State University of New York at Oswego Community Heat Pump Study

Final Report | Report Number 24-03 | November 2023

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State University of New York at Oswego Community Heat Pump Study

Final Report

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Notice

Abstract

The State University of New York at Oswego desires carbon neutrality by 2050, which requires an electrified heating solution. A community geothermal heat pump loop was explored for a cluster of five buildings and compared against both the existing buildings and code-compliant individual heat pump systems. Each option was investigated for feasibility with a utility analysis, block load energy modeling, and life cycle cost analysis. Additionally, incentive opportunities, regulatory roadblocks, and complementary technologies were explored for a holistic evaluation of the proposed system. Ultimately, a community geothermal system as proposed would reduce the carbon emissions of the included buildings by an estimated 52% and provides a framework for the electrification of the campus heating systems.

Keywords

community heat pumps; district thermal network; ground source heat pumps; geothermal; decarbonization; electrification

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Acronyms and Abbreviations

A	ampere
AC	air conditioning
AHJ	authority having jurisdiction
AHU	air handling unit
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
Btu	British thermal unit
CBECS	Commercial Building Energy Consumption Survey
CDG	community distributed generation
CESIR	Coordinated Electric System Interconnection Review
CHW	chilled water
CO_2	carbon dioxide
COP	coefficient of performance
CT	cooling tower
CW	condenser water
DCFC	direct-current fast charger
DOAS	dedicated outdoor air system
DWH	domestic water heater
DX	direct expansion
cfm	cubic feet per minute
CMU	concrete masonry unit
CRAC	computer room air conditioning
ECCCNYS	Energy Conservation Construction Code of New York State
EER	energy efficiency ratio
ERU	energy recovery unit
ERW	energy recovery wheel
EUI	energy utilization index
EV	electric vehicle
FCU	fan coil unit
°F	degrees Fahrenheit
ft	foot
gpm	gallons per minute
GSHP	ground source heat pump
HDPE	high-density polyethylene
HP	horsepower
HSPF	heating seasonal performance factor
HVAC	heating, ventilation, and air conditioning
HW	hot water

IFC	International Fire Code
in	inch
kBtu	thousand British thermal units
kW	kilowatt
kWh	kilowatt hour
lb CO_2e	pounds of carbon dioxide equivalent (greenhouse gas emissions)
LCCA	life-cycle cost analysis
LED	Light Emitting Diode
MAUs	makeup air units
mmBtu	million British thermal units
mBh	thousand British thermal unit per hour
MWh	megawatt hours
NFPA	National Fire Protection Association
NPV	net present value
NYSERDA	New York State Energy Research and Development Authority
NYSIR	New York State Interconnection Requirements
PUE	power usage effectiveness
PV	photovoltaic
RTU	rooftop unit
SEMA	School of Communication, Media and the Arts
SEER	seasonal energy efficiency ratio
SEQR	State Environmental Quality Review Act
SHGC	solar heat gain coefficient
sq. ft	square foot
SUCF	State University Construction Fund
UL	Underwriter’s Laboratory
V	Volt
VAV	variable air volume
VDER	value of distributed energy resources
VFD	variable frequency drive
VRF	variable refrigerant flow
W	watt
W-A	water-to-air
W-W	water-to-water
WC	water cooled
WSHP	water source heat pump

Executive Summary

The State University of New York (SUNY) at Oswego, located in Oswego, NY, is committed to sustainability and aims to become carbon neutral by 2050. To realize this goal, the campus must transition away from a fossil fuel campus plant by utilizing reduced carbon technologies for heating buildings. SUNY Oswego hopes to create a collection of community geothermal heat pump systems via a replicable design strategy. As a college campus, many buildings are in close proximity, which makes the school a good candidate for a community-style geothermal approach.

M/E Engineering, P.C., through the New York State Energy Research and Development Authority (NYSERDA) Community Heat Pump Pilot Program, has evaluated a community geothermal system for a four-building cluster on the SUNY Oswego Campus:

- Cooper Dining Hall
- Culkin Hall
- Funnelle Hall
- Hart Hall

A high-level budget cost estimate, whole-building block load energy modeling, and a life-cycle cost analysis has been completed. Furthermore, additional renewable technologies that may be incorporated into the project have been reviewed, plus potential incentive opportunities and regulatory roadblocks. The results of the analysis are summarized below:

Table ES-1. Budget Cost Estimate for SUNY Oswego Heat Pump Study–Options Summary

Design Option	Construction Cost	Estimated Incentives	Total First Cost	Annual Maintenance	Annual Energy Costs	Total Annual Costs	Annual Carbon (lb CO_2e)	25-Year NPV ($)
Baseline System: Replace systems in kind	$2,114,596	$0	**$2,114,596**	$9,682	$550,390	**$560,072**	**3,222,031**	($12,710,669)
Code-Compliant System: Individual building heat pumps	$15,235,508	$722,912	**$14,512,596**	$15,716	$570,365	**$586,081**	**1,617,806**	($25,384,114)
Proposed System: Community heat pumps	$13,306,349	$4,785,632	**$8,520,717**	$15,316	$539,776	**$555,092**	**1,546,657**	($18,698,228)

1 Project Rationale

The State University of New York (SUNY) at Oswego is committed to sustainability, and in 2012, published their most recent Climate Action Plan which includes a commitment to achieve carbon neutrality by 2050. One component of their five-faceted approach to climate neutrality is to reduce fossil fuel use through the development of campus geothermal systems. Geothermal or ground source heat pump (GSHP) systems have been in use for some time, but technological advances and increased interest in carbon-efficient technologies has improved the feasibility and benefits of a ground source heat pump system installation. The improvement of water-to-water (W-W) heat pumps has especially simplified the integration of geothermal systems into existing buildings, which often include chilled and hot water heating in the northern climate zones.

Geothermal heat pumps provide carbon reduction in two ways: energy efficiency and electrification. First, heat pump technology is significantly more energy efficient than natural gas systems. Heat pumps utilize the refrigeration cycle, with high-efficiency refrigerant and compressors, to provide heating or cooling to water loops or directly to space supply air. Water (or ground) source heat pumps utilize a water loop to either cool or warm the compressor as required for the heat pump loads. Geothermal heat pump systems, in particular, provide enhanced energy efficiency by taking advantage of the constant moderate temperature of the earth to maintain the temperatures of the heat pump loop, pumping water through wells drilled deep below grade.

In a typical natural gas heating situation, the expected maximum thermal efficiency is approximately 98%, with a code minimum efficiency of 80% or less in a campus plant. With geothermal heat pumps, it is possible to achieve a heating seasonal performance factor (HSPF) of up to 13.5, which equates to an overall efficiency of 400%. Even code-minimum ground source heat pumps have a full-load coefficient of performance (COP) of 2.5, or 250% efficiency.

The energy efficiency of a GSHP system is enhanced by the ability to “share” energy through the heat pump water loop. When areas with differing loads are both serviced with heat pumps, heat removed from one area (in cooling mode) can be transferred as “free” energy to add heat to another area (in heating mode). This energy sharing can contribute an estimated additional 30% of energy savings.

Secondly, heat pumps utilize electricity for heating, instead of fossil fuels. Electricity, which is provided by an increasingly cleaner electric grid, provides energy with a continually reduced carbon footprint. The New York State electric grid is already one of the cleanest in the nation and is working toward being 100% fossil fuel free by 2040. Electrified heating systems can be directly offset by on- or off-site solar panels or wind-harvesting technologies as well.

The use of community heat pump systems provide an additional opportunity for energy savings and carbon reduction. Community heat pump systems utilize a common loop as a heat source/sink and in the case of geothermal, the wellfield is applied. All buildings tied into the loop can take advantage of the energy sharing on the heat pump loop, both individually inside the buildings and collectively on the campus loop. In this way, building types with differing loads can obtain the benefits of heat pump energy sharing among other buildings, even when the loads within the building do not differ significantly. Because of the energy sharing, a community wellfield can be downsized from what would be required for each building individually as well.

Because of SUNY Oswego's commitment to carbon neutrality, as well as the advantages of a community heat pump system, several buildings were selected to explore the feasibility for an evaluation of a community heat pump system:

- Cooper Dining Hall
- Culkin Hall
- Funnelle Hall
- Hart Hall

This cluster of buildings is well-suited for a community style heat pump approach for several reasons:

1. The buildings are of a variety of types with differing occupancies, and do not all experience t heir individual heating and cooling loads/peaks simultaneously. This permits load-sharing to improve energy efficiency, and the combined geothermal wellfield can be economically sized.
2. The cluster is adjacent to a previously studied building, Hewitt Hall, which is currently undergoing construction for a geothermal heat pump system. Once complete, Hewitt Hall will house the School of Communication, Media, and the Arts. The associated broadcast, studio, and lab equipment creates high internal loads and requires cooling throughout the year. The accompanying rejection of thermal energy into the heat pump loop provides a complementary heat source for the other community buildings during the heating season.
3. The four buildings are relatively in close proximity, so a heating/cooling loop can be economically installed.

4. SUNY Oswego owns all of the buildings, property, and roadways, and maintains the area encompassing this proposed community heat pump area. Barriers to installation (such as required permissions and variances) will be minimal.

SUNY Oswego hopes to create a collection of community geothermal heat pump systems via a replicable design strategy. Should the university choose to implement the recommendations in the report, this initial heat pump community can be used as a prototype at other locations throughout the campus.

2 Existing Conditions: Utility Baseline

2.1 Site Overview

Founded in 1861, the State University of New York at Oswego is located in Oswego, NY. The public college is home to 7,000 students, with over 180 majors, minors, and advanced degree programs. The buildings in this study are located on the university's main campus, near the intersection of Sweet Road and West End Avenue.

2.2 Establishing a Baseline

Existing utility data for the project buildings was reviewed and analyzed, in order to better understand the building loads and to calibrate the energy models. This establishes a baseline for energy savings calculations and provides estimates for more reliable energy savings. Generally, modeling program defaults based on occupancy for schedules, plug loads, etc., were used to calibrate the models, and modified as required to match the known information regarding the building.

2.3 General Building Information

The four buildings analyzed are in a cluster on the SUNY Oswego campus. Table 1 has the general data for each of the facilities.

Table 1. Building Summary

Building Name	Use	Area (sf)	Building Age	HVAC System Age	Current Heating System	Current Cooling System	Current Domestic Hot Water System	Building Condition (Excellent, Good, Fair, Poor)	HVAC Condition (Excellent, Good, Fair, Poor)	Certified Historic Building (Yes/No)
Cooper Dining Hall	Student Center (dining, meeting rooms, etc.)	24,796	2015	2015	Steam from central plant w/ steam to water heat exchanger, including radiant loop	Chilled Water	Steam to DHW heat exchanger	Fair	Excellent	No
Culkin Hall	Office (administration building)	59,611	1967	2011 CHW upgrades, remainder original	Steam from central plant w/ steam to water heat exchanger, including radiant loop and AHUs	Chilled Water	Steam to DHW heat exchanger	Fair	Excellent	No
Funnelle Hall	Dormitory	40,545	1967	2000	Steam from central plant w/ steam to water heat exchanger, including radiant loop	None	Steam to DHW heat exchanger	Fair	Fair	No
Hart Hall	Dormitory	38,616	1967	2021	Steam from central plant w/ steam to water heat exchanger;, including radiant loop; Corridor MAUs	None (air cooled bathroom and data closets)	Steam to DHW heat exchanger	Fair	Fair	No

Hewitt Hall was not studied in depth in this project, but the geothermal heat pump loads from the Construction Documents submission were previously calculated for the NYSERDA New Construction Program and are included in this community wellfield.

Electricity and natural gas is supplied to the campus primarily through the main site electrical and natural gas services. Some buildings are provided with electrical submetering, but natural gas is not broken out individually. For each building, a limited amount of metered electrical data was available. Assumed consumption was extrapolated based on the data provided combined with weather data and the typical operation of the building type.

The overall utility consumption from the main campus meters is as follows:

Table 2. Main Campus Meter—Utility Consumption

Statement Date	Electricity					Natural Gas					Total Energy			
	Usage (kWh)	Delivery Cost ($)	Supply Cost ($)	Total Cost ($)	Rate ($/kWh)	Usage (therm)	Delivery Cost ($)	Supply Cost ($)	Total Cost ($)	Rate ($/therm)	Usage (mmBtu)	Cost ($)	Carbon Emissions (lb CO_2e)	EUI (kBtu/sf)
Jul-21	1,301,504	$21,694	$133,635	$155,329	$0.119	62,997	$6,985	$22,134	$29,119	$0.462	10,742	$184,448	1,039,260	5.4
Aug-21	1,597,417	$25,081	$194,378	$219,459	$0.137	69,184	$7,543	$27,240	$34,783	$0.503	12,370	$254,242	1,180,375	6.2
Sep-21	1,487,072	$24,456	$144,957	$169,413	$0.114	97,682	$10,124	$41,412	$51,537	$0.528	14,844	$220,950	1,488,103	7.4
Oct-21	1,281,677	$23,791	$127,141	$150,932	$0.118	124,361	$12,422	$71,112	$83,533	$0.672	16,810	$234,465	1,752,473	8.4
Nov-21	1,397,311	$24,944	$82,501	$107,445	$0.077	238,758	$22,225	$144,452	$166,677	$0.698	28,645	$274,122	3,117,518	14.3
Dec-21	1,514,516	$26,717	$33,806	$60,523	$0.040	268,981	$24,815	$142,054	$166,869	$0.620	32,067	$227,392	3,498,285	16.1
Jan-22	1,338,026	$18,661	$199,414	$218,075	$0.163	372,626	$34,873	$142,759	$177,632	$0.477	41,829	$395,707	4,669,696	20.9
Feb-22	1,372,565	$21,956	$125,657	$147,614	$0.108	331,740	$32,262	$202,639	$234,901	$0.708	37,859	$382,514	4,199,446	18.9
Mar-22	1,483,070	$21,340	$79,558	$100,898	$0.068	293,781	$28,806	$128,884	$157,690	$0.537	34,440	$258,588	3,781,083	17.2
Apr-22	1,403,386	$23,666	$75,351	$99,017	$0.071	226,710	$22,699	$117,389	$140,089	$0.618	27,461	$239,105	2,977,995	13.7
May-22	1,174,352	$18,541	*$95,489*	$114,030	$0.097	115,070	$12,498	*$64,112*	$76,611	$0.666	15,515	$190,641	1,618,858	7.8
Jun-22	1,105,835	$16,388	*$84,398*	$100,786	$0.091	45,732	$5,630	*$28,881*	$34,511	$0.755	8,347	$135,297	791,845	4.2
Total	16,456,731	$267,234	$1,376,286	$1,643,520	$0.100	2,247,622	$220,882	$1,133,069	$1,353,951	$0.602	280,929	$2,997,471	30,114,937	140.6

****Green italic text*** indicates assumed utility data as described.

2.4 Cooper Dining Hall

Cooper Dining Hall is a community building, containing a kitchen, servery, dining area, and fitness center. It operates 6:00 a.m.–11:00 p.m. daily, with reduced weekend operation, and is closed in the summer and over breaks. The overall gross square footage is 33,564 square feet (sq. ft.) and includes two floors and a mezzanine. The gathering spaces are cooled, but the kitchen is not.

The overall energy utilization index (EUI) of the building is 209.4 thousand British thermal units per square foot per year (kBtu/sf/yr), which is less than the 325.6 for a typical restaurant per the Commercial Building Energy Consumption Survey (CBECS) as published by Energy Star® Portfolio Manager. However, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers Standard 100-2018 Energy and Emissions Building Performance Standard for Existing Buildings (ASHRAE 100) goal for an efficient restaurant in the 5A climate is 179 EUI, which suggests room for improvement in the building.

The provided electricity data shows relatively flat usage throughout the year, which indicates that the consumption is mainly process-driven, such as for lighting and cooking. Natural gas was assumed based largely on weather data plus the ASHRAE 100 fuel EUI goals and adjusted for building inefficiencies.

Assumed utility consumption is as follows:

Figure 1. Cooper Dining Hall—Utility Consumption (Electricity)

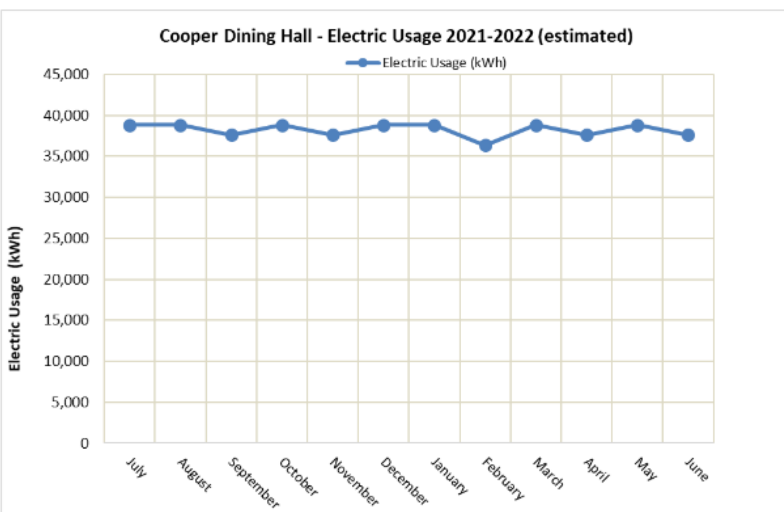


Figure 2. Cooper Dining Hall—Utility Consumption (Natural Gas)

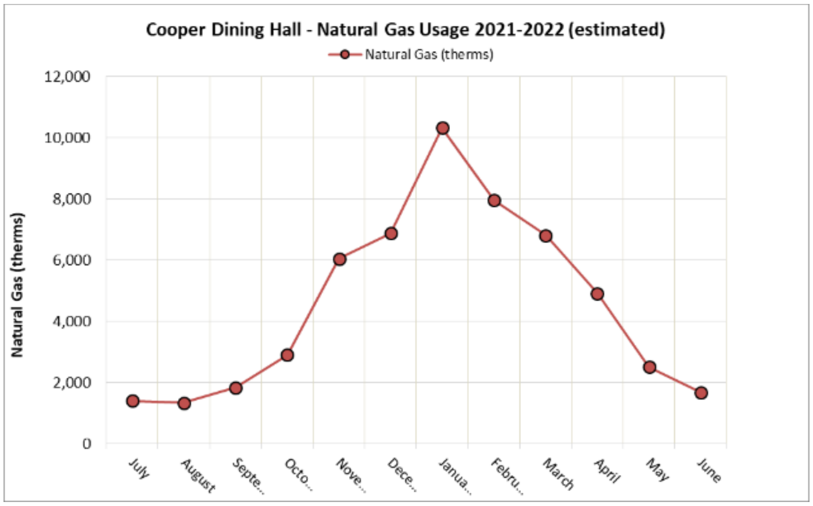


Table 3. Cooper Dining Hall—Utility Bills

Month	Electricity		Natural Gas	Total Energy			
	Metered Consumption (kWh)	Assumed Consumption (kWh)	Assumed Consumption (therm)	Usage (mmBtu)	Cost ($)	Carbon Emissions (lb CO_2e)	EUI (kBtu/sf)
Jul-21	0	38,846	1,405	273	$4,726	25,458	8.1
Aug-21	0	38,846	1,339	267	$4,686	24,689	7.9
Sep-21	0	37,593	1,841	312	$4,863	30,264	9.3
Oct-21	0	38,846	2,902	423	$5,628	42,968	12.6
Nov-21	0	37,593	6,054	734	$7,401	79,551	21.9
Dec-21	25,015	38,846	6,876	820	$8,022	89,463	24.4
Jan-22	38,753	38,846	10,324	1,165	$10,098	129,788	34.7
Feb-22	43,255	36,340	7,956	920	$8,422	101,506	27.4
Mar-22	40,526	38,846	6,819	814	$7,987	88,790	24.3
Apr-22	40,430	37,593	4,924	621	$6,721	66,334	18.5
May-22	29,652	38,846	2,509	383	$5,391	38,373	11.4
Jun-22	38,655	37,593	1,676	296	$4,764	28,336	8.8
Jul-22	33,181	0	0	0	$0	0	0.0
Total	289,466	458,635	54,624	7,028	$78,709	745,520	209.4

2.5 Culkin Hall

Standing nine stories tall including the basement and penthouses, the 63,591 sq. ft. Culkin Hall is an office building. Culkin houses the university administration and operates year-round with typical office hours of approximately 7:00 a.m. to 6:00 p.m. Monday through Friday. The entire building is served by a two-pipe changeover fan coil system.

The overall EUI of the building is 113.2 kBtu/sf/yr, which is high for an office building. The CBECS indicates an average EUI of 52.9, and the ASHRAE 100-2018 goal is 48 EUI. This suggests an inefficient or poorly controlled heating and cooling system in the building.

As expected, the provided electricity data shows the electrical load peaking in the summer months, due to building cooling. Natural gas was assumed to follow weather as well, but with proportionally the same inefficiencies for the fuel EUI when compared to the ASHRAE 100 suggested electrical EUI.

Assumed utility consumption is as follows:

Figure 3. Culkin Hall—Utility Consumption (Electricity)

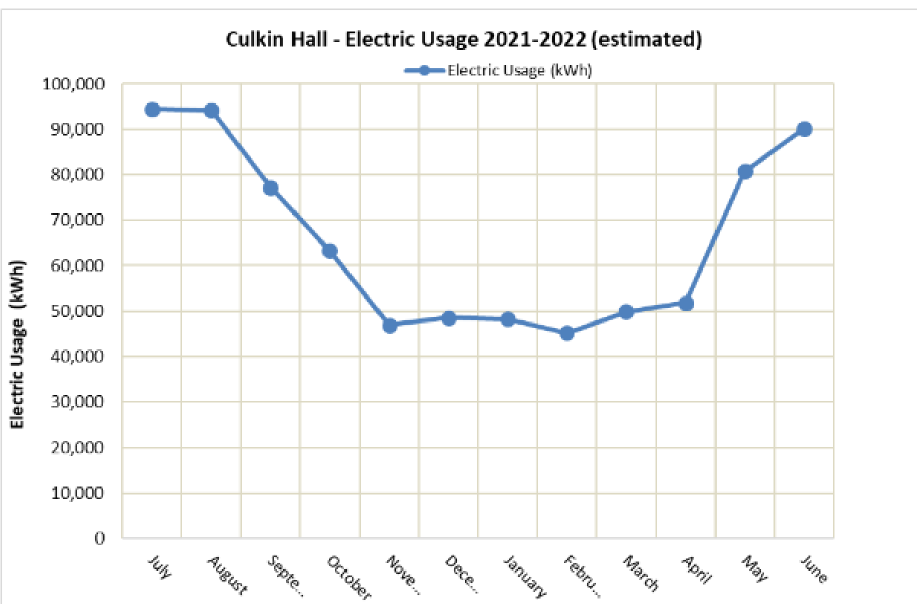


Figure 4. Culkin Hall—Utility Consumption (Natural Gas)

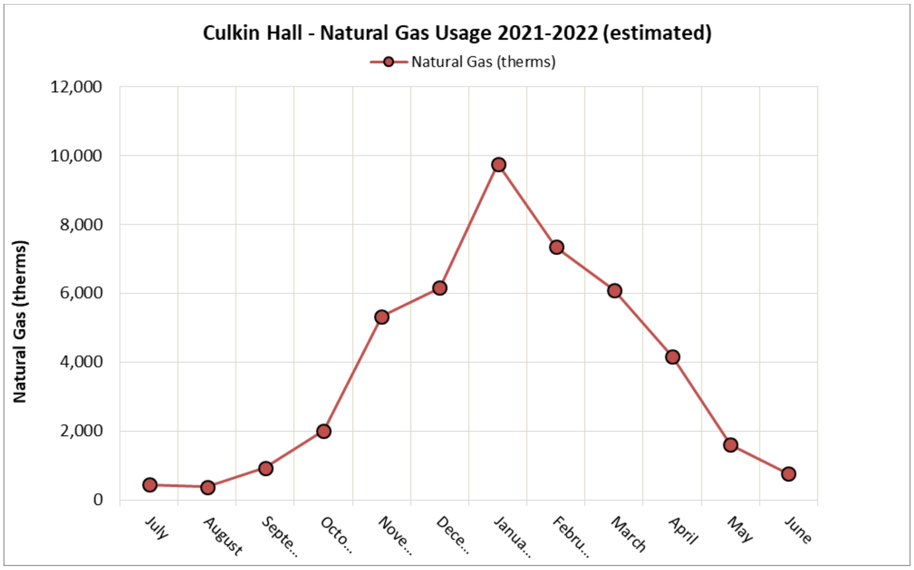


Table 4. Culkin Hall—Utility Bills

Month	Electricity		Natural Gas	Total Energy			
	Metered Consumption (kWh)	Assumed Consumption (kWh)	Assumed Consumption (therm)	Usage (mmBtu)	Cost ($)	Carbon Emissions (lb CO_2e)	EUI (kBtu/sf)
Jul-21	0	94,493	449	367	$9,708	27,208	5.8
Aug-21	0	94,130	381	359	$9,630	26,322	5.7
Sep-21	0	77,192	937	357	$8,273	28,889	5.6
Oct-21	0	63,257	2,011	417	$7,529	38,216	6.6
Nov-21	0	46,945	5,331	693	$7,900	73,271	10.9
Dec-21	0	48,571	6,156	781	$8,559	83,300	12.3
Jan-22	0	48,228	9,752	1,140	$10,691	125,281	17.9
Feb-22	0	45,253	7,348	889	$8,946	96,465	14.0
Mar-22	0	49,886	6,097	780	$8,655	82,904	12.3
Apr-22	4,468	51,802	4,153	592	$7,675	60,613	9.3
May-22	68,299	80,781	1,601	436	$9,032	37,493	6.9
Jun-22	93,082	90,215	765	384	$9,470	29,903	6.0
Jul-22	95,912	0	0	0	$0	0	0.0
Total	**261,762**	**790,754**	**44,981**	**7,197**	**$106,068**	**709,863**	**113.2**

2.6 Funnelle Hall

Recently renovated, the Funnelle residence hall heating, ventilation and air-conditioning (HVAC) was upgraded to improve energy efficiency and reduce campus steam consumption. The building stands at 12 stories, including a basement and two penthouse levels for a total of 114,365 sq. ft. Funnelle utilizes energy recovery in the dedicated outdoor air systems (DOAS), but only data rooms are cooled in the building. The residence hall is generally closed to students during the summer, but is occasionally open for conferences.

The provided electricity data suggests exceptionally low electricity consumption. The ASHRAE 100 electric EUI goal is 25, and the extrapolated EUI based on the metered data is 11.5 EUI, which suggests a less than fully occupied building. In fact, Funnelle was under renovation in 2021, and likely had a reduced occupancy throughout the year. The electricity consumption was adjusted to reflect an assumed 50% occupant reduction for a more reasonable (but still low) electric EUI of 18.3. For a dormitory building, the CBECS shows an average of 57.9 kBtu/sf, and the ASHRAE 100 goal is 65. With the adjusted usage, Funnelle has an overall EUI of 52.4.

As a heating-only building, both natural gas and electricity are expected to peak in winter. The natural gas consumption load profile was determined based upon weather data, using the fuel EUI goal of ASHRAE 100 as a baseline, adjusted for the efficiencies of the heat recovery and campus steam system.

Assumed utility consumption is as follows:

Figure 5. Funnelle Hall—Utility Consumption (Electricity)

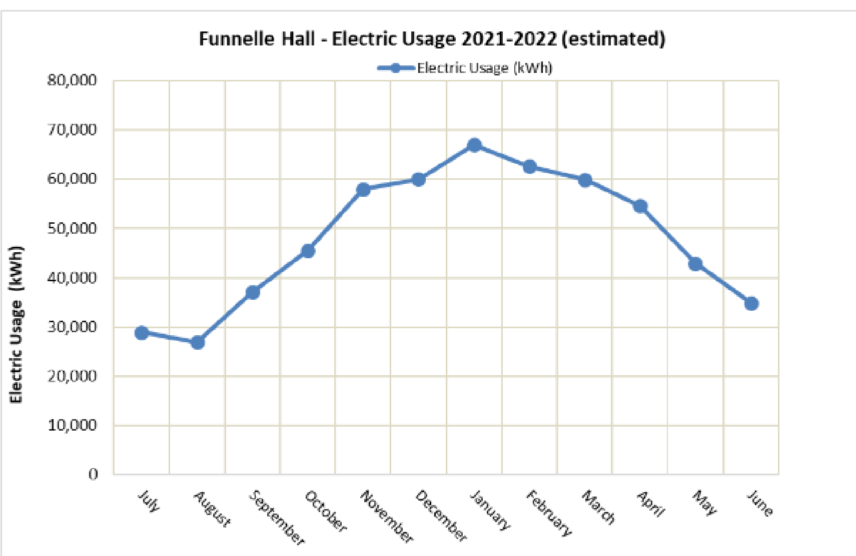


Figure 6. Funnelle Hall—Utility Consumption (Natural Gas)

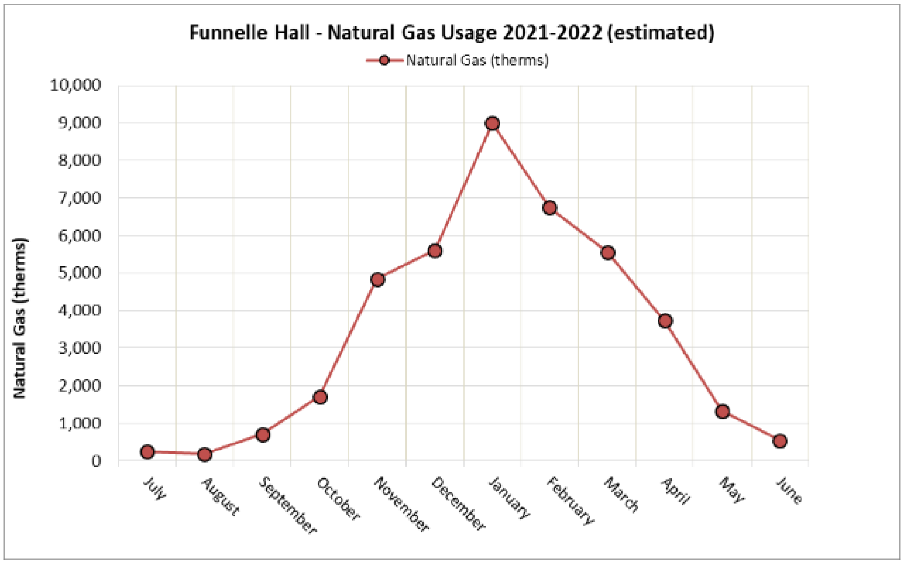


Table 5. Funnelle Hall—Utility Bills

Month	Electricity		Natural Gas	Total Energy			
	Metered Consumption (kWh)	Assumed Consumption (kWh)	Assumed Consumption (therm)	Usage (mmBtu)	Cost ($)	Carbon Emissions (lb CO_2e)	EUI (kBtu/sf)
Jul-21	0	28,912	244	123	$3,034	9,567	1.1
Aug-21	0	26,915	179	110	$2,796	8,348	1.0
Sep-21	0	37,062	708	197	$4,128	16,892	1.7
Oct-21	0	45,526	1,713	327	$5,579	30,615	2.9
Nov-21	0	57,990	4,844	682	$8,709	70,136	6.0
Dec-21	25,963	60,018	5,615	766	$9,376	79,622	6.7
Jan-22	39,271	66,984	8,999	1,128	$12,110	120,826	9.9
Feb-22	47,601	62,641	6,748	889	$10,321	93,483	7.8
Mar-22	46,465	59,877	5,558	760	$9,328	78,930	6.6
Apr-22	47,812	54,584	3,735	560	$7,701	56,370	4.9
May-22	24,568	42,902	1,327	279	$5,084	25,494	2.4
Jun-22	0	34,890	546	174	$3,813	14,494	1.5
Jul-22	0	0	0	0	$0	0	0.0
Total	**231,680**	**578,300**	**40,216**	**5,995**	**$81,980**	**604,777**	**52.4**

2.7 Hart Hall

Hart Hall is a very similar dormitory building to Funnelle, having nearly identical floor plates, although with differing modifications over the years. Like Funnelle, Hart was renovated with an energy recovery DOAS, but is a little less efficient since it was installed in the early 2000s. Hart has a total gross square footage of 114,365 and is majority heating-only.

The overall EUI of the building is 60 kBtu/sf/yr, which is comparable to both the 65 EUI ASHRAE 100 goal and the 57.9 CBECS average EUI for dormitories. The lack of air-conditioning and summer occupancy, combined with the energy recovery, helps to keep this building energy utilization low.

The annual load profile, like Funnelle, largely follows the heating hours. Natural gas was assumed in the same manner as Funnelle, combining the weather with the ASHRAE 100 goal fuel EUI and adjusting for the building HVAC efficiencies.

Assumed utility consumption is as follows:

Figure 7. Hart Hall—Utility Consumption (Electricity)

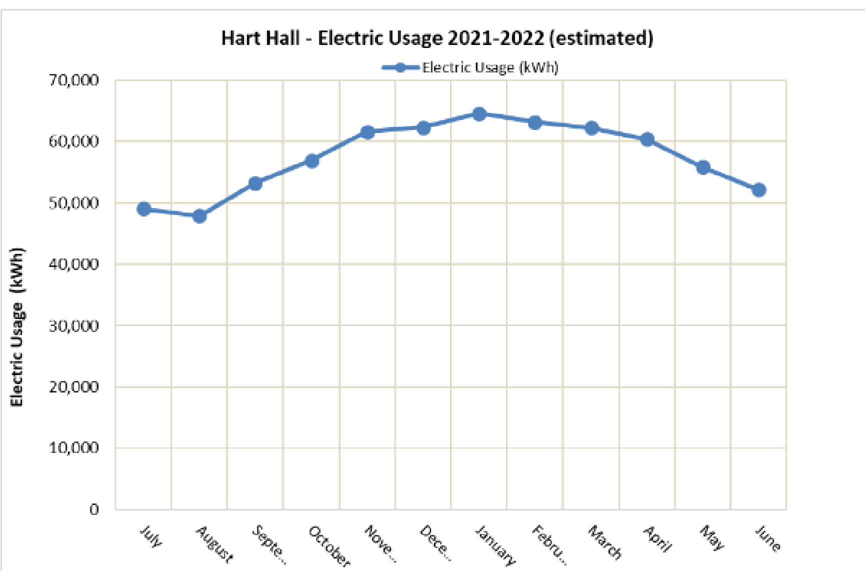


Figure 8. Hart Hall—Utility Consumption (Natural gas)

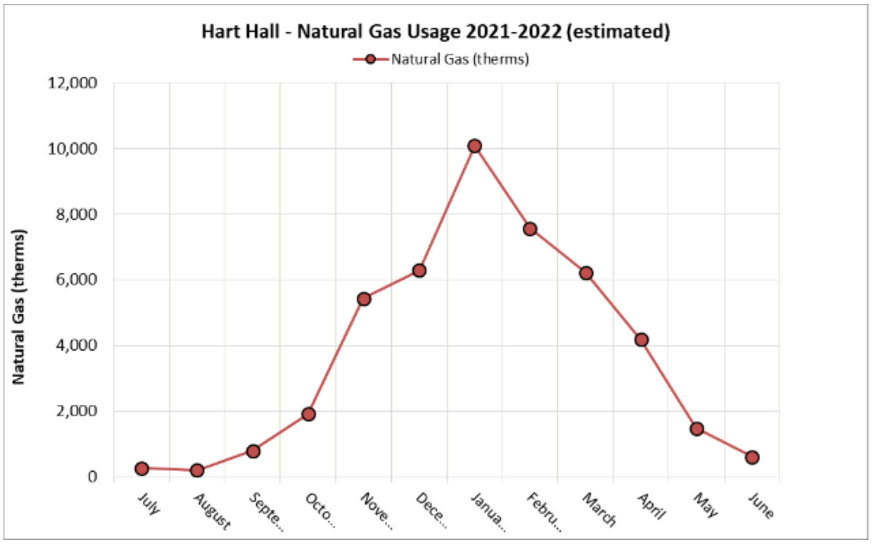


Table 6. Hart Hall—Utility Bills

Month	Electricity		Natural Gas	Total Energy			
	Metered Consumption (kWh)	Assumed Consumption (kWh)	Assumed Consumption (therm)	Usage (mmBtu)	Cost ($)	Carbon Emissions (lb CO_2e)	EUI (kBtu/sf)
Jul-21	0	49,088	273	195	$5,067	14,597	1.7
Aug-21	0	47,951	201	184	$4,910	13,488	1.6
Sep-21	0	53,244	794	261	$5,795	21,651	2.3
Oct-21	0	56,952	1,920	386	$6,844	35,688	3.4
Nov-21	0	61,647	5,429	753	$9,427	77,825	6.6
Dec-21	44,684	62,344	6,292	842	$10,017	88,090	7.4
Jan-22	58,075	64,626	10,085	1,229	$12,529	132,983	10.7
Feb-22	64,469	63,224	7,562	972	$10,869	103,144	8.5
Mar-22	67,041	62,296	6,229	836	$9,974	87,339	7.3
Apr-22	68,832	60,437	4,186	625	$8,557	63,003	5.5
May-22	57,423	55,856	1,488	339	$6,474	30,377	3.0
Jun-22	43,235	52,202	612	239	$5,582	19,287	2.1
Jul-22	36,336	0	0	0	$0	0	0.0
Total	**440,095**	**689,869**	**45,070**	**6,862**	**$96,046**	**687,472**	**60.0**

3 Existing Conditions: Energy Profile

3.1 Developing an Energy Profile

Each of the buildings in this study was modeled to establish a complete energy profile for the heat pump community. To ensure that the calculated load profiles represent the actual building, a calibrated model was attempted to bring the projected energy to within approximately 10% of the assumed consumption of each utility. Without fully metered electric and natural gas, it is challenging to accurately calibrate the buildings, due to a lack of data points to get a complete understanding of the building operation. The summarized modeling results are shown below:

Table 7. Summarized Baseline Modeling Results

Building Name	Existing Energy Consumption					Modeled Baseline Consumption					Model Calibration (% Difference)	
	Electric (kWh)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Electric (kWh)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Electric	Natural Gas
Cooper Dining Hall	458,635	54,624	7,028	745,520	$78,709	497,535	57,687	7,467	790,383	$84,439	8.5%	5.6%
Culkin Hall	790,754	44,981	7,197	709,863	$106,068	806,018	45,033	7,254	714,021	$107,624	1.9%	0.1%
Funnelle Hall	578,300	40,216	5,995	604,777	$81,980	535,419	36,962	5,524	556,749	$75,737	-7.4%	-8.1%
Hart Hall	689,869	45,070	6,862	687,472	$96,046	704,682	45,856	6,991	700,108	$97,999	2.1%	1.7%
Hewitt Hall	--	--	--	--	--	1,829,926	3,050	6,551	460,770	$184,591	--	--

3.2 Cooper Dining Hall

Cooper Dining Hall is a community building, providing meal service, a fitness room, and meeting space. Built in 1967, the exterior walls are largely uninsulated. Like most buildings on campus, the building is heated via campus steam, which is tied into a hot water (HW) heat exchanger. The water-cooled chiller, which provides chilled water (CHW) to the constant volume air-handling units, was replaced in 2015 with the cooling tower. Controls were updated as well. All pumps are constant speed, and the air handling units and fans appear to be original to the building. Perimeter baseboard supplements the air handlers, plus fan coils and unit heaters in select areas. Like the water for building heat, domestic hot water (DHW) is produced by campus steam with a heat exchanger. The corridor and fitness center lighting has been replaced with light-emitting diode (LED) lighting, but the remainder of the building has fluorescent fixtures. The commercial kitchen equipment is older and does not appear to have energy efficiency upgrades.

The building envelope is largely uninsulated, and a recommended energy efficiency measure to bring more value to a community heat pump system is improved insulation and air sealing. The exterior walls appear to be aging and likely allow outdoor air infiltration; combined with exterior insulation, less heat will be required to maintain comfortable building temperatures and can help to reduce the size of the heating equipment and geothermal wellfield.

Table 8. Cooper Dining Hall—Existing Conditions

Existing Conditions	
Building Type	Restaurant/Cafeteria
Square Footage	33564
Year Built	1967
Number of Floors	B, 1-7, P
Exterior Walls	3 in. granite veneer, air gap, 8 in. CMU
Roof	6 in. concrete, built up roof (R-30 assumed)
Window-Wall Ratio	18%
Window Type	Metal framed, double, no thermal break (U-0.9, SHGC-0.57)
HVAC System	Campus steam HW/WC chiller, CV AHUs
HVAC Efficiencies	85% boiler+15% losses, 0.52 kW/ton chiller, constant pumps
Lighting	Approximately equal to 2010 ECCCNYS

Table 9. Cooper Dining Hall—Baseline Modeling

Existing Energy Consumption					Modeled Baseline Consumption					Model Calibration (% Difference)	
Electric (kWh)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Electric (kWh)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Electric	Natural Gas
458,635	54,624	7,028	745,520	$78,709	497,535	57,687	7,467	790,383	$84,439	8.5%	5.6%

3.3 Culkin Hall

Culkin Hall serves as the college's administration building, housing offices that function year-round. The office area is conditioned with a two-pipe fan coil system with supplemental baseboard heating, which appear to be original to the building, as are the air handlers which provide ventilation. The constant volume air handlers are scheduled for ventilation generally 6:00 a.m. to 8:00 p.m. Heat is provided by a steam-to-water heat exchanger from the central plant and a water-cooled chiller (installed in approximately 2017) provides chilled water with a variable airflow cooling tower. The chiller is variable vane, but not variable speed, and all building loops have constant speed pumps. Domestic hot water is also generated via the central plant. Some of the building lighting has been upgraded to a Light Emitting Diode (LED), but most remains fluorescent.

With a two-pipe change-over arrangement, the system must be switched between heating and cooling during the shoulder seasons. Comfort conditions are often compromised when the weather fluctuates during these times. When a HVAC renovation is being considered, replacing the fan coil units with a four-pipe system would improve occupant comfort during those shoulder seasons.

Table 10. Culkin Hall—Existing Conditions

Existing Conditions	
Building Type	Office
Square Footage	63591
Year Built	1967
Number of Floors	1, 2, mezz
Exterior Walls	4 in. precast, 1 in. rigid, 4 in. CMU
Roof	2 in. deck, built up roof (R-20 assumed)
Window-Wall Ratio	47%
Window Type	Metal framed, double, no thermal break (U-0.9, SHGC-0.57)
HVAC System	Campus steam HW/WC chiller, 2-pipe FCU, CV AHUs
HVAC Efficiencies	85% boiler+15% losses, 0.673 kW/ton chiller, constant pumps
Lighting	Approximately equal to 2010 ECCCNYS

Table 11. Culkin Hall – Baseline Modeling

Existing Energy Consumption					Modeled Baseline Consumption					Model Calibration (% Difference)	
Electric (kWh)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Electric (kWh)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Electric	Natural Gas
790,754	44,981	7,197	709,863	$106,068	806,018	45,033	7,254	714,021	$107,624	1.9%	0.1%

3.4 Funnelle Hall

As a residence hall, Funnelle is occupied 24 hours per day, seven days per week, with extremely limited use in the summer months. It contains student lounges, laundry facilities, and a small number of offices as well as 208 dorm rooms with 400 beds. Because of the sparse occupancy during the summer, no cooling has been provided to most of the building, with the exception of a small air-cooled chiller for the data rooms. The HVAC system was renovated in 2021, and a new variable air volume gas-fired DOAS system with energy recovery was provided. Variable speed pumping has been provided as well. Again, hot water and domestic hot water are generated via heat exchanger from the central plant. Most lighting in this building is fluorescent, but LED lighting upgrades were provided in restroom areas in the recent renovation.

Due to the nature of a residential building, Funnelle is continuously ventilated throughout the entire year. Although occupancy is extremely limited during the summer months, ventilation is still provided. To save additional energy, controls can be used to reduce the ventilation when occupancy allows it, utilizing carbon dioxide sensors, occupancy sensors, or scheduling software that adjusts based on conference schedules. Reducing ventilation loads will reduce heating equipment sizes as well.

Table 12. Funnelle Hall—Existing Conditions

Existing Conditions	
Building Type	Residence Hall
Square Footage	114365
Year Built	1967
Number of Floors	B, 1-9, P1, P2
Exterior Walls	2 ½ in. granite, air gap, 6 in. CMU
Roof	6 in. concrete deck, built up roof (R-30 assumed)
Window-Wall Ratio	24%
Window Type	Metal framed, double, no thermal break (U-0.9, SHGC-0.57)
HVAC System	Campus steam HW, gas ERVs, small AC chiller
HVAC Efficiencies	85% boiler+15% losses, 10.1 EER chiller, 65% ERV, VSD pumps
Lighting	Approximately equal to 2010 ECCCNYS

Table 13. Funnelle Hall—Baseline Modeling

Existing Energy Consumption					Modeled Baseline Consumption					Model Calibration (% Difference)	
Electric (kWh)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Electric (kWh)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Electric	Natural Gas
578,300	40,216	5,995	604,777	$81,980	535,419	36,962	5,524	556,749	$75,737	-7.4%	-8.1%

3.5 Hart Hall

Hart Hall is the twin of Funnelle Hall, containing many of the same space types on the same floor plate. The lower two floors are configured somewhat differently, but the building still contains lounges, laundry, and a few offices. Hart also has some classroom space for resident meetings and conferences, plus the 176 dorm rooms with 336 beds. The building operates much the same as Funnelle, with the exception of the cooling in the data room, which is provided with a standalone direct expansion (DX) split system. The energy recovery unit in Hart is older, thus is slightly less efficient than Funnelle, but accomplishes the same goal of energy efficiency.

The ventilation airflow at Hart Hall is almost double that of Funnelle Hall, despite the similarity of the two buildings. Prior to initiating any HVAC upgrades, further investigation should be performed to ensure that the full-design ventilation airflow is actually required to ensure that the system is not wasting energy with unnecessary airflow.

Table 14. Hart Hall—Existing Conditions

Existing Conditions	
Building Type	Residence Hall
Square Footage	114365
Year Built	1967
Number of Floors	B,1-9,P1,P2
Exterior Walls	2 ½ in. granite, air gap, 6 in. CMU
Roof	6 in. concrete deck, built up roof (R-30 assumed)
Window-Wall Ratio	25%
Window Type	Metal framed, double, no thermal break (U-0.9, SHGC-0.57)
HVAC System	Campus steam HW, gas ERVs, small DX units
HVAC Efficiencies	85% boiler+15% losses, 13 SEER DX, 56% ERV, VSD pumps
Lighting	Approximately equal to 2010 ECCCNYS

Table 15. Hart Hall—Baseline Modeling

Existing Energy Consumption					Modeled Baseline Consumption					Model Calibration (% Difference)	
Electric (kWh)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Electric (kWh)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Electric	Natural Gas
689,869	45,070	6,862	687,472	$96,046	704,682	45,856	6,991	700,108	$97,999	2.1%	1.7%

3.6 Hewitt Hall

Adjacent to this building cluster, and currently undergoing major renovation, is Hewitt Hall. Hewitt is a 132,697 sq. ft. three-story School of Communication, Media and the Arts (SCMA) building. The building will contain classrooms, offices, studios, a ballroom, lounges, an internal collaborative core, plus support spaces. A large broadcast machine room will house the audio-video (AV) equipment. Hewitt will be conditioned by water-to-water geothermal heat pumps in conjunction with four-pipe chilled beams. The wellfield, containing 90 boreholes, is expected to be complete the summer of 2022. This building was previously modeled through the NYSERDA New Construction Program, and although the building is not analyzed in this study, the results of the Phase II Construction Documents model are utilized as part of the proposed geothermal community.

Table 16. Hewitt Hall—Baseline Modeling

Electric (kWh)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)
1,829,926	3,050	6,551	460,770	$184,591

3.7 Combined Load Profile

One advantage of a geothermal heat pump system is the ability to share energy on the loop. When one area is heating and another is cooling, the loads offset each other and can reduce the mechanical conditioning required. When sizing a geothermal wellfield, the number of wells can also be reduced.

In a traditional system, each building is separate, and the HVAC system must be sized for the building peak hour. When combining multiple buildings, the equipment size is simply the sum of the peaks, regardless of when the building peak occurs.

Instead, if multiple buildings can share a HVAC system, the overall equipment size can be reduced by considering the hourly additive loads and utilizing that additive peak. Typically, every building peaks at a different time, which provides a significant reduction in equipment size.

In the case of a geothermal system, the heating and cooling loads can offset each other over the course of the year, and the peak hour is only part of the equation for the wellfield. When different buildings in the community are in heating and cooling mode at the same time, the overall peak is reduced. Likewise, when the wellfield is balanced throughout the year, the number of wells required is reduced.

The differences in the building peaks are noted below:

Table 17. Combined Load Profile

Sum of Individual Building Peaks (Code-Compliant System)					Combined Building Loads Peak (Proposed Community System				
Heating Peak (tons)	Cooling Peak (tons)	Number of Wells	No. of Wells w/o Resid. MAUs	No. of Wells w/o DHW	Heating Peak (tons)	Cooling Peak (tons)	Number of Wells	No. of Wells w/o Resid. MAUs	No. of Wells w/o DHW
747	462	451	396	362	647	439	380	306	289

4 Proposed System: Community Geothermal System

4.1 Determining The Optimal Energy Source

Once the energy profile of the buildings has been established, the design for the community heat pump system can be determined. The campus has expressed a preference for maintaining existing building systems, and simply replacing the campus steam equipment and chillers with a water-to-water geothermal heat pump system. Since the majority of the systems use water loops, it is relatively straightforward to implement.

However, the existing systems are designed for approximately 200 degrees Fahrenheit (°F) supply hot water temperature, and the heat pump is only capable of 120°F–140°F supply temperatures. The distributed HW systems may need replacement if the resulting de-rated capacity is insufficient. Older systems tend to be oversized and may have sufficient capacity, so before installing a water-to-water heat pump, the temperature of the loop should be reduced to test the ability of the distributed systems to provide sufficient heat at lower temperatures. Additionally, envelope upgrades, especially on the poorer performing buildings, may reduce the heating load and allow for a lower water temperature.

Equipment is selected based upon the existing systems and feasibility of the upgrade, with a primary goal of energy efficiency. Generally, primary equipment has been selected to match the existing equipment, but the wellfield is sized based upon the calculated energy profile. Energy savings are shown compared against the existing systems, as well as independent individual building heat pump systems with code-minimum efficiencies.

4.2 Test Well

To ensure a properly sized geothermal wellfield, a test well must be drilled to determine the thermal conductivity of the earth. All sites have differing composition, so utilizing assumptions to size a wellfield may either cause capacity problems (undersized) or incur unnecessary expense (oversized).

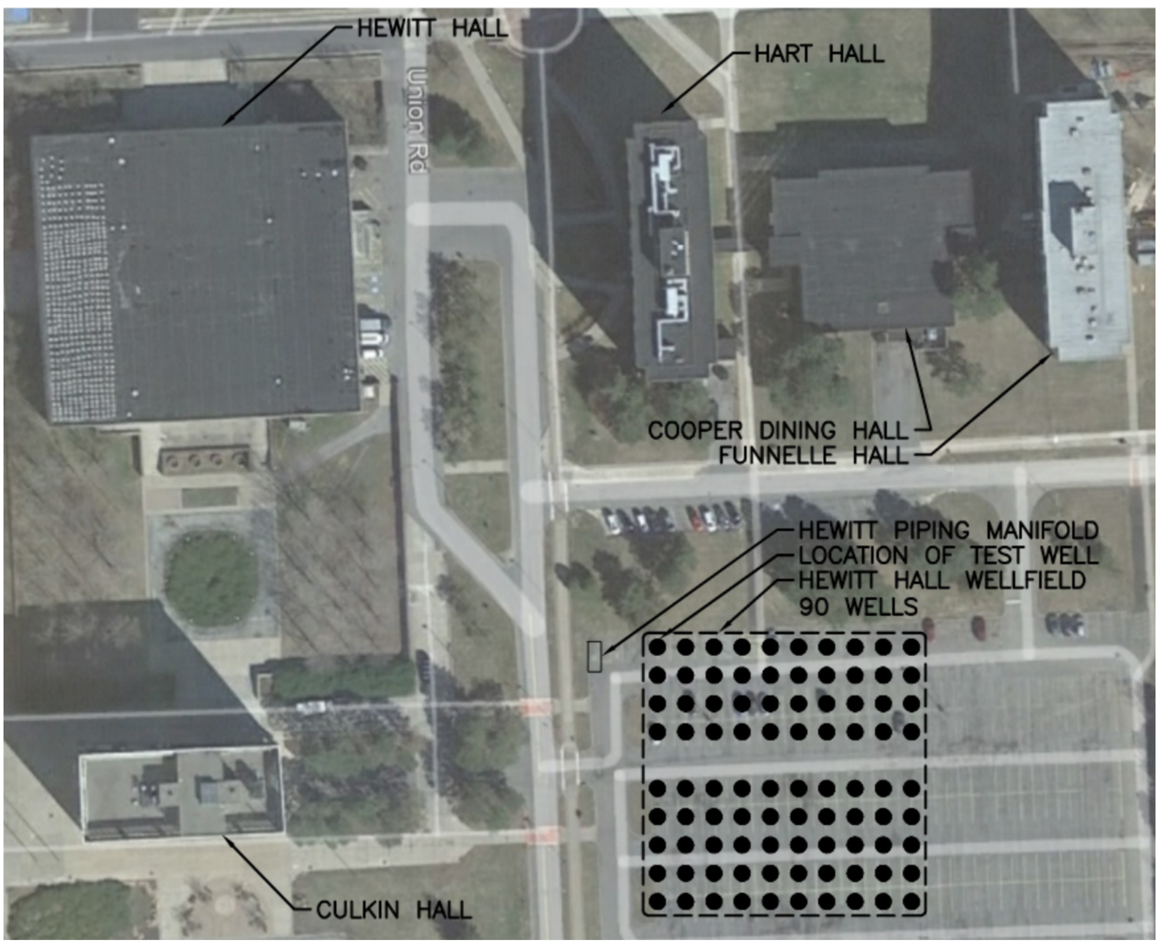
As part of the Hewitt Hall project, a test well was drilled to determine the thermal conductivity of the earth.

American Auger & Ditching Co., Inc., performed the drilling and thermal conductivity testing. The test well drilled is as follows:

- Single vertical well
- 6-inch diameter bore
- 1 1/4 inch DR-11 High Density Polyethylene (HDPE)
- 498-feet deep
- U-Bend
- High performance GeoPro TG Select/Power TEC grout (1.0 Btu/hour [Btu/h]•foot [ft]•°F)
- 48-hour test
- 65 Btu/h•ft., 9.9 gallons per minute (gpm)

Thermal conductivity was calculated to be 2.28 Btu/h•ft•°F with a thermal diffusivity of 1.39 sq ft/day. See appendix for complete test well results.

Figure 9. Existing Site Layout



4.3 Proposed Central Wellfield

To maximize energy sharing, the proposed system is a community heat pump system. The wellfield includes the same deep wells as the test well, on a 20 x 20-foot grid as feasible. Each well must be installed to avoid existing utilities but does not require future access. Typical well locations are in open fields and lawn areas, and below parking lots.

In this case, the test well was drilled in the parking lot central to the building cluster. The well was designed to be a part of the Hewitt Hall wellfield, which was constructed in summer 2022. There is ample room in the parking lot area to locate the balance of the wells for the additional four buildings. There are several underground utilities that run through the lot, such as storm sewers, a water line, and communication cabling, but wells may be installed around the utilities. Prior to initiating construction, a comprehensive survey of the utilities in the area should be undertaken.

Alternatively, there is ample open area on campus, including a small parking lot in front of Culkin Hall, that could be utilized if wells must be distributed throughout the campus due to utility obstacles. Generally, as long as the wellfields are connected via GSHP loop circulation pumps, the energy sharing advantages of community geothermal remain even with satellite wellfields. Additionally, interconnecting future GSHP communities will likely reduce the total number of wells required for the overall campus.

The wellfield will consist of 289 wells circuited together in rows, spaced 20 feet on center. The supply and return of each 4-inch circuit header will be brought back independently into a piping manifold. There is an existing vault which combines the circuits from the Hewitt Hall vault; a new vault would be provided in a central location for the new wellfield circuits. At that point, the branches will be combined into a main 12-inch pipe header for distribution to the cluster.

The 12-inch main will be routed to Culkin Hall, where dedicated variable speed wellfield pumps will control the flow in the wellfield, then routed to the other buildings. The main will also connect to the Hewitt Hall loop, so energy can be shared between all five buildings, and brought to each of the other buildings in the cluster as well. Each building will also have a set of secondary loop pumps to move the condenser water throughout the building, through heat pumps, and back to the main cluster geothermal loop. As an alternative, distributed pumps in individual buildings tied into the central wellfield may be desirable to eliminate the central pumps, but care will need to be taken with the design and installation of the wellfield to ensure that water will properly flow throughout the wellfield.

The total building cluster as modeled requires 380 wells to provide sufficient capacity for all the buildings (including domestic water loads) and to ensure that the wellfield can maintain the water temperatures desired. However, the cluster is unbalanced, and has more heating load than cooling, due in large part to the heating-only buildings and large domestic water requirements of the residence halls. This substantial heating load is an advantage when combined with buildings with significant cooling loads such as Hewitt Hall, but in this case, there is still excess heating on the loop.

A heating-dominated wellfield will cause the earth surrounding the wells to decrease in temperature over time, which decreases the available heat injection capacity of the wellfield and can cause the heat pumps to perform poorly in the heating season. For a cost-effective solution, the domestic water heating is recommended to be kept off the geothermal loop at this time. Due to the low incoming cold water temperatures, domestic water often requires supplemental heat to reach the desired supply temperatures, and efficiency is compromised. Additionally, maintaining the current domestic water system will save first cost by no longer requiring replacement, as well as by reducing the number of wells needed for the system.

If cooling is eventually provided to the residence hall buildings, that additional cooling load will help to offset the domestic hot water load, which will provide for a more balanced well when both are included. Alternatively, instead of leaving the domestic hot water off of the geothermal loop, the makeup air units may be maintained as-is with gas furnaces. The wellfield will be more unbalanced, but the units are relatively new and contain energy recovery and may be kept off until more cooling is added to the system.

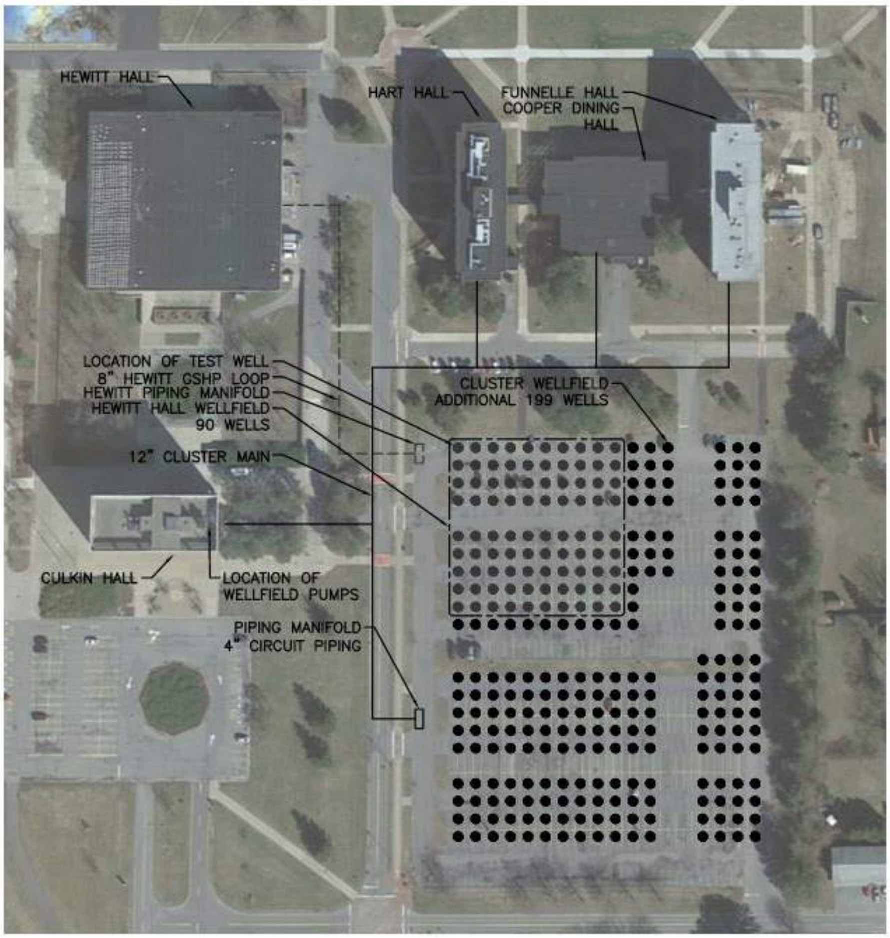
Proposed equipment:

- 289 wells (498 feet, 20 x 20 feet) as described in the section 4.2 of this report (199 additional)
- 4-inch circuit pipe headers, 12-inch cluster loop piping
- Wellfield circulation pumps (x3, n+1 redundant) equipped with variable frequency drives (VFDs), each rated at 25 horsepower (HP).

Table 18. Estimated Overall Savings–Five Building Cluster

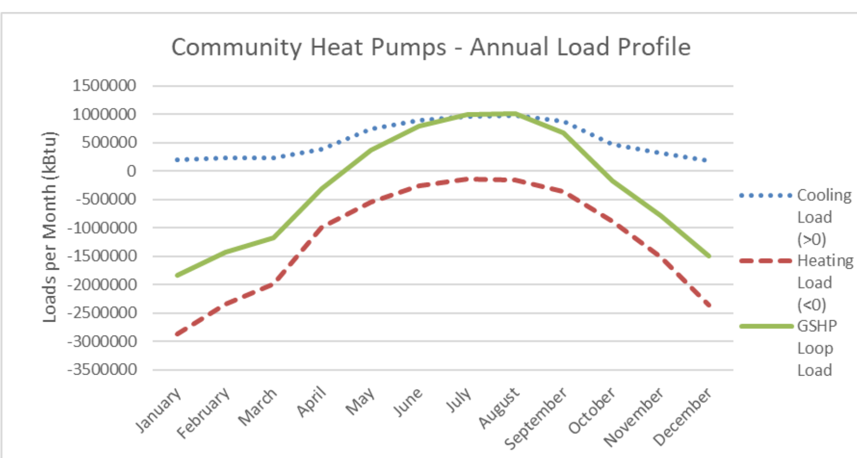
Modeled Option	Modeled Consumption						Savings versus Baseline					
	Electric (kWh)	Demand (kW)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Energy (mmBtu)	Energy (%)	Carbon (lb CO_2e)	Carbo n (%)	Cost ($)	Cost (%)
Existing Baseline	4,373,580	1,745	188,588	33,786	3,222,031	$550,390	—	—	—	—	—	—
Code-Compliant Heat Pumps	5,540,579	1,335	28,273	21,737	1,617,806	$570,365	12,049	36%	1,604,225	50%	($19,975)	-4%
Community Heat Pumps	5,234,297	1,239	28,273	20,692	1,546,657	$539,776	13,094	39%	1,675,374	52%	$10,613	2%

Figure 10. Community Wellfield Layout



The modeled load profile of the community heat pump loop is shown below:

Figure 11. Overall Annual Load Profile



This chart shows that the heating and cooling loads are in contrast to each other; the community is a heating dominated loop. When combined into a geothermal loop, both loads moderate, and the final thermal load is in between the heating and cooling loads. This saves substantial energy over a traditional system, which must handle each load independently of each other.

4.4 Cooper Dining Hall

For all the buildings in the cluster, the campus wishes to maintain the existing HVAC systems as much as feasible and replace the primary equipment. Cooper Dining Hall is conditioned using the central plant steam with an air-cooled chiller. To upgrade to a geothermal system, these central systems can be directly replaced with a water-to-water heat pump system.

This modular water-to-water heat pump will be installed in place of the existing chiller. It functions much like a traditional water-cooled chiller but can simultaneously produce hot water and can accommodate the low water temperatures of the geothermal condenser loop. The condenser loop will either recover the excess heat from the compressors and add it to the community-wide geothermal loop or utilize the heat from other buildings and the wells to assist the heat pump.

The hot and chilled water produced by the heat pump can be provided directly to the existing hot and chilled water loops. The chiller and steam-to-water heat exchangers must be removed and replaced by the heat pumps. The loop pumps are older constant volume units and will be replaced with premium efficient pumps with variable speed drives. The cooling tower and existing condensing water loop may be removed in its entirety, but an additional pair of pumps will be provided for the geothermal condenser water loop.

Domestic hot water is not included in the recommended system, due to the unbalanced geothermal wellfield. The domestic hot water has been assumed to remain in place as is. Other options to remove the domestic hot water from the central plant include a high-efficient gas-fired condensing water heater or an air source heat pump water heater; neither will impact the geothermal system and may be considered independently of the community heat pump project. If additional cooling is added to the community GSHP system, the domestic hot water may be incorporated to keep the system balanced.

A service line upgrade will likely not be required to accommodate the new water-to-water heat pumps. The service is relatively large at 1,600 amperage and there appears to be sufficient capacity available for the heat pumps. The new central heat pump equipment will be located in the chiller room, in the place of the existing chillers.

Equipment to be removed:

- 100-ton water-cooled chiller
- 100-ton cooling tower
- Steam-to-water heat exchanger (2,550 thousand British thermal units per hour [mBh])
- Chilled water pumps (5 HP x2)
- Hot water pumps (5 HP x2)
- Condenser water pump (5 HP)

Proposed equipment:

- Modular 200-ton ground source water-to-water heat pump, 18.2 energy efficiency ratio (EER) cooling, 3.4 coefficient of performance (COP) heating
- Ground source heat pump loop pumps with VFD (10 HP x2)
- Chilled water pumps with VFD (5 HP x2)
- Hot water pumps with VFD (5 HP x2)

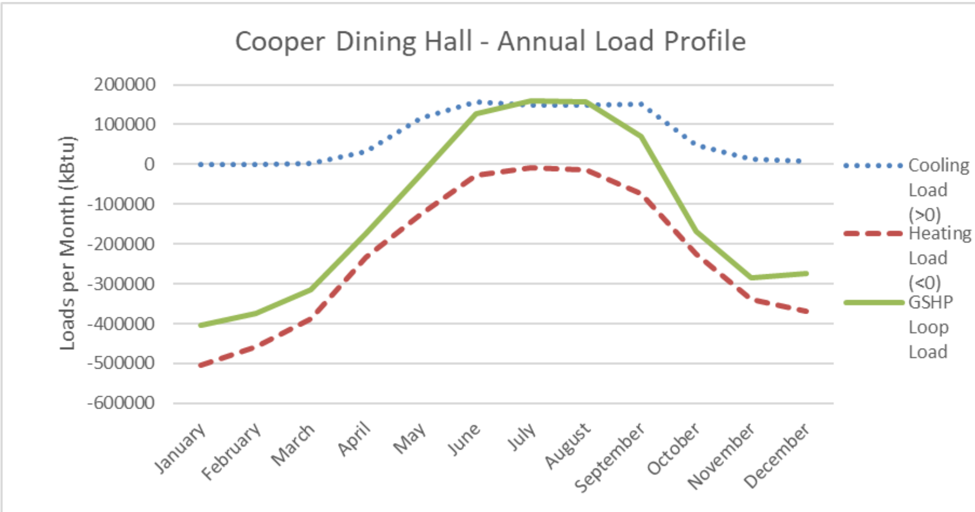
The expected energy savings over the existing systems are as follows:

Table 19. Cooper Dining Hall—Estimated Savings

Modeled Option	Modeled Consumption						Savings versus Baseline					
	Electric (kWh)	Demand (kW)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Energy (mmBtu)	Energy (%)	Carbon (lb CO_2e)	Carbon (%)	Cost ($)	Cost (%)
Existing Baseline	497,535	375	57,687	7,467	790,383	$84,439	--	--	--	--	--	--
Code-Compliant Heat Pumps	791,073	256	12,817	3,982	333,696	$86,725	3,485	47%	456,688	58%	-$2,286	-3%
Community Heat Pumps	683,829	204	12,817	3,616	308,783	$76,014	3,851	52%	481,600	61%	$8,424	10%

Figure 12 illustrates the annual load profile.:

Figure 12. Cooper Dining Hall—Annual Load Profile



4.5 Culkin Hall

The primary HVAC system of Culkin Hall is a two-pipe fan coil system. This system is original to the building, and comfort conditions are compromised in the shoulder seasons. It is recommended that any renovation of this building include the replacement of the fan coil units to a four-pipe system. However, for cost considerations in this study, it is assumed that the space HVAC equipment will remain in place, and only the central equipment will be replaced.

Like Cooper, the building utilizes the campus steam and a water-cooled chiller for the building hot and chilled water loops. A cooling tower is located on the roof for the chiller condenser water. All the primary equipment will be removed and replaced with a modular water-to-water heat pump, which will be tied into the geothermal loop to maximize efficiency. The chiller pumps, baseboard loop pumps, and fan coil loop pumps will all be replaced with premium efficient pumps with variable speed drives. The cooling tower and condensing water loop can be removed in their entirety.

As described in section 4.3, the geothermal wellfield main will be brought into this building as well. Domestic hot water has not been included in the recommended GSHP system.

A service line upgrade will likely not be required to accommodate the new water-to-water heat pumps. Some of the electric load of the heat pump is offset by the removal of the existing chiller, but the heating peak is greater than that of the existing cooling peak. The large geothermal wellfield pumps will also add to the electrical demand, and the building will require an estimated approximately 225 kilowatts (kW) additional power. However, the service is 1,000 A, and based on the energy model, there appears to be sufficient capacity for the new heat pumps. The removal of the chiller plus the spare area in the mechanical room will provide sufficient space for the new heat pumps.

Equipment to be removed:

- 120-ton water-cooled chiller
- 188-ton cooling tower
- Steam-to-water heat exchangers (3500 mBh x1, 1460 mBh x1)
- Chilled water pumps (15 HP x2)
- Hot water pumps (7.5 HP x2)
- Fan coil loop pumps (10 HP x2)
- Condenser water pump (25 HP x1)

Proposed equipment:

- Modular 400-ton ground source water-to-water heat pump, 18.2 EER cooling, 3.4 COP heating
- Ground source heat pump loop pump with VFD (20 HP x2)
- Chilled water pumps with VFD (15 HP x2)
- Hot water pumps with VFD (7.5 HP x2)
- Fan coil loop pumps with VFD (10 HP x2)
- Campus ground-loop equipment as noted in section 4.3 of this report.

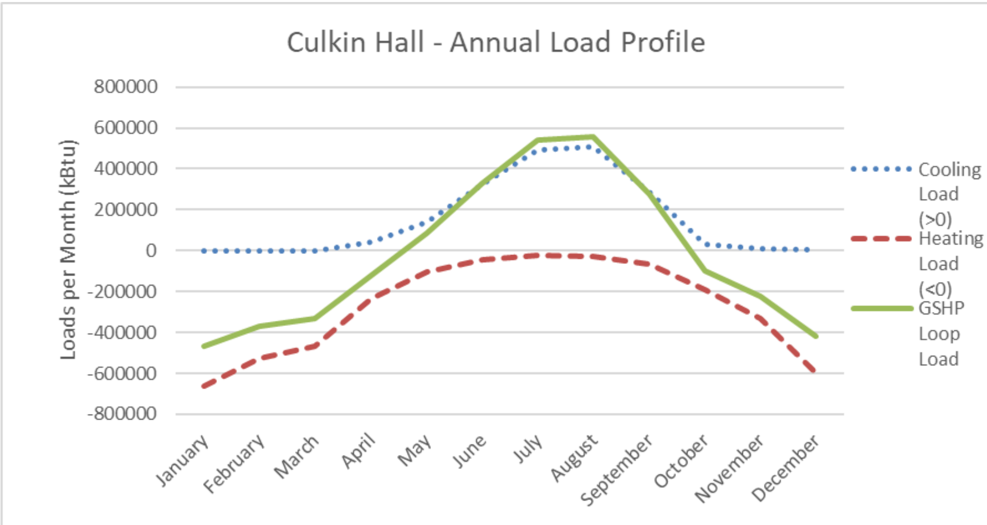
The expected energy savings over the existing systems are as follows:

Table 20. Culkin Hall—Estimated Savings

Modeled Option	Modeled Consumption						Savings versus Baseline					
	Electric (kWh)	Demand (kW)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Energy (mmBtu)	Energy (%)	Carbon (lb CO_2e)	Carbon (%)	Cost ($)	Cost (%)
Existing Baseline	806,018	610	45,033	7,254	714,021	$107,624	–	–	–	–	–	–
Code-Compliant Heat Pumps	999,206	406	830	3,493	241,825	$100,290	3,761	52%	472,196	66%	$7,334	7%
Community Heat Pumps	982,638	453	830	3,437	237,976	$98,635	3,817	53%	476,045	67%	$8,989	8%

Figure 13 illustrates the annual load profile.

Figure 13. Culkin Hall—Annual Load Profile



4.6 Funnelle Hall

The residence halls are not cooled, except for small select areas. Accordingly, the HVAC systems are relatively simple, utilizing primarily radiant heat and dedicated outdoor air units with heat recovery. These systems are recommended to stay in place, with some modifications to the outdoor air units, and the heating steam converter will be replaced for domestic hot water only.

In this building, a new water-to-water heat pump is recommended to be used for hot water generation and to replace the small air-cooled chiller. The hot water will be distributed to the perimeter radiation and the makeup air units (MAUs). These energy recovery units will require a retrofit to include a hot water coil in lieu of the existing gas furnace and may require additional piping and pumps to accommodate the increase hot water required. The existing hot water pumps are new and will be maintained, but a new GSHP condenser water pump will be provided, as well as a small chilled water pump.

As discussed in previous sections, the existing systems are designed for approximately 200°F supply hot water temperature, and geothermal heat pumps are only capable of 120°F–140°F supply temperatures. It is recommended that prior to completing this GSHP retrofit project, the supply setpoint of the existing water loop should be reduced to ensure that the system can handle the lower hot water temperatures. If the temperature is insufficient, supplemental coils or fin-tube radiation may be required to ensure the system will adequately perform at design conditions. This supplemental equipment has not been included in the cost estimates.

Alternatively, other work to reduce the heating load in the building, such as infiltration reduction or additional insulation, may be sufficient to allow the lower water temperatures. Generally, it is recommended that the heating load be reduced as much as feasible prior to initiating a ground source heat pump project in order to minimize the size of the wellfield and required equipment.

Residential halls typically have relatively high domestic hot water usage, due to showers and laundry facilities. Combining this load with the heating-only HVAC equipment adds a significant heating burden on the geothermal wellfield, and is not offset by any cooling loads. At this time, to better balance the wellfield, the domestic hot water has not been included on the community heat pump system. If the residence halls are upgraded to include cooling in the future, this domestic water heat may be added as it is offset by the cooling load.

A service line is not likely to be required to accommodate the new heat pumps. The existing small electric chiller is insufficient to significantly mitigate the load impact of the heat pumps, and the electrical increase is estimated at approximately 100 kW. However, the 1,200 A main appears to have enough capacity to accommodate the increase.

There does not appear to be sufficient available room in the mechanical room for the new heat pumps. Space from other areas in the basement will need to be reclaimed, such as the adjacent storage room. For the purposes of this analysis, the size of the existing equipment has been matched, but a load study is recommended to ensure that the current capacity is indeed required.

Equipment to be removed:

- Air cooled chiller with integrated pumps (12 tons, 3 HP x2)
- Steam-to-water heat exchanger (5,845 mBh x1, 219 mBh x1)
- Energy recovery unit furnace sections (400 mBh x1, 500 mBh x1)

Proposed equipment:

- Modular 450-ton ground source water-to-water heat pump, 18.2 EER cooling, 3.4 COP heating
- Heating coils for makeup air units (400 mBh x1, 500 mBh x1)
- Ground source heat pump loop pump with VFD (25 HP x2)
- Hot water pumps for MAUs with VFD (3 HP x2)
- Chilled water pumps with VFD (3 HP x2)
- Steam-to-water heat exchanger for domestic water (1500 mBh x1)

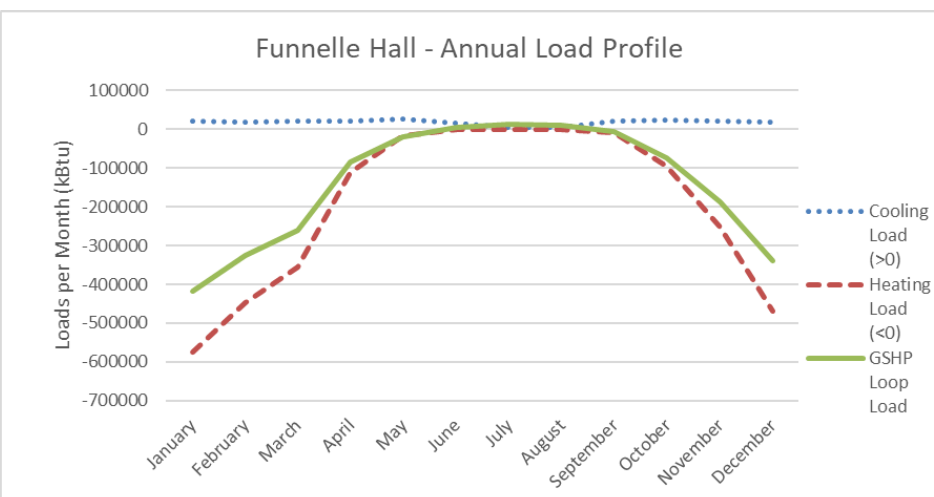
The expected energy savings over the existing systems are as follows:

Table 21. Funnelle Hall—Estimated Savings

Modeled Option	Modeled Consumption						Savings versus Baseline					
	Electric (kWh)	Demand (kW)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Energy (mmBtu)	Energy (%)	Carbon (lb CO_2e)	Carbon (%)	Cost ($)	Cost (%)
Existing Baseline	535,419	279	36,962	5,524	556,749	$75,737	--	--	--	--	--	--
Code-Compliant Heat Pumps	841,001	239	4,738	3,344	250,788	$86,844	2,179	39%	305,960	55%	-$11,107	-15%
Community Heat Pumps	757,716	199	4,738	3,060	231,441	$78,527	2,464	45%	325,308	58%	-$2,789	-4%

The annual load profile is shown below:

Figure 14. Funnelle Hall—Annual Load Profile



The proposed heat pump system saves substantial energy and carbon, but there is a minimal cost penalty. This is due largely to the lack of cooling to offset the cost of electrified heating, despite the energy benefits.

4.7 Hart Hall

Hart Hall was built similarly to Funnelle and contains the same basic systems. There is no cooling, except for a small split system AC (air conditioning) unit in the data room. Like Funnelle, the existing systems will be generally retained with minor modifications, utilizing new heat pumps.

The new water-to-water heat pump is recommended to be used for hot water generation and to replace the split system. The hot water will be distributed to the perimeter radiation and the makeup air units. The MAUs will be retrofitted for hot water coils, and the hot water distribution system will be modified to accommodate the increased load. All new pumps with VFDs will be provided. The steam converter will be replaced for the domestic hot water load only.

Note that Hart appears to have a smaller steam-to-water heat exchanger than its sister building, Funnelle Hall, and sizes should be confirmed prior to undertaking any renovation.

A service line is not likely to be required to accommodate the new heat pumps. The load increase is estimated to be approximately 140 kW, but the 1,600 A main appears to have capacity to accommodate the increase. Hart Hall requires more electrical demand than Funnelle, due in large part to the higher ventilation airflows than its twin.

There does not appear to be sufficient available room in the mechanical room for the new heat pumps. Space from other areas in the basement will need to be reclaimed, such the adjacent storage room.

Equipment to be removed:

- Steam-to-water heat exchanger (4,000 mBh x1, 219 mBh x1)
- Energy recovery unit furnace sections (410 mBh x2)
- Hot water pumps with VFD (5 HP x3, 3 HP x2, 1/4 HP x1)
- Split system AC unit (2 tons)

Proposed equipment:

- Modular 300-ton ground source water-to-water heat pump, 18.2 EER cooling, 3.4 COP heating
- Heating coils for energy recovery units (410 mBh x2)
- Ground source heat pump loop pump with VFD (25 HP x2)
- Hot water pumps with VFD (5 HP x3, 3 HP x2, 1/4 HP x1, +3 HP x2)
- Chilled water pumps with VFD (1 HP x2)
- Fan coil unit (2 ton)
- Steam-to-water heat exchanger for domestic water (1,500 mBh x1)

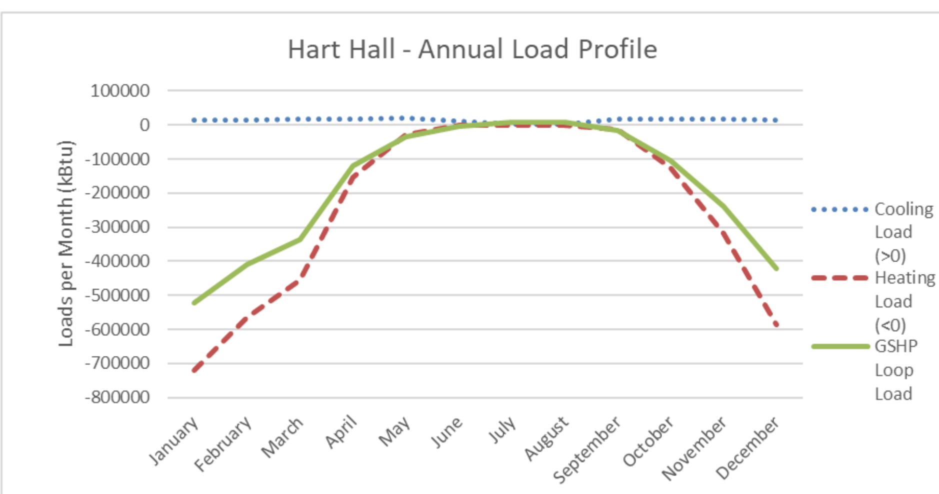
Table 22 details the expected energy savings over existing systems.

Table 22. Hart Hall—Estimated Savings

Modeled Option	Modeled Consumption						Savings versus Baseline					
	Electric (kWh)	Demand (kW)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Energy (mmBtu)	Energy (%)	Carbon (lb CO_2e)	Carbon (%)	Cost ($)	Cost (%)
Existing Baseline	704,682	355	45,856	6,991	700,108	$97,999	--	--	--	--	--	--
Code-Compliant Heat Pumps	1,079,373	308	6,838	4,368	330,727	$111,915	2,623	38%	369,381	53%	-$13,916	-14%
Community Heat Pumps	980,188	258	6,838	4,029	307,687	$102,010	2,961	42%	392,421	56%	-$4,010	-4%

The annual load profile is shown below:

Figure 15. Hart Hall—Annual Load Profile



4.8 Code-Compliant System: Individual Building Geothermal

A community heat pump has its advantages but may not be the ideal scenario for a particular location. Specifically, the large upfront cost of the district wellfield, plus the campus distribution pumps and piping may cost more than is feasible. As a comparison, a code-compliant geothermal heat pump system has been evaluated. For this option, all buildings are assumed to have individual wellfields, with individual wellfield pumps. Where the size of the wellfield indicates, a piping manifold for the wellfield piping is included. Additionally, the heat pumps in the buildings have been modeled with code-minimum efficiencies.

To keep the calculations consistent, the domestic hot water is excluded from this option as well. All other items are the same between both options.

Excluded equipment (versus Proposed System)

- 199 wells (498 ft, 20 x 20) as described in section 4.2 of this report
- 4-inch circuit pipe headers, 12-inch campus loop piping
- Wellfield circulation pumps (x3, n+1 redundant) with VFD (25 HP)

Code-compliant system equipment

- 272 wells (498 feet, 20 x 20 feet) as described in "Test Well" section of this report
- Cooper Dining Hall: Wellfield pumps with VFD (10 HP)
- Culkin Hall: Wellfield pumps with VFD (20 HP)
- Funnelle Hall: Wellfield pumps with VFD (25 HP)
- Hart Hall: Wellfield pumps with VFD (25 HP)

Table 23. Combined Load Profile—-Five Building Cluster

Sum of Individual Building Peaks (Code-Compliant System)					Combined Building Loads Peak (Proposed Community System				
Heating Peak (tons)	Cooling Peak (tons)	Number of Wells	No. of Wells w/o Resid. MAUs	No. of Wells w/o DHW	Heating Peak (tons)	Cooling Peak (tons)	Number of Wells	No. of Wells w/o Resid. MAUs	No. of Wells w/o DHW
747	462	451	396	362	647	439	380	306	289

Table 24. Code-Compliant Estimated Savings

Modeled Option	Modeled Consumption						Savings versus Baseline					
	Electric (kWh)	Demand (kW)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO_2e)	Cost ($)	Energy (mmBtu)	Energy (%)	Carbon (lb CO_2e)	Carbon (%)	Cost ($)	Cost (%)
Code-Compliant Heat Pumps	5,540,579	1,335	28,273	21,737	1,617,806	$570,365	--	--	--	--	--	1,335
Community Heat Pumps	5,234,297	1,239	20,692	1,546,657	$539,776	1,045	5%	71,149	4%	$30,588	5%	5%

5 Economic Analysis

5.1 Analyzing Economic Impacts

While carbon neutrality is the ultimate goal of the university, carbon reduction is one of several factors that needs to be understood for a project of this scale. In order to determine the feasibility of the proposed system, it is necessary to evaluate project costs.

5.2 Summary of Costs

The results of the cost analysis are summarized below. See Cost Estimates in appendix E for a detailed breakdown of the installation and maintenance costs of each system.

Table 25. Economic Summary

Design Option	Construction Cost	Estimated Incentives	Total First Cost	Annual Maintenance	Annual Energy Costs	Total Annual Costs	Annual Carbon (lb CO_2e)
Baseline System: Replace systems in kind	$2,114,596	$0	**$2,114,596**	$9,682	$550,390	**$560,072**	**3,222,031**
Code-Compliant System: Individual building heat pumps	$15,235,508	$722,912	**$14,512,596**	$15,716	$570,365	**$586,081**	**1,617,806**
Proposed System: Community heat pumps	$13,306,349	$4,785,632	**$8,520,717**	$15,316	$539,776	**$555,092**	**1,546,657**

Table 26.Economic Savings versus Baseline

Design Option	First Cost ($)	First Cost (%)	Annual Costs ($)	Annual Costs (%)	Simple Payback (Years)	Annual Carbon (lb CO_2e)	Annual Carbon (%)
Baseline System: Replace systems in kind	–	–	–	–		–	–
Code-Compliant System: Individual building heat pumps	-12,398,001	-586%	-26,009	-5%	N/A	1,604,225	50%
Proposed System: Community heat pumps	-6,406,121	-303%	4,979	1%	1287	1,675,374	52%

Compared to the existing systems and maintaining the status quo, the geothermal wellfield does not provide a reasonable simple payback, due to the relatively high cost of electricity. Therefore, it does not make sense to install the system based on economic reasons alone. However, to achieve net zero carbon in the future, as is the goal for SUNY Oswego, an electrified heating solution is imperative. When compared to individual building geothermal heat pumps, the community system is both less expensive (especially when including financial incentives) and is less costly to operate from an energy perspective. In fact, because of the reduced energy savings, the individual GSHP systems do not provide a simple payback at all.

Although the costs of the proposed option are high, the carbon emission reductions with the community heat pump system is remarkable, saving almost 52% of the entire cluster's emissions. With New York State's ever-greener electrical grid, the carbon reduction will continue to improve with the utility grid. According to United States Environment Protection Agency (US EPA), upstate New York has an emissions factor of 232.3 pounds carbon diodized per megawatt hour (pounds CO_2/MWh) of electricity. For comparison, the midwest has a factor almost seven times as high, 1,584.4 pounds CO_2/MWh. As New York State continues to push for a greener electric grid, a geothermal heat pump system will continue to reduce carbon emissions with no additional energy efficiency measures or costs.

5.3 Life-Cycle Cost Analysis

One advantage of a geothermal heat pump system is the longevity of the equipment. Typical geothermal heat pumps have an expected useful life of 25 years, with the wellfield itself lasting 50 years or longer. Maintenance costs are generally less than traditional systems as well, thanks to the lack of moving parts in the wellfield and the use of a single piece of equipment for both heating and cooling.

To fully understand the proposed system, it is helpful to look at the overall life-cycle cost over the expected useful life of the equipment. Normally, a geothermal heat pump system is expected to last 25 years, and a traditional system is 15 to 20 years. Table 26 shows the expected lifespan of the installed equipment.

Table 27. Equipment Expected Useful Lifespan

Equipment Description	Years	Equipment Description	Years
Air cooled chiller	15	Heat exchangers	25
Water cooled chiller	20	Gas furnaces	15
Cooling tower	15	Heating coils	25
Geothermal W-W heat pump	25	Split system AC	15
Pumps	15	Fan coil unit	25
Controls	15		

When considering the life-cycle cost, we must consider escalation in both utility and construction costs, as well as the discount rate to account for risk and the time value of money. The results of the net present value calculations are summarized in the following table:

Table 28. Life-Cycle Cost Analysis

Discount Rates

Medium-Risk Generative	7.25%	(for energy objectives)

Escalation Rates

Energy Related	6.600%
Electricity	4.10%
All Other Cost Items	2.50%

Energy Rates

Description	Cost	Units	Source	Notes
Electricity:	$0.056	/kWh	Energy Budget	Provided by Owner
Natural Gas:	$0.522	/therm	Energy Budget	Provided by Owner

Life-Cycle Cost Analysis Results

Description	Option	Estimated First Cost	Annual Energy Cost, First Year	Annual Maintenance Cost, First Year	Life Expectancy (Years)	**25-Year** LCCA Net Present Value	NPV Difference vs. Option 1
Baseline System: Replace Systems in Kind	1	($2,114,596)	($550,390)	($9,682)	20	($12,710,669)	--
Code-Compliant System: Individual Building Geothermal Heat Pumps	2	($14,512,596)	($570,365)	($15,716)	25	($25,384,114)	($12,673,445)
Proposed System: Community Geothermal Heat Pumps	3	($8,520,717)	($539,776)	($15,316)	25	($18,698,228)	($5,987,559)

Note: Annual maintenance costs are intended to represent the differences between the measures, in order to determine which measure is more feasible and do not take into consideration all maintenance costs for the building.

Ultimately, both heat pump options have a negative net present value (NPV) when compared to the existing systems. However, thanks in large part to potential incentives offered by the NYSERDA Community Heat Pump Program, the proposed district geothermal system shows an NPV of $6,700,000 more than the individual building systems. The community system is a large financial outlay, indicating that it is prudent to take advantage of the incentive offers available.

5.4 Incentive Programs

To assist in financing, there are many incentive programs through the government and utilities that offer financial support for energy efficiency projects. The programs may be aimed toward specific technologies, or simply based upon energy reduction. Generally, incentives are paid upon completion of the construction project and are subject to program guidelines. Estimated incentives for the proposed project are as follows:

Table 29. Estimated Incentives

Program	Proposed Community Award	Code-Complaint System Award	Included in LCCA?	Comments
NYSERDA Community Heat Pump - Category B (Design)	$500,000	$ -	No	For design study (not construction) based on design fee, competitive process, not available for GSHP individual systems
NYSERDA Community Heat Pump - Category C (Implementation)	$4,000,000	$ -	Yes*	Competitive process, some or all of award may not be granted, not available for individual GSHP systems
NYS Clean Heat Program (National Grid)	$785,632	$722,912	Yes	Assumes only 75% of calculated energy savings is eligible for incentive
NYSERDA New Construction	$651,770	$651,770	No	Only available for gut rehabs, project may not be eligible. Program currently closed but expected to reopen in a different form.
Total	**$5,937,402**	**$1,374,682**		

Note: Additional tax incentives are available for geothermal system, which are not shown above. Please consult with tax attorney for value of these incentives. These incentives can be significant and may increase the feasibility of the project.

Besides rebate-type programs, such as NYSERDA and National Grid, there are tax incentives as well, including tax credits and accelerated depreciation. The value of these incentives is dependent on the tax structure of the project owner. As a nonprofit, SUNY Oswego may not be eligible for the tax incentives, and advice from a tax attorney should be sought for confirmation.

The bulk of the potential incentive is through the NYSERDA Community Heat Pump program, which is a competitive process in a new program, and the likelihood of attaining the award in full or in part is yet to be understood. It may require additional energy efficiency work in the buildings to make this community stand out among other applicants. However, the incentive is significant and progressing in a path to achieve the award is recommended.

Specific incentive programs that may be applicable to this project are described in the following text.

5.4.1 NYSERDA Programs

5.4.1.1 NYSERDA Community Heat Pump Systems Program Opportunity Notice 4614

Project has already won NYSERDA funding for Category A: Site-Specific Scoping Study (this document):

- Competitive bid process with application deadlines.
- Category A: Award of up to $100,000 for a community geothermal feasibility study for a specific cluster of buildings.
- Category B: Award of up to $500,000 or a maximum of ~50% of costs for a more focused design study for implementation.
- Category C: Award of up to $4,000,000 or a maximum of ~50% of costs for the implementation of the community wellfield design project.
- For more information about the program go to https://www.nyserda.ny.gov/All-Programs/Community-Heat-Pump-Systems/Community-Heat-Pumps-Pilot-Program

5.4.1.2 NYSERDA New Construction Program

Note: The New Construction Program (NCP) is currently closed for new projects. The program is expected to be reestablished; however, incentives are unknown at this time and likely to change. It is expected that incentives will be geared toward technical assistance during the design phase and less toward financial assistance. The following information is based on the NCP program that closed in early 2023 and is provided for reference only. (Applicable to All-Electric Projects Only—New Construction or Major Rehabilitation).

Support Level 2 Carbon Neutral Ready

- Technical Support:
  - Compliance Path A:
    - Pre-Schematic/Schematic Design Phase
    - Applicant partners receives funding for a Primary Energy Consultant to complete an Energy Model documenting 15% source energy savings beyond NYS Energy Code. The building may not include any fossil fuel use on site. Eligible projects for Compliance Path A must be a minimum of 5,000 sq. ft.
  - Compliance Path C:
    - Pre-Schematic/Schematic Design Phase.
    - Applicant partners receives funding for a Primary Energy Consultant to complete an Energy Model documenting energy performance to meet NYStretch Code). The building may not include any fossil fuel use on site. Eligible projects for Compliance Path A must be a minimum of 5,000 sq. ft.

- Financial Support:
  - Compliance Path A:
    - Energy performance incentive of 15% AND No Fossil Fuel use on site = $2.00/sq. ft. of the total impacted project area.
    - The maximum Energy Performance Incentive is up to $750,000 per project (up to $800,000 for projects located in a disadvantaged community).
  - Compliance Path C:
    - Design and constructed to meet or exceed NYStretch AND No Fossil Fuel use on site = $1.50/sq. ft. of the total impacted project area.
    - The maximum Energy Performance Incentive is up to $750,000 per project (up to $800,000 for projects located in a disadvantaged community).

- Other Compliance Paths apply to projects that are out of the Pre-Schematic or Schematic Design Phase. Those projects are eligible for financial support, but minimal technical support.

For more information go to:

https://www.nyserda.ny.gov/All-Programs/Programs/New-Construction-Program

5.4.1.3 NY-Sun

- The NY-Sun program offers incentives and financing for New York State businesses purchasing and installing solar panel systems.
- There are also NYS tax credits available, if eligible.
- Current incentives:
  - Non-residential (<200 kW): $0.35/W.
  - Commercial (>200 kW): $0.15/W ($0.12/W expected soon).
  - Incentives reduce over time after a certain number of projects are awarded.

- To determine eligibility, you will need to work with a participating NY-Sun contractor:

    - https://www.nyserda.ny.gov/All-Programs/Programs/NY-Sun/Solar-for-Your-Business/How-to-Go-Solar/Find-a-contractor

- For more information about the program: https://www.nyserda.ny.gov/All-Programs/Programs/NY-Sun

5.4.1.4 NYSERDA Flexible Technical Assistance (FlexTech)

- Shares the cost to produce an objective, site-specific, and targeted study on how best to implement clean energy and/or energy efficiency technologies (NYSERDA pays 50% of study cost).
- For more information go to: https://www.nyserda.ny.gov/All-Programs/Programs/FlexTech-Program

5.4.2 National Grid Rebates

5.4.2.1 NYS Clean Heat Statewide Heat Pump Program

- Custom incentive of up to $80/million British thermal units (mmBtu) for systems > 300,000 Btu/h full-load heating capacity.
- Must utilize NYSERDA-participating contractor or designer, subject to installation requirements.
- For more information go to: https://www.nationalgridus.com/media/pdfs/bus-ways-to-save/nys_clean_heat_1pager_2022.pdf

5.4.2.2 National Grid Commercial Rebates

- Prescriptive rebates: Fixed dollar amount for specific predetermined measures such as lighting, $4–$275 based on fixture type.
- Custom rebates: Performance-based rebates that require project specific assessment and cost-benefit analysis.
    - $0.197/kilowatt hour [kWh] saved (nonlighting), $0.13/kWh (custom lighting), and $1.00/therm saved, up to 50% of incremental cost of project (compared to code minimum equipment).
- For more information go to: https://www.nationalgridus.com/Upstate-NY-Business/Energy-Saving-Programs/

5.4.2.3 National Grid Make-Ready Program

- Will fund up to 50% (or 90% if made available to the public) of the electric infrastructure costs associated with new vehicle charging stations.
- For more information go to: https://www.nationalgridus.com/media/pdfs/bus-ways-to-save/cm8214-ev-infrastructure-brochure.pdf

5.4.3 Tax Incentives

5.4.3.1 Federal Tax Incentives for Commercial Geothermal Heat Pumps

- Investment Tax Credit:
  - Bonus rate of 30% for geothermal systems based on total system cost.
  - Additional 10% bonus rate for domestic content projects.
  - Construction must begin before January 1, 2035—credit reduces in 2032.
  - Large projects (over 1 megawatt) must meet prevailing wage and apprenticeship requirements.
  - Can offset both regular income taxes and alternative minimum taxes.
- Accelerated Depreciation of Energy Property:
  - Classified as 5-year property.
  - Bonus depreciation of 100% in the first year.

5.4.3.2 Federal Investment Tax Credit for Commercial Solar Photovoltaics

- This is a federal corporate income tax credit based on 10% of the cost of the solar Photovoltaics (PV) system.
- For additional information go to: www.energy.gov/eere/solar

5.4.3.3 New York State Electric Vehicle Recharging Property Tax Credit

- Credit the lesser of $5,000 or 50% of the cost of property less any cost paid from the proceeds of grants.
- For additional information go to: https://www.tax.ny.gov/pit/credits/alt_fuels_elec_vehicles.htm

5.4.4 Energy Efficiency Financing

5.4.4.1 Property Assessed Clean Energy Financing (Open C-PACE)

- The full cost of renewable energy improvements (including solar energy, geothermal heat pumps, and air source heat pumps) can be financed through one's property tax bills. This means that the entire cost of these systems (including all labor as well as the distribution system—and possibly domestic hot water) does not need to be financed through the mortgage. Loan terms may range from 20–30 years, with competitive interest rates from a range of potential capital providers.
- For additional information go to: https://www.eicpace.org/eicopencpace

5.5 Other Business Model Options

A typical construction project involves initiating the project, engaging a design team, selecting an installation contractor, and ultimately being responsible for operating and maintaining the equipment. This has generally worked well for SUNY Oswego because the facilities staff is knowledgeable about how the buildings operate and the school has a robust maintenance staff with the necessary expertise to operate and maintain the buildings. Utilizing the traditional path of constructing the project allows the university to have more input and control in both the design and operation of the building systems. Because of this, a traditional approach is recommended.

The design-build-own-operate-maintain business model follows a similar path, but simplifies the work required by the owner. The owner hires one contractor for a task, and it is up to the contractor to determine the means and methods to ensure that the job is completed as requested. Eventually, after the project is in operation for an agreed upon period of time, it is turned over to the owner. The contractor bears all the responsibility, including construction issues and maintenance. However, SUNY Oswego would give up much of the control in the process.

"Energy as a service" is useful when the customer would like the benefits of a system while minimizing upfront costs. This is typically used when a particular technology is desired, such as solar panels. In this model, the customer engages a service company to install and maintain the desired equipment, in exchange for a monthly lease fee. In the case of renewable energy, instead of a lease, a power purchase agreement may be put into place, in which the customer agrees to buy the energy produced at an agreed upon rate. This model is worth considering for the solar panels. The university would be able to reap the benefits of a solar array without bearing the initial upfront cost.

Similarly, "heat as a service," is when a customer enters into an agreement with a supplier simply to provide heat at a fixed cost and not based on usage. It is the responsibility of the supplier to install and maintain the equipment for the building and ensure comfort conditions. In this case, a separate entity would own the wellfield and the HVAC equipment in the building, and SUNY Oswego would pay a fee for the heating (and cooling) in their buildings. The university would not be responsible for the associated energy bills. This is not recommended as the university has a maintenance staff and generally prefers to maintain control of their own buildings.

6 Additional Technologies

To mitigate the electricity consumption of the electrified heating system and to attempt to achieve net zero carbon emissions, power generation is required. In an ideal situation, 100%of the electricity consumed by the building cluster serviced by the proposed geothermal wellfield would be provided by renewable sources.

6.1 Solar Photovoltaics

Solar PV provide an additional opportunity to reduce the energy consumption and operation cost of the community. PV systems harvest ambient solar energy and convert it to electricity, which can reduce the electricity required from the utility grid. When combined with a high-efficiency all-electric building, utility-supplied energy usage can even be eliminated.

Typically, the on-site PV system is tied into the grid, so any shortage is supplemented by the utility grid and any excess solar energy is delivered back to the utility. New York State has a net metering law which allows the excess production to be credited at the same rate as any energy supplied from the grid. In this way, a facility can take advantage of the energy that is produced, even if the building has low electric use during periods of high sunlight when the panels produce more than the building requires.

Most of the buildings considered are high-rise buildings, which have small roofs and limited area for roof-mounted panels. Hewitt Hall does have a large flat roof that could be utilized for solar PV, as does Cooper Dining Hall. Additionally, the campus is fairly open in a rural setting, with lawn space available for additional ground mounted solar panels. Solar panels can also be installed above a geothermal wellfield if desired; however, the recommended location of the wellfield is beneath a parking lot. At an additional cost, parking canopies can provide a location for solar panels.

Several size arrays were evaluated, based on the desired reduction of energy use per option. Optimally, the solar panels would be sized to offset the electricity in its entirety; however, that requires a large upfront cost and likely additional coordination with the utility company. The options evaluated include 100% of the electricity (to understand what area would be required), the roof area on Hewitt available for solar panels, and the size required to offset only the estimated increase in electric consumption of the community geothermal system. The results are shown in Table 29.

Table 30. Solar Panel Array—Estimated Savings

System Size(kW)	Description	Area of Panel (sf)	Annual Output (kWh)	Annual Electric Savings	Avoided Energy Cost	Installation Cost ($2/W)	Potential Incentives*	Net Cost	Simple Payback (years)
425	10% of proposed electric use	23,320	519,092	10%	$51,841	$850,000	$21,250	$828,750	16.0
725	Consumption differential	39,781	885,480	17%	$88,432	$1,450,000	$36,250	$1,413,750	16.0
780	Roof area available	42,800	952,649	18%	$95,140	$1,560,060	$39,002	$1,521,059	16.0
1075	25% of proposed electric use	58,985	1,312,925	25%	$131,121	$2,150,000	$53,750	$2,096,250	16.0
4300	100% of proposed electric use	235,940	5,251,458	100%	$524,459	$8,600,000	$215,000	$8,385,000	16.0

**Subject to installation requirements and approval by NYSERDA. Requires use of NYSERDA participating contractor. Incentives reduce based on number of approved projects in program.

The interconnection of a solar array requires approval by the utility to ensure that it does not negatively affect the utility grid. All installations must follow the New York State Interconnection Requirements (NYSIR), which lays out the required equipment, procedures, listings standards, and relevant codes. All systems much include an inverter and a disconnect, as well as specific certifications (i.e., UL1741) and other accessories. System designers should also refer to the National Grid Electric Tariff PSC 220 and the National Grid Electric Service Bulletins (ESBs) for additional requirements. Once the system is designed, an application is submitted.

Due to the size of the solar array, a Coordinated Electric System Interconnection Review (CESIR) will be required, performed by the utility to evaluate the proposed design for any concerns. If issues are found, the application could be denied, or additional equipment (such as a dedicated transformer) may be necessary at the owner's cost. Periodic verification testing of the protective equipment is required as well.

No significant issues are expected for the interconnection of the solar grid. Due to the rural setting, the site is not in an underground secondary network area which can cause connection complications for the utility. In 2015, SUNY Oswego successfully installed a large solar array at Shineman Hall as part of LEED certification. Note that a distributed solar field system (i.e., spread throughout campus) would require multiple inverters and interconnection applications to the utility grid. However, smaller sized panel arrays (≤50 kW) can go through a simplified application process. Should solar panels be desired for the university, it is imperative to include the utility at early planning stages.

An alternative to site-installed solar panels is utilizing community distributed generation (CDG), a system in which a developer installs a solar field at an offsite location and the power is injected directly into the grid. The university would join the CDG community for a membership fee, and then would get monthly utility bill credits per the value of distributed energy resources (VDER) tariff, based upon the output of the CDG PV system. In this way, the campus can utilize solar power, without incurring the costs of a solar panel installation. Of course, the cost savings of this method are less than that of a site solar panel system, but does not require a significant financial outlay, construction coordination, or maintenance responsibilities.

6.2 Electric Vehicle Charging

According to the US EPA, the transportation sector is responsible for the majority of carbon emissions in this country. At SUNY Oswego, many students and employees commute on a daily basis, contributing to global emissions through burning fossil fuels and tailpipe emissions. Because carbon-neutrality is the ultimate goal of the university, adding electric vehicle (EV) charging stations to help to offset some of the impact from carbon emissions produced by daily commuters aligns with their ultimate goals.

There are three types of charging stations, each requiring different power demands, for example, Level 1 is a slow charger; Level 2, is a medium-speed charger; and Level 3 is a direct-current fast charger (DCFC). Level 1 is best for hybrids and overnight charging requiring only a standard household plug. This is typically feasible for places with long-term parking. Level 2 requires 240-volt (V) chargers, and can fill an EV in several hours, such as during the workday. This requires more infrastructure than a Level 1 charger but is generally more useful for public use. The Level 3 fast charger provides full charging in less than an hour, but requires more intensive electrical infrastructure, including a 480 V service and has minimally 50 kW demand (up to approximately 400 kW at present). There are no industry standard DCFC plugs, and they are most useful at locations with transient occupants.

At a university, most occupants stay several hours, either for work, classes, or staying home, and EVs can remain plugged in for an extended period. Therefore, Level 2 charging is the most suitable type of charger for a university. To determine the proper number of charging stations for the site occupants, an EV survey of the occupants is recommended to determine interest. This will ensure that there are a sufficient number of stations and to encourage EV usage on campus. In lieu of a survey, NYStretch Energy Code suggests a total of 5% of parking spaces be provided with Level 2 EV charging stations.

The university may choose to offer free charging to vehicles on site or may charge to generate revenue with the stations to recoup installation and energy costs. With current volatile prices of energy, it is recommended to offer paid charging. SUNY Oswego has previously installed 6 EV chargers as part of the Shineman Hall LEED certification process, which are currently offered for free for several hours and then a flat hourly fee.

The energy and cost implications of the EV charging stations for the parking lots nearby the building cluster are as follows:

Table 31. Electric Vehicle Charging—Estimated Savings

Building	Number of Parking Spaces	Number of Charging Stations	Estimated Installation Cost	Estimated Incentive (National Grid)	Total Cost	Daily Uses per Station	Peak Demand (kW)	Estimated Annual Energy Consumption (kWh)	Estimated Annual Energy Cost	Potential Annual Revenue	Simple Payback (Years)
E-6	86	4	$40,600	$15,000	$25,600	0.5	38.4	11,744	$1,173	$3,174	13
R-9	322	16	$162,400	$60,000	$102,400	0.5	153.6	46,976	$4,691	$12,695	13
E-18	228	12	$121,800	$45,000	$76,800	0.5	115.2	35,232	$3,519	$9,521	13
C-18	43	2	$20,300	$7,500	$12,800	0.5	19.2	5,872	$586	$1,587	13
C-32	231	12	$121,800	$45,000	$76,800	0.5	115.2	35,232	$3,519	$9,521	13
Total	**910**	**46**	**$466,900**	**$172,500**	**$294,400**		**441.6**	**135,055**	**$13,488**	**$36,498**	13

Note: Assumes 30% reduction of use in June, July, and August.

Table 32. Annual EV Cabon Emissions

Electric			Gasoline		Savings versus Gasoline	
Fuel Efficiency: Average as Published (kWh/mi)	Annual Mileage (mi)	Carbon Emissions (lb CO_2e)	Fuel Efficiency: US EPA Average (mi/gal)	Carbon Consumption (lb CO_2e)*	Carbon Savings (lb CO_2e)	Carbon Savings (%)
0.346	390,331	31,373	22	347,610	316,237	91%

*US EPA: 8887 g CO_2/gal.

With the green electric grid of Upstate New York, electric vehicles consume 91% less carbon emissions when compared to gasoline vehicles, and the installation payback is reasonable. However, the peak demand of a large number of charging stations can add an additional burden on the building electric service, so it is recommended that the stations be installed in conjunction with solar panels.

An alternative method of financing electric vehicle charging station is employing the "Charging as a Service" business model. In this method, the university partners with an electric vehicle charging company (such as WattsLogic or EVConnect) to install the stations. The university does not pay for the installation, but instead pays a monthly subscription fee to cover the installation, maintenance, and software costs of the stations. The charging company is responsible for the upkeep. This is ultimately more costly than a self-financed installation but transfers the burden of ownership to a third party. The university may still choose to offer either paid or free charging. Due to the large first cost of the Community Heat Pump System, requiring payment may be a preferable option for the university.

6.3 Battery Energy Storage

Solar PV, while excellent at providing renewable energy, only provide electricity while there is adequate sunlight. At all other times, the building must utilize the grid for electricity needs. This means that solar PV will reduce the grid-supplied electricity consumed in a building but may not impact the overall demand on the grid if conditions are not favorable during periods of high demand. In particular, with an electrified heating system, the winter demand peaks are often early in the morning or late in the day, when outdoor temperatures are cooler and the ventilation systems are operating and when, in Northern climates, it may still be dark.

The use of battery energy storage allows for “peak shaving,” which uses smart controls to manage the stored energy in the battery to provide electricity at the demand peak, which reduces the overall strain on the energy grid. A well-designed battery storage system may also minimize required electrical service upgrades for the proposed community heat pump system, by allowing the battery to operate in lieu of the electrical service. This type of energy storage can be used as a carbon-friendly replacement to fossil-fuel emergency generators as they utilize the sun to build up the reserve power. Generators are very inefficient for making electricity, and carbon savings are significant even when batteries are charged with traditional grid-supplied electricity. When the battery is part of a solar PV system, the carbon savings are compounded.

Besides the benefits to the electricity grid, battery storage saves cost by reduced demand charges. The current National Grid cost per kilowatt peak demand for Large General Service class SC-3A (for customers with a primary service less than 15 kilovolts [kV] and more than 2,000 kW demand) is $11.42, and when eliminated, can show significant savings. Three scenarios are analyzed for sizing purposes: (1) batteries sized per building based on smoothing the peak of the demand day; (2) sized to match the existing building peak; and (3) sized for four-hour standby power instead of a gas generator. The results are summarized as follows:

Table 33. Battery Charging: Demand Day—Estimated Savings

Building	Battery Size (kW)	Storage Capacity (kWh)	Peak Demand (kW)	Peak Demand with Battery (kW)	Average Monthly Demand Savings (kW)	Annual Demand Savings (kW)	Annual Demand Charge Savings ($)	Estimated Installation Cost	Simple Payback (Years)
Cooper Dining Hall	48	62	204	159	39.6	475	$5,425	$75,345	13.9
Culkin Hall	140	521	453	323	118.4	1421	$16,228	$220,436	13.6
Funnelle Hall	27	101	199	174	16.0	192	$2,194	$42,850	19.5
Hart Hall	35	129	258	226	23.2	279	$3,185	$54,658	17.2
Total	**250**	**813**	**1113**	**881**	**197.3**	**2367**	**$27,031**	**$393,289**	**14.5**

Table 34. Battery Charging: Existing Peaks—Estimated Savings

Building	Battery Size (kW)	Storage Capacity (kWh)	Peak Demand (kW)	Peak Demand with Battery (kW)	Average Monthly Demand Savings (kW)	Annual Demand Savings (kW)	Annual Demand Charge Savings ($)	Estimated Installation Cost	Simple Payback (Years)
Cooper Dining Hall	80	277	204	137	46.8	561	$6,408	$126,449	19.7
Culkin Hall	207	771	453	260	127.0	1524	$17,401	$326,285	18.8
Funnelle Hall	109	152	199	165	18.2	218	$2,490	$171,050	68.7
Hart Hall	152	194	258	210	26.1	313	$3,576	$238,740	66.8
Total	**548**	**1393**	**1113**	**772**	**218.0**	**2616**	**$29,874**	**$862,524**	**28.9**

Table 35. Battery Charging: Emergency Generation—Estimated Savings

Building	Battery Size (kW)	Storage Capacity (kWh)	Generator Exercise NGas Use (therm)	Generator NGas Costs ($)	Equiv. Battery Testing (kWh)	Battery Electric Costs ($)	Carbon Savings (lb CO_2e)	Carbon Savings (%)	Estimated Installation Cost	Estimated Generator Cost	Estimated Incremental Cost	Simple Payback (Years)
Cooper Dining Hall	122	489	125	$75	61	$6	1,449	99%	$192,463	$54,990	$137,474	1984.6
Culkin Hall	272	1086	278	$168	136	$14	3,221	99%	$427,767	$122,219	$305,548	1984.6
Funnelle Hall	119	478	122	$74	60	$6	1,416	99%	$188,056	$53,730	$134,326	1984.6
Hart Hall	155	619	158	$95	77	$8	1,836	99%	$243,782	$69,652	$174,130	1984.6
Total	**668**	**2672**	**684**	**$412**	**334**	**$33**	**7,923**	99%	**$1,052,068**	**$300,591**	**$751,477**	**1984.6**

Battery storage is a cost-effective solution when sized appropriately. Due to the shorter paybacks, batteries sized for the building peaks are recommended. Should generators be due for replacement, battery storage may be a viable alternative thanks to the carbon reduction, depending on building requirements for emergency power. Unfortunately, from a simple payback perspective, battery storage is not yet cost-effective as a generator replacement. Should the generator be required to operate for a longer term during the year, it will increase the energy and carbon savings based on usage.

Due to the chemicals in the batteries, they can be a fire hazard and have strict code considerations. They require a separate fire-rated room, ventilation, fire suppression, and may also require a certified large-scale fire test to determine allowable separations. An alternative to modifying the existing building is to install the battery system in an exterior enclosure, although many of the same requirements remain. Batteries lose efficiency during extreme temperatures, especially in cold temperatures, so any outdoor location may require supplemental heat. Small systems (<20 kW) may be exterior wall mounted.

Should the CDG option for solar panels be selected, a battery storage system may still make sense. Ultimately, it functions the same as the battery without solar, except that power to charge the battery will come directly from the grid during periods of low demand (i.e., overnight), and the costs for doing so will be largely offset by VDER credits.

Battery storage requires the same application process with the utility company as solar PV, including specific equipment and testing.

7 Regulatory Requirements

All construction projects must undergo a permitting process to ensure the proposed design meets the requirements of the authority having jurisdiction (AHJ). The campus site at SUNY Oswego is located in the Town of Oswego and is a part of the State University of New York campus system. Should public funding be utilized for campus projects through SUNY entities such as the State University Construction Fund (SUCF) or the Dormitory Authority of the State of New York (DASNY), the relevant entity will be considered the AHJ. The campus must also abide by any Town of Oswego requirements. SUCF or DASNY, working with SUNY Oswego, will set a timeline for the development and review of design documents and ultimately the permitting process. Typically, projects are broken down into several phases and reviewed by the AHJ at each phase to ensure compliance with all NYS directives and code requirements. SUNY Oswego has previously installed geothermal projects on campus with little issue, and regulatory hurdles are not expected.

All buildings are required to follow the 2020 New York State Uniform Fire Prevention and Building Code and the 2020 Energy Conservation Construction Code and all referenced standards within. As part of the building permit application, a Short Environmental Assessment Form is to be submitted to the AHJ to ensure that the construction will not negatively impact the surrounding environment. A sample form has been provided for a test well (see appendix), although the assessment was already provided and submitted for the construction of the test well and Hewitt Hall project. Due to the size of the proposed wellfield, the site will also likely require a Stormwater Pollution Protection Plan. However, all the site trenching will be backfilled and graded, and returned back to the previous ground cover (either pavement or lawn) and is likely to have a minimal impact on stormwater except during construction. The site is not located on or near protected wetlands, nor within the 100-year floodplain.

Both PV and battery storage systems require approval by National Grid. This process may take two months for approval for large systems, because the utility must perform a study to determine if the grid can handle the power generation. Working with the utility company from early design is imperative to ensure that the full costs are understood, and requirements are met prior to committing to this path.

Battery storage has historically been a point of contention in some jurisdictions, due to the fire hazard, and some permit offices were reluctant to approve them. However, in 2018 and again in 2021, the codes regarding battery storage (i.e., NFPA 1 and IFC) were updated to increase the stringency of installation requirements, which alleviates much of the fear surrounding the batteries. Combined with increased climate awareness and the carbon-neutrality push of New York State, AHJ reluctance has largely subsided, and no issues are expected.

The entire site, including the buildings, roadways, and the surrounding infrastructure are owned and maintained by SUNY Oswego. Therefore, right-of-way permits will not be required. There are a number of utilities located in the area of the proposed wellfields, but because the utilities are all owned by the university, any crossing or rerouting will require the proper permits only and no easement or utility franchise agreements will be necessary.

Although a district geothermal is not yet a common design for building HVAC systems, traditional geothermal heat pump systems have been approved for installations for decades. Ultimately, since SUNY Oswego owns all the buildings and land in question and is responsible for all the utility bills, the installation can be considered from a regulatory perspective as a typical installation, albeit a large one. Phasing, financing, and other potential obstacles are strictly at the owner's discretion and are not expected to pose difficulty in the permitting process.

8 Educational Opportunities

SUNY Oswego is, at its core, an educational institute. As a center for learning, the university looks to use capital improvement projects and sustainability initiatives as a learning opportunity for the students on campus. A large community heat pump project can provide educational growth for both individual students engaged in the design process, as well as the campus at large.

8.1 Promoting Campus Engagement

The installation of a geothermal system involves a significant disturbance to a large area of land and will be noticed by most students on campus. This provides an opportunity for those involved with the construction project on campus to promote the benefits of the geothermal project specifically as well as sustainability in general. A simple way to engage students is to provide informational signage at areas of interest as renewable energy projects are brought on board. For example, a plaque may be installed near the geothermal field explaining the technology, or a website may include a live graph visually depicting the energy moving through the wells. As the project is underway, arranging a tour for interested students can further showcase the work that SUNY Oswego is undertaking to reduce their carbon footprint.

The university has already established a Climate Action Plan and an Office of Sustainability and incorporates educational tracks and degree programs relating to sustainability. There are a number of green initiatives in place on campus. The proposed community heat pump project can be leveraged further by speakers addressing the school at large as well as in classes to promote the need for climate action as it relates to campus operations, and to encourage the school population to consider the impacts of climate change in their activities at SUNY Oswego.

8.2 Internships

To incorporate the campus and utilize the talents of interested students, the idea of engaging a SUNY Oswego intern to assist in the development of this report was explored. Ultimately, due to timing and the bulk of the work on this project occurring over the summer months, the plan was abandoned.

However, the campus has expressed an interest in utilizing this analysis and the associated proposed project as a prototype for future community wellfields. Although another comprehensive analysis may not be required for future communities, much of the legwork will still be required to properly design a geothermal system. An intern may be helpful in gathering data and performing a preliminary review of the potential system. Additionally, future interns may find value in performing some of the tasks that have already been completed to better understand this analysis and the process of designing a community geothermal system.

Several areas of work were considered for an intern to assist with this analysis:

- Gather data:
  - Locate and forward data required for study.
  - Review existing documentation and compile descriptions of existing buildings (e.g., determine building envelope constructions).
- Utility analysis:
  - Review data for missing months or other anomalies.
  - Graph monthly data; determine if utility consumption follows weather conditions as expected for building type.
  - Compare actual building Energy Utilization Index to typical buildings
- Wellfield layout:
  - Overlay 20 x 20 feet wellfield onto site plan, taking into account utilities and other items.
- Regulatory review:
  - Talk to parties involved with previous geothermal projects to note any regulatory hurdles and problems or issues.
  - Prepare preliminary State Environmental Quality Review Act (SEQR) short form review for potential wellfield.
- Solar feasibility:
  - Determine required solar panel array size (utilizing PV Watts tool) based on projected electricity consumption.
  - Review site plan to determine potential locations for solar array.
- Possible incentives:
  - Compile list of possible incentive programs.

9 Analysis

9.1 Site Considerations

This study encompassed five buildings on the SUNY Oswego Campus as previously described. The building cluster contains many different building types, including office, food service, academic, and residential areas. Combining the buildings on a large thermal network to offset the differing loads both increases energy efficiency of the buildings and allows for a reduction in the number of wells required for the buildings to operate.

SUNY Oswego is the only member in the proposed community and is the sole arbiter of this project moving forward. The project does not demonstrate a reasonable payback, but the carbon benefits are great, and an electrified heating system is necessary for the university to meet their carbon-neutrality goals in the future. Combined with the current potential incentive available for the installation, it may be sufficient to bring this concept into design.

A properly phased project is one that provides the most value in the beginning phases. In this community, the first phase has already begun with the construction of the Hewitt Hall wellfield and subsequent renovation. The cooling-dominated building provides a balance for the additional heating-dominated buildings in the cluster.

Once the project as proposed is underway, the next phase should include the wellfield and distribution network, bringing the piping into Culkin Hall. The lateral geothermal piping should be connected to each building in the cluster, and the wellfield pumps installed in Culkin Hall. With the wells in place, the building heat pumps can be added with little disruption.

Each building can be brought online one by one and scheduled based on the needs of the campus. Since existing systems are generally being maintained, the construction timeline is relatively brief. Once the wellfield is in place, Hart Hall and Cooper Dining Hall may be upgraded next. They are sparsely used over the summer, so any upgrades should be scheduled for that timeframe. Funnelle Hall was recently renovated and has the newest equipment. Thus, it is recommended that it be upgraded last.

The upgrades at Culkin Hall may be more complicated if the two-pipe fan coil unit system is replaced as part of the renovations. Additional time may be required for the design of any upgrades, and it may be necessary to complete the building in a later phase, depending on the extent of the building renovations.

The site lends itself well to a community geothermal system. Located in a rural setting, the site is reasonably flat with a fair amount of open land as well as parking lots. As with most communities, there are underground utilities throughout the campus, which require careful coordination, although installation of wells around the utilities is feasible. However, the proposed location of the wellfield has minimal utilities and has ample room for the installation. Any future additions to the community heat pump system will require an additional site; there are several nearby parking lots and open lawn areas that may be utilized for satellite wellfields. Also, since the university owns the streets in this community, wells could be installed beneath the pavement.

Generally, this study focused on the buildings included in the current opportunity for NYSERDA. However, with the number of nearby buildings, the district system could be easily expanded. The proposed design can be utilized as a prototype, and several nearby clusters can be formed similarly. Ultimately, all clusters may be combined and share energy throughout the campus to maximize efficiency and minimize the total number of wells required.

9.2 Technologies Assessed

The proposed design includes a ground source heat pump system. This type of technology utilizes the refrigerant cycle to efficiently move energy from the earth (via water loop) into the buildings (into another water loop or the air directly). When a heat pump removes heat from a space, for example, it must have an area in which to place the heat. These heat pumps use the ground source water loop to dissipate that heat into the earth. Ultimately, the recommended in-building systems are primarily water-to-water heat pumps. Generally, high-efficient equipment was selected and compared against both the existing building systems and geothermal heat pumps with code-minimum efficiencies.

For a wellfield, it is important to keep the thermal load balanced. Over time, if there is more cooling than heating, for example, that heat causes the ground temperature to slowly increase, which in turn increases the temperatures in the water piping. This provides less capacity for the in-building system, reduces efficiency, and can eventually cause equipment failure in the cooling mode. An unbalanced load profile requires a larger number of wells to slow the heat gain or loss from the surrounding earth, which may delay the complications to beyond the useful life of the geothermal system. However, given a long enough time, the impacts of the imbalance will be seen.

In this community, the combined building loads are not well balanced, thanks to some heating-only buildings. To maintain a better balance and to achieve longevity in the wellfield operation, the domestic hot water loads have been excluded from the community heat pump system. Because the goal of the campus is to have net zero carbon, additional cooling-dominated buildings should be added to the geothermal network to offset domestic hot water loads. Otherwise, an alternative electrified water heating solution should be utilized, such as air source heat pumps.

Because the geothermal system is an electrified heating system in a heating dominated climate, the system will cause increased strain on the electric grid. To mitigate the impacts, distributed clean energy systems are of increased value on these projects. Solar PV harvest energy from the sun to offset the electric consumption and provide free electricity for the operation of the heat pumps. However, solar energy does not help in reducing the peak demand on the electricity grid. Combining the solar energy with energy storage allows the solar panels to charge the battery with free electricity, and then discharge it during periods of high demand. This way electricity consumption of the building is optimized for the utility grid and thus the energy bills.

9.3 Analytical Methods

Every building was modeled utilizing the eQuest 3.65 simulation program, and simulated over a one-year period, utilizing Syracuse, NY, typical meteorological year (TMY2) weather data.

All models are identical, except as indicated as part of the HVAC system design. Generally, the models follow the guidelines set forth for the proposed model in ASHRAE Standard 90.1—2016 Energy Standard for Buildings Except Low-Rise Residential Buildings—Appendix G, in conjunction with COMNET modeling guidelines and industry standard energy modeling assumptions. Code minimum efficiencies are based on 2020 NYS Energy Code. Additional sources include the US EPA, United States Department of Energy, NYSERDA, PV Watts, ASHRAE standards, and others as noted.

A test well was drilled for the Hewitt Hall project to determine the thermal properties of the ground in the area of the drilling site. The wellfield was sized based on the resulting data in conjunction with the eQuest model output data. The hourly thermal load data on the geothermal loop was combined into a monthly load profile and sized utilizing GLHEPro v5.0.4. Instead of sizing based on peak tonnage on the system, which is an outdated way of sizing the wellfield, the number of wells is determined based on both the monthly heating and cooling loads and peaks over the course of a year.

The eQuest energy model includes all components of the geothermal system, including pumps and compressors, both of which add heat to the geothermal loop. In fact, given the same load and same efficiency in both heating and cooling seasons, the energy added or removed to the loop is greater in cooling season, due to the compressor itself supplementing the heat in heating mode, which adds to the load in cooling mode.

To provide a workable solution to SUNY Oswego, this study focused on how to incorporate a district geothermal system that utilizes the building systems as they stand today to mitigate first cost, while upgrading systems where necessary to ensure energy efficiency. Because of the large capital costs that must be shouldered entirely by the university, it is necessary to be prudent with the cost of recommendations.

9.4 Proposed Design

To determine the optimal conceptual design for the university, various options were analyzed, finally landing on the proposed design. Generally, the design was intended to minimize equipment replacement within buildings and not to require major overhauling of building systems.

All of the buildings are connected to the campus plant for hot water heating. To maintain similar systems, heat generation is required; once there is a heat pump in place to provide heat, it makes sense to utilize it for cooling as well. Other systems, such as traditional water-to-air heat pump systems were considered, but ultimately the hot water/chilled water systems were more cost efficient and feasible for the current layout and usage of the buildings. One major advantage of water-to-water heat pumps is the centralized location for the heat pump compressors, so maintenance for the systems are in one place, and the noise in the conditioned spaces is reduced.

Water source variable refrigerant flow (VRF) systems were also considered and ultimately rejected. In addition to the cost of upgrading the building systems, the amount of refrigerant required can be great. This is a concern when considering leakage, especially in light of refrigerant regulation changes expected in the next few years. Instead, premium efficiency ground source heat pumps were selected, which can mitigate most of the efficiency benefits of VRF.

Domestic hot water with heat pump systems can pose a challenge. For carbon emission reduction, an electrified water heating solution is desired. Air source heat pumps do not yet function well in the Oswego climate zone, due to cold winter temperatures (outdoor units) or the cooling it adds to the space (indoor units). Tank-type geothermal water heaters are not yet commercially viable, so a boiler and storage tank system would be required, though this takes up a fair amount of floor space. Regardless, due to the heating-dominated nature of the wellfield loop, GSHP domestic water heaters have not been recommended for the buildings at this time.

Phasing to minimize disruption to the building occupants should provide little challenge. The proposed main heat pumps will directly swap in to replace existing equipment and will occupy the same floor space. There is little distributed equipment that is expected to require upgrade. However, as discussed in previous sections, the lower temperature hot water may pose an issue if the building systems cannot provide sufficient heat with the reduced temperatures. This should be evaluated prior to initiating the design process. If supplemental heat is required to maintain comfortable conditions, the project will become more complicated, increasing costs, and extending the timeline required for renovation.

Individual building heat pump systems are unable to share energy among buildings and require many distributed wellfields along with the associated accessories. Space is required for each of these wellfields and the wellfields require careful planning and coordination with utilities. The total number of wells is increased as a result; however, individual systems reduce the piping required to interconnect all the buildings. The additional district loop piping adds some heat to the system via friction. Piping should be slightly oversized to reduce the friction, which also reduces pump head and allows for smaller district pumps. The long piping runs have an additional benefit as well, as the additional thermal loss through the distribution network can function somewhat as additional wells by tempering water temperatures in the loop.

9.5 Business Model

Since SUNY Oswego is the sole owner of the site and the surrounding land, the district thermal network does not require special considerations, such as contractual agreements between interested parties, other than typical contractor or incentive program terms. As the only interested party, the university can take advantage of all eligible monetary and tax incentives and would receive the full award, assuming compliance with all program requirements. Most incentives are awarded after construction, so funding must be secured to finance the project prior to receipt, although typically an offer letter is initiated at the end of design. Regulatory hurdles are limited with this project.

9.6 System Impact

The difference in the number of geothermal wells required in the individual building scenario in contrast to the district wellfield is great, that is, 362 versus 289. Because of the close proximity of the buildings, there is not much extra infrastructure required to connect the buildings in a community system, so installation costs stay comparatively low with the community system. The energy and carbon savings is improved in the district energy system, although not by a great amount, which saves modest annual operating costs. Ongoing maintenance costs are also slightly less with the centralized system. Fundamentally, there is not a major difference between the selected systems, except for potential incentives.

The available incentives are substantial, especially through the NYSERDA Community Heat Pump program. In fact, ultimately, this large incentive would make up the majority of the difference between the individual system and the community system, should the project be awarded this competitive incentive—an award that is not guaranteed. From a life-cycle cost standpoint, this sets the community energy system apart.

Although cost is a primary consideration of any construction project, the overarching goal is not cost savings, it is carbon reduction. When compared against the existing baseline system, the geothermal system saves almost half of the overall carbon. This carbon savings will be compounded with a renewable energy system and will continue to grow as the grid evolves.

The following is a summary of the data:

Table 36. Options Summary

Design Option	Construction Cost	Estimated Incentives	Total First Cost	Annual Maintenance	Annual Energy Costs	Total Annual Costs	Annual Carbon (lb CO_2e)	25-Year NPV ($)
Baseline System: Replace systems in kind	$2,114,596	$0	**$2,114,596**	$9,682	$550,390	**$560,072**	**3,222,031**	($12,710,669)
Code-Compliant System: Individual building heat pumps	$15,235,508	$722,912	**$14,512,596**	$15,716	$570,365	**$586,081**	**1,617,806**	($25,384,114)
Proposed System: Community heat pumps	$13,306,349	$4,785,632	**$8,520,717**	$15,316	$539,776	**$555,092**	**1,546,657**	($18,698,228)

Table 37. Savings over Existing Systems

Design Option	First Cost ($)	First Cost (%)	Annual Costs ($)	Annual Costs (%)	Simple Payback (Years)	Annual Carbon (lb CO_2e)	Annual Carbon (%)	25-Year NPV ($)	25-Year NPV (%)
Baseline System: Replace systems in kind	–	–	–	–		–	–		
Code-Compliant System: Individual building heat pumps	-$12,398,001	-586%	-$26,009	-5%	N/A	1,604,225	50%	-$12,673,445	-100%
Proposed System: Community heat pumps	-$6,406,121	-303%	$4,979	1%	1286.5	1,675,374	52%	-$5,987,559	-47%

Table 38. Comparison of Heat Pump Systems versus Individual Systems

Design Option	First Cost ($)	First Cost (%)	Annual Costs ($)	Annual Costs (%)	Simple Payback (Years)	Annual Carbon (lb CO_2e)	Annual Carbon (%)	25-Year NPV ($)	25-Year NPV (%)
Code-Compliant System: Individual building heat pumps	–	–	–	–	–	–	–	–	–
Proposed System: Community heat pumps	$5,991,879	41%	$30,988	5%	193.4	71,149	5%	$6,685,886	26%

9.7 Conclusions

The recommended system from this analysis is the community heat pump system. The solar panels and battery storage will provide additional value but come at a cost premium. The ideal size of a solar array is to offset the power completely, with a battery storage system to match, but any amount will help to reduce the carbon footprint of the building cluster.

The next step, should SUNY Oswego choose to move forward with the community heat pump system, is to transition to the design phase, and to apply for the category B incentive through the NYSERDA Community Heat Pump Program to assist in the design effort. During the design, additional team members will be brought into the project, such as design engineers, the utilities, heat pump manufacturer representatives, and additional key stakeholders from the university.

For additional value, the district system can also be designed for future expansion. Mainly, it would require oversized district piping to allow for future flows, and a larger pipe manifold to accommodate additional circuits. There can be several satellite wellfields as well to contribute to the thermal network, interconnected via district piping. Wellfields require little maintenance, and once in place, permit the use of the land above as usual, so additional concerns for satellite wellfields are limited, and can continually be added if desired.

The community wellfield will provide great energy and carbon reduction, making great strides in moving SUNY Oswego to their goal of carbon-neutrality by 2050.

Appendix A. Project Contacts

Site Owner

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Primary Energy Consultant

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Appendix B. Modeling Program Outputs

B.1 Baseline Models

Cooper Dining Hall

Cooper Hall DOE-2.3-50h 8/05/2022 14:42:17 BDL RUN 19

REPORT- BEPU Building Utility Performance WEATHER FILE- SYRACUSE, NY

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY KWH	120085.	0.	97889.	0.	62405.	3365.	39621.	171918.	0.	0.	0.	2252.	497535.
FM1 NATURAL-GAS THERM	0.	0.	3612.	44876.	0.	0.	0.	0.	0.	0.	9198.	0.	57687.

Culkin Hall

Culkin Hall DOE-2.3-50h 8/05/2022 14:41:00 BDL RUN 18

REPORT- BEPU Building Utility Performance WEATHER FILE- SYRACUSE, NY

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY KWH	216467.	0.	141914.	0.	71223.	2393.	153898.	216060.	0.	0.	0.	4062.	806018.
FM1 NATURAL-GAS THERM	0.	0.	0.	44203.	0.	0.	0.	0.	0.	0.	830.	0.	45033.

Funnelle Hall

Funnelle Hall DOE-2.3-50h 8/05/2022 14:51:07 BDL RUN 24

REPORT- BEPU Building Utility Performance WEATHER FILE- SYRACUSE, NY

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY KWH	296649.	0.	125966.	0.	19999.	0.	897.	84616.	0.	0.	0.	7291.	535419.
FM1 NATURAL-GAS THERM	0.	0.	0.	32224.	0.	0.	0.	0.	0.	0.	4738.	0.	36962.

Hart Hall

Hart Hall DOE-2.3-50h 8/05/2022 14:55:29 BDL RUN 25

REPORT- BEPU Building Utility Performance WEATHER FILE- SYRACUSE, NY

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY KWH	303365.	0.	148399.	0.	15879.	0.	7590.	222129.	0.	0.	0.	7320.	704682.
FM1 NATURAL-GAS THERM	0.	0.	0.	41553.	0.	0.	0.	0.	0.	0.	4303.	0.	45856.

Hewitt Hall

Hewitt Hall DOE-2.3-50h 8/05/2022 16:56:12 BDL RUN 1

REPORT- BEPU Building Utility Performance WEATHER FILE- SYRACUSE, NY

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY KWH	185015.	31866.	906722.	81556.	205413.	0.	143364.	144972.	64877.	0.	44206.	21900.	1829893.
EM2 ELECTRICITY KWH	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
EM3 ELECTRICITY KWH	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FM1 NATURAL-GAS THERM	0.	0.	3049.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3049.

B.2 Proposed Models

Cooper Dining Hall

Cooper Hall DOE-2.3-50h 12/31/2022 0:14:07 BDL RUN 2

REPORT- BEPU Building Utility Performance WEATHER FILE- SYRACUSE, NY

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY KWH	120085.	0.	97889.	241190.	30339.	0.	15866.	176209.	0.	0.	0.	2252.	683829.
FM1 NATURAL-GAS THERM	0.	0.	3612.	0.	0.	0.	0.	0.	0.	0.	9205.	0.	12817.

Culkin Hall

Culkin Hall DOE-2.3-50h 12/31/2022 0:16:21 BDL RUN 4

REPORT- BEPU Building Utility Performance WEATHER FILE- SYRACUSE, NY

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY KWH	216467.	0.	141914.	280335.	67548.	0.	34593.	217941.	0.	0.	0.	4062.	962862.
FM1 NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	830.	0.	830.

Funnelle Hall

Funnelle Hall DOE-2.3-50h 12/31/2022 0:21:39 BDL RUN 8

REPORT- BEPU Building Utility Performance WEATHER FILE- SYRACUSE, NY

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY KWH	296649.	0.	125966.	207870.	11507.	0.	23816.	84616.	0.	0.	0.	7291.	757716.
FM1 NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4738.	0.	4738.

Hart Hall

Hart Hall DOE-2.3-50h 12/31/2022 0:26:06 BDL RUN 1

REPORT- BEPU Building Utility Performance WEATHER FILE- SYRACUSE, NY

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY KWH	303365.	0.	148399.	263215.	9885.	0.	25876.	222128.	0.	0.	0.	7320.	980188.
FM1 NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	6838.	0.	6838.

B.3 Code-Compliant Model

Cooper Dining Hall

Cooper Hall DOE-2.3-50h 12/31/2022 0:14:13 BDL RUN 2

REPORT- BEPU Building Utility Performance WEATHER FILE- SYRACUSE, NY

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY KWH	120085.	0.	97889.	327716.	47114.	0.	19808.	176209.	0.	0.	0.	2252.	791073.
FM1 NATURAL-GAS THERM	0.	0.	3612.	0.	0.	0.	0.	0.	0.	0.	9205.	0.	12817.

Culkin Hall

Culkin Hall DOE-2.3-50h 12/31/2022 0:16:21 BDL RUN 4

REPORT- BEPU Building Utility Performance WEATHER FILE- SYRACUSE, NY

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY KWH	216467.	0.	141914.	280335.	67548.	0.	34593.	217941.	0.	0.	0.	4062.	962862.
FM1 NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	830.	0.	830.

Funnelle Hall

Funnelle Hall DOE-2.3-50h 12/31/2022 0:22:18 BDL RUN 8

REPORT- BEPU Building Utility Performance WEATHER FILE- SYRACUSE, NY

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY KWH	296649.	0.	125966.	278637.	17398.	0.	30444.	84616.	0.	0.	0.	7291.	841001.
FM1 NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4738.	0.	4738.

Hart Hall

Hart Hall DOE-2.3-50h 12/31/2022 0:26:40 BDL RUN 1

REPORT- BEPU Building Utility Performance WEATHER FILE- SYRACUSE, NY

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY KWH	303365.	0.	148399.	351151.	14941.	0.	32070.	222128.	0.	0.	0.	7320.	1079373.
FM1 NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	6838.	0.	6838.

Appendix C. Test Well Results

FORMATION THERMAL CONDUCTIVITY
TEST & DATA ANALYSIS

TEST LOCATION **SUNY-Oswego Hewitt Hall**
Oswego, NY

TEST DATE July 10-12, 2020

ANALYSIS FOR MEP, a Salas O'Brien Company
Grand Oak Office Center
860 Blue Gentian Rd. Suite 175
Eagan, MN 55121
Phone: (651) 379-9120

TEST PERFORMED BY Geothermal Resource Technologies, Inc.

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PO Box 256, Elkton, SD 57026
P: 866-991-4784 F: 605-542-6099

SOUTHERN OFFICE
PO Box 150, Bowie, TX 76230
P: 940-872-2222

EASTERN OFFICE
6 William Warren Dr Asheville NC 28806
P: 828-225-9166

EXECUTIVE SUMMARY

A formation thermal conductivity test was performed at the SUNY-Oswego campus at Hewitt Hall at a GPS location of N 43° 27' 06.0" (latitude), W 76° 32' 34.2" (longitude) in Oswego, New York. The vertical bore was completed on June 19, 2020 by American Auger & Ditching Co., Inc. Geothermal Resource Technologies' (GRTI) test unit was attached to the vertical bore on the afternoon of July 10, 2020.

This report provides an overview of the test procedures and analysis process, along with plots of the loop temperature and input heat rate data. The collected data was analyzed using the "line source" method and the following average formation thermal conductivity was determined.

Formation Thermal Conductivity = 2.28 Btu/hr-ft-°F

Due to the necessity of a thermal diffusivity value in the design calculation process, an estimate of the average thermal diffusivity was made for the encountered formation.

Formation Thermal Diffusivity ≈ 1.39 ft^2/day

Bore thermal resistance calculations were made on the test data using the method outlined in the Gehlin Doctoral Thesis[1]. Since the average value listed below was empirically determined from the test data it may not directly correlate with values found in loopfield design programs.

Bore Thermal Resistance = 0.220 hr-ft-°F/Btu

The undisturbed formation temperature for the tested bore was established from the initial loop temperature data collected at startup.

Undisturbed Formation Temperature ≈ 52.3-54.2°F

The formation thermal properties determined by this test do not directly translate into a loop length requirement (i.e. feet of bore per ton). These parameters, along with many others, are inputs to commercially available loop-field design software to determine the required loop length. Additional questions concerning the use of these results are discussed in the frequently asked question (FAQ) section at www.grti.com.

[1] Signhild Gehlin. "Thermal Response Test - Method Development and Evaluation," (Doctoral Thesis, Lulea University of Technology, 2002).

TEST PROCEDURES

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) has published recommended procedures for performing formation thermal conductivity tests in the ASHRAE HVAC Applications Handbook, Geothermal Energy Chapter. The International Ground Source Heat Pump Association (IGSHPA) also lists test procedures in their Design and Installation Standards. GRTI's test procedures meet or exceed those recommended by ASHRAE and IGSHPA, with the specific procedures described below:

Grouting Procedure for Test Loops – To ensure against bridging and voids, it is recommended that the bore annulus is uniformly grouted from the bottom to the top via tremie pipe.

Time Between Loop Installation and Testing – A minimum delay of five days between loop installation and test startup is recommended for bores that are air drilled, and a minimum waiting period of two days for mud rotary drilling.

Undisturbed Formation Temperature Measurement – The undisturbed formation temperature should be determined by recording the loop temperature as the water returns from the u-bend at test startup.

Required Test Duration – A minimum test duration of 36 hours is recommended, with a preference toward 48 hours**.**

Data Acquisition Frequency - Test data is recorded at five minute intervals.

Equipment Calibration/Accuracy – Transducers and datalogger are calibrated per manufacturer recommendations. Manufacturer stated accuracy of power transducers is less than ±2%. Temperature sensor accuracy is periodically checked via ice water bath.

Power Quality – The standard deviation of the power should be less than or equal to 1.5% of the average power, with maximum power variation of less than or equal to 10% of the average power.

Input Heat Rate – The heat flux rate should be 51 Btu/hr (15 W) to 85 Btu/hr (25 W) per foot of installed bore depth to best simulate the expected peak loads on the u-bend.

Insulation – GRTI's equipment has 1 inch of foam insulation on the FTC unit and 1/2 inch of insulation on the hose kit connection. An additional 2 inches of insulation is provided for both the FTC unit and loop connections by insulating blankets.

Retesting in the Event of Failure – In the event that a test fails prematurely, a retest may not be performed until the bore temperature is within 0.5°F of the original undisturbed formation temperature or until a period of 14 days has elapsed.

Data Analysis

Geothermal Resource Technologies, Inc. (GRTI) uses the "line source" method of data analysis to determine the thermal conductivity of the formation. The line source method assumes an infinitely thin line source of heat in a continuous medium. A plot of the late-time temperature rise of the line source temperature versus the natural log of elapsed time will follow a linear trend. The linear slope is inversely proportional to the thermal conductivity of the medium. Applying the line source method to a u-bend grouted in a borehole, the test must be run long enough to allow the finite dimensions of the u-bend pipes and the grout to become insignificant. Experience has shown that approximately ten hours is required to allow the error of early test times and the effects of finite borehole dimensions to become insignificant.

In the analysis of the data from the formation thermal conductivity test, the average temperature of the water entering and exiting the u-bend heat exchanger was plotted versus the natural log of elapsed testing time. Using the Method of Least Squares, linear coefficients were calculated that produce a line that fit the data. This procedure was repeated for various time intervals to ensure that variations in the power or other effects did not produce inaccurate results.

Bore thermal resistance was determined using the formula outlined in Gehlin's Doctoral Thesis[2]. A serial development was used to approximate the exponential integral. The calculated bore resistance applies only to the test conditions, a bore in an operating loopfield could have a significantly different resistance due to changes in the loop fluid temperature, flow rate and presence of antifreeze.

The calculated results are based on test bore information submitted by the driller/testing agency. GRTI is not responsible for inaccuracies in the results due to erroneous bore information. All data analysis is performed by personnel that have an engineering degree from an accredited university with a background in heat transfer and experience with line source theory. The test results apply specifically to the tested bore. Additional bores at the site may have significantly different results depending upon variations in geology and hydrology.

Through the analysis process, the collected raw data is converted to spreadsheet format (Microsoft Excel®) for final analysis. If desired, please contact GRTI and a copy of the data will be made available in either a hard copy or electronic format.

Contact: Chad Martin
Regional Managing Engineer
Asheville, NC
(828) 225-9166
cmartin@grti.com

[2]Gehlin, 12-13.

Test Bore Details
(As Provided by American Auger & Ditching Co., Inc.)

Site Name	SUNY-Oswego, Hewitt Hall
Location	Oswego, NY
Driller	American Auger & Ditching Co., Inc.
Installed Date	June 19, 2020
Borehole Diameter	8 3/4 inches, 0-39 ft 6 inches, 39-499 ft
Casing	6 inch permanent steel casing to 39 ft
U-Bend Size	1 1/4 inch DR-11 HDPE U-Bend
U-Bend Depth Below Grade	498 ft
Grout Type	GeoPro TG Select/PowerTEC 1.0
Grout Mixture	100 lb TG Select, 32 lb PowerTEC, 33 gal water
Grouted Portion	Entire bore

Drill Log

Formation Description	Depth (ft)
Pavement, stone	0'-1'
Silty clay	1'-6'
Hard glacial till, with boulders	6'-37'
Top of bedrock (red sandstone)	37'-47'
Rock turned gray and stayed gray to 499'	47'-499'

Note: No water was encountered while drilling.

Thermal Conductivity Test Data

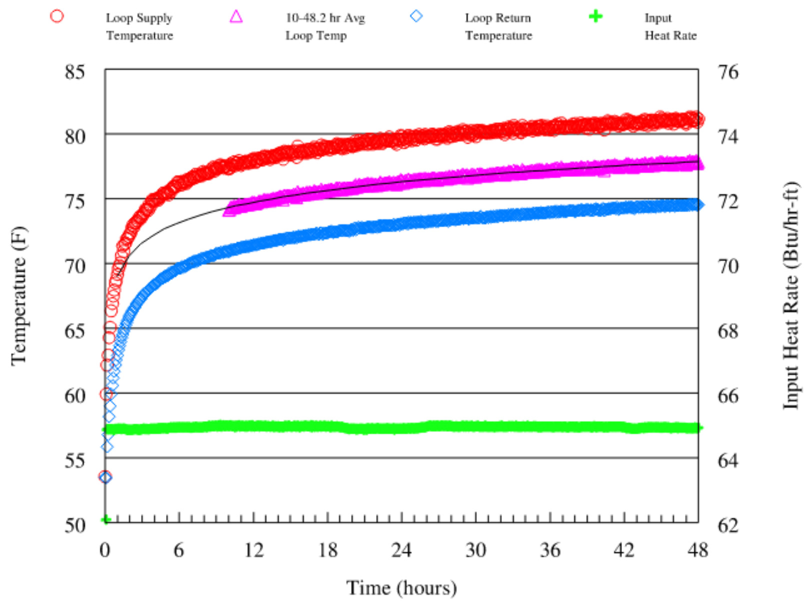

Fig. 1: Temperature & Heat Rate Data Vs Time

Figure 1 above shows the loop temperature and heat input rate data versus the elapsed time of the test. The temperature of the fluid supplied to and returning from the U-bend are plotted on the left axis, while the amount of heat supplied to the fluid is plotted on the right axis on a per foot of bore basis. In the test statistics below, calculations on the power data were performed over the analysis time period listed in the Line Source Data Analysis section.

Summary Test Statistics

Test Date	July 10-12, 2020
Undisturbed Formation Temperature	Approx. 52.3-54.2°F
Duration	48.2 hr
Average Voltage	243.3 V
Average Heat Input Rate	32,347 Btu/hr (9,478 W)
Avg Heat Input Rate per Foot of Bore	65.0 Btu/hr-ft (19.0 W/ft)
Circulator Flow Rate	9.9 gpm
Standard Deviation of Power	0.05%
Maximum Variation in Power	0.12%

LINE SOURCE DATA ANALYSIS

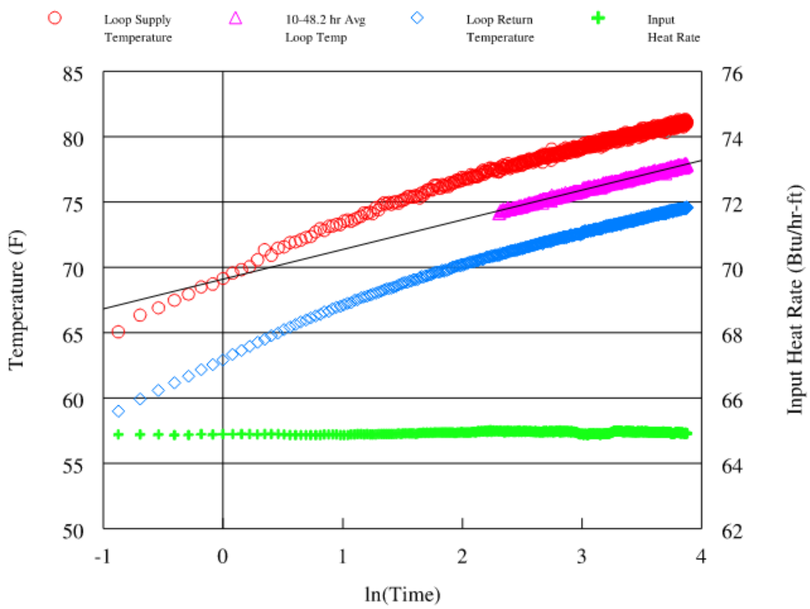

FIG. 2: TEMPERATURE & HEAT RATE VS NATURAL LOG OF TIME

The loop temperature and input heat rate data versus the natural log of elapsed time are shown above in Figure 2. The temperature versus time data was analyzed using the line source method (see page 3) in conformity with ASHRAE and IGSHPA guidelines. A linear curve fit was applied to the average of the supply and return loop temperature data between 10 and 48.2 hours. The slope of the curve fit was found to be 2.26. The resulting thermal conductivity was found to be **2.28 Btu/hr-ft-°F**.

THERMAL DIFFUSIVITY

The reported drilling log for this test borehole indicated that the formation consisted of silty clay, glacial till, boulders, and sandstone. A heat capacity value for sandstone was calculated from specific heat and density values listed by Kavanaugh and Rafferty[3]. A weighted average of heat capacity values based on the indicated formation was used to determine an average heat capacity of 39.3 Btu/ft^3-°F for the formation. A diffusivity value was then found using the calculated formation thermal conductivity and the estimated heat capacity. The thermal diffusivity for this formation was estimated to be **1.39 ft^2/day**.

[3]Stephen P. Kavanaugh and Kevin Rafferty, Geothermal Heating and Cooling: Design of Ground-Source Heat Pump Systems (Atlanta: ASHRAE, 2014), 75.

BORE THERMAL RESISTANCE

Resistance to heat transfer from a geothermal bore can be viewed as consisting of two components, bore resistance and ground resistance. This relationship is diagrammed in Figure 3, where t_f is the loop fluid temperature, t_b is the bore wall temperature and t_g is the ground temperature. The ground resistance is dependent upon the formation thermal conductivity and diffusivity. Factors that affect bore thermal resistance include the resistance of the pipe material, diameter of the heat exchanger, position of the heat exchanger in the bore, the bore diameter, casing length and type, and the thermal conductivity of the grout/backfill in the bore annulus. A detailed examination of bore resistance is discussed by Kavanaugh and Rafferty[4].

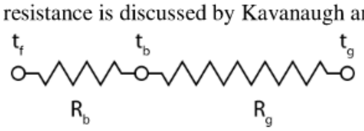

FIG. 3: RESISTANCE DIAGRAM FOR A GEOTHERMAL BORE

Bore thermal resistance calculations were made on the test data according to the formula below as outlined in the Gehlin Doctoral Thesis[5]. The calculated formation thermal conductivity and thermal diffusivity from the Line Source Analysis were used in the formula, along with the average undisturbed formation temperature of 53.3°F. The average bore thermal resistance from 10-48.2 hrs was found to be **0.220 hr-ft-°F/Btu** .

The calculated bore resistances apply only to the test conditions, and a bore in an operating loopfield could have a significantly different resistance due to changes in the loop fluid temperature, flow rate, and presence of antifreeze. Additional information on bore resistance may be found in the study by Oklahoma State University and Oklahoma Gas & Electric where various vertical bore heat exchanger configurations were tested[6].

$$R_b = \frac{H}{Q} * \left\{ T(t) - T_g - \frac{Q}{4\pi\lambda_g H} * \left[Ei\left(\frac{r_b^2}{4\alpha_g t}\right)\right]\right\}$$

Where:	R_b	Borehole thermal resistance (hr-ft-°F/Btu)
	H	Active U-bend depth (ft)
	Q	Average heat injected (Btu/hr)
	$T(t)$	Temperature dependent on time t (°F)
	T_g	Undisturbed ground temperature
	λ_g	Formation thermal conductivity (Btu/hr-ft-°F)
	r_b	Average borehole radius (in)
	α_g	Formation thermal diffusivity (ft^2/hr)

[4]Stephen P. Kavanaugh and Kevin Rafferty, Geothermal Heating and Cooling: Design of Ground-Source Heat Pump Systems (Atlanta: ASHRAE, 2014), pages 58-67.
[5]Gehlin, 12-13.
[6] Beier, R. and Ewbank, G. (2012, August). *In-Situ Test Thermal Response Tests Interpretations, OG&E Ground Source Heat Exchange Study*. Retrieved from http://ghpok.org/

CERTIFICATE OF CALIBRATION

GRTI maintains calibration of the datalogger, current transducer and voltage transducer on a regular schedule. The components are calibrated by the manufacturer using recognized national or international measurement standards such as those maintained by the National Institute of Standards and Technology (NIST).

FTC Unit 211

DA Unit 62

Primary Equipment		
Component	Calibration Date	Calibration Due Date
Datalogger	2/26/2020	2/26/2023
Current Transducer	2/24/2020	2/24/2023
Voltage Transducer	2/24/2020	2/24/2023

GRTI periodically verifies the combined temperature sensor/datalogger accuracy via a water bath. Temperature readings are simultaneously taken with a digital thermometer that has been calibrated using instruments traceable to NIST.

Date	3/9/2020			
Thermocouple 1 (°F)	32.2 32.1 32.1			
Thermocouple 2 (°F)	32.1 32.1 32.1			
Thermocouple 3 (°F)	32.1 32.1 32.1			
Thermocouple 4 (°F)	32.1 32.1 32.1			
Digital Thermometer (°F)	32.3 32.2 32.1			

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Southern Office
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Eastern Office
6 William Warren Dr Asheville NC 28806
P: 828-225-9166

Appendix D. Cut Sheets

Tranquility® Water-To-Water (TMW) Series

Models TMW036 - 840 60Hz - HFC - 410A

The Tranquility® Modular Water-to-Water (TMW) Series offers high efficiency and high capacity with advanced features, quiet operation and application flexibility at competitive prices. ClimateMaster's Tranquility® Modular Water-to-Water Series can be used for radiant floor heating, snow/ice melt, chilled water for fan coils, industrial process control, potable hot water generation*, hot/chilled water for make-up air, and many other types of HVAC and industrial applications that require cost effective heated or chilled water.

Advantages of the Water-To-Water TMW Series:

- Copeland scroll compressor(s)
- Dual independent refrigeration circuits on size 120, 340, 360, and 600
- Exclusive single side service access (front of unit) allows multiple units to be installed side-by-side for large capacity installations (360 through 840 require front and rear access)
- Top water connections on sizes 170, 340, 360, 600, and 840 staggered for ease of manifolding multiple units
- Exceeds ASHRAE 90.1 efficiencies
- Heavy gauge galvanized steel construction with polyester powder coat paint and stainless steel front access panels (036-340)
- Insulated compressor compartment
- Small footprint
- TXV metering devices
- Load leaving temperature range from 25 to 140°F, -4.4 to 60°C (see submittal for specific model range)
- Source entering temperature range from 20 to 130°F, -6.7 to 54.4°C (see submittal for specific model range)
- Microprocessor controls for 036-340. DDC controls for 360-840
- BACnet, Modbus and Johnson N2 compatibility options for DDC controls

Unit Size

Model		W	D	H
036-060	in. (cm)	25.4 (64.5)	30.6 (77.8)	33.0 (83.8)
120	in. (cm)	52.9 (134.4)	30.6 (77.8)	37.0 (94.0)
170-340	in. (cm)	26.3 (66.9)	45.1 (114.6)	64.5 (163.8)
360-840	in. (cm)	34.0 (86.4)	55.5 (141.0)	65.1 (165.4)

* Requires feild supplied secondary heat exchanger

Physical Data

Model	TMW036	TMW060	TMW120	TMW170	TMW340
Compressor (qty)	Scroll (1)		Scroll (2)	Scroll (1)	Scroll (2)
Factory Charge R410A (lbs) [kg] / Circuit	4.5 [2.04]	5.5 [2.49]	5.5 [2.49]	14.9 [6.75]	14.9 [6.75]
Indoor / Load Water connection sizes FPT (in)	3/4"	1"	1-1/2"	2"	
Outdoor / Source Water connection Size FPT (in)	3/4"	1"	1-1/2"	2"	
HWG Water In/Out IPT (in)	1/2"			N/A	
Weight - Operating (lbs) [kg]	348 [158]	360 [163]	726 [329]	790 [358]	1330 [603]
Weight - Shipping (lbs) [kg]	373 [169]	385 [175]	770 [349]	800 [363]	1340 [608]
Water Volume (Source)					
Gallons (LIters)	0.96 (3.64)	1.33 (5.04)	2.65 (10.02)	3.50 (13.27)	6.72 (25.44)

Dual isolated compressor mounting
Balanced port expansion valve (TXV)
Compressor on (green) and fault (red) light

Model	TMW360	TMW600	TMW840
Compressor (qty)	Scroll (2)	Scroll (2)	Scroll (2)
Compressor Oil Type	POE	PVE	PVE
Factory Charge HFC-410A (lbs) [kg] / circuit	15 [6.8]	27.5 [12.5]	33.8 [15.4]
Indoor / Load Water connection sizes FPT (in)	2	2-1/2	2-1/2
Outdoor / Source Water connection size FPT (in)	2	2-1/2	2-1/2
Weight - Operating (lbs) [kg]	1400 [635]	2055 [932]	2305 [1042]
Weight - Shipping (lbs) [kg]	1325 [601]	1925 [873]	2175 [983]
Water Volume (Source)			
Gallons [Liters]	4.7 [17.8]	8.3 [31.4]	9.5 [36]
Water Volume (Load)			
Gallons [Liters]	4.4 [16.7]	7.3 [27.6]	8.5 [32.2]

Tested To ASHRAE/AHRI/ISO 13256-1 English (I-P) Units

Model	Refrigerant	Water Loop Heat Pump				Ground Water Heat Pump				Ground Loop Heat Pump			
		Cooling		Heating		Cooling		Heating		Cooling		Heating	
		Indoor 53.6°F [12°C] Outdoor 86°F [30°C]		Indoor 104°F [40°C] Outdoor 68°F [20°C]		Indoor 53.6°F [12°C] Outdoor 59°F [15°C]		Indoor 104°F [40°C] Outdoor 50°F [10°C]		Indoor 53.6°F [12°C] Outdoor 77°F [25°C]		Indoor 104°F [40°C] Outdoor 32°F [0°C]	
		Capacity	EER	Capacity	COP	Capacity	EER	Capacity	COP	Capacity	EER	Capacity	COP
		Btuh [kW]	Btuh/W [W/W]	Btuh [kW]		Btuh [kW]	Btuh/W [W/W]	Btuh [kW]		Btuh [kW]	Btuh/W [W/W]	Btuh [kW]	
TMW-036	**HFC-410A**	32,300 [9.47]	14.60 [4.28]	43,100 [12.64]	4.90	36,200 [10.62]	23.10 [6.77]	35,300 [10.35]	4.00	33,300 [9.77]	16.40 [4.81]	27,400 [8.04]	3.10
TMW-060	**HFC-410A**	52,800 [15.48]	14.00 [4.10]	72,700 [21.32]	4.60	56,600 [16.60]	20.30 [5.95]	60,300 [17.68]	3.80	55,600 [16.31]	15.10 [4.43]	48,500 [14.22]	2.90
TMW-120	**HFC-410A**	105,600 [30.97]	13.80 [4.04]	145,400 [42.64]	4.50	113,200 [33.20]	20.10 [5.89]	120,600 [35.37]	3.70	111,200 [32.61]	15.00 [4.40]	97,000 [28.45]	2.90
TMW-170	**HFC-410A**	123,500 [36.22]	13.30 [3.90]	164,600 [48.27]	4.30	138,400 [40.59]	19.30 [5.66]	136,200 [39.94]	3.70	130,300 [38.21]	15.30 [4.49]	108,600 [31.85]	2.90
TMW-340	**HFC-410A**	253,500 [74.34]	13.60 [3.99]	336,000 [98.53]	4.40	282,000 [82.70]	19.60 [5.75]	277,000 [81.23]	3.70	266,600 [78.18]	15.60 [4.57]	220,000 [64.52]	3.00
TMW-360	**HFC-410A**	380,300 [111.46]	16.00 [4.70]	531,000 [155.63]	5.10	438,000 [128.37]	24.20 [7.10]	416,000 [121.92]	4.20	399,600 [117.12]	18.40 [5.39]	316,000 [92.61]	3.40
TMW-600	**HFC-410A**	619,800 [181.65]	16.00 [4.70]	873,000 [255.86]	5.20	707,400 [207.33]	23.20 [6.80]	680,000 [199.30]	4.30	649,600 [190.39]	18.20 [5.33]	517,000 [151.52]	3.40
TMW-840	HFC-410A	814,800 [238.80]	16.20 [4.75]	1,141,000 [334.41]	5.30	925,700 [271.31]	23.30 [6.83]	894,000 [262.02]	4.40	852,600 [249.88]	18.40 [5.39]	677,000 [198.42]	3.40

All ratings based upon operation at the lower voltage of dual voltage rated models.
* Indoor = Load side heat exchanger; Outdoor = Source side heat exchanger.

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Appendix E. Cost Estimates

Mechanical/Electrical
Engineering Consultants
60 LAKEFRONT BLVD, SUITE 320
BUFFALO, NY 14202

Budget Pricing Cost Estimate			
PROJECT NAME: SUNY OSWEGO			
NYSERDA COMMUNITY HEAT PUMP PROGRAM			
M/E REFERENCE:	211199	DATE:	12/22/2022
DIVISION:	HVAC	BY:	AES

ITEM	DESCRIPTION	QTY.	UNIT	LABOR COST	MATERIAL COST	TOTAL ITEM COST
	BASELINE SYSTEM: REPLACE SYSTEMS IN KIND					
1	**Campus System**			**$0**	**$0**	**$0**
2	No central equipment	0	LS	$0	$0	$0
3						
4	**Cooper Dining Hall**			**$96,450**	**$247,100**	**$343,550**
5	Water-cooled chiller (100 ton)	1	EA	$27,700	$83,500	$111,200
6	Cooling tower (100 ton)	1	EA	$13,300	$33,600	$46,900
7	Steam-to-water heat exchanger (245 gpm)	1	EA	$21,700	$5,400	$27,100
8	Chilled water pumps (5 HP)	2	EA	$5,625	$19,100	$49,450
9	Hot water pumps (5 HP)	2	EA	$5,625	$19,100	$49,450
10	Condenser water pumps (5 HP)	2	EA	$5,625	$19,100	$49,450
11	Demolition	1	LS	$0	$10,000	$10,000
12						
13	**Culkin Hall**			**$170,105**	**$538,025**	**$708,130**
14	Water-cooled chiller (120 ton)	1	EA	$30,900	$83,900	$114,800
15	Cooling tower (188 ton)	1	EA	$16,700	$41,400	$58,100
16	Steam-to-water heat exchanger (350 gpm)	1	EA	$23,875	$67,625	$91,500
17	Steam-to-water heat exchanger (300 mbh)	1	EA	$25,180	$75,800	$100,980
18	Chilled water pumps (15 HP)	2	EA	$9,875	$32,400	$84,550
19	Hot water pumps (7.5 HP)	2	EA	$6,675	$21,700	$56,750
20	Fan coil loop pumps (10 HP)	2	EA	$8,275	$27,050	$70,650
21	Condenser water pumps (25 HP)	2	EA	$11,900	$43,500	$110,800
22	Demolition	1	LS	$0	$20,000	$20,000
23						
24	**Funnelle Hall**			**$47,000**	**$134,133**	**$181,133**
25	Air-cooled chiller with pumps (12 tons)	1	EA	$12,700	$28,100	$40,800
26	Steam-to-water heat exchanger (400 gpm)	1	EA	$18,100	$66,500	$84,600
27	Steam-to-water heat exchanger (18 gpm)	1	EA	$8,850	$17,200	$26,050
28	Air-handler furnace section (400 mbh)	1	EA	$3,675	$7,300	$10,975
29	Air-handler furnace section (500 mbh)	1	EA	$3,675	$9,033	$12,708
30	Demolition	1	LS	$0	$6,000	$6,000
31						

32	**Hart Hall**			**$78,051**	**$251,942**	**$329,993**
33	Steam-to-water heat exchanger (400 gpm)	1	EA	$18,100	$66,500	$84,600
34	Steam-to-water heat exchanger (18 gpm)	1	EA	$8,850	$17,200	$26,050
35	Air-handler furnace section (410 mbh)	2	EA	$3,675	$7,300	$21,950
36	Hot water pumps + VFD (5 HP)	3	EA	$6,240	$21,150	$82,170
37	Hot water pumps + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
38	Hot water pumps + VFD (1/4 HP)	1	EA	$1,863	$5,842	$7,705
39	AC Split system (2 ton)	1	EA	$11,988	$42,300	$54,288
40	Demolition	1	LS	$0	$7,000	$7,000
41						
42	**BASELINE SYSTEM SUBTOTAL**			**$391,606**	**$1,171,200**	**$1,562,806**
43						
44	Overhead (Labor x 10%)					$39,161
45	Profit (Labor Incl. OH + Material x 10%)					$160,197
46	Design Contingency (Subtotal+OHP x 10%)					$176,216
47	Construction Contingency (Subtotal+OHP x 10%)					$176,216
48						
	BASELINE SYSTEM TOTAL					**$2,114,596**

Pricing from RSMeans Building Cost Data. Includes differences between options only.

Mechanical/Electrical
Engineering Consultants
60 LAKEFRONT BLVD, SUITE 320
BUFFALO, NY 14202

Budget Pricing Cost Estimate

PROJECT NAME: SUNY OSWEGO			
NYSERDA COMMUNITY HEAT PUMP PROGRAM			
M/E REFERENCE: 211199		DATE:	12/22/2022
DIVISION:	HVAC	BY:	AES

ITEM	DESCRIPTION	QTY.	UNIT	LABOR COST	MATERIAL COST	TOTAL ITEM COST
PROPOSED SYSTEM: COMMUNITY GEOTHERMAL HEAT PUMPS						
1	**Campus System**			**$3,080,410**	**$2,276,420**	**$5,356,830**
2	Geothermal wellfield (498 ft wells)	199	EA	$12,500	$7,500	$3,980,000
3	Wellfield pumps + VFD (25 HP)	3	EA	$24,450	$49,150	$220,800
4	Distribution piping + earthwork	2700	LF	$44	$34	$209,034
5	Well piping	13520	LF	$20	$11	$420,066
6	Piping manifold	1	LS	$25,440	$74,800	$100,240
7	Repaving	139	kSF	$510	$2,200	$376,690
8	Controls	1	LS	$30,000	$20,000	$50,000
9						
10	**Cooper Dining Hall**			**$173,780**	**$470,750**	**$644,530**
11	Modular water-to-water heat pump (50 ton)	4	EA	$32,700	$79,125	$447,300
12	GSHP Loop pumps + VFD (10 HP)	2	EA	$9,010	$29,825	$77,670
13	CHW pumps + VFD (5 HP)	2	EA	$6,240	$21,150	$54,780
14	HW pumps + VFD (5 HP)	2	EA	$6,240	$21,150	$54,780
15	Demolition	1	LS	$0	$10,000	$10,000
16						
17	**Culkin Hall**			**$340,365**	**$917,250**	**$1,257,615**
18	Modular water-to-water heat pump (50 ton)	8	EA	$32,700	$79,125	$894,600
19	GSHP Loop pumps + VFD (20 HP)	2	EA	$11,988	$42,300	$108,575
20	CHW pumps + VFD (15 HP)	2	EA	$10,975	$35,850	$93,650
21	HW pumps + VFD (7.5 HP)	2	EA	$7,410	$24,150	$63,120
22	Fan coil loop pumps + VFD (10 HP)	2	EA	$9,010	$29,825	$77,670
23	Demolition	1	LS	$0	$20,000	$20,000
24						
25	**Funnelle Hall**			**$368,832**	**$923,525**	**$1,292,357**
26	Modular water-to-water heat pump (50 ton)	9	EA	$32,700	$79,125	$1,006,425
27	Heating coils for air-handling unit (400 mbh)	1	EA	$3,920	$8,325	$12,245
28	Heating coils for air-handling unit (500 mbh)	1	EA	$4,704	$9,990	$14,694
29	GSHP Loop Pumps + VFD (25 HP)	2	EA	$13,375	$48,625	$124,000
30	HW pumps for MUAs + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
31	CHW Pumps + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
32	Steam-to-water heat exchanger (1500 mbh)	1	EA	$1,925	$3,400	$5,325
33	Piping (interior) + insulation	450	LF	$33	$36	$31,208
34	Demolition	1	LS	$0	$6,000	$6,000
35						

36	**Hart Hall**			**$304,920**	**$797,485**	**$1,102,405**
37	Modular water-to-water heat pump (50 ton)	6	EA	$32,700	$79,125	$670,950
38	Heating coils for air-handling unit (410 mbh)	2	EA	$3,920	$8,325	$24,490
39	Hot water pumps + VFD (5 HP)	3	EA	$6,240	$21,150	$82,170
40	Hot water pumps + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
41	Hot water pumps + VFD (1/4 HP)	1	EA	$1,863	$5,842	$7,705
42	GSHP Loop Pumps + VFD (20 HP)	2	EA	$11,988	$42,300	$108,575
43	HW pumps for MUAs + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
44	CHW Pumps + VFD (1 HP)	2	EA	$1,863	$5,842	$15,410
45	Fan coil unit (2 tons)	1	EA	$3,375	$4,775	$8,150
46	Steam-to-water heat exchanger (1500 mbh)	1	EA	$11,988	$42,300	$54,288
47	Piping (interior) + insulation	450	LF	$33	$36	$31,208
48	Demolition	1	LS	$0	$7,000	$7,000
49						
50	**PROPOSED SYSTEM SUBTOTAL**			**$4,268,307**	**$5,385,430**	**$9,653,737**
51						
52	Overhead (Labor x 10%)					$426,831
53	Profit (Labor Incl. OH + Material x 10%)					$1,008,057
54	Design Contingency (Subtotal+OHP x 10%)					$1,108,862
55	Construction Contingency (Subtotal+OHP x 10%)					$1,108,862
56						
	PROPOSED SYSTEM TOTAL					**$13,306,349**

Pricing from RSMeans Building Cost Data. Includes differences between options only.

Mechanical/Electrical
Engineering Consultants
60 LAKEFRONT BLVD, SUITE 320
BUFFALO, NY 14202

Budget Pricing Cost Estimate			
PROJECT NAME: SUNY OSWEGO			
NYSERDA COMMUNITY HEAT PUMP PROGRAM			
M/E REFERENCE: 211199		DATE:	12/22/2022
DIVISION:	HVAC	BY:	AES

ITEM	DESCRIPTION	QTY.	UNIT	LABOR COST	MATERIAL COST	TOTAL ITEM COST
CODE-COMPLIANT SYSTEM: INDIVIDUAL BUILDING GEOTHERMAL HEAT PUMPS						
1	**Distibuted Wellfields**			**$4,105,603**	**$3,037,468**	**$7,143,070**
2	Geothermal wellfield (498 ft wells)	272	EA	$12,500	$7,500	$5,440,000
3	Cooper Dining Hall: Wellfield Pumps + VFD (10 HP)	2	EA	$10,975	$35,850	$93,650
4	Culkin Hall: Wellfield Pumps + VFD (20 HP)	2	EA	$11,988	$42,300	$108,575
5	Funnelle Hall: Wellfield Pumps + VFD (25 HP)	2	EA	$13,375	$48,625	$124,000
6	Hart Hall: Wellfield Pumps + VFD (25 HP)	2	EA	$13,375	$48,625	$124,000
7	Piping manifolds	4	EA	$29,185	$88,500	$470,740
8	Grade restoration	190	kSF	$86	$198	$54,043
9	Well piping	21180	LF	$20	$11	$658,063
10	Controls	1	LS	$42,000	$28,000	$70,000
11						
12	**Cooper Dining Hall**			**$173,780**	**$407,450**	**$581,230**
13	Modular water-to-water heat pump (50 ton)	4	EA	$32,700	$63,300	$384,000
14	GSHP Loop pumps + VFD (10 HP)	2	EA	$9,010	$29,825	$77,670
15	CHW pumps + VFD (5 HP)	2	EA	$6,240	$21,150	$54,780
16	HW pumps + VFD (5 HP)	2	EA	$6,240	$21,150	$54,780
17	Demolition	1	LS	$0	$10,000	$10,000
18						
19	**Culkin Hall**			**$340,365**	**$790,650**	**$1,131,015**
20	Modular water-to-water heat pump (50 ton)	8	EA	$32,700	$63,300	$768,000
21	GSHP Loop pumps + VFD (20 HP)	2	EA	$11,988	$42,300	$108,575
22	CHW pumps + VFD (15 HP)	2	EA	$10,975	$35,850	$93,650
23	HW pumps + VFD (7.5 HP)	2	EA	$7,410	$24,150	$63,120
24	Fan coil loop pumps + VFD (10 HP)	2	EA	$9,010	$29,825	$77,670
25	Demolition	1	LS	$0	$20,000	$20,000
26						

27	**Funnelle Hall**			**$368,832**	**$781,100**	**$1,149,932**
28	Modular water-to-water heat pump (50 ton)	9	EA	$32,700	$63,300	$864,000
29	Heating coils for air-handling unit (400 mbh)	1	EA	$3,920	$8,325	$12,245
30	Heating coils for air-handling unit (500 mbh)	1	EA	$4,704	$9,990	$14,694
31	GSHP Loop Pumps + VFD (25 HP)	2	EA	$13,375	$48,625	$124,000
32	HW pumps for MUAs + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
33	CHW Pumps + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
34	Steam-to-water heat exchanger (1500 mbh)	1	EA	$1,925	$3,400	$5,325
35	Piping (interior) + insulation	450	LF	$33	$36	$31,208
36	Demolition	1	LS	$0	$6,000	$6,000
37						
38	**Hart Hall**			**$304,920**	**$702,535**	**$1,007,455**
39	Modular water-to-water heat pump (50 ton)	6	EA	$32,700	$63,300	$576,000
40	Heating coils for air-handling unit (410 mbh)	2	EA	$3,920	$8,325	$24,490
41	Hot water pumps + VFD (5 HP)	3	EA	$6,240	$21,150	$82,170
42	Hot water pumps + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
43	Hot water pumps + VFD (1/4 HP)	1	EA	$1,863	$5,842	$7,705
44	GSHP Loop Pumps + VFD (20 HP)	2	EA	$11,988	$42,300	$108,575
45	HW pumps for MUAs + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
46	CHW Pumps + VFD (1 HP)	2	EA	$1,863	$5,842	$15,410
47	Fan coil unit (2 tons)	1	EA	$3,375	$4,775	$8,150
48	Steam-to-water heat exchanger (1500 mbh)	1	EA	$11,988	$42,300	$54,288
49	Piping (interior) + insulation	450	LF	$33	$36	$31,208
50	Demolition	1	LS	$0	$7,000	$7,000
51						
52	**CODE-COMPLIANT SYSTEM SUBTOTAL**			**$5,293,499**	**$5,719,203**	**$11,012,702**
53						
54	Overhead (Labor x 10%)					$529,350
55	Profit (Labor Incl. OH + Material x 10%)					$1,154,205
56	Design Contingency (Subtotal+OHP x 10%)					$1,269,626
57	Construction Contingency (Subtotal+OHP x 10%)					$1,269,626
58						
	CODE-COMPLIANT SYSTEM TOTAL					**$15,235,508**

Pricing from RSMeans Building Cost Data. Includes differences between options only.

Mechanical/Electrical
Engineering Consultants
60 LAKEFRONT BLVD, SUITE 320
BUFFALO, NY 14202

Annual Maintenance Cost Estimate			
PROJECT NAME: SUNY OSWEGO			
NYSERDA COMMUNITY HEAT PUMP PROGRAM			
M/E REFERENCE: 211199		DATE:	12/22/2022
DIVISION:	HVAC	BY:	AES

ITEM	DESCRIPTION	QTY.	UNIT	LABOR COST	MATERIAL COST	TOTAL ITEM COST
	BASELINE SYSTEM: REPLACE SYSTEMS IN KIND					
1	**Campus System**			**$0**	**$0**	**$0**
2	No central equipment	0	LS	$0	$0	$0
3						
4	**Cooper Dining Hall**			**$3,416**	**$338**	**$3,754**
5	Water-cooled chiller (100 ton)	1	EA	$2,275	$87	$2,362
6	Cooling tower (100 ton)	1	EA	$680	$156	$836
7	Steam-to-water heat exchanger (245 gpm)	1	EA	$53	$23	$76
8	Chilled water pumps (5 HP)	2	EA	$68	$12	$160
9	Hot water pumps (5 HP)	2	EA	$68	$12	$160
10	Condenser water pumps (5 HP)	2	EA	$68	$12	$160
11						
12	**Culkin Hall**			**$3,605**	**$385**	**$3,990**
13	Water-cooled chiller (120 ton)	1	EA	$2,275	$87	$2,362
14	Cooling tower (188 ton)	1	EA	$680	$156	$836
15	Steam-to-water heat exchanger (350 gpm)	1	EA	$53	$23	$76
16	Steam-to-water heat exchanger (300 mbh)	1	EA	$53	$23	$76
17	Chilled water pumps (15 HP)	2	EA	$68	$12	$160
18	Hot water pumps (7.5 HP)	2	EA	$68	$12	$160
19	Fan coil loop pumps (10 HP)	2	EA	$68	$12	$160
20	Condenser water pumps (25 HP)	2	EA	$68	$12	$160
21						
22	**Funnelle Hall**			**$533**	**$292**	**$825**
23	Air-cooled chiller with pumps (12 tons)	1	EA	$331	$150	$481
24	Steam-to-water heat exchanger (400 gpm)	1	EA	$53	$23	$76
25	Steam-to-water heat exchanger (18 gpm)	1	EA	$53	$23	$76
26	Air-handler furnace section (400 mbh)	1	EA	$48	$48	$96
27	Air-handler furnace section (500 mbh)	1	EA	$48	$48	$96
28						

29	**Hart Hall**			**$845**	**$268**	**$1,113**
30	Steam-to-water heat exchanger (400 gpm)	1	EA	$53	$23	$76
31	Steam-to-water heat exchanger (18 gpm)	1	EA	$53	$23	$76
32	Air-handler furnace section (410 mbh)	2	EA	$68	$12	$160
33	Hot water pumps + VFD (5 HP)	3	EA	$68	$12	$240
34	Hot water pumps + VFD (3 HP)	2	EA	$68	$12	$160
35	Hot water pumps + VFD (1/4 HP)	1	EA	$68	$12	$80
36	AC Split system (2 ton)	1	EA	$195	$126	$321
37						
	BASELINE SYSTEM TOTAL			**$8,399**	**$1,283**	**$9,682**

Pricing from RSMeans Building Cost Data. Includes differences between options only.

Mechanical/Electrical
Engineering Consultants
60 LAKEFRONT BLVD, SUITE 320
BUFFALO, NY 14202

Annual Maintenance Cost Estimate			
PROJECT NAME: SUNY OSWEGO			
NYSERDA COMMUNITY HEAT PUMP PROGRAM			
M/E REFERENCE: 211199		DATE:	12/22/2022
DIVISION:	HVAC	BY:	AES

ITEM	DESCRIPTION	QTY.	UNIT	LABOR COST	MATERIAL COST	TOTAL ITEM COST
PROPOSED SYSTEM: COMMUNITY GEOTHERMAL HEAT PUMPS						
1	**Campus System**			**$277**	**$47**	**$324**
2	Wellfield pumps + VFD (25 HP)	3	EA	$68	$12	$240
3	Controls	1	LS	$73	$11	$84
4						
5	**Cooper Dining Hall**			**$1,292**	**$704**	**$1,996**
6	Modular water-to-water heat pump (50 ton)	4	EA	$221	$158	$1,516
7	GSHP Loop pumps + VFD (10 HP)	2	EA	$68	$12	$160
8	CHW pumps + VFD (5 HP)	2	EA	$68	$12	$160
9	HW pumps + VFD (5 HP)	2	EA	$68	$12	$160
10						
11	**Culkin Hall**			**$2,312**	**$1,360**	**$3,672**
12	Modular water-to-water heat pump (50 ton)	8	EA	$221	$158	$3,032
13	GSHP Loop pumps + VFD (20 HP)	2	EA	$68	$12	$160
14	CHW pumps + VFD (15 HP)	2	EA	$68	$12	$160
15	HW pumps + VFD (7.5 HP)	2	EA	$68	$12	$160
16	Fan coil loop pumps + VFD (10 HP)	2	EA	$68	$12	$160
17						
18	**Funnelle Hall**			**$3,220**	**$1,619**	**$4,839**
19	Modular water-to-water heat pump (50 ton)	9	EA	$221	$158	$3,411
20	Heating coils for air-handling unit (400 mbh)	1	EA	$385	$51	$436
21	Heating coils for air-handling unit (500 mbh)	1	EA	$385	$51	$436
22	GSHP Loop Pumps + VFD (25 HP)	2	EA	$68	$12	$160
23	HW pumps for MUAs + VFD (3 HP)	2	EA	$68	$12	$160
24	CHW Pumps + VFD (3 HP)	2	EA	$68	$12	$160
25	Steam-to-water heat exchanger (1500 mbh)	1	EA	$53	$23	$76
26						

27	**Hart Hall**			**$3,156**	**$1,329**	**$4,485**
28	Modular water-to-water heat pump (50 ton)	6	EA	$221	$158	$2,274
29	Heating coils for air-handling unit (410 mbh)	2	EA	$385	$51	$872
30	Hot water pumps + VFD (5 HP)	3	EA	$68	$12	$240
31	Hot water pumps + VFD (3 HP)	2	EA	$68	$12	$160
32	Hot water pumps + VFD (1/4 HP)	1	EA	$68	$12	$80
33	GSHP Loop Pumps + VFD (20 HP)	2	EA	$68	$12	$160
34	HW pumps for MUAs + VFD (3 HP)	2	EA	$68	$12	$160
35	CHW Pumps + VFD (1 HP)	2	EA	$68	$12	$160
36	Fan coil unit (2 tons)	1	EA	$191	$112	$303
37	Steam-to-water heat exchanger (1500 mbh)	1	EA	$53	$23	$76
38						
	PROPOSED SYSTEM TOTAL			**$10,257**	**$5,059**	**$15,316**

Pricing from RSMeans Building Cost Data. Includes differences between options only.

Mechanical/Electrical
Engineering Consultants
60 LAKEFRONT BLVD, SUITE 320
BUFFALO, NY 14202

Annual Maintenance Cost Estimate	
PROJECT NAME: SUNY OSWEGO	
NYSERDA COMMUNITY HEAT PUMP PROGRAM	
M/E REFERENCE: 211199	DATE: 12/22/2022
DIVISION: **HVAC**	BY: AES

ITEM	DESCRIPTION	QTY.	UNIT	LABOR COST	MATERIAL COST	TOTAL ITEM COST
CODE-COMPLIANT SYSTEM: INDIVIDUAL BUILDING GEOTHERMAL HEAT PUMPS						
1	**Distibuted Wellfields**			**$617**	**$107**	**$724**
2	Cooper Dining Hall: Wellfield Pumps + VFD (10 HP)	2	EA	$68	$12	$160
3	Culkin Hall: Wellfield Pumps + VFD (20 HP)	2	EA	$68	$12	$160
4	Funnelle Hall: Wellfield Pumps + VFD (25 HP)	2	EA	$68	$12	$160
5	Hart Hall: Wellfield Pumps + VFD (25 HP)	2	EA	$68	$12	$160
6	Controls	1	LS	$73	$11	$84
7						
8	**Cooper Dining Hall**			**$1,292**	**$704**	**$1,996**
9	Modular water-to-water heat pump (50 ton)	4	EA	$221	$158	$1,516
10	GSHP Loop pumps + VFD (10 HP)	2	EA	$68	$12	$160
11	CHW pumps + VFD (5 HP)	2	EA	$68	$12	$160
12	HW pumps + VFD (5 HP)	2	EA	$68	$12	$160
13						
14	**Culkin Hall**			**$2,312**	**$1,360**	**$3,672**
15	Modular water-to-water heat pump (50 ton)	8	EA	$221	$158	$3,032
16	GSHP Loop pumps + VFD (20 HP)	2	EA	$68	$12	$160
17	CHW pumps + VFD (15 HP)	2	EA	$68	$12	$160
18	HW pumps + VFD (7.5 HP)	2	EA	$68	$12	$160
19	Fan coil loop pumps + VFD (10 HP)	2	EA	$68	$12	$160
20						
21	**Funnelle Hall**			**$3,220**	**$1,619**	**$4,839**
22	Modular water-to-water heat pump (50 ton)	9	EA	$221	$158	$3,411
23	Heating coils for air-handling unit (400 mbh)	1	EA	$385	$51	$436
24	Heating coils for air-handling unit (500 mbh)	1	EA	$385	$51	$436
25	GSHP Loop Pumps + VFD (25 HP)	2	EA	$68	$12	$160
26	HW pumps for MUAs + VFD (3 HP)	2	EA	$68	$12	$160
27	CHW Pumps + VFD (3 HP)	2	EA	$68	$12	$160
28	Steam-to-water heat exchanger (1500 mbh)	1	EA	$53	$23	$76
29						

30	**Hart Hall**			**$3,156**	**$1,329**	**$4,485**
31	Modular water-to-water heat pump (50 ton)	6	EA	$221	$158	$2,274
32	Heating coils for air-handling unit (410 mbh)	2	EA	$385	$51	$872
33	Hot water pumps + VFD (5 HP)	3	EA	$68	$12	$240
34	Hot water pumps + VFD (3 HP)	2	EA	$68	$12	$160
35	Hot water pumps + VFD (1/4 HP)	1	EA	$68	$12	$80
36	GSHP Loop Pumps + VFD (20 HP)	2	EA	$68	$12	$160
37	HW pumps for MUAs + VFD (3 HP)	2	EA	$68	$12	$160
38	CHW Pumps + VFD (1 HP)	2	EA	$68	$12	$160
39	Fan coil unit (2 tons)	1	EA	$191	$112	$303
40	Steam-to-water heat exchanger (1500 mbh)	1	EA	$53	$23	$76
41						
	CODE-COMPLIANT SYSTEM TOTAL			**$10,597**	**$5,119**	**$15,716**

Pricing from RSMeans Building Cost Data. Includes differences between options only.

Appendix F. Life-Cycle Cost Analysis

Life-Cycle Cost Analysis Summary

LIFE-CYCLE COST ANALYSIS

Prepared by: M/E Engineering, P.C.

Project Information

Date:	December 22, 2022
Client Name:	SUNY Oswego
Project Name:	NYSERDA Community Heat Pump Program
Project Number:	211199
Project Address:	7060 State Route 104 Oswego, NY 13126
Building Name:	**Community Heat Pump Cluster**
Construction Year:	2024
Project Objective:	Energy Objective

Discount Rates

Medium-Risk Generative	7.25%	(for energy objectives)

Escalation Rates

Energy Related:	6.60%
Electricity:	4.10%
All Other Cost Items:	2.50%

Energy Rates

Description	Cost	Units	Source	Notes
Electricity:	$0.100	/kWh	Energy Budget	Provided by Owner
Natural Gas:	$0.602	/therm	Energy Budget	Provided by Owner

Life-Cycle Cost Analysis Results

Description	Option	Estimated First Cost	Annual Energy Cost, First Year	Annual Maintenance Cost, First Year	Life Expectancy (Years)	**25-Year** LCCA Net Present Value	NPV Difference vs. Option 1
Baseline System: Replace Systems in Kind	1	($2,114,596)	($550,390)	($9,682)	20	($12,710,669)	--
Code-Compliant System: Individual Building Geothermal Heat Pumps	2	($14,512,596)	($570,365)	($15,716)	25	($25,384,114)	($12,673,445)
Proposed System: Community Geothermal Heat Pumps	3	($8,520,717)	($539,776)	($15,316)	25	($18,698,228)	($5,987,559)

Note: Annual Maintenance Costs are intended to represent the differences between the measures, in order to determine which measure is more feasible and do not take into consideration all maintenance costs for the building.

LCCA by Year - Baseline System

Project Year	0	1	2	3	4	5	6	7	8	9
Calendar Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032

OPTION 1

Life Expectancy:	20	years								
Measure Description:	Baseline System: Replace Systems in kind									
Objective:	Energy Objective									
Discount Rate:	7.25%									
Investment Costs										
Project Cost:	($2,114,596)	0	0	0	0	0	0	0	0	0
Design/Support:	0	0	0	0	0	0	0	0	0	0
Recurring Expenses:	0	0	0	0	0	0	0	0	0	0
Revenue:	0	0	0	0	0	0	0	0	0	0
Operational Costs										
Electric Cost:	0	($436,786)	-454694	-473337	-492743	-512946	-533977	-555870	-578660	-602385
Natural Gas Cost:	0	($113,604)	-121102	-129095	-137615	-146697	-156379	-166701	-177703	-189431
Maintenance:	0	($9,682)	-9924	-10172	-10426	-10687	-10954	-11228	-11509	-11797
Other Costs/Savings:	0	0	0	0	0	0	0	0	0	0
Salvage/Residual Value:	0	0	0	0	0	0	0	0	0	0
Total:	-2114596	-560072	-585720	-612603	-640785	-670330	-701310	-733798	-767872	-803613
Present Value:	-2114596	-522212	-509208	-496578	-484309	-472392	-460815	-449568	-438642	-428027
Net Present Value:	-2114596	-2636807	-3146015	-3642593	-4126903	-4599295	-5060109	-5509678	-5948320	-6376347

Project Year	10	11	12	13	14	15	16	17	18	19
Calendar Year	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042

OPTION 1

Investment Costs										
Project Cost:	0	0	0	0	0	($1,671,443)	0	0	0	0
Design/Support:	0	0	0	0	0	0	0	0	0	0
Recurring Expenses:	0	0	0	0	0	0	0	0	0	0
Revenue:	0	0	0	0	0	0	0	0	0	0
Operational Costs										
Electric Cost:	-627083	-652794	-679558	-707420	-736424	-766618	-798049	-830769	-864830	-900288

Natural Gas Cost:	-201934	-215261	-229468	-244613	-260758	-277968	-296314	-315870	-336718	-358941
Maintenance:	-12091	-12394	-12704	-13021	-13347	-13680	-14022	-14373	-14732	-15101
Other Costs/Savings:	0	0	0	0	0	0	0	0	0	0
Salvage/Residual Value:	0	0	0	0	0	0	0	0	0	0
Total:	-841108	-880449	-921730	-965055	-1010529	-2729709	-1108385	-1161012	-1216281	-1274330
Present Value:	-417714	-407693	-397957	-388496	-379303	-955337	-361688	-353250	-345050	-337080
Net Present Value:	-6794061	-7201754	-7599711	-7988208	-8367511	-9322848	-9684536	-10037786	-10382837	-10719917

Project Year	20	21	22	23	24	25
Calendar Year	2043	2044	2045	2046	2047	2048

OPTION 1

Investment Costs						
Project Cost:	($501,081)	0	0	0	0	0
Design/Support:	0	0	0	0	0	0
Recurring Expenses:	0	0	0	0	0	0
Revenue:	0	0	0	0	0	0
Operational Costs						
Electric Cost:	-937200	-975626	-1015626	-1057267	-1100615	-1145740
Natural Gas Cost:	-382631	-407885	-434806	-463503	-494094	-526704
Maintenance:	-15478	-15865	-16262	-16668	-17085	-17512
Other Costs/Savings:	0	0	0	0	0	0
Salvage/Residual Value:	0	0	0	0	0	0
Total:	-1836391	-1399376	-1466693	-1537438	-1611794	-1689956
Present Value:	-452918	-321804	-314484	-307369	-300451	-293726
Net Present Value:	-11172835	-11494638	-11809122	-12116491	-12416942	-12710669

LCCA by Year - Code-Compliant System

Project Year	0	1	2	3	4	5	6	7	8	9
Calendar Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
<u>OPTION 2</u>										
Life Expectancy:	30	years								
Measure Description:	Code-Compliant System: Individual Building Geothermal Heat Pumps									
Objective:	Energy Objective									
Discount Rate:	7.25%									
Investment Costs										
Project Cost:	($14,512,596)	0	0	0	0	0	0	0	0	0
Design/Support:	0	0	0	0	0	0	0	0	0	0
Recurring Expenses:	0	0	0	0	0	0	0	0	0	0
Revenue:	0	0	0	0	0	0	0	0	0	0
Operational Costs										
Electric Cost:	0	($553,333)	-576020	-599637	-624222	-649815	-676457	-704192	-733064	-763119
Natural Gas Cost:	0	($17,031)	-18156	-19354	-20631	-21993	-23444	-24992	-26641	-28399
Maintenance:	0	($15,716)	-16109	-16512	-16924	-17348	-17781	-18226	-18681	-19148
Other Costs/Savings:	0	0	0	0	0	0	0	0	0	0
Salvage/Residual Value:	0	0	0	0	0	0	0	0	0	0
Total:	-14512596	-586081	-610284	-635502	-661777	-689155	-717683	-747409	-778386	-810667
Present Value:	-14512596	-546462	-530564	-515140	-500176	-485658	-471573	-457907	-444648	-431784
Net Present Value:	-14512596	-15059058	-15589622	-16104762	-16604937	-17090595	-17562168	-18020075	-18464723	-18896508

Project Year	10	11	12	13	14	15	16	17	18	19
Calendar Year	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
<u>OPTION 2</u>										
Investment Costs										
Project Cost:	0	0	0	0	0	($2,996,613)	0	0	0	0
Design/Support:	0	0	0	0	0	0	0	0	0	0
Recurring Expenses:	0	0	0	0	0	0	0	0	0	0
Revenue:	0	0	0	0	0	0	0	0	0	0
Operational Costs										
Electric Cost:	-794407	-826978	-860884	-896180	-932924	-971174	-1010992	-1052442	-1095592	-1140512

Natural Gas Cost:	-30274	-32272	-34402	-36672	-39093	-41673	-44423	-47355	-50481	-53812
Maintenance:	-19627	-20118	-20621	-21136	-21665	-22206	-22761	-23330	-23914	-24512
Other Costs/Savings:	0	0	0	0	0	0	0	0	0	0
Salvage/Residual Value:	0	0	0	0	0	0	0	0	0	0
Total:	-844308	-879368	-915907	-953989	-993681	-4031666	-1078176	-1123128	-1169987	-1218836
Present Value:	-419303	-407193	-395443	-384042	-372979	-1410994	-351830	-341724	-331917	-322401
Net Present Value:	-19315811	-19723004	-20118446	-20502488	-20875467	-22286461	-22638291	-22980015	-23311932	-23634333

Project Year	20	21	22	23	24	25
Calendar Year	2043	2044	2045	2046	2047	2048

OPTION 2

Investment Costs						
Project Cost:	$0	0	0	0	0	0
Design/Support:	0	0	0	0	0	0
Recurring Expenses:	0	0	0	0	0	0
Revenue:	0	0	0	0	0	0
Operational Costs						
Electric Cost:	-1187273	-1235951	-1286625	-1339377	-1394291	-1451457
Natural Gas Cost:	-57364	-61150	-65186	-69488	-74074	-78963
Maintenance:	-25124	-25752	-26396	-27056	-27733	-28426
Other Costs/Savings:	0	0	0	0	0	0
Salvage/Residual Value:	0	0	0	0	0	0
Total:	-1269761	-1322853	-1378207	-1435921	-1496098	-1558846
Present Value:	-313167	-304206	-295511	-287073	-278885	-270938
Net Present Value:	-23947500	-24251706	-24547217	-24834290	-25113175	-25384114

LCCA by Year - Proposed System

Project Year	0	1	2	3	4	5	6	7	8	9
Calendar Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032

OPTION 3

Life Expectancy:	30	years								
Measure Description:	Proposed System: Community Geothermal Heat Pumps									
Objective:	Energy Objective									
Discount Rate:	7.25%									
Investment Costs										
Project Cost:	($8,520,717)	0	0	0	0	0	0	0	0	0
Design/Support:	0	0	0	0	0	0	0	0	0	0
Recurring Expenses:	0	0	0	0	0	0	0	0	0	0
Revenue:	0	0	0	0	0	0	0	0	0	0
Operational Costs										
Electric Cost:	0.0	($522,745)	-544178	-566489	-589715	-613893	-639063	-665264	-692540	-720934
Natural Gas Cost:	0	($17,031)	-18156	-19354	-20631	-21993	-23444	-24992	-26641	-28399
Maintenance:	0	($15,316)	-15699	-16091	-16494	-16906	-17329	-17762	-18206	-18661
Other Costs/Savings:	0	0	0	0	0	0	0	0	0	0
Salvage/Residual Value:	0	0	0	0	0	0	0	0	0	0
Total:	-8520717	-555092	-578032	-601934	-626840	-652792	-679836	-708018	-737387	-767995
Present Value:	-8520717	-517569	-502525	-487929	-473770	-460032	-446704	-433774	-421228	-409056
Net Present Value:	-8520717	-9038286	-9540810	-10028739	-10502509	-10962541	-11409246	-11843019	-12264247	-12673303

Project Year	10	11	12	13	14	15	16	17	18	19
Calendar Year	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042

OPTION 3

Investment Costs										
Project Cost:	0	0	0	0	0	($2,487,674)	0	0	0	0
Design/Support:	0	0	0	0	0	0	0	0	0	0
Recurring Expenses:	0	0	0	0	0	0	0	0	0	0
Revenue:	0	0	0	0	0	0	0	0	0	0
Operational Costs										
Electric Cost:	-750493	-781263	-813295	-846640	-881352	-917487	-955104	-994264	-1035028	-1077465

Natural Gas Cost:	-30274	-32272	-34402	-36672	-39093	-41673	-44423	-47355	-50481	-53812
Maintenance:	-19128	-19606	-20096	-20598	-21113	-21641	-22182	-22737	-23305	-23888
Other Costs/Savings:	0	0	0	0	0	0	0	0	0	0
Salvage/Residual Value:	0	0	0	0	0	0	0	0	0	0
Total:	-799894	-833140	-867792	-903910	-941558	-3468475	-1021710	-1064355	-1108814	-1155165
Present Value:	-397246	-385787	-374669	-363882	-353415	-1213889	-333404	-323842	-314563	-305559
Net Present Value:	-13070549	-13456336	-13831006	-14194888	-14548303	-15762192	-16095596	-16419437	-16734000	-17039559

Project Year	20	21	22	23	24	25
Calendar Year	2043	2044	2045	2046	2047	2048

OPTION 3

Investment Costs						
Project Cost:	$0	0	0	0	0	0
Design/Support:	0	0	0	0	0	0
Recurring Expenses:	0	0	0	0	0	0
Revenue:	0	0	0	0	0	0
Operational Costs						
Electric Cost:	-1121641	-1167628	-1215501	-1265336	-1317215	-1371221
Natural Gas Cost:	-57364	-61150	-65186	-69488	-74074	-78963
Maintenance:	-24485	-25097	-25724	-26368	-27027	-27702
Other Costs/Savings:	0	0	0	0	0	0
Salvage/Residual Value:	0	0	0	0	0	0
Total:	-1203489	-1253875	-1306411	-1361192	-1418316	-1477886
Present Value:	-296822	-288344	-280117	-272133	-264386	-256867
Net Present Value:	-17336381	-17624725	-17904842	-18176975	-18441361	-18698228

Appendix G. Short Environmental Assessment Form

Short Environmental Assessment Form
Part 1 - Project Information

Instructions for Completing

Part 1 – Project Information. The applicant or project sponsor is responsible for the completion of Part 1. Responses become part of the application for approval or funding, are subject to public review, and may be subject to further verification. Complete Part 1 based on information currently available. If additional research or investigation would be needed to fully respond to any item, please answer as thoroughly as possible based on current information.

Complete all items in Part 1. You may also provide any additional information which you believe will be needed by or useful to the lead agency; attach additional pages as necessary to supplement any item.

Part 1 – Project and Sponsor Information

Name of Action or Project:
NYSERDA Community Heat Pump Study - Geo Exchange Test Well

Project Location (describe, and attach a location map):
SUNY Oswego, 7060 State Route 104, Oswego NY 13126; Tax parcel 127.18-02-01; Site location: Large parking lot at Union Rd by Cooper/Culkin

Brief Description of Proposed Action:
M/E Engineering is currently working ona Drilling of a 6 inch diameter 498 ft deep geo exchange test well for thermal conductivity to determine the feasibility of a potential ground coupled geothermal well field.

M/E Engineering is currently working on a study for SUNY Oswego through the NYSERDA Community Geothermal Heat Pump Program. We are studying the feasibility of connecting five buildings to a common geothermal well field with heat pumps serving the buildings in various methods and capacities. These may take the form of ground-coupled water to water, ground-coupled water to air, centralized or distributed or with a hybrid approach. The well field is conceptually planned to be located on a parcel of land on the SUNY Oswego Campus, in Oswego, NY 13126. However, before proceeding with this design, we require that a vertical test bore and subsequent thermal conductivity report be performed.

Name of Applicant or Sponsor:	Telephone: 716-845-5092 x1207
M/E Engineering P.C on behalf of SUNY Oswego, Melanie Stachowiak PE - Partner	E-Mail: mgstachowiak@meengineering.com

Address:
60 Lakefront Boulevard, Suite 320

City/PO:	State:	Zip Code:
Buffalo	NY	14202

	NO	YES
1. Does the proposed action only involve the legislative adoption of a plan, local law, ordinance, administrative rule, or regulation? If Yes, attach a narrative description of the intent of the proposed action and the environmental resources that may be affected in the municipality and proceed to Part 2. If no, continue to question 2.	☑	☐
2. Does the proposed action require a permit, approval or funding from any other government Agency? If Yes, list agency(s) name and permit or approval: Funding from NYSERDA through the Community Heat Pump program	☐	☑

3. a. Total acreage of the site of the proposed action? <0.025 acres
b. Total acreage to be physically disturbed? <0.025 acres
c. Total acreage (project site and any contiguous properties) owned or controlled by the applicant or project sponsor? 146.72 acres

4. Check all land uses that occur on, are adjoining or near the proposed action:
☐ Urban ☐ Rural (non-agriculture) ☐ Industrial ☑ Commercial ☑ Residential (suburban)
☐ Forest ☐ Agriculture ☐ Aquatic ☑ Other(Specify): Institutional (SUNY Oswego)
☐ Parkland

	NO	YES	N/A
5. Is the proposed action,			
a. A permitted use under the zoning regulations?	☐	☐	☑
b. Consistent with the adopted comprehensive plan?	☐	☐	☑

	NO	YES
6. Is the proposed action consistent with the predominant character of the existing built or natural landscape?	☐	☑

	NO	YES
7. Is the site of the proposed action located in, or does it adjoin, a state listed Critical Environmental Area? If Yes, identify:	☑	☐

	NO	YES
8. a. Will the proposed action result in a substantial increase in traffic above present levels?	☑	☐
b. Are public transportation services available at or near the site of the proposed action?	☑	☐
c. Are any pedestrian accommodations or bicycle routes available on or near the site of the proposed action?	☑	☐

	NO	YES
9. Does the proposed action meet or exceed the state energy code requirements? If the proposed action will exceed requirements, describe design features and technologies: This is a geo exchange test well. The energy code requirements do not apply until this is connected to HVAC systems. However the installation and materials (i.e thermal conductivity) used will meet the state code requirements.	☐	☑

	NO	YES
10. Will the proposed action connect to an existing public/private water supply? If No, describe method for providing potable water: Potable water will be used for mixing grout, filling piping, and general washing up and clean up, but no permanent connection.	☑	☐

	NO	YES
11. Will the proposed action connect to existing wastewater utilities? If No, describe method for providing wastewater treatment: There will be no need for waste water utilities. There may be some ground water generated on the site during drilling but this is expected to be limited and contained. A geotextile bag will be used to contain all the drill cuttings and filter the water before it enters the storm drain.	☑	☐

	NO	YES
12. a. Does the project site contain, or is it substantially contiguous to, a building, archaeological site, or district which is listed on the National or State Register of Historic Places, or that has been determined by the Commissioner of the NYS Office of Parks, Recreation and Historic Preservation to be eligible for listing on the State Register of Historic Places?	☑	☐
b. Is the project site, or any portion of it, located in or adjacent to an area designated as sensitive for archaeological sites on the NY State Historic Preservation Office (SHPO) archaeological site inventory?	☑	☐

	NO	YES
13. a. Does any portion of the site of the proposed action, or lands adjoining the proposed action, contain wetlands or other waterbodies regulated by a federal, state or local agency?	☑	☐
b. Would the proposed action physically alter, or encroach into, any existing wetland or waterbody?	☑	☐
If Yes, identify the wetland or waterbody and extent of alterations in square feet or acres:		

14. Identify the typical habitat types that occur on, or are likely to be found on the project site. Check all that apply:

☐ Shoreline ☐ Forest ☐ Agricultural/grasslands ☐ Early mid-successional

☐ Wetland ☐ Urban ☑ Suburban

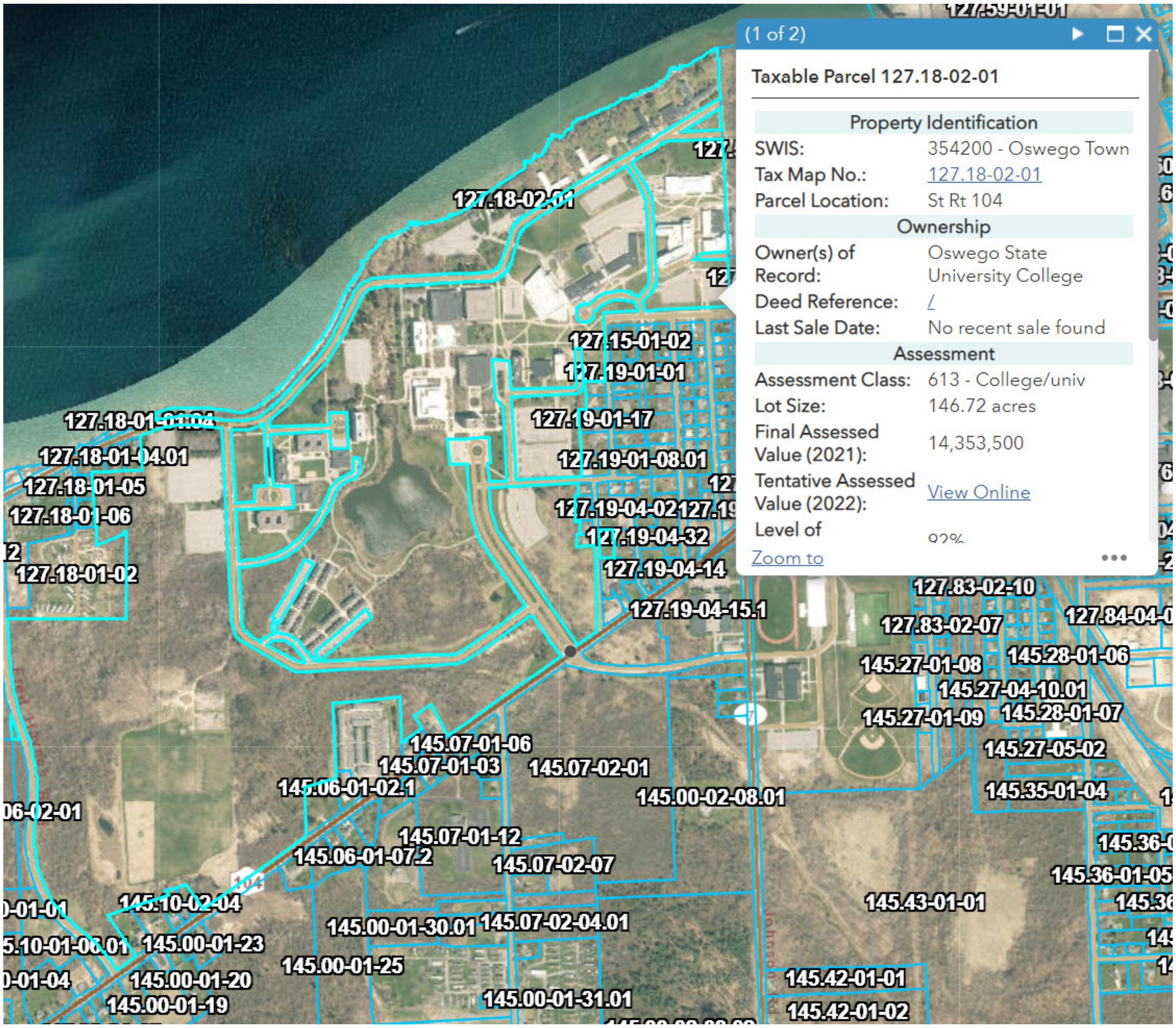
	NO	YES
15. Does the site of the proposed action contain any species of animal, or associated habitats, listed by the State or Federal government as threatened or endangered?	☑	☐
16. Is the project site located in the 100-year flood plan?	☑	☐
17. Will the proposed action create storm water discharge, either from point or non-point sources? If Yes,	☑	☐
a. Will storm water discharges flow to adjacent properties?	☑	☐
b. Will storm water discharges be directed to established conveyance systems (runoff and storm drains)? If Yes, briefly describe:	☑	☐
18. Does the proposed action include construction or other activities that would result in the impoundment of water or other liquids (e.g., retention pond, waste lagoon, dam)? If Yes, explain the purpose and size of the impoundment:	☑	☐
19. Has the site of the proposed action or an adjoining property been the location of an active or closed solid waste management facility? If Yes, describe:	☑	☐
20. Has the site of the proposed action or an adjoining property been the subject of remediation (ongoing or completed) for hazardous waste? If Yes, describe:	☑	☐

I CERTIFY THAT THE INFORMATION PROVIDED ABOVE IS TRUE AND ACCURATE TO THE BEST OF MY KNOWLEDGE

Applicant/sponsor/name: M/E Engineering, P.C. Date: ____________

Signature: ____________ Title: ____________

PRINT FORM


(1 of 2)
Taxable Parcel 127.18-02-01
Property Identification
SWIS: 354200 - Oswego Town
Tax Map No.: 127.18-02-01
Parcel Location: St Rt 104
Ownership
Owner(s) of Record: Oswego State University College
Deed Reference: /
Last Sale Date: No recent sale found
Assessment
Assessment Class: 613 - College/univ
Lot Size: 146.72 acres
Final Assessed Value (2021): 14,353,500
Tentative Assessed Value (2022): View Online
Level of
Zoom to
127.18-02-01
127.18-01-04.01
127.18-01-05
127.18-01-06
127.18-01-02
127.15-01-02
127.19-01-01
127.19-01-17
127.19-01-08.01
127.19-04-32
127.19-04-14
127.19-04-15.1
127.83-02-10
127.83-02-07
145.27-01-08
145.28-01-06
145.27-04-10.01
145.27-01-09
145.28-01-07
145.27-05-02
145.35-01-04
145.36-01-05
145.43-01-01
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145.42-01-02
145.07-01-06
145.07-01-03
145.07-02-01
145.06-01-02.1
145.00-02-08.01
145.07-01-12
145.06-01-07.2
145.07-02-07
145.10-02-04
145.00-01-30.01
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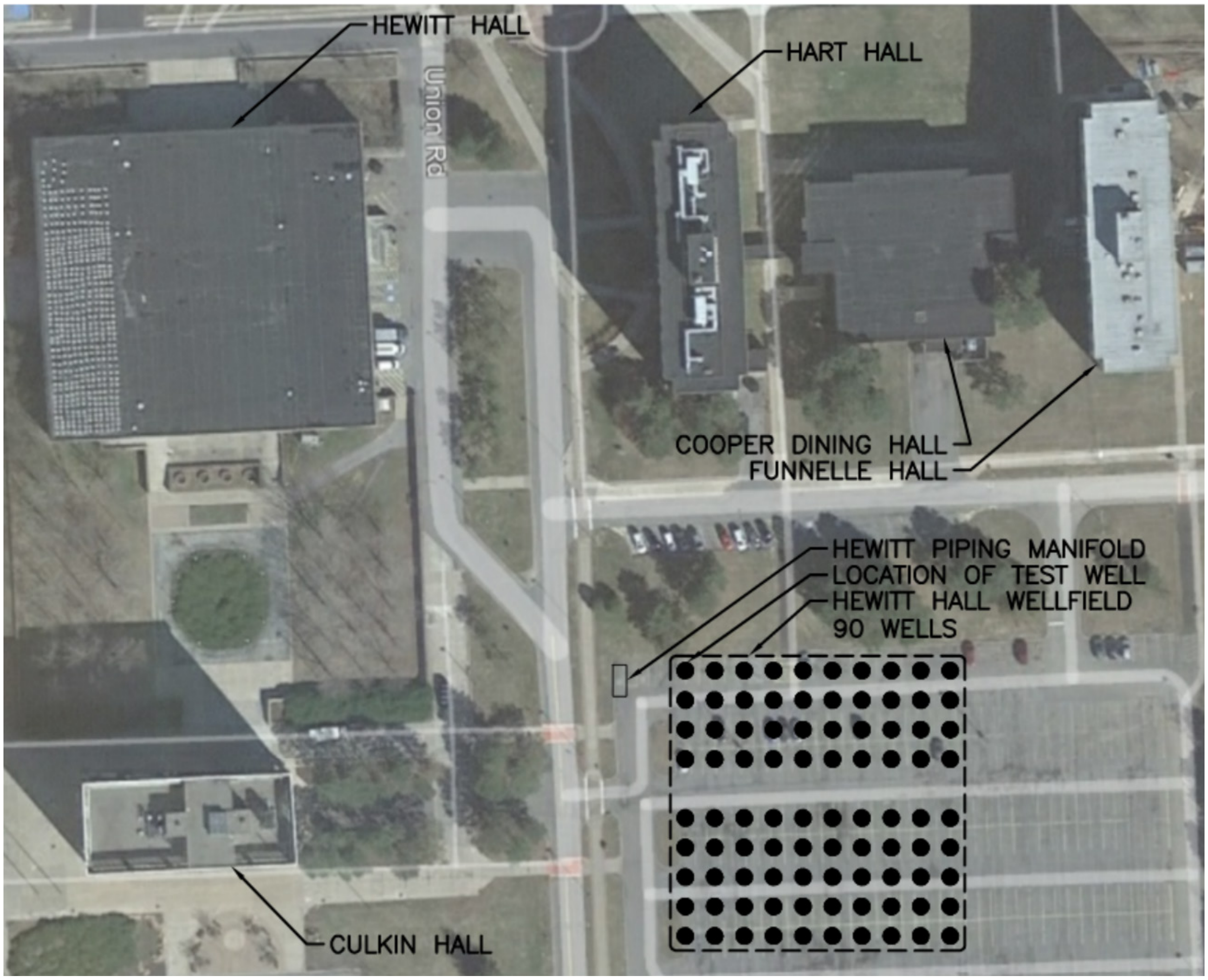
145.00-01-31.01


HEWITT HALL
HART HALL
Union Rd
COOPER DINING HALL
FUNNELLE HALL
HEWITT PIPING MANIFOLD
LOCATION OF TEST WELL
HEWITT HALL WELLFIELD
90 WELLS
CULKIN HALL

Appendix H. Kickoff Meeting Notes

Mechanical/Electrical Engineering Consultants
Buffalo • Rochester • Syracuse • Capital District

MEETING MINUTES

PROJECT: **SUNY OSWEGO COMMUNITY HEAT PUMP SYSTEM STUDY**
NYSERDA 176822

M/E REFERENCE: 211199

DATE OF MEETING: Tuesday March 1, 2022, 9:00 AM

PRESENT:

Name	Company	Phone Number	E-Mail
Lori Armstrong	NYSERDA		lori.armstrong@nyserda.ny.gov
Melanie Stachowiak	M/E Engineering	(716) 845-5092 x1207	mgstachowiak@meengineering.com
Anna Szweda	M/E Engineering	(716) 845-5092 x1223	aeszweda@meengineering.com
Allen Bradberry	SUNY Oswego	(315) 312-6600	allen.bradberry@oswego.edu
Kate Spector	SUNY Oswego	(315) 312-6616	katherine.spector@oswego.edu
Kim Conant	SUCF	(518) 320-1705	kimberly.conant@suny.edu

The following minutes were prepared by M/E Engineering, P.C. and will be assumed correct unless written notification is received:

A. INTRODUCTIONS - NAMES AND PROJECT ROLES

1. NYSERDA Project Manager: Lori Armstrong (Clean Heating & Cooling team)
2. Primary Energy Consultant: M/E Engineering, P.C.
   a. Oversight: Melanie Stachowiak - Partner
   b. Energy Engineer: Anna Szweda - Senior Energy Engineer
3. Project Owner / Client: SUNY Oswego
   a. Allen Bradberry - Facility Services Department, Director of Major Projects
   b. Kate Spector - Campus Sustainability Manager
   c. Kim Conant - State University Construction Fund
4. SUNY Oswego is moving toward net-zero, aims to combine academic and dorm buildings to create an efficient community heat pump system
5. SUCF is supportive of Campus desire for GSHP/clean energy and scoping study for future wells

60 Lakefront Boulevard, Suite 320 | Buffalo, NY 14202 | 716.845.5092 | www.meengineering.com

B. COMMUNITY HEAT PUMP PROGRAM - PROGRAM OVERVIEW

1. Program Goals:

   a. Determine feasibility of Community Heat Pump system, in order to expand clean energy options for buildings within SUNY Oswego community.

      1) Decarbonization

      2) Scalability/replication

   b. Assessment of additional technologies for electrical demand relief and added project value geared toward these buildings

2. Process

   a. Project kickoff

   b. Establish baseline conditions - documentation, conversations, site visits

   c. Develop energy profile - utility bills, previous studies

3. Determine optimal energy source and develop conceptual design - aerial views, wellfield layout

      1) Test well - likely not needed - one was done for Hewitt Hall in area (within a few hundred feet) of the area we are looking at. An additional header is being installed to be able to increase capacity at the Hewitt Hall wellfield. SUNY Oswego will provide previous test well data.

      2) SEQR (State Environmental Quality Review) - Short Form Part 1 - only required if test well is done

   b. Perform economic and financial analysis - include cost of carbon/carbon footprint as part of the analysis

   c. Perform assessment of additional technologies to improve project value and/or mitigate demand on electric grid - high level, preliminary calculations

      1) Solar PV

      2) EV Charging

      3) Battery energy storage

   d. Conduct permitting and regulatory review

   e. Leverage education opportunity of the project (internship) - consider how to integrate interns into process.

      1) 3 interns with Kate (2 listening in on call), 6 interns in Allen's office - perhaps use one from each office? Current interns available until May

      2) M/E to consider and provide ideas of ways to integrate interns

   f. Written report

C. PROJECT OVERVIEW

1. Building Description:

   a. Cluster of four buildings on SUNY Oswego campus

Building Name	Use	Area G.S.F.	Bldg. Age	HVAC System Age	Current Heating System	Current Cooling System	Current Domestic Hot Water System	Building Condition (Excellent, Good, Fair, Poor)	HVAC Condition (Excellent, Good, Fair, Poor)	Certified Historic Building (Yes/No)
Cooper Dining Hall	Student Center (Dining, Meeting Rooms, etc)	24,796	2015	2015	Steam from central plant w/ steam to water heat exchanger, including radiant loop	Chilled Water	Steam to DHW heat exchanger	Fair	Excellent	No
Culkin Hall	Office (Administration Building)	59,611	1967	2011 CHW upgrades, remainder is original.	Steam from central plant w/ steam to water heat exchanger, including radiant loop and AHUs	Chilled Water	Steam to DHW heat exchanger	Fair	Excellent	No
Funnelle Hall	Dormitory	40,545	1967	2000	Steam from central plant w/ steam to water heat exchanger, including radiant loop	None	Steam to DHW heat exchanger	Fair	Fair	No
Hart Hall	Dormitory	38,616	1967	2021	Steam from central plant w/ steam to water heat exchanger, including radiant loop. Corridor MAUs.	None (air cooled bathrooms and data closets)	Steam to DHW heat exchanger	Fair	Fair	No

   b. Geothermal wellfield with shared heat pump loop:

      1) Other GSHPs on campus typically include water to water heat pumps (with chilled & hot water). Consider how/if to incorporate existing systems, especially where HVAC system was recently installed.

      2) Water to air (traditional above-ceiling heat pumps) may be used where it makes sense.

      3) Ultimately the intent is for several "community" geo loops to tie in with other loop/communities (e.g. the science building loop)

2. Benchmark systems:

   a. Existing building HVAC systems

   b. Code minimum, individual building geothermal heat pump system

3. Utility Companies:

   a. Electric - National Grid

   b. Natural Gas - National Grid

   c. Energy Cap to access data (can make available to M/E) - SUNY Oswego working on determining monthly breakdowns

D. INFORMATION SHARING

1. Data required:

Data / Information	Provider
Building Arch./MEP drawings	SUNY Oswego
Site Plans	SUNY Oswego
Utility information	National Grid
Building past energy use	SUNY Oswego / National Grid
Access to buildings	SUNY Oswego
Building occupancy/use information	SUNY Oswego
Potential incentives associated with design/implementation	NYSERDA / National Grid

2. Data received to date:

   a. Preliminary building data (i.e. occupancy, HVAC systems outline, etc.)

   b. 3-year overall annual energy use by building

3. M/E to provide SUNY Oswego list of documentation requested - provide Newforma link for upload

E. PROJECT SCHEDULE

1. Schedule of Project:

Project Task	Time Frame (Weeks)
0. Project Management and Project Reporting	40
1. Establish Baseline Conditions	7
2. Develop Energy Profile	6
3. Determine Optimal Energy Source	9
4. Perform Economic and Financial Analysis	8
5. Perform Assessment of Additional Technologies	2
6. Conduct Permitting and Regulatory Review	9
7. Establish an Internship and Hire an Intern	7
8. Produce Final Report	9*
Total	**40**

*Includes development of draft report, NYSERDA review, comment period, a development of final.

2. Periodic progress reports as tasks completed (some tasks combined)

3. Scheduling of test well - likely not required

   a. Previous test well data is available

F. RELATED NYSERDA PON OPPORTUNITES

1. SUNY Oswego would like to continue on and pursue the related NYSERDA PONs regarding the design & installation of the wellfield.

2. Each phase must be preceded by piece before (i.e. scoping study, then design, then construction) - scoping study must be complete and submitted (but doesn't not require approval) to proceed to the next phase

3. Goal is to have multiple communities & shared loops, and to replace the campus steam system. There is much interest in expanding the campus geothermal (including an East Campus community as well).

4. Multiple design projects may be submitted simultaneously

G. ACTION ITEMS

1. M/E to submit meeting minutes
2. M/E to provide list of data requested from SUNY Oswego (attached) and Newforma upload link
3. M/E to provide list of ideas for tasks that interns could take on (attached)
4. SUNY Oswego to provide additional building data
5. M/E to begin analysis/modeling tasks as information becomes available

The foregoing constitutes our understanding of matters discussed and conclusions reached. If there are any errors or omissions, please notify M/E Engineering, P.C. in writing.

Respectfully Submitted,

M/E ENGINEERING, P.C.

Anna E. Szweda, LEED AP BD+C, CEA, CMVP, CPD
Senior Energy Engineer

NYSERDA, a public benefit corporation, offers objective information and analysis, innovative programs, technical expertise, and support to help New Yorkers increase energy efficiency, save money, use renewable energy, and reduce reliance on fossil fuels. NYSERDA professionals work to protect the environment and create clean-energy jobs. NYSERDA has been developing partnerships to advance innovative energy solutions in New York State since 1975.

To learn more about NYSERDA's programs and funding opportunities, visit nyserda.ny.gov or follow us on X, Facebook, YouTube, or Instagram.

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