $210,796 | $273,418 | $705,650 | $69,194 | $2,759,523 | $4,838,244 |
| **GEOTHERMAL WELLFIELD** | | | | | | | |
| Geohermal Borefield | $20,790,000 | $2,137,500 | $2,767,500 | $3,600,000 | $2,407,500 | $31,702,500 | $55,583,676 |
| Geothermal Controls | $100,000 | $100,000 | $100,000 | $100,000 | $100,000 | $500,000 | $876,645 |
| Geohermal Loop Pumps | $397,750 | $84,900 | $99,150 | $98,040 | $81,450 | $761,290 | $1,334,762 |
| Geohermal Loop Pump Controls | $25,000 | $15,000 | $15,000 | $15,000 | $15,000 | $85,000 | $149,030 |
| Heat Pumps | $3,149,600 | $375,200 | $473,840 | $443,840 | $315,200 | $4,757,680 | $8,341,593 |
| Heat Pump Controls | $40,000 | $20,000 | $20,000 | $20,000 | $20,000 | $120,000 | $210,395 |
| Geothermal Misc. | $2,143,648 | $661,693 | $957,575 | $684,407 | $555,420 | $5,002,743 | $8,771,259 |
| **HEATING THERMAL ENERGY TANKS** | | | | | | | |
| TES | $1,485,000 | $184,500 | $216,000 | $324,000 | $216,000 | $2,425,500 | $4,252,605 |
| TES Controls | $14,000 | $14,000 | $14,000 | $14,000 | $14,000 | $70,000 | $122,730 |
| TES Pumps | $94,860 | $39,260 | $37,660 | $57,100 | $37,660 | $266,540 | $467,322 |
| TES Pump Controls | $10,000 | $10,000 | $10,000 | $10,000 | $10,000 | $50,000 | $87,665 |
| TES Misc | $647,667 | $326,991 | $330,715 | $376,277 | $330,715 | $2,012,366 | $3,528,260 |
| **DRY COOLER BOREFIELD BALANCING** | | | | | | | |
| Dry Cooler | $273,600 | $48,555 | $46,980 | $97,650 | $79,515 | $546,300 | $957,822 |
| Dry Cooler Controls | $15,000 | $15,000 | $15,000 | $15,000 | $15,000 | $75,000 | $131,497 |
| Dry Cooler Pumps | $397,750 | $84,900 | $99,150 | $57,100 | $81,450 | $720,350 | $1,262,982 |
| Dry Cooler Pump Controls | $25,000 | $15,000 | $15,000 | $10,000 | $15,000 | $80,000 | $140,263 |
| Dry Cooler Misc | $91,296 | $91,296 | $91,296 | $91,296 | $91,296 | $456,482 | $800,345 |
| **PEAKING GAS BOILERS** | | | | | | | |
| Boilers | $670,000 | $156,640 | $106,640 | $160,960 | $108,640 | $1,202,880 | $2,108,997 |
| Boiler Controls | $60,000 | $30,000 | $30,000 | $30,000 | $30,000 | $180,000 | $315,592 |
| Boiler Flue and Vent | $45,600 | $11,760 | $11,760 | $11,760 | $8,320 | $89,200 | $156,393 |
| Nat Gas Piping | $0 | $0 | $0 | $84,318 | $0 | $84,318 | $147,834 |
| Boiler Misc | $208,760 | $45,780 | $45,780 | $45,780 | $31,499 | $377,599 | $662,041 |
| **CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES** | | | | | | | |
| SUBSTATION 1 UPGRADES | | | | | | $7,916,100 | $13,879,219 |
| SUBSTATION 2 UPGRADES | | | | | | $0 | $0 |
| BUILDING SERVICE UPGRADES | $454,800 | $114,300 | $264,300 | $452,500 | $0 | $1,285,900 | $2,254,556 |
| **TOTAL** | **$39,623,111** | **$6,050,971** | **$7,013,050** | **$9,808,386** | **$5,450,381** | **$75,861,998** | **$133,008,083** |

## Sc.2b

| | Cluster C | Cluster N | Cluster E | Cluster W | Cluster S | Subtotal | Markups |
|---|---|---|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | | | | | | |
| DHW | $996,575 | $194,175 | $168,750 | $340,250 | $69,060 | $1,768,810 | $3,101,237 |
| **THERMAL DISTRIBUTION** | | | | | | | |
| 2-Pipe Distribution | $3,414,650 | $684,569 | $364,042 | $977,597 | $389,449 | $5,830,307 | $10,222,218 |
| Distribution Pumps/VFDs | $371,620 | $96,785 | $96,785 | $126,680 | $71,925 | $763,795 | $1,339,154 |
| **HOT WATER HEAT EXCHANGERS** | | | | | | | |
| HW HX | $2,200,470 | $282,371 | $342,707 | $859,181 | $287,087 | $3,971,816 | $6,963,745 |
| **CHILLED WATER HEAT EXCHANGERS** | | | | | | | |
| CHW HX | $1,500,465 | $210,796 | $273,418 | $705,650 | $69,194 | $2,759,523 | $4,838,244 |
| **GEOTHERMAL WELLFIELD** | | | | | | | |
| Geohermal Borefield | $20,790,000 | $2,137,500 | $2,767,500 | $3,600,000 | $2,407,500 | $31,702,500 | $55,583,676 |
| Geothermal Controls | $100,000 | $100,000 | $100,000 | $100,000 | $100,000 | $500,000 | $876,645 |
| Geohermal Loop Pumps | $397,750 | $84,900 | $99,150 | $98,040 | $81,450 | $761,290 | $1,334,762 |
| Geohermal Loop Pump Controls | $25,000 | $15,000 | $15,000 | $15,000 | $15,000 | $85,000 | $149,030 |
| Heat Pumps | $3,149,600 | $375,200 | $473,840 | $443,840 | $315,200 | $4,757,680 | $8,341,593 |
| Heat Pump Controls | $40,000 | $20,000 | $20,000 | $20,000 | $20,000 | $120,000 | $210,395 |
| Geothermal Misc. | $2,143,648 | $661,693 | $957,575 | $684,407 | $555,420 | $5,002,743 | $8,771,259 |
| **HEATING THERMAL ENERGY TANKS** | | | | | | | |
| TES | $1,485,000 | $184,500 | $216,000 | $324,000 | $216,000 | $2,425,500 | $4,252,605 |
| TES Controls | $14,000 | $14,000 | $14,000 | $14,000 | $14,000 | $70,000 | $122,730 |
| TES Pumps | $94,860 | $39,260 | $37,660 | $57,100 | $37,660 | $266,540 | $467,322 |
| TES Pump Controls | $10,000 | $10,000 | $10,000 | $10,000 | $10,000 | $50,000 | $87,665 |
| TES Misc | $647,667 | $326,991 | $330,715 | $376,277 | $330,715 | $2,012,366 | $3,528,260 |
| **DRY COOLER BOREFIELD BALANCING** | | | | | | | |
| Dry Cooler | $273,600 | $48,555 | $46,980 | $97,650 | $79,515 | $546,300 | $957,822 |
| Dry Cooler Controls | $15,000 | $15,000 | $15,000 | $15,000 | $15,000 | $75,000 | $131,497 |
| Dry Cooler Pumps | $397,750 | $84,900 | $99,150 | $57,100 | $81,450 | $720,350 | $1,262,982 |
| Dry Cooler Pump Controls | $25,000 | $15,000 | $15,000 | $10,000 | $15,000 | $80,000 | $140,263 |
| Dry Cooler Misc | $91,296 | $91,296 | $91,296 | $91,296 | $91,296 | $456,482 | $800,345 |
| **PEAKING ELECTRIC BOILERS** | | | | | | | |
| Boilers | $1,070,820 | $229,680 | $154,920 | $234,000 | $157,680 | $1,847,100 | $3,238,502 |
| Boiler Controls | $60,000 | $30,000 | $30,000 | $30,000 | $30,000 | $180,000 | $315,592 |
| Boiler Flue and Vent | | | | | | $0 | $0 |
| Nat Gas Piping | | | | | | $0 | $0 |
| Boiler Misc | $208,760 | $45,780 | $45,780 | $45,780 | $31,499 | $377,599 | $662,041 |
| **CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES** | | | | | | | |
| SUBSTATION 1 UPGRADES | | | | | | $9,082,000 | $15,923,380 |
| SUBSTATION 2 UPGRADES | | | | | | $627,300 | $1,099,839 |
| BUILDING SERVICE UPGRADES | $454,800 | $565,100 | $565,100 | $698,500 | $565,100 | $2,848,600 | $4,994,422 |
| **TOTAL** | **$39,978,331** | **$6,563,051** | **$7,350,370** | **$10,031,348** | **$6,056,201** | **$79,688,600** | **$139,717,226** |

## Sc.4a

| | Centralized | Cluster S | Subtotal | Markups |
|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | | | |
| DHW | $1,699,750 | $69,060 | $1,768,810 | $3,101,237 |
| **THERMAL DISTRIBUTION** | | | | |
| 2-Pipe Distribution | $6,919,370 | $389,449 | $7,308,819 | $12,814,479 |
| Distribution Pumps/VFDs | $408,487 | $71,925 | $480,412 | $842,301 |
| **HOT WATER HEAT EXCHANGERS** | | | | |
| HW HX | $3,684,729 | $287,087 | $3,971,816 | $6,963,745 |
| **CHILLED WATER HEAT EXCHANGERS** | | | | |
| CHW HX | $2,690,329 | $69,194 | $2,759,523 | $4,838,244 |
| **GEOTHERMAL WELLFIELD** | | | | |
| Geohermal Borefield | $24,637,500 | $2,407,500 | $27,045,000 | $47,417,728 |
| Geothermal Controls | $100,000 | $100,000 | $200,000 | $350,658 |
| Geohermal Loop Pumps | $662,917 | $81,450 | $744,367 | $1,305,091 |
| Geohermal Loop Pump Controls | $25,000 | $15,000 | $40,000 | $70,132 |
| Heat Pumps | $4,472,723 | $315,200 | $4,787,923 | $8,394,618 |
| Heat Pump Controls | $40,000 | $20,000 | $60,000 | $105,197 |
| Geothermal Misc. | $3,949,031 | $555,420 | $4,504,451 | $7,897,609 |
| **HEATING THERMAL ENERGY TANKS** | | | | |
| TES | $2,209,500 | $216,000 | $2,425,500 | $4,252,605 |
| TES Controls | $14,000 | $14,000 | $28,000 | $49,092 |
| TES Pumps | $118,575 | $37,660 | $156,235 | $273,925 |
| TES Pump Controls | $10,000 | $10,000 | $20,000 | $35,066 |
| TES Misc | $1,683,203 | $330,715 | $2,013,919 | $3,530,983 |
| **DRY COOLER BOREFIELD BALANCING** | | | | |
| Dry Cooler | $375,771 | $79,515 | $455,286 | $798,249 |
| Dry Cooler Controls | $15,000 | $15,000 | $30,000 | $52,599 |
| Dry Cooler Pumps | $397,750 | $81,450 | $479,200 | $840,177 |
| Dry Cooler Pump Controls | $25,000 | $15,000 | $40,000 | $70,132 |
| Dry Cooler Misc | $91,296 | $91,296 | $182,593 | $320,138 |
| **PEAKING GAS BOILERS** | | | | |
| Boilers | $996,106 | $108,640 | $1,104,746 | $1,936,940 |
| Boiler Controls | $60,000 | $30,000 | $90,000 | $157,796 |
| Boiler Flue and Vent | $51,300 | $8,320 | $59,620 | $104,531 |
| Nat Gas Piping | $0 | $0 | $0 | $0 |
| Boiler Misc | $268,669 | $31,499 | $300,168 | $526,281 |
| **CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES** | | | | |
| SUBSTATION 1 UPGRADES | | | $7,916,100 | $13,879,219 |
| SUBSTATION 2 UPGRADES | | | $0 | $0 |
| BUILDING SERVICE UPGRADES | $645,858 | $0 | $645,858 | $1,132,376 |
| **TOTAL** | **$56,251,864** | **$5,450,381** | **$69,618,345** | **$122,061,148** |

## Sc.4b

| | Centralized | Cluster S | Subtotal | Markups |
|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | | | |
| DHW | $1,699,750 | $69,060 | $1,768,810 | $3,101,237 |
| **THERMAL DISTRIBUTION** | | | | |
| 2-Pipe Distribution | $6,919,370 | $389,449 | $7,308,819 | $12,814,479 |
| Distribution Pumps/VFDs | $408,487 | $71,925 | $480,412 | $842,301 |
| **HOT WATER HEAT EXCHANGERS** | | | | |
| HW HX | $3,684,729 | $287,087 | $3,971,816 | $6,963,745 |
| **CHILLED WATER HEAT EXCHANGERS** | | | | |
| CHW HX | $2,690,329 | $69,194 | $2,759,523 | $4,838,244 |
| **GEOTHERMAL WELLFIELD** | | | | |
| Geohermal Borefield | $24,637,500 | $2,407,500 | $27,045,000 | $47,417,728 |
| Geothermal Controls | $100,000 | $100,000 | $200,000 | $350,658 |
| Geohermal Loop Pumps | $662,917 | $81,450 | $744,367 | $1,305,091 |
| Geohermal Loop Pump Controls | $25,000 | $15,000 | $40,000 | $70,132 |
| Heat Pumps | $4,472,723 | $315,200 | $4,787,923 | $8,394,618 |
| Heat Pump Controls | $40,000 | $20,000 | $60,000 | $105,197 |
| Geothermal Misc. | $3,949,031 | $555,420 | $4,504,451 | $7,897,609 |
| **HEATING THERMAL ENERGY TANKS** | | | | |
| TES | $2,209,500 | $216,000 | $2,425,500 | $4,252,605 |
| TES Controls | $14,000 | $14,000 | $28,000 | $49,092 |
| TES Pumps | $118,575 | $37,660 | $156,235 | $273,925 |
| TES Pump Controls | $10,000 | $10,000 | $20,000 | $35,066 |
| TES Misc | $1,683,203 | $330,715 | $2,013,919 | $3,530,983 |
| **DRY COOLER BOREFIELD BALANCING** | | | | |
| Dry Cooler | $375,771 | $79,515 | $455,286 | $798,249 |
| Dry Cooler Controls | $15,000 | $15,000 | $30,000 | $52,599 |
| Dry Cooler Pumps | $397,750 | $81,450 | $479,200 | $840,177 |
| Dry Cooler Pump Controls | $25,000 | $15,000 | $40,000 | $70,132 |
| Dry Cooler Misc | $91,296 | $91,296 | $182,593 | $320,138 |
| **PEAKING ELECTRIC BOILERS** | | | | |
| Boilers | $1,592,016 | $157,680 | $1,749,696 | $3,067,724 |
| Boiler Controls | $60,000 | $30,000 | $90,000 | $157,796 |
| Boiler Flue and Vent | $0 | $0 | $0 | $0 |
| Nat Gas Piping | $0 | $0 | $0 | $0 |
| Boiler Misc | $307,730 | $31,499 | $339,229 | $594,767 |
| **CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES** | | | | |
| SUBSTATION 1 UPGRADES | | | $9,082,000 | $15,923,380 |
| SUBSTATION 2 UPGRADES | | | $627,300 | $1,099,839 |
| BUILDING SERVICE UPGRADES | $694,604 | $565,100 | $1,259,704 | $2,208,626 |
| **TOTAL** | **$56,884,280** | **$6,056,201** | **$72,649,781** | **$127,376,135** |

## Sc.5b

| | Centralized | Cluster S | Subtotal | Total With Markups |
|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | | | |
| DHW | $1,699,750 | $69,060 | $1,768,810 | $3,101,237 |
| **THERMAL DISTRIBUTION** | | | | |
| 2-Pipe Distribution | $6,919,370 | $389,449 | $7,308,819 | $12,814,479 |
| Distribution Pumps/VFDs | $408,487 | $71,925 | $480,412 | $842,301 |
| **HOT WATER HEAT EXCHANGERS** | | | | |
| HW HX | $3,684,729 | $287,087 | $3,971,816 | $6,963,745 |
| **CHILLED WATER HEAT EXCHANGERS** | | | | |
| CHW HX | $2,690,329 | $69,194 | $2,759,523 | $4,838,244 |
| **GEOTHERMAL WELLFIELD** | | | | |
| Geohermal Borefield | $20,025,000 | $2,407,500 | $22,432,500 | $39,330,678 |
| Geothermal Controls | $100,000 | $100,000 | $200,000 | $350,658 |
| Geohermal Loop Pumps | $331,458 | $81,450 | $412,908 | $723,948 |
| Geohermal Loop Pump Controls | $25,000 | $15,000 | $40,000 | $70,132 |
| Heat Pumps | $4,472,723 | $315,200 | $4,787,923 | $8,394,618 |
| Heat Pump Controls | $40,000 | $20,000 | $60,000 | $105,197 |
| Geothermal Misc. | $3,296,892 | $555,420 | $3,852,311 | $6,754,219 |
| **HEATING THERMAL ENERGY TANKS** | | | | |
| TES | $2,209,500 | $216,000 | $2,425,500 | $4,252,605 |
| TES Controls | $14,000 | $14,000 | $28,000 | $49,092 |
| TES Pumps | $118,575 | $37,660 | $156,235 | $273,925 |
| TES Pump Controls | $10,000 | $10,000 | $20,000 | $35,066 |
| TES Misc | $1,683,203 | $330,715 | $2,013,919 | $3,530,983 |
| **DRY COOLER BOREFIELD BALANCING** | | | | |
| Dry Cooler | $0 | $79,515 | $79,515 | $139,413 |
| Dry Cooler Controls | $0 | $15,000 | $15,000 | $26,299 |
| Dry Cooler Pumps | $0 | $81,450 | $81,450 | $142,805 |
| Dry Cooler Pump Controls | $0 | $15,000 | $15,000 | $26,299 |
| Dry Cooler Misc | $0 | $91,296 | $91,296 | $160,069 |
| **PEAKING ELECTRIC BOILERS** | | | | |
| Boilers | $1,592,016 | $108,640 | $1,700,656 | $2,981,742 |
| Boiler Controls | $60,000 | $30,000 | $90,000 | $157,796 |
| Boiler Flue and Vent | $0 | $8,320 | $8,320 | $14,587 |
| Nat Gas Piping | $0 | $0 | $0 | $0 |
| Boiler Misc | $307,730 | $31,499 | $339,229 | $594,767 |
| **WASTE WATER ENERGY RECOVERY** | | | | |
| WASTE WATER ENERGY RECOVERY | $4,657,167 | $0 | $4,657,167 | $8,165,365 |
| **CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES** | | | | |
| SUBSTATION 1 UPGRADES | | | $9,082,000 | $15,923,380 |
| SUBSTATION 2 UPGRADES | | | $627,300 | $1,099,839 |
| BUILDING SERVICE UPGRADES | $694,604 | $565,100 | $1,259,704 | $2,208,626 |
| **TOTAL** | **$55,040,532** | **$6,015,481** | **$70,765,312** | **$124,072,115** |

## Sc.6a

| | Centralized | Cluster S | Subtotal | Markups |
|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | | | |
| DHW | $1,699,750 | $69,060 | $1,768,810 | $3,101,237 |
| **THERMAL DISTRIBUTION** | | | | |
| 2-Pipe Distribution | $6,919,370 | $389,449 | $7,308,819 | $12,814,479 |
| Distribution Pumps/VFDs | $408,487 | $71,925 | $480,412 | $842,301 |
| **HOT WATER HEAT EXCHANGERS** | | | | |
| HW HX | $3,684,729 | $287,087 | $3,971,816 | $6,963,745 |
| **CHILLED WATER HEAT EXCHANGERS** | | | | |
| CHW HX | $2,690,329 | $69,194 | $2,759,523 | $4,838,244 |
| **GEOTHERMAL WELLFIELD** | | | | |
| Geohermal Borefield | $24,637,500 | $2,407,500 | $27,045,000 | $47,417,728 |
| Geothermal Controls | $100,000 | $100,000 | $200,000 | $350,658 |
| Geohermal Loop Pumps | $662,917 | $81,450 | $744,367 | $1,305,091 |
| Geohermal Loop Pump Controls | $25,000 | $15,000 | $40,000 | $70,132 |
| Heat Pumps | $9,444,520 | $315,200 | $9,759,720 | $17,111,619 |
| Heat Pump Controls | $40,000 | $20,000 | $60,000 | $105,197 |
| Geothermal Misc. | $3,949,031 | $555,420 | $4,504,451 | $7,897,609 |
| **HEATING THERMAL ENERGY TANKS** | | | | |
| TES | $2,209,500 | $216,000 | $2,425,500 | $4,252,605 |
| TES Controls | $14,000 | $14,000 | $28,000 | $49,092 |
| TES Pumps | $118,575 | $37,660 | $156,235 | $273,925 |
| TES Pump Controls | $10,000 | $10,000 | $20,000 | $35,066 |
| TES Misc | $1,683,203 | $330,715 | $2,013,919 | $3,530,983 |
| **DRY COOLER BOREFIELD BALANCING** | | | | |
| Dry Cooler | | $79,515 | $79,515 | $139,413 |
| Dry Cooler Controls | | $15,000 | $15,000 | $26,299 |
| Dry Cooler Pumps | | $81,450 | $81,450 | $142,805 |
| Dry Cooler Pump Controls | | $15,000 | $15,000 | $26,299 |
| Dry Cooler Misc | | $91,296 | $91,296 | $160,069 |
| **PEAKING GAS BOILERS** | | | | |
| Boilers | $996,106 | $108,640 | $1,104,746 | $1,936,940 |
| Boiler Controls | $60,000 | $30,000 | $90,000 | $157,796 |
| Boiler Flue and Vent | $51,300 | $8,320 | $59,620 | $104,531 |
| Nat Gas Piping | $0 | $0 | $0 | $0 |
| Boiler Misc | $268,669 | $31,499 | $300,168 | $526,281 |
| **CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES** | | | | |
| SUBSTATION 1 UPGRADES | | | $7,916,100 | $13,879,219 |
| SUBSTATION 2 UPGRADES | | | $0 | $0 |
| BUILDING SERVICE UPGRADES | $645,858 | $0 | $645,858 | $1,132,376 |
| **TOTAL** | **$60,318,843** | **$5,450,381** | **$73,685,323** | **$129,191,741** |

## Sc.6b

| | Centralized | Cluster S | Subtotal | Markups |
|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | | | |
| DHW | $1,699,750 | $69,060 | $1,768,810 | $3,101,237 |
| **THERMAL DISTRIBUTION** | | | | |
| 2-Pipe Distribution | $6,919,370 | $389,449 | $7,308,819 | $12,814,479 |
| Distribution Pumps/VFDs | $408,487 | $71,925 | $480,412 | $842,301 |
| **HOT WATER HEAT EXCHANGERS** | | | | |
| HW HX | $3,684,729 | $287,087 | $3,971,816 | $6,963,745 |
| **CHILLED WATER HEAT EXCHANGERS** | | | | |
| CHW HX | $2,690,329 | $69,194 | $2,759,523 | $4,838,244 |
| **GEOTHERMAL WELLFIELD** | | | | |
| Geohermal Borefield | $24,637,500 | $2,407,500 | $27,045,000 | $47,417,728 |
| Geothermal Controls | $100,000 | $100,000 | $200,000 | $350,658 |
| Geohermal Loop Pumps | $662,917 | $81,450 | $744,367 | $1,305,091 |
| Geohermal Loop Pump Controls | $25,000 | $15,000 | $40,000 | $70,132 |
| Heat Pumps | $9,444,520 | $315,200 | $9,759,720 | $17,111,619 |
| Heat Pump Controls | $40,000 | $20,000 | $60,000 | $105,197 |
| Geothermal Misc. | $3,949,031 | $555,420 | $4,504,451 | $7,897,609 |
| **HEATING THERMAL ENERGY TANKS** | | | | |
| TES | $2,209,500 | $216,000 | $2,425,500 | $4,252,605 |
| TES Controls | $14,000 | $14,000 | $28,000 | $49,092 |
| TES Pumps | $118,575 | $37,660 | $156,235 | $273,925 |
| TES Pump Controls | $10,000 | $10,000 | $20,000 | $35,066 |
| TES Misc | $1,683,203 | $330,715 | $2,013,919 | $3,530,983 |
| **DRY COOLER BOREFIELD BALANCING** | | | | |
| Dry Cooler | | $79,515 | $79,515 | $139,413 |
| Dry Cooler Controls | | $15,000 | $15,000 | $26,299 |
| Dry Cooler Pumps | | $81,450 | $81,450 | $142,805 |
| Dry Cooler Pump Controls | | $15,000 | $15,000 | $26,299 |
| Dry Cooler Misc | | $91,296 | $91,296 | $160,069 |
| **PEAKING ELECTRIC BOILERS** | | | | |
| Boilers | $1,592,016 | $157,680 | $1,749,696 | $3,067,724 |
| Boiler Controls | $60,000 | $30,000 | $90,000 | $157,796 |
| Boiler Flue and Vent | $0 | $0 | $0 | $0 |
| Nat Gas Piping | $0 | $0 | $0 | $0 |
| Boiler Misc | $307,730 | $31,499 | $339,229 | $594,767 |
| **CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES** | | | | |
| SUBSTATION 1 UPGRADES | | | $9,082,000 | $15,923,380 |
| SUBSTATION 2 UPGRADES | | | $627,300 | $1,099,839 |
| BUILDING SERVICE UPGRADES | $694,604 | $565,100 | $1,259,704 | $2,208,626 |
| **TOTAL** | **$60,951,259** | **$6,056,201** | **$76,716,760** | **$134,506,728** |

TROPHY POINT
Construction Services & Consulting

# CAMPUS ENERGY MASTER PLAN ESTIMATE

CAMPUS ENERGY STUDY
SUNY OSWEGO

OSWEGO, NY

PREPARED FOR:
RAMBOL

PROJECT NO: 23-0287a

August 09, 2023
(Revision 1)


**Trophy Point, LLC**
Construction Services & Consulting

4588 South Park Avenue
Blasdell, NY 14219

347 West 36th St., Suite 1101
New York, NY 10018

787 Pine Valley Drive, Suite A
Pittsburgh, PA 15239

Highland Pkwy, Suite 875A
Downers Grove, IL 60515

WWW.TROPHYPOINT.COM


Confidential

## ESTIMATE NOTES / ASSUMPTIONS / CLARIFICATIONS

- BASED ON RAMBOL CAMPUS ENERGY MASTER PLAN DOCUMENTS DATED 05/11/2023.
- NEW YORK STATE PREVAILING WAGE RATES FOR OSWEGO COUNTY.
- NORMAL WORKING HOURS AND CONDITIONS; EXCLUDES ANY PREMIUMS FOR A CONDENSED CONSTRUCTION SCHEDULE.
- SINGLE PRIME CONTRACT (COMPETITIVELY BID).
- PREMISES TO BE OCCUPIED DURING CONSTRUCTION.
- PROJECT WILL BE PHASED OVER A 27 YEAR PERIOD.

EXCLUSIONS:

- SOFT COSTS (DESIGN FEES, ETC.)
- CONSTRUCTION CONTINGENCY (OWNER CHANGE ORDER RESERVE)
- CONSTRUCTION MANAGER FEES, MARKUPS OR GENERAL CONDITIONS
- PROJECT LABOR AGREEMENTS
- ROCK EXCAVATION
- NO PROVISIONS FOR UNSTABLE SOILS
- SOIL REMEDIATION
- ASBESTOS AND HAZARDOUS MATERIALS ABATEMENT (IF APPLICABLE)
- A/V CABLING AND EQUIPMENT
- FF&E

*Note: This estimate represents a reasonable opinion of cost based on several public and proprietary sources of information. It is not a prediction of the successful bid from a contractor as bids will vary due to fluctuating market conditions, errors and omissions, proprietary specifications, lack of surplus bidders, perception of risk, and so on. Consequently, this estimate is expected to fall within the range of bids from multiple competitive contractors or subcontractors. However, we do not warrant that bids or negotiated prices will not vary from the final construction cost estimate.*

| PROJECT SUMMARY | TOTAL COST |
|---|---|
| **CLUSTER C** | **$ 68,673,409** |
| **CLUSTER E** | **$ 11,832,515** |
| **CLUSTER N** | **$ 10,408,705** |
| **CLUSTER S** | **$ 9,556,098** |
| **CLUSTER W** | **$ 16,403,582** |
| **CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES** | **$ 16,133,775** |
| **SCENARIO 2a TOTAL** | **$ 133,008,083** |
| | |
| **PEAKING NATURAL GAS BOILERS** | **$ (3,390,858)** |
| **PEAKING ELECTRIC BOILERS** | **$ 4,216,135** |
| **CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES (NATURAL GAS BOILERS)** | **$ (16,133,775)** |
| **CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES (ELECTRIC BOILERS)** | **$ 22,017,640** |
| **SCENARIO 2b TOTAL** | **$ 139,717,226** |
| | |
| **WASTE WATER ENERGY RECOVERY** | **$ 8,165,365** |

## CLUSTER C SUMMARY

| SUMMARY | | TOTAL MATERIAL | TOTAL LABOR | TOTAL COST | % OF TOTAL |
|---|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | $627,607 | $368,968 | $996,575 | 1.45% |
| **HOT WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | $3,662,264 | $2,324,476 | $5,986,740 | 8.72% |
| **CHILLED WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | $1,065,957 | $434,508 | $1,500,465 | 2.18% |
| **GEOTHERMAL WELLFIELD** | | $17,033,838 | $9,612,160 | $26,645,998 | 38.80% |
| **HEATING THERMAL ENERGY TANKS** | | $1,490,920 | $760,608 | $2,251,527 | 3.28% |
| **DRY COOLER BOREFIELD BALANCING** | | $659,476 | $143,170 | $802,646 | 1.17% |
| **PEAKING GAS BOILERS** | | $652,160 | $332,200 | $984,360 | 1.43% |
| **SUBTOTAL - CLUSTER C SUMMARY** | | | | **$39,168,311** | **100.00%** |
| GENERAL CONDITIONS | 15.0% | | | $5,875,247 | 8.56% |
| OVERHEAD AND PROFIT | 10.0% | | | $4,504,356 | 6.56% |
| DESIGN CONTINGENCY | 20.0% | | | $9,909,583 | 14.43% |
| BID CONTINGENCY | 5.0% | | | $2,972,875 | 4.33% |
| PHASING | 10.0% | | | $6,243,037 | 9.09% |
| **TOTAL - CLUSTER C SUMMARY** | | | | **$68,673,409** | **100.00%** |
| **PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | $394,100 | -$38,880 | $355,220 | 0.51% |
| GENERAL CONDITIONS | 15.0% | | | $53,283 | 0.08% |
| OVERHEAD AND PROFIT | 10.0% | | | $40,850 | 0.06% |
| DESIGN CONTINGENCY | 20.0% | | | $89,871 | 0.13% |
| BID CONTINGENCY | 5.0% | | | $26,961 | 0.04% |
| PHASING | 10.0% | | | $56,619 | 0.08% |
| **TOTAL - PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | | | **$622,804** | **0.90%** |
| **WASTE WATER ENERGY RECOVERY** | | $2,526,467 | $2,130,700 | $4,657,167 | 6.78% |
| GENERAL CONDITIONS | 15.0% | | | $698,575 | 1.01% |
| OVERHEAD AND PROFIT | 10.0% | | | $535,574 | 0.77% |
| DESIGN CONTINGENCY | 20.0% | | | $1,178,263 | 1.70% |
| BID CONTINGENCY | 5.0% | | | $353,479 | 0.51% |
| PHASING | 10.0% | | | $742,306 | 1.07% |
| **TOTAL - WASTE WATER ENERGY RECOVERY** | | | | **$8,165,365** | **11.84%** |

## CLUSTER C DETAIL

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | | | | | |
| **POINT OF USE WATER HEATERS** | | | | | | |
| J C Park Hall Cluster C | 5 EA | $1,855.00 | $9,275 | $720.00 | $3,600 | $12,875 |
| Campus Center Cluster C | 14 EA | $1,855.00 | $25,970 | $720.00 | $10,080 | $36,050 |
| I Poucher Hall Cluster C | 3 EA | $1,855.00 | $5,565 | $720.00 | $2,160 | $7,725 |
| M V Lee Hall Cluster C | 5 EA | $1,855.00 | $9,275 | $720.00 | $3,600 | $12,875 |
| J Lanigan Hall Cluster C | 7 EA | $1,855.00 | $12,985 | $720.00 | $5,040 | $18,025 |
| J Tyler Hall Cluster C | 9 EA | $1,855.00 | $16,695 | $720.00 | $6,480 | $23,175 |
| Wilber Hall Cluster C | 8 EA | $1,855.00 | $14,840 | $720.00 | $5,760 | $20,600 |
| M E Mahar Hall Cluster C | 7 EA | $1,855.00 | $12,985 | $720.00 | $5,040 | $18,025 |
| J Penfield Lib Cluster C | 14 EA | $1,855.00 | $25,970 | $720.00 | $10,080 | $36,050 |
| Culkin Hall Cluster C | 5 EA | $1,855.00 | $9,275 | $720.00 | $3,600 | $12,875 |
| Hewitt Hall Cluster C | 10 EA | $1,855.00 | $18,550 | $720.00 | $7,200 | $25,750 |
| **ELECTRIC DOMESTIC WATER HEATERS WITH TANKS** | | | | | | |
| Central Heating Plant (12.3 kW) Cluster C | 1 EA | $3,150.00 | $3,150 | $1,440.00 | $1,440 | $4,590 |
| **DOMESTIC WATER AIR SOURCE HEAT PUMP** | | | | | | |
| Rec & Convocation Ctr (300 mbh) Cluster C | 1 EA | $17,500.00 | $17,500 | $1,800.00 | $1,800 | $19,300 |
| Richard S Shineman (800 mbh) Cluster C | 2 EA | $48,560.00 | $97,120 | $3,600.00 | $7,200 | $104,320 |
| Hart Hall (900 mbh) Cluster C | 1 EA | $52,300.00 | $52,300 | $3,600.00 | $3,600 | $55,900 |
| Cooper DH (300 mbh) Cluster C | 1 EA | $17,500.00 | $17,500 | $1,800.00 | $1,800 | $19,300 |
| Funnelle Hall (900 mbh) Cluster C | 1 EA | $52,300.00 | $52,300 | $3,600.00 | $3,600 | $55,900 |
| Domestic water piping, above slab, copper type L, 2" diameter (20 lf per water piece of equipment | 1,880 LF | $36.60 | $68,808 | $23.10 | $43,428 | $112,236 |
| Domestic water piping fiberglass insulation with all service jacket, 1" thickness for copper piping, 2" diameter | 1,880 LF | $3.80 | $7,144 | $9.50 | $17,860 | $25,004 |
| Direct digital control of domestic water heaters(est 4 pts each) | 94 EA | $1,600.00 | $150,400 | $2,400.00 | $225,600 | $376,000 |
| **TOTAL DOMESTIC WATER HEATING EQUIPMENT** | | | **$627,607** | | **$368,968** | **$996,575** |
| **HOT WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | | | | |
| J C Park Hall (1921 mbh) Cluster C | 1 EA | $23,052.00 | $23,052 | $2,880.00 | $2,880 | $25,932 |
| Campus Center (5619 mbh) Cluster C | 2 EA | $56,190.00 | $112,380 | $5,400.00 | $10,800 | $123,180 |

**CLUSTER C DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| I Poucher Hall (1269 mbh) Cluster C | 1 EA | $15,228.00 | $15,228 | $2,880.00 | $2,880 | $18,108 |
| Rec & Convocation (3904 mbh) Cluster C | 2 EA | $46,848.00 | $93,696 | $3,600.00 | $7,200 | $100,896 |
| M V Lee Hall (1303 mbh) Cluster C | 1 EA | $15,636.00 | $15,636 | $2,880.00 | $2,880 | $18,516 |
| Central Heating Plant (284 mbh) Cluster C | 1 EA | $4,260.00 | $4,260 | $1,440.00 | $1,440 | $5,700 |
| J Lanigan Hall (3074 mbh) Cluster C | 2 EA | $36,888.00 | $73,776 | $4,500.00 | $9,000 | $82,776 |
| J Tyler Hall (3084 mbh) Cluster C | 2 EA | $37,008.00 | $74,016 | $4,500.00 | $9,000 | $83,016 |
| Richard S Shineman (17659 mbh) Cluster C | 2 EA | $158,931.00 | $317,862 | $10,800.00 | $21,600 | $339,462 |
| Wilber Hall (2531 mbh) Cluster C | 2 EA | $30,372.00 | $60,744 | $2,880.00 | $5,760 | $66,504 |
| M E Mahar Hall (1857 mbh) Cluster C | 2 EA | $22,284.00 | $44,568 | $2,160.00 | $4,320 | $48,888 |
| J Penfield Lib (3365 mbh) Cluster C | 2 EA | $123,365.00 | $246,730 | $3,800.00 | $7,600 | $254,330 |
| Culkin Hall (399 mbh) Cluster C | 1 EA | $5,985.00 | $5,985 | $2,160.00 | $2,160 | $8,145 |
| Hewitt Hall (2454 mbh) Cluster C | 2 EA | $29,448.00 | $58,896 | $3,600.00 | $7,200 | $66,096 |
| Hart Hall (2844 mbh) Cluster C | 2 EA | $34,128.00 | $68,256 | $3,600.00 | $7,200 | $75,456 |
| Cooper DH (786 mbh) Cluster C | 1 EA | $11,790.00 | $11,790 | $2,160.00 | $2,160 | $13,950 |
| Funnelle Hall (2798 mbh) Cluster C | 2 EA | $33,468.00 | $66,936 | $3,600.00 | $7,200 | $74,136 |
| Pumps, end suction base mounted, 4711 gpm, 247 ft hd, 450 hp, including VFDs and accessories Cluster C | 2 EA | $144,300.00 | $288,600 | $21,600.00 | $43,200 | $331,800 |
| Direct digital control of heat exchangers (est 8 pts each) | 28 EA | $3,200.00 | $89,600 | $4,800.00 | $134,400 | $224,000 |
| Direct digital control of pumps (est 5 pts each) | 2 EA | $2,000.00 | $4,000 | $3,000.00 | $6,000 | $10,000 |
| Isolation valves, automatic | 112 EA | $745.00 | $83,440 | $570.00 | $63,840 | $147,280 |
| Flow meters, ultrasonic | 17 EA | $1,500.00 | $25,500 | $760.00 | $12,920 | $38,420 |
| Temperature transmitters | 224 EA | $150.00 | $33,600 | $95.00 | $21,280 | $54,880 |
| Differential pressure switch | 28 EA | $875.00 | $24,500 | $190.00 | $5,320 | $29,820 |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (80 lf per HX) | | | | | | |
| - 2-1/2" diameter | 240 LF | $32.00 | $7,679 | $56.30 | $13,512 | $21,191 |
| - 3" diameter | 160 LF | $33.90 | $5,424 | $61.50 | $9,840 | $15,264 |
| - 4" diameter | 1,200 LF | $48.40 | $58,080 | $72.00 | $86,400 | $144,480 |
| - 6" diameter | 560 LF | $64.60 | $36,176 | $81.00 | $45,360 | $81,536 |
| - 8" diameter | 80 LF | $112.50 | $9,000 | $100.60 | $8,048 | $17,048 |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |

**CLUSTER C DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| - 2-1/2" diameter | 240 LF | $6.90 | $1,656 | $10.60 | $2,544 | $4,200 |
| - 3" diameter | 160 LF | $7.30 | $1,168 | $11.20 | $1,792 | $2,960 |
| - 4" diameter | 1,200 LF | $8.30 | $9,960 | $13.50 | $16,200 | $26,160 |
| - 6" diameter | 560 LF | $9.80 | $5,488 | $17.30 | $9,688 | $15,176 |
| - 8" diameter | 80 LF | $13.60 | $1,088 | $21.20 | $1,696 | $2,784 |
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 3" diameter Cluster C | 486 LF | $39.80 | $19,343 | $81.60 | $39,658 | $59,000 |
| - 4" diameter Cluster C | 124 LF | $47.30 | $5,865 | $92.40 | $11,458 | $17,323 |
| - 5" diameter Cluster C | 1,300 LF | $56.30 | $73,190 | $100.50 | $130,650 | $203,840 |
| - 6" diameter Cluster C | 1,574 LF | $62.80 | $98,847 | $106.50 | $167,631 | $266,478 |
| - 8" diameter Cluster C | 1,318 LF | $108.00 | $142,344 | $123.10 | $162,246 | $304,590 |
| - 10" diameter Cluster C | 2,504 LF | $156.60 | $392,126 | $150.10 | $375,850 | $767,977 |
| - 12" diameter Cluster C | 1,498 LF | $195.20 | $292,410 | $195.60 | $293,009 | $585,418 |
| - 14" diameter Cluster C | 1,186 LF | $236.30 | $280,252 | $241.10 | $285,945 | $566,196 |
| - 16" diameter Cluster C | 536 LF | $281.40 | $150,830 | $284.40 | $152,438 | $303,269 |
| Site utilities earthwork including excavation, select backfill and disposal on site (6' wide by 4' deep trench), single trench for chilled and hot water | 4,678 CY | $48.80 | $228,286 | $24.00 | $112,272 | $340,558 |
| **TOTAL HOT WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | **$3,662,264** | | **$2,324,476** | **$5,986,740** |
| **CHILLED WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | | | | |
| J C Park Hall (1739 mbh) Cluster C | 1 EA | $20,868.00 | $20,868 | $2,160.00 | $2,160 | $23,028 |
| Campus Center (4758 mbh) Cluster C | 2 EA | $52,338.00 | $104,676 | $4,500.00 | $9,000 | $113,676 |
| I Poucher Hall (1016 mbh) Cluster C | 1 EA | $12,192.00 | $12,192 | $2,160.00 | $2,160 | $14,352 |
| Rec & Convocation (1694 mbh) Cluster C | 2 EA | $20,328.00 | $40,656 | $2,160.00 | $4,320 | $44,976 |
| M V Lee Hall (0 mbh) Cluster C | 0 EA | $0.00 | $0 | $0.00 | $0 | $0 |
| Central Heating Plant (0 mbh) Cluster C | 0 EA | $0.00 | $0 | $0.00 | $0 | $0 |
| J Lanigan Hall (3002 mbh) Cluster C | 2 EA | $36,024.00 | $72,048 | $2,880.00 | $5,760 | $77,808 |
| J Tyler Hall (2563 mbh) Cluster C | 2 EA | $30,756.00 | $61,512 | $2,880.00 | $5,760 | $67,272 |
| Richard S Shineman (5385 mbh) Cluster C | 2 EA | $59,235.00 | $118,470 | $4,500.00 | $9,000 | $127,470 |

**CLUSTER C DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Wilber Hall (2805 mbh) Cluster C | 2 EA | $33,660.00 | $67,320 | $2,880.00 | $5,760 | $73,080 |
| M E Mahar Hall (1790 mbh) Cluster C | 2 EA | $21,480.00 | $42,960 | $2,880.00 | $5,760 | $48,720 |
| J Penfield Lib (4337 mbh) Cluster C | 2 EA | $52,044.00 | $104,088 | $3,800.00 | $7,600 | $111,688 |
| Culkin Hall (563 mbh) Cluster C | 1 EA | $8,445.00 | $8,445 | $2,160.00 | $2,160 | $10,605 |
| Hewitt Hall (2290 mbh) Cluster C | 2 EA | $27,480.00 | $54,960 | $3,600.00 | $7,200 | $62,160 |
| Hart Hall (0 mbh) Cluster C | 0 EA | $0.00 | $0 | $0.00 | $0 | $0 |
| Cooper DH (508 mbh) Cluster C | 1 EA | $7,620.00 | $7,620 | $2,160.00 | $2,160 | $9,780 |
| Funnelle Hall (0 mbh) Cluster C | 0 EA | $0.00 | $0 | $0.00 | $0 | $0 |
| Direct digital control of heat exchangers (est 8 pts each) | 22 EA | $3,200.00 | $70,400 | $4,800.00 | $105,600 | $176,000 |
| Isolation valves, automatic | 88 EA | $745.00 | $65,560 | $570.00 | $50,160 | $115,720 |
| Flow meters, ultrasonic | 13 EA | $1,500.00 | $19,500 | $760.00 | $9,880 | $29,380 |
| Temperature transmitters | 176 EA | $150.00 | $26,400 | $95.00 | $16,720 | $43,120 |
| Differential pressure switch | 22 EA | $875.00 | $19,250 | $190.00 | $4,180 | $23,430 |
| Chilled water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (80 lf per HX) | | | | | | |
| - 3" diameter | 160 LF | $33.90 | $5,424 | $61.50 | $9,840 | $15,264 |
| - 4" diameter | 80 LF | $48.40 | $3,872 | $72.00 | $5,760 | $9,632 |
| - 6" diameter | 1,040 LF | $64.60 | $67,184 | $81.00 | $84,240 | $151,424 |
| - 8" diameter | 480 LF | $112.50 | $54,000 | $100.60 | $48,288 | $102,288 |
| Chilled water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 3" diameter | 160 LF | $7.30 | $1,168 | $11.20 | $1,792 | $2,960 |
| - 4" diameter | 80 LF | $8.30 | $664 | $13.50 | $1,080 | $1,744 |
| - 6" diameter | 1,040 LF | $9.80 | $10,192 | $17.30 | $17,992 | $28,184 |
| - 8" diameter | 480 LF | $13.60 | $6,528 | $21.20 | $10,176 | $16,704 |
| **TOTAL CHILLED WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | **$1,065,957** | | **$434,508** | **$1,500,465** |

**GEOTHERMAL WELLFIELD**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Wellfield piping, includes vertical piping within the wellfield and distribution connecting each well, 924 bore holes, 500' depth | 1 LS | $12,474,000 | $12,474,000 | $8,316,000 | $8,316,000 | $20,790,000 |

TROPHY POINT
Construction Services & Consulting

**CLUSTER C DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Direct digital control of wellfield (est 100 pts each) | 1 LS | $40,000.00 | $40,000 | $60,000.00 | $60,000 | $100,000 |
| Water to water heat pumps, serving the geothermal wellfield, 8222 mbh | 4 EA | $755,000.00 | $3,020,000 | $32,400.00 | $129,600 | $3,149,600 |
| Direct digital control of WWHP (est 10 pts each) | 4 EA | $4,000.00 | $16,000 | $6,000.00 | $24,000 | $40,000 |
| Electrical service upgrade, 5kV, including MCC, transformers and panels | 1 LS | $200,000.00 | $200,000 | $300,000.00 | $300,000 | $500,000 |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | 400 SF | $5.50 | $2,200 | $6.10 | $2,440 | $4,640 |
| Wellfield water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (from wellfield to HP) | | | | | | |
| - 12" diameter | 4,320 LF | $193.10 | $834,192 | $153.50 | $663,120 | $1,497,312 |
| Site utilities earthwork including excavation, select backfill and disposal on site (6' wide by 4' deep trench) | 1,920 CY | $48.80 | $93,696 | $25.00 | $48,000 | $141,696 |
| Pumps, end suction base mounted, 3300 gpm, 50 ft hd, 60 hp, including VFDs and accessories | 5 EA | $68,750.00 | $343,750 | $10,800.00 | $54,000 | $397,750 |
| Direct digital control of pumps (est 5 pts each) | 5 EA | $2,000.00 | $10,000 | $3,000.00 | $15,000 | $25,000 |
| **TOTAL GEOTHERMAL WELLFIELD** | | | **$17,033,838** | | **$9,612,160** | **$26,645,998** |
| **HEATING THERMAL ENERGY TANKS** | | | | | | |
| Thermal energy storage tank, serving heating hot water system, 330000 gallons | 1 EA | $1,039,500.00 | $1,039,500 | $445,500.00 | $445,500 | $1,485,000 |
| Direct digital control of tanks (est 14 pts each) | 1 EA | $5,600.00 | $5,600 | $8,400.00 | $8,400 | $14,000 |
| 36" concrete slab material foundation, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, forms, finish, cure and protect | 3,844 SF | $38.30 | $147,225 | $33.00 | $126,852 | $274,077 |
| Foundation support for the concrete pad | 1 LS | $30,000.00 | $30,000 | $20,000.00 | $20,000 | $50,000 |
| Shoring for excavation | 1,548 SF | $20.00 | $30,960 | $24.70 | $38,236 | $69,196 |
| Earthwork including excavation, select backfill and disposal on site for tank pad (half tank buried) | 1,210 CY | $48.80 | $59,048 | $25.00 | $30,250 | $89,298 |
| Foundation support for the concrete pad | 1 LS | $30,000.00 | $30,000 | $20,000.00 | $20,000 | $50,000 |

**CLUSTER C DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Pumps, end suction base mounted, 1710 gpm, 60 ft hd, 40hp, including VFDs and accessories | 2 EA | $38,430.00 | $76,860 | $9,000.00 | $18,000 | $94,860 |
| Direct digital control of pumps (est 5 pts each) | 2 EA | $2,000.00 | $4,000 | $3,000.00 | $6,000 | $10,000 |
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 12" diameter | 200 LF | $195.20 | $39,040 | $195.60 | $39,120 | $78,160 |
| Earthwork including excavation, select backfill and disposal on site for pipe | 178 CY | $48.80 | $8,686 | $25.00 | $4,450 | $13,136 |
| Nitrogen generator, 20 cfm | 1 EA | $20,000.00 | $20,000 | $3,800.00 | $3,800 | $23,800 |
| **TOTAL HEATING THERMAL ENERGY TANKS** | | | **$1,490,920** | | **$760,608** | **$2,251,527** |
| **DRY COOLER BOREFIELD BALANCING** | | | | | | |
| Dry cooler (1260 tons) | 1 EA | $252,000.00 | $252,000 | $21,600.00 | $21,600 | $273,600 |
| Direct digital control of dry coolers (est 15 pts each) | 1 EA | $6,000.00 | $6,000 | $9,000.00 | $9,000 | $15,000 |
| Pumps, end suction base mounted, 3300 gpm, 50 ft hd, 60 hp, including VFDs and accessories | 5 EA | $68,750.00 | $343,750 | $10,800.00 | $54,000 | $397,750 |
| Direct digital control of pumps (est 5 pts each) | 5 EA | $2,000.00 | $10,000 | $3,000.00 | $15,000 | $25,000 |
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 12" diameter | 200 LF | $195.20 | $39,040 | $195.60 | $39,120 | $78,160 |
| Earthwork including excavation, select backfill and disposal on site for pipe | 178 CY | $48.80 | $8,686 | $25.00 | $4,450 | $13,136 |
| **TOTAL DRY COOLER BOREFIELD BALANCING** | | | **$659,476** | | **$143,170** | **$802,646** |
| **PEAKING GAS BOILERS** | | | | | | |
| Boiler, natural gas, 8475 mbh, serving the hot water system | 4 EA | $124,300.00 | $497,200 | $43,200.00 | $172,800 | $670,000 |

**CLUSTER C DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Direct digital control of boilers (est 15 pts each) | 4 EA | $6,000.00 | $24,000 | $9,000.00 | $36,000 | $60,000 |
| Heating hot water system components | 1 LS | $75,000.00 | $75,000 | $60,000.00 | $60,000 | $135,000 |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | 400 SF | $5.50 | $2,200 | $6.20 | $2,480 | $4,680 |
| Boiler flue and vent | 4 EA | $6,000.00 | $24,000 | $5,400.00 | $21,600 | $45,600 |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (80 lf per HX) | | | | | | |
| - 6" diameter | 400 LF | $64.60 | $25,840 | $81.00 | $32,400 | $58,240 |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 6" diameter | 400 LF | $9.80 | $3,920 | $17.30 | $6,920 | $10,840 |
| **TOTAL PEAKING GAS BOILERS** | | | **$652,160** | | **$332,200** | **$984,360** |
| **PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | | | | | |
| Boiler, natural gas, 8250 mbh, serving the hot water system | -4 EA | $124,300.00 | ($497,200) | $43,200.00 | ($172,800) | ($670,000) |
| Direct digital control of boilers (est 15 pts each) | -4 EA | $6,000.00 | ($24,000) | $9,000.00 | ($36,000) | ($60,000) |
| Heating hot water system components | -1 LS | $75,000.00 | ($75,000) | $60,000.00 | ($60,000) | ($135,000) |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | -400 SF | $5.50 | ($2,200) | $6.20 | ($2,480) | ($4,680) |
| Boiler flue and vent | -4 EA | $6,000.00 | ($24,000) | $5,400.00 | ($21,600) | ($45,600) |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (80 lf per HX) | | | | | | |
| - 6" diameter | -400 LF | $64.60 | ($25,840) | $81.00 | ($32,400) | ($58,240) |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 6" diameter | -400 LF | $9.80 | ($3,920) | $17.30 | ($6,920) | ($10,840) |
| Boiler, electric, 8250 mbh, serving the hot water system | 4 EA | $228,825.00 | $915,300 | $38,880.00 | $155,520 | $1,070,820 |

**CLUSTER C DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Direct digital control of boilers (est 15 pts each) | 4 EA | $6,000.00 | $24,000 | $9,000.00 | $36,000 | $60,000 |
| Heating hot water system components | 1 LS | $75,000.00 | $75,000 | $60,000.00 | $60,000 | $135,000 |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | 400 SF | $5.50 | $2,200 | $6.20 | $2,480 | $4,680 |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (80 lf per HX) | | | | | | |
| - 6" diameter | 400 LF | $64.60 | $25,840 | $81.00 | $32,400 | $58,240 |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 6" diameter | 400 LF | $9.80 | $3,920 | $17.30 | $6,920 | $10,840 |
| **TOTAL PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | | **$394,100** | | **($38,880)** | **$355,220** |
| **WASTE WATER ENERGY RECOVERY** | | | | | | |
| Wastewater heat exchanger (16400 mbh) | 1 EA | $147,600.00 | $147,600 | $10,800.00 | $10,800 | $158,400 |
| Pumps, end suction base mounted, 660 gpm, 80 ft hd, 50 hp, including VFDs and accessories Cluster W | 4 EA | $49,700.00 | $198,800 | $9,000.00 | $36,000 | $234,800 |
| Direct digital control of heat exchangers (est 8 pts each) | 1 EA | $3,200.00 | $3,200 | $4,800.00 | $4,800 | $8,000 |
| Direct digital control of pumps (est 5 pts each) | 4 EA | $2,000.00 | $8,000 | $3,000.00 | $12,000 | $20,000 |
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 12" diameter | 10,000 LF | $195.20 | $1,952,000 | $195.60 | $1,956,000 | $3,908,000 |
| Earthwork including excavation, select backfill and disposal on site for pipe | 4,444 CY | $48.80 | $216,867 | $25.00 | $111,100 | $327,967 |
| **TOTAL WASTE WATER ENERGY RECOVERY** | | | **$2,526,467** | | **$2,130,700** | **$4,657,167** |

**CLUSTER E SUMMARY**

| SUMMARY | | TOTAL MATERIAL | TOTAL LABOR | TOTAL COST | % OF TOTAL |
|---|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | $88,818 | $79,932 | $168,750 | 1.43% |
| **HOT WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | $452,378 | $351,156 | $803,534 | 6.79% |
| **CHILLED WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | $161,416 | $112,002 | $273,418 | 2.31% |
| **GEOTHERMAL WELLFIELD** | | $2,678,280 | $1,754,785 | $4,433,065 | 37.47% |
| **HEATING THERMAL ENERGY TANKS** | | $382,600 | $225,776 | $608,375 | 5.14% |
| **DRY COOLER BOREFIELD BALANCING** | | $183,176 | $84,250 | $267,426 | 2.26% |
| **PEAKING GAS BOILERS** | | $133,440 | $60,740 | $194,180 | 1.64% |
| **SUBTOTAL - CLUSTER E SUMMARY** | | | | **$6,748,750** | **100.00%** |
| GENERAL CONDITIONS | 15.0% | | | $1,012,312 | 8.56% |
| OVERHEAD AND PROFIT | 10.0% | | | $776,106 | 6.56% |
| DESIGN CONTINGENCY | 20.0% | | | $1,707,434 | 14.43% |
| BID CONTINGENCY | 5.0% | | | $512,230 | 4.33% |
| PHASING | 10.0% | | | $1,075,683 | 9.09% |
| **TOTAL - CLUSTER E SUMMARY** | | | | **$11,832,515** | **100.00%** |
| **PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | $43,000 | -$6,480 | $36,520 | 0.31% |
| GENERAL CONDITIONS | 15.0% | | | $5,478 | 0.05% |
| OVERHEAD AND PROFIT | 10.0% | | | $4,200 | 0.04% |
| DESIGN CONTINGENCY | 20.0% | | | $9,240 | 0.08% |
| BID CONTINGENCY | 5.0% | | | $2,772 | 0.02% |
| PHASING | 10.0% | | | $5,821 | 0.05% |
| **TOTAL - PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | | | **$64,030** | **0.54%** |

**CLUSTER E DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | | | | | |
| **POINT OF USE WATER HEATERS** | | | | | | |
| Sheldon Hall Cluster E | 9 EA | $1,855.00 | $16,695 | $720.00 | $6,480 | $23,175 |
| Rich Hall Cluster E | 4 EA | $1,855.00 | $7,420 | $720.00 | $2,880 | $10,300 |
| Mackin Hall Cluster E | 3 EA | $1,855.00 | $5,565 | $720.00 | $2,160 | $7,725 |
| Moreland Hall Cluster E | 2 EA | $1,855.00 | $3,710 | $720.00 | $1,440 | $5,150 |
| Lonis Hall Cluster E | 2 EA | $1,855.00 | $3,710 | $720.00 | $1,440 | $5,150 |
| **ELECTRIC DOMESTIC WATER HEATERS WITH TANKS** | | | | | | |
| Gar-20 (4.5 kW) Cluster E | 1 EA | $1,150.00 | $1,150 | $1,440.00 | $1,440 | $2,590 |
| **DOMESTIC WATER AIR SOURCE HEAT PUMP** | | | | | | |
| Domestic water piping, above slab, copper type L, 2" diameter (20 lf per water piece of equipment | 420 LF | $36.60 | $15,372 | $23.10 | $9,702 | $25,074 |
| Domestic water piping fiberglass insulation with all service jacket, 1" thickness for copper piping, 2" diameter | 420 LF | $3.80 | $1,596 | $9.50 | $3,990 | $5,586 |
| Direct digital control of domestic water heaters(est 4 pts each) | 21 EA | $1,600.00 | $33,600 | $2,400.00 | $50,400 | $84,000 |
| **TOTAL DOMESTIC WATER HEATING EQUIPMENT** | | | **$88,818** | | **$79,932** | **$168,750** |
| **HOT WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | | | | |
| Sheldon Hall (3840 mbh) Cluster E | 2 EA | $46,080.00 | $92,160 | $4,500.00 | $9,000 | $101,160 |
| Rich Hall (1513 mbh) Cluster E | 1 EA | $22,695.00 | $22,695 | $2,880.00 | $2,880 | $25,575 |
| Mackin Hall (740 mbh) Cluster E | 1 EA | $11,100.00 | $11,100 | $2,160.00 | $2,160 | $13,260 |
| Moreland Hall (448 mbh) Cluster E | 1 EA | $6,720.00 | $6,720 | $2,160.00 | $2,160 | $8,880 |
| Lonis Hall (509 mbh) Cluster E | 1 EA | $7,635.00 | $7,635 | $2,160.00 | $2,160 | $9,795 |
| Gar-20 (333 mbh) Cluster E | 1 EA | $4,995.00 | $4,995 | $2,160.00 | $2,160 | $7,155 |
| Pumps, end suction base mounted, 580 gpm, 102 ft hd, 25 hp, including VFDs and accessories Cluster E | 2 EA | $32,465.00 | $64,930 | $7,200.00 | $14,400 | $79,330 |
| Direct digital control of heat exchangers (est 8 pts each) | 7 EA | $3,200.00 | $22,400 | $4,800.00 | $33,600 | $56,000 |
| Direct digital control of pumps (est 5 pts each) | 2 EA | $2,000.00 | $4,000 | $3,000.00 | $6,000 | $10,000 |
| Isolation valves, automatic | 28 EA | $745.00 | $20,860 | $570.00 | $15,960 | $36,820 |
| Flow meters, ultrasonic | 6 EA | $1,500.00 | $9,000 | $760.00 | $4,560 | $13,560 |

## CLUSTER E DETAIL

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Temperature transmitters | 56 EA | $150.00 | $8,400 | $95.00 | $5,320 | $13,720 |
| Differential pressure switch | 7 EA | $875.00 | $6,125 | $190.00 | $1,330 | $7,455 |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (80 lf per HX) | | | | | | |
| - 2-1/2" diameter | 320 LF | $32.00 | $10,238 | $56.30 | $18,016 | $28,254 |
| - 3" diameter | 80 LF | $33.90 | $2,712 | $61.50 | $4,920 | $7,632 |
| - 6" diameter | 80 LF | $64.60 | $5,168 | $81.00 | $6,480 | $11,648 |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 2-1/2" diameter | 320 LF | $6.90 | $2,208 | $10.60 | $3,392 | $5,600 |
| - 3" diameter | 80 LF | $7.30 | $584 | $11.20 | $896 | $1,480 |
| - 6" diameter | 80 LF | $9.80 | $784 | $17.30 | $1,384 | $2,168 |
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 2-1/2" diameter Cluster E | 518 LF | $37.50 | $19,425 | $73.50 | $38,073 | $57,498 |
| - 4" diameter Cluster E | 244 LF | $47.30 | $11,541 | $92.40 | $22,546 | $34,087 |
| - 5" diameter Cluster E | 1,310 LF | $56.30 | $73,753 | $100.50 | $131,655 | $205,408 |
| Site utilities earthwork including excavation, select backfill and disposal on site (6' wide by 4' deep trench), single trench for chilled and hot water | 921 CY | $48.80 | $44,945 | $24.00 | $22,104 | $67,049 |
| **TOTAL HOT WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | **$452,378** | | **$351,156** | **$803,534** |
| **CHILLED WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | | | | |
| Sheldon Hall (1982 mbh) Cluster E | 2 EA | $23,784.00 | $47,568 | $2,880.00 | $5,760 | $53,328 |
| Rich Hall (1207 mbh) Cluster E | 1 EA | $14,484.00 | $14,484 | $2,880.00 | $2,880 | $17,364 |
| Mackin Hall (121 mbh) Cluster E | 1 EA | $1,815.00 | $1,815 | $1,440.00 | $1,440 | $3,255 |
| Moreland Hall (85 mbh) Cluster E | 1 EA | $1,275.00 | $1,275 | $1,440.00 | $1,440 | $2,715 |
| Lonis Hall (93 mbh) Cluster E | 1 EA | $1,395.00 | $1,395 | $1,440.00 | $1,440 | $2,835 |
| Gar-20 (344 mbh) Cluster E | 1 EA | $5,160.00 | $5,160 | $2,160.00 | $2,160 | $7,320 |
| Direct digital control of heat exchangers (est 8 pts each) | 7 EA | $3,200.00 | $22,400 | $4,800.00 | $33,600 | $56,000 |
| Isolation valves, automatic | 28 EA | $745.00 | $20,860 | $570.00 | $15,960 | $36,820 |

## CLUSTER E DETAIL

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Flow meters, ultrasonic | 6 EA | $1,500.00 | $9,000 | $760.00 | $4,560 | $13,560 |
| Temperature transmitters | 56 EA | $150.00 | $8,400 | $95.00 | $5,320 | $13,720 |
| Differential pressure switch | 7 EA | $875.00 | $6,125 | $190.00 | $1,330 | $7,455 |
| Chilled water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (80 lf per HX) | | | | | | |
| - 2-1/2" diameter | 320 LF | $32.00 | $10,238 | $56.30 | $18,016 | $28,254 |
| - 4" diameter | 80 LF | $48.40 | $3,872 | $72.00 | $5,760 | $9,632 |
| - 6" diameter | 80 LF | $64.60 | $5,168 | $81.00 | $6,480 | $11,648 |
| Chilled water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 2-1/2" diameter | 320 LF | $6.90 | $2,208 | $10.60 | $3,392 | $5,600 |
| - 4" diameter | 80 LF | $8.30 | $664 | $13.50 | $1,080 | $1,744 |
| - 6" diameter | 80 LF | $9.80 | $784 | $17.30 | $1,384 | $2,168 |
| **TOTAL CHILLED WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | **$161,416** | | **$112,002** | **$273,418** |
| **GEOTHERMAL WELLFIELD** | | | | | | |
| Wellfield piping, includes vertical piping within the wellfield and distribution connecting each well, 123 bore holes, 500' depth | 1 LS | $1,660,500 | $1,660,500 | $1,107,000 | $1,107,000 | $2,767,500 |
| Direct digital control of wellfield (est 100 pts each) | 1 LS | $40,000.00 | $40,000 | $60,000.00 | $60,000 | $100,000 |
| Water to water heat pumps, serving the geothermal wellfield, 2302 mbh | 2 EA | $211,000.00 | $422,000 | $25,920.00 | $51,840 | $473,840 |
| Direct digital control of WWHP (est 10 pts each) | 2 EA | $4,000.00 | $8,000 | $6,000.00 | $12,000 | $20,000 |
| Electrical service upgrade, 5kV, including MCC, transformers and panels | 1 LS | $200,000.00 | $200,000 | $300,000.00 | $300,000 | $500,000 |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | 200 SF | $5.50 | $1,100 | $6.10 | $1,220 | $2,320 |
| Wellfield water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (from wellfield to HP) | | | | | | |
| - 12" diameter | 1,200 LF | $193.10 | $231,720 | $153.50 | $184,200 | $415,920 |

## CLUSTER E DETAIL

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Site utilities earthwork including excavation, select backfill and disposal on site (6' wide by 4' deep trench) | 533 CY | $48.80 | $26,010 | $25.00 | $13,325 | $39,335 |
| Pumps, end suction base mounted, 950 gpm, 50 ft hd, 20 hp, including VFDs and accessories | 3 EA | $27,650.00 | $82,950 | $5,400.00 | $16,200 | $99,150 |
| Direct digital control of pumps (est 5 pts each) | 3 EA | $2,000.00 | $6,000 | $3,000.00 | $9,000 | $15,000 |
| **TOTAL GEOTHERMAL WELLFIELD** | | | **$2,678,280** | | **$1,754,785** | **$4,433,065** |
| **HEATING THERMAL ENERGY TANKS** | | | | | | |
| Thermal energy storage tank, serving heating hot water system, 48000 gallons | 1 EA | $151,200.00 | $151,200 | $64,800.00 | $64,800 | $216,000 |
| Direct digital control of tanks (est 14 pts each) | 1 EA | $5,600.00 | $5,600 | $8,400.00 | $8,400 | $14,000 |
| 36" concrete slab material foundation, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, forms, finish, cure and protect | 1,156 SF | $38.30 | $44,275 | $33.00 | $38,148 | $82,423 |
| Foundation support for the concrete pad | 1 LS | $30,000.00 | $30,000 | $20,000.00 | $20,000 | $50,000 |
| Shoring for excavation | 424 SF | $20.00 | $8,480 | $24.70 | $10,473 | $18,953 |
| Earthwork including excavation, select backfill and disposal on site for tank pad (half tank buried) | 193 CY | $48.80 | $9,418 | $25.00 | $4,825 | $14,243 |
| Foundation support for the concrete pad | 1 LS | $30,000.00 | $30,000 | $20,000.00 | $20,000 | $50,000 |
| Pumps, end suction base mounted, 220 gpm, 60 ft hd, 7.5 hp, including VFDs and accessories | 2 EA | $15,950.00 | $31,900 | $2,880.00 | $5,760 | $37,660 |
| Direct digital control of pumps (est 5 pts each) | 2 EA | $2,000.00 | $4,000 | $3,000.00 | $6,000 | $10,000 |
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 12" diameter | 200 LF | $195.20 | $39,040 | $195.60 | $39,120 | $78,160 |
| Earthwork including excavation, select backfill and disposal on site for pipe | 178 CY | $48.80 | $8,686 | $25.00 | $4,450 | $13,136 |
| Nitrogen generator, 20 cfm | 1 EA | $20,000.00 | $20,000 | $3,800.00 | $3,800 | $23,800 |
| **TOTAL HEATING THERMAL ENERGY TANKS** | | | **$382,600** | | **$225,776** | **$608,375** |

## CLUSTER E DETAIL

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| **DRY COOLER BOREFIELD BALANCING** | | | | | | |
| Dry cooler (180 tons) | 1 EA | $40,500.00 | $40,500 | $6,480.00 | $6,480 | $46,980 |
| Direct digital control of dry coolers (est 15 pts each) | 1 EA | $6,000.00 | $6,000 | $9,000.00 | $9,000 | $15,000 |
| Pumps, end suction base mounted, 950 gpm, 50 ft hd, 20 hp, including VFDs and accessories | 3 EA | $27,650.00 | $82,950 | $5,400.00 | $16,200 | $99,150 |
| Direct digital control of pumps (est 5 pts each) | 3 EA | $2,000.00 | $6,000 | $3,000.00 | $9,000 | $15,000 |
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 12" diameter | 200 LF | $195.20 | $39,040 | $195.60 | $39,120 | $78,160 |
| Earthwork including excavation, select backfill and disposal on site for pipe | 178 CY | $48.80 | $8,686 | $25.00 | $4,450 | $13,136 |
| **TOTAL DRY COOLER BOREFIELD BALANCING** | | | **$183,176** | | **$84,250** | **$267,426** |
| **PEAKING GAS BOILERS** | | | | | | |
| Boiler, natural gas, 2450 mbh, serving the hot water system | 2 EA | $49,000.00 | $98,000 | $4,320.00 | $8,640 | $106,640 |
| Direct digital control of boilers (est 15 pts each) | 2 EA | $6,000.00 | $12,000 | $9,000.00 | $18,000 | $30,000 |
| Heating hot water system components | 1 LS | $5,000.00 | $5,000 | $10,000.00 | $10,000 | $15,000 |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | 200 SF | $5.50 | $1,100 | $6.20 | $1,240 | $2,340 |
| Boiler flue and vent | 2 EA | $3,000.00 | $6,000 | $2,880.00 | $5,760 | $11,760 |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (100 lf per boiler) | | | | | | |
| - 4" diameter | 200 LF | $48.40 | $9,680 | $72.00 | $14,400 | $24,080 |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 4" diameter | 200 LF | $8.30 | $1,660 | $13.50 | $2,700 | $4,360 |

## CLUSTER E DETAIL

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| **TOTAL PEAKING GAS BOILERS** | | | **$133,440** | | **$60,740** | **$194,180** |
| **PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | | | | | |
| Boiler, natural gas, 2450 mbh, serving the hot water system | -2 EA | $49,000.00 | ($98,000) | $4,320.00 | ($8,640) | ($106,640) |
| Direct digital control of boilers (est 15 pts each) | -2 EA | $6,000.00 | ($12,000) | $9,000.00 | ($18,000) | ($30,000) |
| Heating hot water system components | -1 LS | $5,000.00 | ($5,000) | $10,000.00 | ($10,000) | ($15,000) |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | -200 SF | $5.50 | ($1,100) | $6.20 | ($1,240) | ($2,340) |
| Boiler flue and vent | -2 EA | $3,000.00 | ($6,000) | $2,880.00 | ($5,760) | ($11,760) |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (100 lf per boiler) | | | | | | |
| - 4" diameter | -200 LF | $48.40 | ($9,680) | $72.00 | ($14,400) | ($24,080) |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 4" diameter | -200 LF | $8.30 | ($1,660) | $13.50 | ($2,700) | ($4,360) |
| Boiler, electric, 2450 mbh, serving the hot water system | 2 EA | $73,500.00 | $147,000 | $3,960.00 | $7,920 | $154,920 |
| Direct digital control of boilers (est 15 pts each) | 2 EA | $6,000.00 | $12,000 | $9,000.00 | $18,000 | $30,000 |
| Heating hot water system components | 1 LS | $5,000.00 | $5,000 | $10,000.00 | $10,000 | $15,000 |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | 200 SF | $5.50 | $1,100 | $6.20 | $1,240 | $2,340 |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (100 lf per boiler) | | | | | | |
| - 4" diameter | 200 LF | $48.40 | $9,680 | $72.00 | $14,400 | $24,080 |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 4" diameter | 200 LF | $8.30 | $1,660 | $13.50 | $2,700 | $4,360 |
| **TOTAL PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | | **$43,000** | | **($6,480)** | **$36,520** |

## CLUSTER N SUMMARY

| SUMMARY | | TOTAL MATERIAL | TOTAL LABOR | TOTAL COST | % OF TOTAL |
|---|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | $153,387 | $40,788 | $194,175 | 1.87% |
| **HOT WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | $520,299 | $543,426 | $1,063,725 | 10.22% |
| **CHILLED WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | $122,614 | $88,182 | $210,796 | 2.03% |
| **GEOTHERMAL WELLFIELD** | | $2,028,528 | $1,365,765 | $3,394,293 | 32.61% |
| **HEATING THERMAL ENERGY TANKS** | | $360,136 | $214,615 | $574,751 | 5.52% |
| **DRY COOLER BOREFIELD BALANCING** | | $170,501 | $84,250 | $254,751 | 2.45% |
| **PEAKING GAS BOILERS** | | $183,440 | $60,740 | $244,180 | 2.35% |
| **SUBTOTAL - CLUSTER N SUMMARY** | | | | **$5,936,671** | **100.00%** |
| GENERAL CONDITIONS | 15.0% | | | $890,501 | 8.56% |
| OVERHEAD AND PROFIT | 10.0% | | | $682,717 | 6.56% |
| DESIGN CONTINGENCY | 20.0% | | | $1,501,978 | 14.43% |
| BID CONTINGENCY | 5.0% | | | $450,593 | 4.33% |
| PHASING | 10.0% | | | $946,246 | 9.09% |
| **TOTAL - CLUSTER N SUMMARY** | | | | **$10,408,705** | **100.00%** |
| **PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | $130,000 | -$6,720 | $123,280 | 1.16% |
| GENERAL CONDITIONS | 15.0% | | | $18,492 | 0.17% |
| OVERHEAD AND PROFIT | 10.0% | | | $14,177 | 0.13% |
| DESIGN CONTINGENCY | 20.0% | | | $31,190 | 0.29% |
| BID CONTINGENCY | 5.0% | | | $9,357 | 0.09% |
| PHASING | 10.0% | | | $19,650 | 0.18% |
| **TOTAL - PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | | | **$216,146** | **2.03%** |

**CLUSTER N DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | | | | | |
| **POINT OF USE WATER HEATERS** | | | | | | |
| Shady Shore Cluster N | 1 EA | $1,855.00 | $1,855 | $720.00 | $720 | $2,575 |
| Mary Walker Health Cluster N | 2 EA | $1,855.00 | $3,710 | $720.00 | $1,440 | $5,150 |
| **DOMESTIC WATER AIR SOURCE HEAT PUMP** | | | | | | |
| Johnson Hall (500 mbh) Cluster N | 1 EA | $26,890.00 | $26,890 | $2,160.00 | $2,160 | $29,050 |
| Lakeside DH (300 mbh) Cluster N | 2 EA | $17,500.00 | $35,000 | $1,800.00 | $3,600 | $38,600 |
| Riggs Hall (400 mbh) Cluster N | 1 EA | $21,420.00 | $21,420 | $1,800.00 | $1,800 | $23,220 |
| Waterbury Hall (400 mbh) Cluster N | 1 EA | $21,420.00 | $21,420 | $1,800.00 | $1,800 | $23,220 |
| Scales Hall (400 mbh) Cluster N | 1 EA | $21,420.00 | $21,420 | $1,800.00 | $1,800 | $23,220 |
| Domestic water piping, above slab, copper type L, 2" diameter (20 lf per water piece of equipment | 180 LF | $36.60 | $6,588 | $23.10 | $4,158 | $10,746 |
| Domestic water piping fiberglass insulation with all service jacket, 1" thickness for copper piping, 2" diameter | 180 LF | $3.80 | $684 | $9.50 | $1,710 | $2,394 |
| Direct digital control of domestic water heaters(est 4 pts each) | 9 EA | $1,600.00 | $14,400 | $2,400.00 | $21,600 | $36,000 |
| **TOTAL DOMESTIC WATER HEATING EQUIPMENT** | | | **$153,387** | | **$40,788** | **$194,175** |
| **HOT WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | | | | |
| Shady Shore (161 mbh) Cluster N | 1 EA | $2,415.00 | $2,415 | $1,440.00 | $1,440 | $3,855 |
| Mary Walker Health (461 mbh) Cluster N | 1 EA | $6,915.00 | $6,915 | $2,160.00 | $2,160 | $9,075 |
| Johnson Hall (1578 mbh) Cluster N | 1 EA | $18,936.00 | $18,936 | $2,880.00 | $2,880 | $21,816 |
| Lakeside DH (606 mbh) Cluster N | 1 EA | $9,090.00 | $9,090 | $2,160.00 | $2,160 | $11,250 |
| Riggs Hall (1238 mbh) Cluster N | 1 EA | $14,856.00 | $14,856 | $2,880.00 | $2,880 | $17,736 |
| Waterbury Hall (1195 mbh) Cluster N | 1 EA | $14,340.00 | $14,340 | $2,880.00 | $2,880 | $17,220 |
| Scales Hall (1195 mbh) Cluster N | 1 EA | $14,340.00 | $14,340 | $2,880.00 | $2,880 | $17,220 |
| Pumps, end suction base mounted, 600 gpm, 104 ft hd, 25 hp, including VFDs and accessories Cluster N | 2 EA | $32,465.00 | $64,930 | $7,200.00 | $14,400 | $79,330 |
| Direct digital control of heat exchangers (est 8 pts each) | 7 EA | $3,200.00 | $22,400 | $4,800.00 | $33,600 | $56,000 |
| Direct digital control of pumps (est 5 pts each) | 2 EA | $2,000.00 | $4,000 | $3,000.00 | $6,000 | $10,000 |
| Isolation valves, automatic | 28 EA | $745.00 | $20,860 | $570.00 | $15,960 | $36,820 |

**CLUSTER N DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Flow meters, ultrasonic | 7 EA | $1,500.00 | $10,500 | $760.00 | $5,320 | $15,820 |
| Temperature transmitters | 56 EA | $150.00 | $8,400 | $95.00 | $5,320 | $13,720 |
| Differential pressure switch | 7 EA | $875.00 | $6,125 | $190.00 | $1,330 | $7,455 |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (80 lf per HX) | | | | | | |
| - 2-1/2" diameter | 240 LF | $32.00 | $7,679 | $56.30 | $13,512 | $21,191 |
| - 3" diameter | 320 LF | $33.90 | $10,848 | $61.50 | $19,680 | $30,528 |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 2-1/2" diameter | 240 LF | $6.90 | $1,656 | $10.60 | $2,544 | $4,200 |
| - 3" diameter | 320 LF | $7.30 | $2,336 | $11.20 | $3,584 | $5,920 |
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 1-1/2" diameter Cluster N | 554 LF | $22.90 | $12,687 | $51.10 | $28,309 | $40,996 |
| - 3" diameter Cluster N | 142 LF | $39.80 | $5,652 | $81.60 | $11,587 | $17,239 |
| - 4" diameter Cluster N | 1,392 LF | $47.30 | $65,842 | $92.40 | $128,621 | $194,462 |
| - 5" diameter Cluster N | 1,926 LF | $56.30 | $108,434 | $100.50 | $193,563 | $301,997 |
| Site utilities earthwork including excavation, select backfill and disposal on site (6' wide by 4' deep trench), single trench for chilled and hot water | 1,784 CY | $48.80 | $87,059 | $24.00 | $42,816 | $129,875 |
| **TOTAL HOT WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | **$520,299** | | **$543,426** | **$1,063,725** |
| | | | | | | |
| **CHILLED WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | | | | |
| Shady Shore (136 mbh) Cluster N | 1 EA | $2,040.00 | $2,040 | $1,440.00 | $1,440 | $3,480 |
| Mary Walker Health (770 mbh) Cluster N | 1 EA | $11,550.00 | $11,550 | $2,160.00 | $2,160 | $13,710 |
| Johnson Hall (1432 mbh) Cluster N | 1 EA | $17,184.00 | $17,184 | $2,880.00 | $2,880 | $20,064 |
| Lakeside DH (599 mbh) Cluster N | 1 EA | $8,985.00 | $8,985 | $2,160.00 | $2,160 | $11,145 |
| Riggs Hall (1054 mbh) Cluster N | 1 EA | $12,648.00 | $12,648 | $2,880.00 | $2,880 | $15,528 |
| Waterbury Hall (0 mbh) Cluster N | 0 EA | $0.00 | $0 | $0.00 | $0 | $0 |
| Scales Hall (0 mbh) Cluster N | 0 EA | $0.00 | $0 | $0.00 | $0 | $0 |
| Direct digital control of heat exchangers (est 8 pts each) | 5 EA | $3,200.00 | $16,000 | $4,800.00 | $24,000 | $40,000 |

**CLUSTER N DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Isolation valves, automatic | 20 EA | $745.00 | $14,900 | $570.00 | $11,400 | $26,300 |
| Flow meters, ultrasonic | 5 EA | $1,500.00 | $7,500 | $760.00 | $3,800 | $11,300 |
| Temperature transmitters | 40 EA | $150.00 | $6,000 | $95.00 | $3,800 | $9,800 |
| Differential pressure switch | 5 EA | $875.00 | $4,375 | $190.00 | $950 | $5,325 |
| Chilled water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (80 lf per HX) | | | | | | |
| - 2-1/2" diameter | 80 LF | $32.00 | $2,560 | $56.30 | $4,504 | $7,064 |
| - 3" diameter | 80 LF | $33.90 | $2,712 | $61.50 | $4,920 | $7,632 |
| - 4" diameter | 160 LF | $48.40 | $7,744 | $72.00 | $11,520 | $19,264 |
| - 6" diameter | 80 LF | $64.60 | $5,168 | $81.00 | $6,480 | $11,648 |
| Chilled water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 2-1/2" diameter | 80 LF | $6.90 | $552 | $10.60 | $848 | $1,400 |
| - 3" diameter | 80 LF | $7.30 | $584 | $11.20 | $896 | $1,480 |
| - 4" diameter | 160 LF | $8.30 | $1,328 | $13.50 | $2,160 | $3,488 |
| - 6" diameter | 80 LF | $9.80 | $784 | $17.30 | $1,384 | $2,168 |
| **TOTAL CHILLED WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | **$122,614** | | **$88,182** | **$210,796** |
| **GEOTHERMAL WELLFIELD** | | | | | | |
| Wellfield piping, includes vertical piping within the wellfield and distribution connecting each well, 95 bore holes, 500' depth | 1 LS | $1,282,500 | $1,282,500 | $855,000 | $855,000 | $2,137,500 |
| Direct digital control of wellfield (est 100 pts each) | 1 LS | $40,000.00 | $40,000 | $60,000.00 | $60,000 | $100,000 |
| Water to water heat pumps, serving the geothermal wellfield, 1809 mbh | 2 EA | $166,000.00 | $332,000 | $21,600.00 | $43,200 | $375,200 |
| Direct digital control of WWHP (est 10 pts each) | 2 EA | $4,000.00 | $8,000 | $6,000.00 | $12,000 | $20,000 |
| Electrical service upgrade, 5kV, including MCC, transformers and panels | 1 LS | $200,000.00 | $200,000 | $300,000.00 | $300,000 | $500,000 |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | 200 SF | $5.50 | $1,100 | $6.10 | $1,220 | $2,320 |

**CLUSTER N DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Wellfield water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (from wellfield to HP) | | | | | | |
| - 12" diameter | 420 LF | $193.10 | $81,102 | $153.50 | $64,470 | $145,572 |
| Site utilities earthwork including excavation, select backfill and disposal on site (6' wide by 4' deep trench) | 187 CY | $48.80 | $9,126 | $25.00 | $4,675 | $13,801 |
| Pumps, end suction base mounted, 750 gpm, 50 ft hd, 15 hp, including VFDs and accessories | 3 EA | $22,900.00 | $68,700 | $5,400.00 | $16,200 | $84,900 |
| Direct digital control of pumps (est 5 pts each) | 3 EA | $2,000.00 | $6,000 | $3,000.00 | $9,000 | $15,000 |
| **TOTAL GEOTHERMAL WELLFIELD** | | | **$2,028,528** | | **$1,365,765** | **$3,394,293** |
| **HEATING THERMAL ENERGY TANKS** | | | | | | |
| Thermal energy storage tank, serving heating hot water system, 41000 gallons | 1 EA | $129,150.00 | $129,150 | $55,350.00 | $55,350 | $184,500 |
| Direct digital control of tanks (est 14 pts each) | 1 EA | $5,600.00 | $5,600 | $8,400.00 | $8,400 | $14,000 |
| 36" concrete slab material foundation, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, forms, finish, cure and protect | 1,156 SF | $38.30 | $44,275 | $33.00 | $38,148 | $82,423 |
| Foundation support for the concrete pad | 1 LS | $30,000.00 | $30,000 | $20,000.00 | $20,000 | $50,000 |
| Shoring for excavation | 377 SF | $20.00 | $7,540 | $24.70 | $9,312 | $16,852 |
| Earthwork including excavation, select backfill and disposal on site for tank pad (half tank buried) | 171 CY | $48.80 | $8,345 | $25.00 | $4,275 | $12,620 |
| Foundation support for the concrete pad | 1 LS | $30,000.00 | $30,000 | $20,000.00 | $20,000 | $50,000 |
| Pumps, end suction base mounted, 270 gpm, 60 ft hd, 7.5 hp, including VFDs and accessories | 2 EA | $16,750.00 | $33,500 | $2,880.00 | $5,760 | $39,260 |
| Direct digital control of pumps (est 5 pts each) | 2 EA | $2,000.00 | $4,000 | $3,000.00 | $6,000 | $10,000 |
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 12" diameter | 200 LF | $195.20 | $39,040 | $195.60 | $39,120 | $78,160 |
| Earthwork including excavation, select backfill and disposal on site for pipe | 178 CY | $48.80 | $8,686 | $25.00 | $4,450 | $13,136 |

**CLUSTER N DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Nitrogen generator, 20 cfm | 1 EA | $20,000.00 | $20,000 | $3,800.00 | $3,800 | $23,800 |
| **TOTAL HEATING THERMAL ENERGY TANKS** | | | **$360,136** | | **$214,615** | **$574,751** |
| **DRY COOLER BOREFIELD BALANCING** | | | | | | |
| Dry cooler (187 tons) | 1 EA | $42,075.00 | $42,075 | $6,480.00 | $6,480 | $48,555 |
| Direct digital control of dry coolers (est 15 pts each) | 1 EA | $6,000.00 | $6,000 | $9,000.00 | $9,000 | $15,000 |
| Pumps, end suction base mounted, 750 gpm, 50 ft hd, 15 hp, including VFDs and accessories | 3 EA | $22,900.00 | $68,700 | $5,400.00 | $16,200 | $84,900 |
| Direct digital control of pumps (est 5 pts each) | 3 EA | $2,000.00 | $6,000 | $3,000.00 | $9,000 | $15,000 |
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 12" diameter | 200 LF | $195.20 | $39,040 | $195.60 | $39,120 | $78,160 |
| Earthwork including excavation, select backfill and disposal on site for pipe | 178 CY | $48.80 | $8,686 | $25.00 | $4,450 | $13,136 |
| **TOTAL DRY COOLER BOREFIELD BALANCING** | | | **$170,501** | | **$84,250** | **$254,751** |
| **PEAKING GAS BOILERS** | | | | | | |
| Boiler, natural gas, 3700 mbh, serving the hot water system | 2 EA | $74,000.00 | $148,000 | $4,320.00 | $8,640 | $156,640 |
| Direct digital control of boilers (est 15 pts each) | 2 EA | $6,000.00 | $12,000 | $9,000.00 | $18,000 | $30,000 |
| Heating hot water system components | 1 LS | $5,000.00 | $5,000 | $10,000.00 | $10,000 | $15,000 |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | 200 SF | $5.50 | $1,100 | $6.20 | $1,240 | $2,340 |
| Boiler flue and vent | 2 EA | $3,000.00 | $6,000 | $2,880.00 | $5,760 | $11,760 |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (100 lf per boiler) | | | | | | |
| - 4" diameter | 200 LF | $48.40 | $9,680 | $72.00 | $14,400 | $24,080 |

## CLUSTER N DETAIL

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 4" diameter | 200 LF | $8.30 | $1,660 | $13.50 | $2,700 | $4,360 |
| **TOTAL PEAKING GAS BOILERS** | | | **$183,440** | | **$60,740** | **$244,180** |
| **PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | | | | | |
| Boiler, natural gas, 2150 mbh, serving the hot water system | -2 EA | $43,000.00 | ($86,000) | $4,320.00 | ($8,640) | ($94,640) |
| Direct digital control of boilers (est 15 pts each) | -2 EA | $6,000.00 | ($12,000) | $9,000.00 | ($18,000) | ($30,000) |
| Heating hot water system components | -1 LS | $5,000.00 | ($5,000) | $10,000.00 | ($10,000) | ($15,000) |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | -200 SF | $5.50 | ($1,100) | $6.20 | ($1,240) | ($2,340) |
| Boiler flue and vent | -2 EA | $3,000.00 | ($6,000) | $2,880.00 | ($5,760) | ($11,760) |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (100 lf per boiler) | | | | | | |
| - 4" diameter | -200 LF | $48.40 | ($9,680) | $72.00 | ($14,400) | ($24,080) |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 4" diameter | -200 LF | $8.30 | ($1,660) | $13.50 | ($2,700) | ($4,360) |
| Boiler, electric, 3700 mbh, serving the hot water system | 2 EA | $111,000.00 | $222,000 | $3,840.00 | $7,680 | $229,680 |
| Direct digital control of boilers (est 15 pts each) | 2 EA | $6,000.00 | $12,000 | $9,000.00 | $18,000 | $30,000 |
| Heating hot water system components | 1 LS | $5,000.00 | $5,000 | $10,000.00 | $10,000 | $15,000 |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | 200 SF | $5.50 | $1,100 | $6.20 | $1,240 | $2,340 |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (100 lf per boiler) | | | | | | |
| - 4" diameter | 200 LF | $48.40 | $9,680 | $72.00 | $14,400 | $24,080 |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |

**CLUSTER N DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| - 4" diameter | 200 LF | $8.30 | $1,660 | $13.50 | $2,700 | $4,360 |
| **TOTAL PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | | **$130,000** | | **($6,720)** | **$123,280** |

## CLUSTER S SUMMARY

| SUMMARY | | TOTAL MATERIAL | TOTAL LABOR | TOTAL COST | % OF TOTAL |
|---|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | $37,444 | $31,616 | $69,060 | 0.72% |
| **HOT WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | $414,507 | $333,954 | $748,461 | 7.83% |
| **CHILLED WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | $36,422 | $32,772 | $69,194 | 0.72% |
| **GEOTHERMAL WELLFIELD** | | $2,066,910 | $1,427,660 | $3,494,570 | 36.57% |
| **HEATING THERMAL ENERGY TANKS** | | $382,600 | $225,776 | $608,375 | 6.37% |
| **DRY COOLER BOREFIELD BALANCING** | | $195,851 | $86,410 | $282,261 | 2.95% |
| **PEAKING GAS BOILERS** | | $127,879 | $50,580 | $178,459 | 1.87% |
| **SUBTOTAL - CLUSTER S SUMMARY** | | | | **$5,450,381** | **100.00%** |
| GENERAL CONDITIONS | 15.0% | | | $817,557 | 8.56% |
| OVERHEAD AND PROFIT | 10.0% | | | $626,794 | 6.56% |
| DESIGN CONTINGENCY | 20.0% | | | $1,378,946 | 14.43% |
| BID CONTINGENCY | 5.0% | | | $413,684 | 4.33% |
| PHASING | 10.0% | | | $868,736 | 9.09% |
| **TOTAL - CLUSTER S SUMMARY** | | | | **$9,556,098** | **100.00%** |
| **PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | $46,000 | -$5,280 | $40,720 | 0.42% |
| GENERAL CONDITIONS | 15.0% | | | $6,108 | 0.06% |
| OVERHEAD AND PROFIT | 10.0% | | | $4,683 | 0.05% |
| DESIGN CONTINGENCY | 20.0% | | | $10,302 | 0.11% |
| BID CONTINGENCY | 5.0% | | | $3,091 | 0.03% |
| PHASING | 10.0% | | | $6,490 | 0.07% |
| **TOTAL - PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | | | **$71,394** | **0.74%** |

**CLUSTER S DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | | | | | |
| **POINT OF USE WATER HEATERS** | | | | | | |
| Commissary Bldg Cluster S | 2 EA | $1,855.00 | $3,710 | $720.00 | $1,440 | $5,150 |
| Romney Field House Cluster S | 4 EA | $1,855.00 | $7,420 | $720.00 | $2,880 | $10,300 |
| **ELECTRIC DOMESTIC WATER HEATERS WITH TANKS** | | | | | | |
| Maintenance Bldg (4.5 kW) Cluster S | 1 EA | $1,150.00 | $1,150 | $1,440.00 | $1,440 | $2,590 |
| Laker Hall (18 kW) Cluster S | 1 EA | $5,900.00 | $5,900 | $1,440.00 | $1,440 | $7,340 |
| **DOMESTIC WATER AIR SOURCE HEAT PUMP** | | | | | | |
| Domestic water piping, above slab, copper type L, 2" diameter (20 lf per water piece of equipment | 160 LF | $36.60 | $5,856 | $23.10 | $3,696 | $9,552 |
| Domestic water piping fiberglass insulation with all service jacket, 1" thickness for copper piping, 2" diameter | 160 LF | $3.80 | $608 | $9.50 | $1,520 | $2,128 |
| Direct digital control of domestic water heaters(est 4 pts each) | 8 EA | $1,600.00 | $12,800 | $2,400.00 | $19,200 | $32,000 |
| **TOTAL DOMESTIC WATER HEATING EQUIPMENT** | | | **$37,444** | | **$31,616** | **$69,060** |
| **HOT WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | | | | |
| Commissary Bldg (743 mbh) Cluster S | 1 EA | $11,145.00 | $11,145 | $2,160.00 | $2,160 | $13,305 |
| Maintenance Bldg (161 mbh) Cluster S | 1 EA | $2,415.00 | $2,415 | $1,440.00 | $1,440 | $3,855 |
| Laker Hall (4878 mbh) Cluster S | 2 EA | $53,658.00 | $107,316 | $4,500.00 | $9,000 | $116,316 |
| Romney Field House (1956 mbh) Cluster S | 1 EA | $23,472.00 | $23,472 | $2,880.00 | $2,880 | $26,352 |
| Pumps, end suction base mounted, 361 gpm, 90 ft hd, 15 hp, including VFDs and accessories Cluster S | 2 EA | $22,900.00 | $45,800 | $5,400.00 | $10,800 | $56,600 |
| Direct digital control of heat exchangers (est 8 pts each) | 5 EA | $3,200.00 | $16,000 | $4,800.00 | $24,000 | $40,000 |
| Direct digital control of pumps (est 5 pts each) | 2 EA | $2,000.00 | $4,000 | $3,000.00 | $6,000 | $10,000 |
| Isolation valves, automatic | 20 EA | $745.00 | $14,900 | $570.00 | $11,400 | $26,300 |
| Flow meters, ultrasonic | 4 EA | $1,500.00 | $6,000 | $760.00 | $3,040 | $9,040 |
| Temperature transmitters | 40 EA | $150.00 | $6,000 | $95.00 | $3,800 | $9,800 |
| Differential pressure switch | 5 EA | $875.00 | $4,375 | $190.00 | $950 | $5,325 |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (80 lf per HX) | | | | | | |

## CLUSTER S DETAIL

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| - 2-1/2" diameter | 160 LF | $32.00 | $5,119 | $56.30 | $9,008 | $14,127 |
| - 4" diameter | 80 LF | $48.40 | $3,872 | $72.00 | $5,760 | $9,632 |
| - 6" diameter | 80 LF | $64.60 | $5,168 | $81.00 | $6,480 | $11,648 |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 2-1/2" diameter | 160 LF | $6.90 | $1,104 | $10.60 | $1,696 | $2,800 |
| - 4" diameter | 80 LF | $8.30 | $664 | $13.50 | $1,080 | $1,744 |
| - 6" diameter | 80 LF | $9.80 | $784 | $17.30 | $1,384 | $2,168 |
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 3" diameter Cluster S | 1,402 LF | $39.80 | $55,800 | $81.60 | $114,403 | $170,203 |
| - 4" diameter Cluster S | 782 LF | $47.30 | $36,989 | $92.40 | $72,257 | $109,245 |
| - 5" diameter Cluster S | 208 LF | $56.30 | $11,710 | $100.50 | $20,904 | $32,614 |
| Site utilities earthwork including excavation, select backfill and disposal on site (6' wide by 4' deep trench), single trench for chilled and hot water | 1,063 CY | $48.80 | $51,874 | $24.00 | $25,512 | $77,386 |
| **TOTAL HOT WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | **$414,507** | | **$333,954** | **$748,461** |
| **CHILLED WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | | | | |
| Commissary Bldg (0 mbh) Cluster S | 0 EA | $0.00 | $0 | $0.00 | $0 | $0 |
| Maintenance Bldg (0 mbh) Cluster S | 0 EA | $0.00 | $0 | $0.00 | $0 | $0 |
| Laker Hall (394 mbh) Cluster S | 2 EA | $5,910.00 | $11,820 | $2,160.00 | $4,320 | $16,140 |
| Romney Field House (0 mbh) Cluster S | 0 EA | $0.00 | $0 | $0.00 | $0 | $0 |
| Direct digital control of heat exchangers (est 8 pts each) | 2 EA | $3,200.00 | $6,400 | $4,800.00 | $9,600 | $16,000 |
| Isolation valves, automatic | 8 EA | $745.00 | $5,960 | $570.00 | $4,560 | $10,520 |
| Flow meters, ultrasonic | 1 EA | $1,500.00 | $1,500 | $760.00 | $760 | $2,260 |
| Temperature transmitters | 16 EA | $150.00 | $2,400 | $95.00 | $1,520 | $3,920 |
| Differential pressure switch | 2 EA | $875.00 | $1,750 | $190.00 | $380 | $2,130 |
| Chilled water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (80 lf per HX) | | | | | | |
| - 3" diameter | 160 LF | $33.90 | $5,424 | $61.50 | $9,840 | $15,264 |

**CLUSTER S DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Chilled water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 3" diameter | 160 LF | $7.30 | $1,168 | $11.20 | $1,792 | $2,960 |
| **TOTAL CHILLED WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | **$36,422** | | **$32,772** | **$69,194** |
| **GEOTHERMAL WELLFIELD** | | | | | | |
| Wellfield piping, includes vertical piping within the wellfield and distribution connecting each well, 107 bore holes, 500' depth | 1 LS | $1,444,500 | $1,444,500 | $963,000 | $963,000 | $2,407,500 |
| Direct digital control of wellfield (est 100 pts each) | 1 LS | $40,000.00 | $40,000 | $60,000.00 | $60,000 | $100,000 |
| Water to water heat pumps, serving the geothermal wellfield, 1480 mbh | 2 EA | $136,000.00 | $272,000 | $21,600.00 | $43,200 | $315,200 |
| Direct digital control of WWHP (est 10 pts each) | 2 EA | $4,000.00 | $8,000 | $6,000.00 | $12,000 | $20,000 |
| Electrical service upgrade, 5kV, including MCC, transformers and panels | 1 LS | $200,000.00 | $200,000 | $300,000.00 | $300,000 | $500,000 |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | 200 SF | $5.50 | $1,100 | $6.10 | $1,220 | $2,320 |
| Wellfield water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (from wellfield to HP) | | | | | | |
| - 12" diameter | 140 LF | $193.10 | $27,034 | $153.50 | $21,490 | $48,524 |
| Site utilities earthwork including excavation, select backfill and disposal on site (6' wide by 4' deep trench) | 62 CY | $48.80 | $3,026 | $25.00 | $1,550 | $4,576 |
| Pumps, end suction base mounted, 600 gpm, 50 ft hd, 15 hp, including VFDs and accessories | 3 EA | $21,750.00 | $65,250 | $5,400.00 | $16,200 | $81,450 |
| Direct digital control of pumps (est 5 pts each) | 3 EA | $2,000.00 | $6,000 | $3,000.00 | $9,000 | $15,000 |
| **TOTAL GEOTHERMAL WELLFIELD** | | | **$2,066,910** | | **$1,427,660** | **$3,494,570** |

**HEATING THERMAL ENERGY TANKS**

**CLUSTER S DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Thermal energy storage tank, serving heating hot water system, 48000 gallons | 1 EA | $151,200.00 | $151,200 | $64,800.00 | $64,800 | $216,000 |
| Direct digital control of tanks (est 14 pts each) | 1 EA | $5,600.00 | $5,600 | $8,400.00 | $8,400 | $14,000 |
| 36" concrete slab material foundation, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, forms, finish, cure and protect | 1,156 SF | $38.30 | $44,275 | $33.00 | $38,148 | $82,423 |
| Foundation support for the concrete pad | 1 LS | $30,000.00 | $30,000 | $20,000.00 | $20,000 | $50,000 |
| Shoring for excavation | 424 SF | $20.00 | $8,480 | $24.70 | $10,473 | $18,953 |
| Earthwork including excavation, select backfill and disposal on site for tank pad (half tank buried) | 193 CY | $48.80 | $9,418 | $25.00 | $4,825 | $14,243 |
| Foundation support for the concrete pad | 1 LS | $30,000.00 | $30,000 | $20,000.00 | $20,000 | $50,000 |
| Pumps, end suction base mounted, 220 gpm, 60 ft hd, 7.5 hp, including VFDs and accessories | 2 EA | $15,950.00 | $31,900 | $2,880.00 | $5,760 | $37,660 |
| Direct digital control of pumps (est 5 pts each) | 2 EA | $2,000.00 | $4,000 | $3,000.00 | $6,000 | $10,000 |
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 12" diameter | 200 LF | $195.20 | $39,040 | $195.60 | $39,120 | $78,160 |
| Earthwork including excavation, select backfill and disposal on site for pipe | 178 CY | $48.80 | $8,686 | $25.00 | $4,450 | $13,136 |
| Nitrogen generator, 20 cfm | 1 EA | $20,000.00 | $20,000 | $3,800.00 | $3,800 | $23,800 |
| **TOTAL HEATING THERMAL ENERGY TANKS** | | | **$382,600** | | **$225,776** | **$608,375** |
| **DRY COOLER BOREFIELD BALANCING** | | | | | | |
| Dry cooler (315 tons) | 1 EA | $70,875.00 | $70,875 | $8,640.00 | $8,640 | $79,515 |
| Direct digital control of dry coolers (est 15 pts each) | 1 EA | $6,000.00 | $6,000 | $9,000.00 | $9,000 | $15,000 |
| Pumps, end suction base mounted, 600 gpm, 50 ft hd, 15 hp, including VFDs and accessories | 3 EA | $21,750.00 | $65,250 | $5,400.00 | $16,200 | $81,450 |
| Direct digital control of pumps (est 5 pts each) | 3 EA | $2,000.00 | $6,000 | $3,000.00 | $9,000 | $15,000 |

**CLUSTER S DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 12" diameter | 200 LF | $195.20 | $39,040 | $195.60 | $39,120 | $78,160 |
| Earthwork including excavation, select backfill and disposal on site for pipe | 178 CY | $48.80 | $8,686 | $25.00 | $4,450 | $13,136 |
| **TOTAL DRY COOLER BOREFIELD BALANCING** | | | **$195,851** | | **$86,410** | **$282,261** |
| **PEAKING GAS BOILERS** | | | | | | |
| Boiler, natural gas, 2500 mbh, serving the hot water system | 2 EA | $50,000.00 | $100,000 | $4,320.00 | $8,640 | $108,640 |
| Direct digital control of boilers (est 15 pts each) | 2 EA | $6,000.00 | $12,000 | $9,000.00 | $18,000 | $30,000 |
| Heating hot water system components | 1 LS | $3,000.00 | $3,000 | $5,000.00 | $5,000 | $8,000 |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | 200 SF | $5.50 | $1,100 | $6.20 | $1,240 | $2,340 |
| Boiler flue and vent | 2 EA | $2,000.00 | $4,000 | $2,160.00 | $4,320 | $8,320 |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (100 lf per boiler) | | | | | | |
| - 2-1/2" diameter | 200 LF | $32.00 | $6,399 | $56.30 | $11,260 | $17,659 |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 2-1/2" diameter | 200 LF | $6.90 | $1,380 | $10.60 | $2,120 | $3,500 |
| **TOTAL PEAKING GAS BOILERS** | | | **$127,879** | | **$50,580** | **$178,459** |
| **PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | | | | | |
| Boiler, natural gas, 2500 mbh, serving the hot water system | -2 EA | $50,000.00 | ($100,000) | $4,320.00 | ($8,640) | ($108,640) |
| Direct digital control of boilers (est 15 pts each) | -2 EA | $6,000.00 | ($12,000) | $9,000.00 | ($18,000) | ($30,000) |
| Heating hot water system components | -1 LS | $3,000.00 | ($3,000) | $5,000.00 | ($5,000) | ($8,000) |

## CLUSTER S DETAIL

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | -200 SF | $5.50 | ($1,100) | $6.20 | ($1,240) | ($2,340) |
| Boiler flue and vent | -2 EA | $2,000.00 | ($4,000) | $2,160.00 | ($4,320) | ($8,320) |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (100 lf per boiler) | | | | | | |
| - 2-1/2" diameter | -200 LF | $32.00 | ($6,399) | $56.30 | ($11,260) | ($17,659) |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 2-1/2" diameter | -200 LF | $6.90 | ($1,380) | $10.60 | ($2,120) | ($3,500) |
| Boiler, electric, 2500 mbh, serving the hot water system | 2 EA | $75,000.00 | $150,000 | $3,840.00 | $7,680 | $157,680 |
| Direct digital control of boilers (est 15 pts each) | 2 EA | $6,000.00 | $12,000 | $9,000.00 | $18,000 | $30,000 |
| Heating hot water system components | 1 LS | $3,000.00 | $3,000 | $5,000.00 | $5,000 | $8,000 |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | 200 SF | $5.50 | $1,100 | $6.20 | $1,240 | $2,340 |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (100 lf per boiler) | | | | | | |
| - 2-1/2" diameter | 200 LF | $32.00 | $6,399 | $56.30 | $11,260 | $17,659 |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 2-1/2" diameter | 200 LF | $6.90 | $1,380 | $10.60 | $2,120 | $3,500 |
| **TOTAL PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | | **$46,000** | | **($5,280)** | **$40,720** |

## CLUSTER W SUMMARY

| SUMMARY | | TOTAL MATERIAL | TOTAL LABOR | TOTAL COST | % OF TOTAL |
|---|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | $235,126 | $105,124 | $340,250 | 2.07% |
| **HOT WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | $1,024,480 | $938,977 | $1,963,458 | 11.97% |
| **CHILLED WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | $361,774 | $343,876 | $705,650 | 4.30% |
| **GEOTHERMAL WELLFIELD** | | $2,992,022 | $1,969,265 | $4,961,287 | 30.25% |
| **HEATING THERMAL ENERGY TANKS** | | $497,451 | $283,926 | $781,377 | 4.76% |
| **DRY COOLER BOREFIELD BALANCING** | | $190,876 | $80,170 | $271,046 | 1.65% |
| **PEAKING GAS BOILERS** | | $227,762 | $105,056 | $332,818 | 2.03% |
| **SUBTOTAL - CLUSTER W SUMMARY** | | | | **$9,355,886** | **100.00%** |
| GENERAL CONDITIONS | 15.0% | | | $1,403,383 | 8.56% |
| OVERHEAD AND PROFIT | 10.0% | | | $1,075,927 | 6.56% |
| DESIGN CONTINGENCY | 20.0% | | | $2,367,039 | 14.43% |
| BID CONTINGENCY | 5.0% | | | $710,112 | 4.33% |
| PHASING | 10.0% | | | $1,491,235 | 9.09% |
| **TOTAL - CLUSTER W SUMMARY** | | | | **$16,403,582** | **100.00%** |
| **PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | $23,678 | -$46,716 | -$23,038 | -0.14% |
| GENERAL CONDITIONS | 15.0% | | | -$3,456 | -0.02% |
| OVERHEAD AND PROFIT | 10.0% | | | -$2,649 | -0.02% |
| DESIGN CONTINGENCY | 20.0% | | | -$5,829 | -0.04% |
| BID CONTINGENCY | 5.0% | | | -$1,749 | -0.01% |
| PHASING | 10.0% | | | -$3,672 | -0.02% |
| **TOTAL - PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | | | **-$40,392** | **-0.25%** |

**CLUSTER W DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| **DOMESTIC WATER HEATING EQUIPMENT** | | | | | | |
| **ELECTRIC DOMESTIC WATER HEATERS WITH TANKS** | | | | | | |
| Littlepage DH (4.5 kW) Cluster W | 1 EA | $1,150.00 | $1,150 | $1,440.00 | $1,440 | $2,590 |
| **DOMESTIC WATER AIR SOURCE HEAT PUMP** | | | | | | |
| Pathfinder DH (300 mbh) Cluster W | 2 EA | $17,500.00 | $35,000 | $1,800.00 | $3,600 | $38,600 |
| Seneca Hall (400 mbh) Cluster W | 1 EA | $21,420.00 | $21,420 | $1,800.00 | $1,800 | $23,220 |
| Cayuga Hall (300 mbh) Cluster W | 1 EA | $17,500.00 | $17,500 | $1,800.00 | $1,800 | $19,300 |
| Onondaga Hall (400 mbh) Cluster W | 1 EA | $21,420.00 | $21,420 | $1,800.00 | $1,800 | $23,220 |
| Oneida Hall (300 mbh) Cluster W | 1 EA | $17,500.00 | $17,500 | $1,800.00 | $1,800 | $19,300 |
| **DOMESTIC WATER STORAGE TANKS** | | | | | | |
| Townhouse A (50 gallon) Cluster W | 5 EA | $930.00 | $4,650 | $540.00 | $2,700 | $7,350 |
| Townhouse B (50 gallon) Cluster W | 5 EA | $930.00 | $4,650 | $540.00 | $2,700 | $7,350 |
| Townhouse C (50 gallon) Cluster W | 5 EA | $930.00 | $4,650 | $540.00 | $2,700 | $7,350 |
| Townhouse D (50 gallon) Cluster W | 5 EA | $930.00 | $4,650 | $540.00 | $2,700 | $7,350 |
| Townhouse E (50 gallon) Cluster W | 5 EA | $930.00 | $4,650 | $540.00 | $2,700 | $7,350 |
| Townhouse F (50 gallon) Cluster W | 5 EA | $930.00 | $4,650 | $540.00 | $2,700 | $7,350 |
| Townhouse G (50 gallon) Cluster W | 5 EA | $930.00 | $4,650 | $540.00 | $2,700 | $7,350 |
| Townhouse H (50 gallon) Cluster W | 5 EA | $930.00 | $4,650 | $540.00 | $2,700 | $7,350 |
| Townhouse I (50 gallon) Cluster W | 5 EA | $930.00 | $4,650 | $540.00 | $2,700 | $7,350 |
| Townhouse J (50 gallon) Cluster W | 5 EA | $930.00 | $4,650 | $540.00 | $2,700 | $7,350 |
| Townhouse K (50 gallon) Cluster W | 5 EA | $930.00 | $4,650 | $540.00 | $2,700 | $7,350 |
| Townhouse L (50 gallon) Cluster W | 5 EA | $930.00 | $4,650 | $540.00 | $2,700 | $7,350 |
| Domestic water piping, above slab, copper type L, 2" diameter (20 lf per water piece of equipment | 1,340 LF | $36.60 | $49,044 | $23.10 | $30,954 | $79,998 |
| Domestic water piping fiberglass insulation with all service jacket, 1" thickness for copper piping, 2" diameter | 1,340 LF | $3.80 | $5,092 | $9.50 | $12,730 | $17,822 |
| Direct digital control of domestic water heaters(est 4 pts each) | 7 EA | $1,600.00 | $11,200 | $2,400.00 | $16,800 | $28,000 |
| **TOTAL DOMESTIC WATER HEATING EQUIPMENT** | | | **$235,126** | | **$105,124** | **$340,250** |
| **HOT WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | | | | |
| Pathfinder DH (779 mbh) Cluster W | 1 EA | $11,685.00 | $11,685 | $2,160.00 | $2,160 | $13,845 |

**CLUSTER W DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Seneca Hall (2559 mbh) Cluster W | 2 EA | $30,708.00 | $61,416 | $3,600.00 | $7,200 | $68,616 |
| Cayuga Hall (1786 mbh) Cluster W | 2 EA | $21,432.00 | $42,864 | $2,880.00 | $5,760 | $48,624 |
| Onondaga Hall (2569 mbh) Cluster W | 2 EA | $30,828.00 | $61,656 | $3,600.00 | $7,200 | $68,856 |
| Littlepage DH (583 mbh) Cluster W | 1 EA | $8,745.00 | $8,745 | $2,160.00 | $2,160 | $10,905 |
| Oneida Hall (1723 mbh) Cluster W | 2 EA | $20,676.00 | $41,352 | $2,880.00 | $5,760 | $47,112 |
| Townhouse A (119 mbh) Cluster W | 1 EA | $1,785.00 | $1,785 | $1,440.00 | $1,440 | $3,225 |
| Townhouse B (94 mbh) Cluster W | 1 EA | $1,410.00 | $1,410 | $1,440.00 | $1,440 | $2,850 |
| Townhouse C (147 mbh) Cluster W | 1 EA | $2,205.00 | $2,205 | $1,440.00 | $1,440 | $3,645 |
| Townhouse D (147 mbh) Cluster W | 1 EA | $2,205.00 | $2,205 | $1,440.00 | $1,440 | $3,645 |
| Townhouse E (185 mbh) Cluster W | 1 EA | $2,775.00 | $2,775 | $1,440.00 | $1,440 | $4,215 |
| Townhouse F (213 mbh) Cluster W | 1 EA | $3,195.00 | $3,195 | $1,440.00 | $1,440 | $4,635 |
| Townhouse G (111 mbh) Cluster W | 1 EA | $1,665.00 | $1,665 | $1,440.00 | $1,440 | $3,105 |
| Townhouse H (140 mbh) Cluster W | 1 EA | $2,100.00 | $2,100 | $1,440.00 | $1,440 | $3,540 |
| Townhouse I (172 mbh) Cluster W | 1 EA | $2,580.00 | $2,580 | $1,440.00 | $1,440 | $4,020 |
| Townhouse J (172 mbh) Cluster W | 1 EA | $2,580.00 | $2,580 | $1,440.00 | $1,440 | $4,020 |
| Townhouse K (228 mbh) Cluster W | 1 EA | $420.00 | $420 | $1,440.00 | $1,440 | $1,860 |
| Townhouse L (172 mbh) Cluster W | 1 EA | $2,580.00 | $2,580 | $1,440.00 | $1,440 | $4,020 |
| Pumps, end suction base mounted, 725 gpm, 143 ft hd, 40 hp, including VFDs and accessories Cluster W | 2 EA | $37,625.00 | $75,250 | $9,000.00 | $18,000 | $93,250 |
| Direct digital control of heat exchangers (est 8 pts each) | 22 EA | $3,200.00 | $70,400 | $4,800.00 | $105,600 | $176,000 |
| Direct digital control of pumps (est 5 pts each) | 2 EA | $2,000.00 | $4,000 | $3,000.00 | $6,000 | $10,000 |
| Isolation valves, automatic | 88 EA | $745.00 | $65,560 | $570.00 | $50,160 | $115,720 |
| Flow meters, ultrasonic | 18 EA | $1,500.00 | $27,000 | $760.00 | $13,680 | $40,680 |
| Temperature transmitters | 176 EA | $150.00 | $26,400 | $95.00 | $16,720 | $43,120 |
| Differential pressure switch | 22 EA | $875.00 | $19,250 | $190.00 | $4,180 | $23,430 |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (80 lf per HX) | | | | | | |
| - 2-1/2" diameter | 1,040 LF | $32.00 | $33,275 | $56.30 | $58,552 | $91,827 |
| - 3" diameter | 640 LF | $33.90 | $21,696 | $61.50 | $39,360 | $61,056 |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 2-1/2" diameter | 1,040 LF | $6.90 | $7,176 | $10.60 | $11,024 | $18,200 |

**CLUSTER W DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| - 3" diameter | 640 LF | $7.30 | $4,672 | $11.20 | $7,168 | $11,840 |
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 3" diameter Cluster W | 124 LF | $39.80 | $4,935 | $81.60 | $10,118 | $15,054 |
| - 4" diameter Cluster W | 1,984 LF | $47.30 | $93,843 | $92.40 | $183,322 | $277,165 |
| - 5" diameter Cluster W | 44 LF | $56.30 | $2,477 | $100.50 | $4,422 | $6,899 |
| - 6" diameter Cluster W | 2,102 LF | $62.80 | $132,006 | $106.50 | $223,863 | $355,869 |
| - 8" diameter Cluster W | 702 LF | $108.00 | $75,816 | $123.10 | $86,416 | $162,232 |
| Site utilities earthwork including excavation, select backfill and disposal on site (6' wide by 4' deep trench), single trench for chilled and hot water | 2,203 CY | $48.80 | $107,506 | $24.00 | $52,872 | $160,378 |
| **TOTAL HOT WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | **$1,024,480** | | **$938,977** | **$1,963,458** |
| | | | | | | |
| **CHILLED WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | | | | |
| Pathfinder DH (728 mbh) Cluster W | 1 EA | $10,920.00 | $10,920 | $2,160.00 | $2,160 | $13,080 |
| Seneca Hall (232 mbh) Cluster W | 2 EA | $3,480.00 | $6,960 | $1,440.00 | $2,880 | $9,840 |
| Cayuga Hall (160 mbh) Cluster W | 2 EA | $2,400.00 | $4,800 | $1,440.00 | $2,880 | $7,680 |
| Onondaga Hall (232 mbh) Cluster W | 2 EA | $3,480.00 | $6,960 | $1,440.00 | $2,880 | $9,840 |
| Littlepage DH (605 mbh) Cluster W | 1 EA | $9,075.00 | $9,075 | $2,160.00 | $2,160 | $11,235 |
| Oneida Hall (160 mbh) Cluster W | 2 EA | $2,400.00 | $4,800 | $1,440.00 | $2,880 | $7,680 |
| Townhouse A (180 mbh) Cluster W | 1 EA | $2,130.00 | $2,130 | $1,440.00 | $1,440 | $3,570 |
| Townhouse B (142 mbh) Cluster W | 1 EA | $2,130.00 | $2,130 | $1,440.00 | $1,440 | $3,570 |
| Townhouse C (221 mbh) Cluster W | 1 EA | $3,315.00 | $3,315 | $1,440.00 | $1,440 | $4,755 |
| Townhouse D (221 mbh) Cluster W | 1 EA | $3,315.00 | $3,315 | $1,440.00 | $1,440 | $4,755 |
| Townhouse E (279 mbh) Cluster W | 1 EA | $4,185.00 | $4,185 | $1,440.00 | $1,440 | $5,625 |
| Townhouse F (320 mbh) Cluster W | 1 EA | $4,800.00 | $4,800 | $2,160.00 | $2,160 | $6,960 |
| Townhouse G (146 mbh) Cluster W | 1 EA | $2,190.00 | $2,190 | $1,440.00 | $1,440 | $3,630 |
| Townhouse H (185 mbh) Cluster W | 1 EA | $2,775.00 | $2,775 | $1,440.00 | $1,440 | $4,215 |
| Townhouse I (227 mbh) Cluster W | 1 EA | $3,405.00 | $3,405 | $1,440.00 | $1,440 | $4,845 |
| Townhouse J (228 mbh) Cluster W | 1 EA | $3,420.00 | $3,420 | $1,440.00 | $1,440 | $4,860 |
| Townhouse K (301 mbh) Cluster W | 1 EA | $4,515.00 | $4,515 | $1,440.00 | $1,440 | $5,955 |

**CLUSTER W DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Townhouse L (227 mbh) Cluster W | 1 EA | $3,405.00 | $3,405 | $1,440.00 | $1,440 | $4,845 |
| Direct digital control of heat exchangers (est 8 pts each) | 22 EA | $3,200.00 | $70,400 | $4,800.00 | $105,600 | $176,000 |
| Isolation valves, automatic | 88 EA | $745.00 | $65,560 | $570.00 | $50,160 | $115,720 |
| Flow meters, ultrasonic | 18 EA | $1,500.00 | $27,000 | $760.00 | $13,680 | $40,680 |
| Temperature transmitters | 176 EA | $150.00 | $26,400 | $95.00 | $16,720 | $43,120 |
| Differential pressure switch | 22 EA | $875.00 | $19,250 | $190.00 | $4,180 | $23,430 |
| Chilled water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (80 lf per HX) | | | | | | |
| - 2-1/2" diameter | 1,600 LF | $32.00 | $51,192 | $56.30 | $90,080 | $141,272 |
| - 3" diameter | 80 LF | $33.90 | $2,712 | $61.50 | $4,920 | $7,632 |
| - 4" diameter | 80 LF | $48.40 | $3,872 | $72.00 | $5,760 | $9,632 |
| Chilled water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 2-1/2" diameter | 1,600 LF | $6.90 | $11,040 | $10.60 | $16,960 | $28,000 |
| - 3" diameter | 80 LF | $7.30 | $584 | $11.20 | $896 | $1,480 |
| - 4" diameter | 80 LF | $8.30 | $664 | $13.50 | $1,080 | $1,744 |
| **TOTAL CHILLED WATER HEAT EXCHANGERS AND CAMPUS DISTRIBUTION** | | | **$361,774** | | **$343,876** | **$705,650** |

**GEOTHERMAL WELLFIELD**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Wellfield piping, includes vertical piping within the wellfield and distribution connecting each well, 107 bore holes, 500' depth | 1 LS | $2,160,000 | $2,160,000 | $1,440,000 | $1,440,000 | $3,600,000 |
| Direct digital control of wellfield (est 100 pts each) | 1 LS | $40,000.00 | $40,000 | $60,000.00 | $60,000 | $100,000 |
| Water to water heat pumps, serving the geothermal wellfield, 2138 mbh | 2 EA | $196,000.00 | $392,000 | $25,920.00 | $51,840 | $443,840 |
| Direct digital control of WWHP (est 10 pts each) | 2 EA | $4,000.00 | $8,000 | $6,000.00 | $12,000 | $20,000 |
| Electrical service upgrade, 5kV, including MCC, transformers and panels | 1 LS | $200,000.00 | $200,000 | $300,000.00 | $300,000 | $500,000 |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | 200 SF | $5.50 | $1,100 | $6.10 | $1,220 | $2,320 |

## CLUSTER W DETAIL

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Wellfield water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (from wellfield to HP) | | | | | | |
| - 12" diameter | 480 LF | $193.10 | $92,688 | $153.50 | $73,680 | $166,368 |
| Site utilities earthwork including excavation, select backfill and disposal on site (6' wide by 4' deep trench) | 213 CY | $48.80 | $10,394 | $25.00 | $5,325 | $15,719 |
| Pumps, end suction base mounted, 900 gpm, 50 ft hd, 20 hp, including VFDs and accessories | 3 EA | $27,280.00 | $81,840 | $5,400.00 | $16,200 | $98,040 |
| Direct digital control of pumps (est 5 pts each) | 3 EA | $2,000.00 | $6,000 | $3,000.00 | $9,000 | $15,000 |
| **TOTAL GEOTHERMAL WELLFIELD** | | | **$2,992,022** | | **$1,969,265** | **$4,961,287** |
| **HEATING THERMAL ENERGY TANKS** | | | | | | |
| Thermal energy storage tank, serving heating hot water system, 72000 gallons | 1 EA | $226,800.00 | $226,800 | $97,200.00 | $97,200 | $324,000 |
| Direct digital control of tanks (est 14 pts each) | 1 EA | $5,600.00 | $5,600 | $8,400.00 | $8,400 | $14,000 |
| 36" concrete slab material foundation, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, forms, finish, cure and protect | 1,600 SF | $38.30 | $61,280 | $33.00 | $52,800 | $114,080 |
| Foundation support for the concrete pad | 1 LS | $30,000.00 | $30,000 | $20,000.00 | $20,000 | $50,000 |
| Shoring for excavation | 565 SF | $20.00 | $11,300 | $24.70 | $13,956 | $25,256 |
| Earthwork including excavation, select backfill and disposal on site for tank pad (half tank buried) | 296 CY | $48.80 | $14,445 | $25.00 | $7,400 | $21,845 |
| Foundation support for the concrete pad | 1 LS | $30,000.00 | $30,000 | $20,000.00 | $20,000 | $50,000 |
| Pumps, end suction base mounted, 450 gpm, 60 ft hd, 15 hp, including VFDs and accessories | 2 EA | $23,150.00 | $46,300 | $5,400.00 | $10,800 | $57,100 |
| Direct digital control of pumps (est 5 pts each) | 2 EA | $2,000.00 | $4,000 | $3,000.00 | $6,000 | $10,000 |
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 12" diameter | 200 LF | $195.20 | $39,040 | $195.60 | $39,120 | $78,160 |
| Earthwork including excavation, select backfill and disposal on site for pipe | 178 CY | $48.80 | $8,686 | $25.00 | $4,450 | $13,136 |

**CLUSTER W DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Nitrogen generator, 20 cfm | 1 EA | $20,000.00 | $20,000 | $3,800.00 | $3,800 | $23,800 |
| **TOTAL HEATING THERMAL ENERGY TANKS** | | | **$497,451** | | **$283,926** | **$781,377** |
| **DRY COOLER BOREFIELD BALANCING** | | | | | | |
| Dry cooler (386 tons) | 1 EA | $86,850.00 | $86,850 | $10,800.00 | $10,800 | $97,650 |
| Direct digital control of dry coolers (est 15 pts each) | 1 EA | $6,000.00 | $6,000 | $9,000.00 | $9,000 | $15,000 |
| Pumps, end suction base mounted, 450 gpm, 60 ft hd, 15 hp, including VFDs and accessories | 2 EA | $23,150.00 | $46,300 | $5,400.00 | $10,800 | $57,100 |
| Direct digital control of pumps (est 5 pts each) | 2 EA | $2,000.00 | $4,000 | $3,000.00 | $6,000 | $10,000 |
| Buried hydronic piping, schedule 10, welded black steel, factory applied polyurethane foam with exterior HDPE jacket including integral leak detection cable | | | | | | |
| - 12" diameter | 200 LF | $195.20 | $39,040 | $195.60 | $39,120 | $78,160 |
| Earthwork including excavation, select backfill and disposal on site for pipe | 178 CY | $48.80 | $8,686 | $25.00 | $4,450 | $13,136 |
| **TOTAL DRY COOLER BOREFIELD BALANCING** | | | **$190,876** | | **$80,170** | **$271,046** |
| **PEAKING GAS BOILERS** | | | | | | |
| Boiler, natural gas, 3700 mbh, serving the hot water system | 2 EA | $74,000.00 | $148,000 | $6,480.00 | $12,960 | $160,960 |
| Direct digital control of boilers (est 15 pts each) | 2 EA | $6,000.00 | $12,000 | $9,000.00 | $18,000 | $30,000 |
| Heating hot water system components | 1 LS | $5,000.00 | $5,000 | $10,000.00 | $10,000 | $15,000 |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | 200 SF | $5.50 | $1,100 | $6.20 | $1,240 | $2,340 |
| Boiler flue and vent | 2 EA | $3,000.00 | $6,000 | $2,880.00 | $5,760 | $11,760 |
| Natural gas piping, above slab, welded black steel, schedule 40, 10" diameter | 200 LF | $166.30 | $33,260 | $122.90 | $24,580 | $57,840 |
| Natural gas distribution piping, below grade, polyethylene yellow PE2406, stick 10" diameter, including earthwork | 10 LF | $106.20 | $1,062 | $41.60 | $416 | $1,478 |

## CLUSTER W DETAIL

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Natural gas piping system accessories | 1 LS | $10,000.00 | $10,000 | $15,000.00 | $15,000 | $25,000 |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (100 lf per boiler) | | | | | | |
| - 4" diameter | 200 LF | $48.40 | $9,680 | $72.00 | $14,400 | $24,080 |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 4" diameter | 200 LF | $8.30 | $1,660 | $13.50 | $2,700 | $4,360 |
| **TOTAL PEAKING GAS BOILERS** | | | **$227,762** | | **$105,056** | **$332,818** |
| **PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | | | | | |
| Boiler, natural gas, 1700 mbh, serving the hot water system | -2 EA | $74,000.00 | ($148,000) | $6,480.00 | ($12,960) | ($160,960) |
| Direct digital control of boilers (est 15 pts each) | -2 EA | $6,000.00 | ($12,000) | $9,000.00 | ($18,000) | ($30,000) |
| Heating hot water system components | -1 LS | $5,000.00 | ($5,000) | $10,000.00 | ($10,000) | ($15,000) |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | -200 SF | $5.50 | ($1,100) | $6.20 | ($1,240) | ($2,340) |
| Boiler flue and vent | -2 EA | $3,000.00 | ($6,000) | $2,880.00 | ($5,760) | ($11,760) |
| Natural gas piping, above slab, welded black steel, schedule 40, 10" diameter | -200 LF | $166.30 | ($33,260) | $122.90 | ($24,580) | ($57,840) |
| Natural gas distribution piping, below grade, polyethylene yellow PE2406, stick 10" diameter, including earthwork | -10 LF | $106.20 | ($1,062) | $41.60 | ($416) | ($1,478) |
| Natural gas piping system accessories | -1 LS | $10,000.00 | ($10,000) | $15,000.00 | ($15,000) | ($25,000) |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (100 lf per boiler) | | | | | | |
| - 4" diameter | -200 LF | $48.40 | ($9,680) | $72.00 | ($14,400) | ($24,080) |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 4" diameter | -200 LF | $8.30 | ($1,660) | $13.50 | ($2,700) | ($4,360) |
| Boiler, electric, 3700 mbh, serving the hot water system | 2 EA | $111,000.00 | $222,000 | $6,000.00 | $12,000 | $234,000 |
| Direct digital control of boilers (est 15 pts each) | 2 EA | $6,000.00 | $12,000 | $9,000.00 | $18,000 | $30,000 |

**CLUSTER W DETAIL**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| Heating hot water system components | 1 LS | $5,000.00 | $5,000 | $10,000.00 | $10,000 | $15,000 |
| 4" concrete slab, vapor barrier, 6x6 6/6 welded wire mesh, 6" stone base, bulkheads and edge forms, finish, cure and protect | 200 SF | $5.50 | $1,100 | $6.20 | $1,240 | $2,340 |
| Heating hot water piping, welded black steel, schedule 40, on yoke & roll hanger assemblies, 10' OC, (100 lf per boiler) | | | | | | |
| - 4" diameter | 200 LF | $48.40 | $9,680 | $72.00 | $14,400 | $24,080 |
| Heating hot water fiberglass pipe insulation with all service jacket, 1-1/2" thickness for iron piping | | | | | | |
| - 4" diameter | 200 LF | $8.30 | $1,660 | $13.50 | $2,700 | $4,360 |
| **TOTAL PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | | **$23,678** | | **($46,716)** | **($23,038)** |

## ELECTRICAL UPGRADES SUMMARY

| SUMMARY | | TOTAL MATERIAL | TOTAL LABOR | TOTAL COST | % OF TOTAL |
|---|---|---|---|---|---|
| **CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES - NATURAL GAS PEAKING BOILER SCENARIO** | | $7,011,250 | $2,190,750 | $9,202,000 | 57.04% |
| **SUBTOTAL - ELECTRICAL UPGRADES SUMMAR\`** | | | | **$9,202,000** | **100.00%** |
| GENERAL CONDITIONS | 15.0% | | | $1,380,300 | 8.56% |
| OVERHEAD AND PROFIT | 10.0% | | | $1,058,230 | 6.56% |
| DESIGN CONTINGENCY | 20.0% | | | $2,328,106 | 14.43% |
| BID CONTINGENCY | 5.0% | | | $698,432 | 4.33% |
| PHASING | 10.0% | | | $1,466,707 | 9.09% |
| **TOTAL - ELECTRICAL UPGRADES SUMMARY** | | | | **$16,133,775** | **100.00%** |
| **CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES - PEAKING ELECTRIC BOILERS - ADD ALTERNATE** | | $9,818,750 | $2,739,150 | $12,557,900 | 32.92% |
| GENERAL CONDITIONS | 15.0% | | | $1,883,685 | 4.94% |
| OVERHEAD AND PROFIT | 10.0% | | | $1,444,159 | 3.79% |
| DESIGN CONTINGENCY | 20.0% | | | $3,177,149 | 8.33% |
| BID CONTINGENCY | 5.0% | | | $953,145 | 2.50% |
| PHASING | 10.0% | | | $2,001,604 | 5.25% |
| **TOTAL - ELECTRICAL UPGRADES - ADD ALTERNATE** | | | | **$22,017,640** | **57.71%** |

## ELECTRICAL UPGRADES DETAIL

| | | MATERIAL | | LABOR | | |
|---|---|---|---|---|---|---|
| DESCRIPTION | QUANTITY | UNIT PRICE | TOTAL | UNIT PRICE | TOTAL | TOTAL |
| **CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES** | | | | | | |
| **SUBSTATION 1 UPGRADES** | | | | | | |
| 34.5 kV overhead electrical distribution service feeder | 1,000 LF | $115 | $115,000 | $50 | $50,000 | $165,000 |
| Utility pole including cross arms, insulators, network protectors, earthwork, etc (assume [1] pole / 100 LF) | 10 EA | $12,500.00 | $125,000 | $7,500.00 | $75,000 | $200,000 |
| Below grade and conduit risers including trench excavation, concrete encasement, and backfill | 1 ALLOW | $18,750.00 | $18,750 | $18,750.00 | $18,750 | $37,500 |
| 34.5 kV outdoor unit substation including concrete pad and grounding | 1 EA | $1,250,000.00 | $1,250,000 | $50,000.00 | $50,000 | $1,300,000 |
| H-frame with air switches, NYPA metering, surge arrestors, and lightning protection | 1 ALLOW | $75,000.00 | $75,000 | $12,500.00 | $12,500 | $87,500 |
| 7.5 / 10 / 12.5 MVA transformer including concrete pad and grounding - 34.5 kV > 13.2 kV | 2 EA | $150,000.00 | $300,000 | $16,800.00 | $33,600 | $333,600 |
| 2000 amp 15 kV switchgear with main breaker, feeder breakers, and tie-breaker including concrete pad and grounding | 2 EA | $350,000.00 | $700,000 | $25,000.00 | $50,000 | $750,000 |
| Below grade feeder duct bank including [2] 6" conduits, [3] #500 15 kV MV-105, concrete encasement, excavation, and backfill | | | | | | |
| - Lee Hall | 2,000 LF | $250.00 | $500,000 | $125.00 | $250,000 | $750,000 |
| - Mackin Hall | 1,000 LF | $250.00 | $250,000 | $125.00 | $125,000 | $375,000 |
| - Littlepage Hall | 7,000 LF | $250.00 | $1,750,000 | $125.00 | $875,000 | $2,625,000 |
| - Riggs Hall | 3,000 LF | $250.00 | $750,000 | $125.00 | $375,000 | $1,125,000 |
| Medium voltage cable terminations and testing | 1 LS | $15,000.00 | $15,000 | $27,500.00 | $27,500 | $42,500 |
| Site restoration | 1 ALLOW | $50,000.00 | $50,000 | $50,000.00 | $50,000 | $100,000 |
| Miscellaneous electrical (shutdowns, switchovers, temp power, etc) | 1 EA | $12,500.00 | $12,500 | $12,500.00 | $12,500 | $25,000 |
| **BUILDING SERVICE UPGRADES** | | | | | | |
| **LEE HALL** | | | | | | |
| 7500 kVA transformer including primary and secondary feeders, concrete pad, and grounding | 1 EA | $100,000.00 | $100,000 | $15,000.00 | $15,000 | $115,000 |
| 5 kV switchgear including concrete pad and grounding | 1 EA | $250,000.00 | $250,000 | $27,300.00 | $27,300 | $277,300 |
| 300 kVA replacement transformer including removals, primary and secondary feeders, concrete pad, and grounding | 1 EA | $50,000.00 | $50,000 | $12,500.00 | $12,500 | $62,500 |

## ELECTRICAL UPGRADES DETAIL

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| **MACKIN HALL** | | | | | | |
| 1500 kVA replacement transformer including removals, primary and secondary feeders, concrete pad, and grounding | 1 EA | $75,000.00 | $75,000 | $22,500.00 | $22,500 | $97,500 |
| 2000 amp 480v replacement switchboard including removals, primary and secondary feeders, concrete pad, and grounding | 1 EA | $150,000.00 | $150,000 | $16,800.00 | $16,800 | $166,800 |
| **LITTLEPAGE HALL** | | | | | | |
| 2500 kVA replacement transformer including removals, primary and secondary feeders, concrete pad, and grounding | 1 EA | $175,000.00 | $175,000 | $31,500.00 | $31,500 | $206,500 |
| 3000 amp 480v replacement switchboard including removals, primary and secondary feeders, concrete pad, and grounding | 1 EA | $225,000.00 | $225,000 | $21,000.00 | $21,000 | $246,000 |
| **RIGGS HALL** | | | | | | |
| 1500 kVA replacement transformer including removals, primary and secondary feeders, concrete pad, and grounding | 1 EA | $75,000.00 | $75,000 | $22,500.00 | $22,500 | $97,500 |
| 2000 amp 480v replacement switchboard including removals, primary and secondary feeders, concrete pad, and grounding | 1 EA | $0.00 | $0 | $16,800.00 | $16,800 | $16,800 |
| **TOTAL CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES** | | | **$7,011,250** | | **$2,190,750** | **$9,202,000** |

**CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES - ADD ALTERNATE**

| DESCRIPTION | QUANTITY | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|
| **SUBSTATION 1 UPGRADES** | | | | | | |
| 115 kV overhead electrical distribution service feeder | 1,000 LF | $135 | $135,000 | $50 | $50,000 | $185,000 |
| Below grade and conduit risers including trench excavation, concrete encasement, and backfill | 1 ALLOW | $18,750.00 | $18,750 | $18,750.00 | $18,750 | $37,500 |
| 115 kV outdoor unit substation including concrete pad and grounding | 1 EA | $1,500,000.00 | $1,500,000 | $75,000.00 | $75,000 | $1,575,000 |
| 3-gang operated 115 kV disconnect switches, [2] class circuit switchers, surge arrestors, metering, and structures | 1 ALLOW | $200,000.00 | $200,000 | $50,000.00 | $50,000 | $250,000 |
| 15 / 20 / 25 MVA transformer including concrete pad and grounding - 115 kV > 13.2 kV | 2 EA | $225,000.00 | $450,000 | $21,000.00 | $42,000 | $492,000 |
| 2000 amp 15 kV switchgear with main breaker, feeder breakers, and tie-breaker including concrete pad and grounding | 2 EA | $350,000.00 | $700,000 | $25,000.00 | $50,000 | $750,000 |

**ELECTRICAL UPGRADES DETAIL**

| DESCRIPTION | QUANTITY | | MATERIAL UNIT PRICE | MATERIAL TOTAL | LABOR UNIT PRICE | LABOR TOTAL | TOTAL |
|---|---|---|---|---|---|---|---|
| Below grade feeder duct bank including [2] 6" conduits, [3] #500 15 kV MV-105, concrete encasement, excavation, and backfill | | | | | | | |
| - Lee Hall - [2] sets | 4,000 | LF | $250.00 | $1,000,000 | $125.00 | $500,000 | $1,500,000 |
| - Mackin Hall | 1,000 | LF | $250.00 | $250,000 | $125.00 | $125,000 | $375,000 |
| - Littlepage Hall | 7,000 | LF | $250.00 | $1,750,000 | $125.00 | $875,000 | $2,625,000 |
| - Riggs Hall | 3,000 | LF | $250.00 | $750,000 | $125.00 | $375,000 | $1,125,000 |
| Medium voltage cable terminations and testing | 1 | LS | $15,000.00 | $15,000 | $27,500.00 | $27,500 | $42,500 |
| Site restoration | 1 | ALLOW | $50,000.00 | $50,000 | $50,000.00 | $50,000 | $100,000 |
| Miscellaneous electrical (shutdowns, switchovers, temp power, etc) | 1 | EA | $12,500.00 | $12,500 | $12,500.00 | $12,500 | $25,000 |
| **SUBSTATION 2 UPGRADES** | | | | | | | |
| Extend fencing at substation location | 1 | ALLOW | $12,500 | $12,500 | $12,500 | $12,500 | $25,000 |
| 2500 / 3125 kVA replacement transformer including removals, primary and secondary feeders, concrete pad, and grounding | 1 | EA | $200,000.00 | $200,000 | $27,300.00 | $27,300 | $227,300 |
| Below grade feeder duct bank including [2] 6" conduits, [3] #500 15 kV MV-105, concrete encasement, excavation, and backfill - Laker Hall | 1,000 | LF | $250.00 | $250,000 | $125.00 | $125,000 | $375,000 |
| **BUILDING SERVICE UPGRADES** | | | | | | | |
| **LEE HALL** | | | | | | | |
| 7500 kVA transformer including primary and secondary feeders, concrete pad, and grounding | 1 | EA | $100,000.00 | $100,000 | $15,000.00 | $15,000 | $115,000 |
| 5 kV switchgear including concrete pad and grounding | 1 | EA | $250,000.00 | $250,000 | $27,300.00 | $27,300 | $277,300 |
| 300 kVA replacement transformer including removals, primary and secondary feeders, concrete pad, and grounding | 1 | EA | $50,000.00 | $50,000 | $12,500.00 | $12,500 | $62,500 |
| **MACKIN HALL** | | | | | | | |
| 2500 kVA replacement transformer including removals, primary and secondary feeders, concrete pad, and grounding | 1 | EA | $175,000.00 | $175,000 | $31,500.00 | $31,500 | $206,500 |
| 4000 amp 480v replacement switchboard including removals, primary and secondary feeders, concrete pad, and grounding | 1 | EA | $325,000.00 | $325,000 | $33,600.00 | $33,600 | $358,600 |
| **LITTLEPAGE HALL** | | | | | | | |
| 3750 kVA replacement transformer including removals, primary and secondary feeders, concrete pad, and grounding | 1 | EA | $225,000.00 | $225,000 | $35,700.00 | $35,700 | $260,700 |

**ELECTRICAL UPGRADES DETAIL**

| | | MATERIAL | | LABOR | | |
|---|---|---|---|---|---|---|
| DESCRIPTION | QUANTITY | UNIT PRICE | TOTAL | UNIT PRICE | TOTAL | TOTAL |
| 5000 amp 480v replacement switchboard including removals, primary and secondary feeders, concrete pad, and grounding | 1 EA | $400,000.00 | $400,000 | $37,800.00 | $37,800 | $437,800 |
| **RIGGS HALL** | | | | | | |
| 2500 kVA replacement transformer including removals, primary and secondary feeders, concrete pad, and grounding | 1 EA | $175,000.00 | $175,000 | $31,500.00 | $31,500 | $206,500 |
| 4000 amp 480v replacement switchboard including removals, primary and secondary feeders, concrete pad, and grounding | 1 EA | $325,000.00 | $325,000 | $33,600.00 | $33,600 | $358,600 |
| **LAKER HALL** | | | | | | |
| 2500 kVA replacement transformer including removals, primary and secondary feeders, concrete pad, and grounding | 1 EA | $175,000.00 | $175,000 | $31,500.00 | $31,500 | $206,500 |
| 4000 amp 480v replacement switchboard including removals, primary and secondary feeders, concrete pad, and grounding | 1 EA | $325,000.00 | $325,000 | $33,600.00 | $33,600 | $358,600 |
| **TOTAL CAMPUS ELECTRICAL INFRASTRUCTURE UPGRADES - ADD ALTERNA** | | | **$9,818,750** | | **$2,739,150** | **$12,557,900** |