Syracuse University: Community Heat Pump Study

Final Report | Report Number 22-36 | September 2022

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Syracuse University: Community Heat Pump Study

Final Report

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Notice

Abstract

Syracuse University desires carbon neutrality by 2040, which requires an electrified heating solution. A community geothermal heat pump loop was explored for eight buildings on the south campus 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 46 percent 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, Refrigeration, and Air conditioning Engineers
Btu	British thermal unit
CBECS	Commercial Building Energy Consumption Survey
CHW	chilled water
CO_2	carbon dioxide
COP	coefficient of performance
CT	cooling tower
CW	condenser water
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
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
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
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
PUE	power usage effectiveness
PV	photovoltaic
RTU	rooftop unit
SEER	seasonal energy efficiency ratio
Sf	square foot
SHGC	solar heat gain coefficient
UL	Underwriter's Laboratory
V	Volt
VAV	variable air volume
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

Syracuse University, located in Syracuse, NY, has committed to carbon neutrality by 2040. To reach this goal, reduced carbon technologies such as geothermal heat pumps will be necessary in campus buildings. As a city 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 eight buildings on the Syracuse University South Campus:

- 623 Skytop Data Center
- 621 Skytop Office Building
- Tennity Ice Skating Pavilion
- Goldstein Student Center
- Skytop Office Building
- Ski Lodge
- 460 Winding Ridge Apartments
- 480 Winding Ridge Apartments

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 can be incorporated into the project have been reviewed, as well as potential incentive opportunities and regulatory roadblocks. The results of the analysis are summarized below:

Table ES-1. Budget Cost Estimate for Syracuse University 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	$4,918,071	$0	**$4,918,071**	$72,218	$576,589	**$648,807**	**4,258,576**	($17,310,608)
Code-Compliant System: Individual building heat pumps	$17,719,877	$789,601	**$16,930,276**	$57,679	$567,206	**$624,885**	**2,445,722**	($30,466,790)
Proposed System: Community heat pumps	$17,628,502	$5,201,701	**$12,426,801**	$58,127	$536,322	**$594,449**	**2,319,039**	($24,376,589)

1 Project Rationale

Syracuse University is committed to sustainability, and in 2009, published their climate action plan with a commitment to obtain carbon neutrality by 2040. One component of their five-faceted approach is to attain energy efficiency through emerging technologies. Ground source heat pump (GSHP or geothermal) 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 geothermal heat pump system installation. In particular, the improvement of water-to-water heat pumps has 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 percent, with a code minimum efficiency of 80 percent. 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 percent. Even code-minimum ground source heat pumps have a full-load Coefficient of Performance (COP) of 2.5, or 250 percent 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 percent 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 percent 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 in the building do not contrast significantly. Because of the energy sharing, the wellfield can be downsized from what it would need to be for each building individually as well.

Because of Syracuse University'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:

- 623 Skytop Data Center
- 621 Skytop Office Building
- Tennity Ice Skating Pavilion
- Goldstein Student Center
- Skytop Office Building
- Ski Lodge
- 460 Winding Ridge Apartments
- 480 Winding Ridge Apartments

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 their individual heating and cooling loads/peaks simultaneously. This permits load-sharing to improve energy efficiency, and the combined geothermal well field can be economically sized.
2. The project includes a data center that is continually rejecting a significant amount of thermal energy. This introduction of thermal energy into the heat pump loop provides a continuous "free" heat source during the heating season.

3. The eight buildings are relatively in close proximity, so a heating/cooling loop can be economically installed.
4. Syracuse University owns all of the buildings and property and maintains the systems that involve this proposed community heat pump area. Barriers to installation (such as required permissions and variances) will be minimal.

Should the university choose to implement the recommendations in the report, this initial heat pump community can be used as a prototype for future communities at other locations throughout the campus.

2 Existing Conditions: Utility Baseline

2.1 Site Overview

Founded in 1870, Syracuse University is located in Syracuse, NY. The private research institution is home to 21,322 students, with over 200 majors and advanced degree programs. The buildings in this study are located on the University's South Campus, on or near Skytop Road.

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 buildings analyzed are eight buildings in a cluster on the Syracuse University South Campus. General data for each of the facilities are shown in Table 1.

Table 1. Building Summary

Building Name	Use	Area (sf)	Daily Operating Hours	Building Age	HVAC System Age	Current Heating System	Current Cooling System	Current Domestic Hot Water System	Comments
623 Skytop Data Center	Data Center	12,073	24/7	2009	2009	Hot Water	Chilled Water	Hot Water	Building systems are excellent. The central plant equipment is lacking proper redundancy.
621 Skytop Office Building	Office	95,800	7:00 AM - 6:00 PM M-F	1968	1968	Steam Boilers	Chilled Water	Gas Fired	623 and 621 Share central heating/ cooling plant equipment. 621 is a dual duct system served by steam/ chilled water air handlers.
Tennity Ice Skating Pavilion	Ice Rink	47,823	24/7	2000	2000	Gas fired dehumidification unit	Chilled Water	Gas Fired	Cooling is only provided by rink. Chiller and tower replaced in 2014.
Goldstein Student Center	Student Center	43,888	6:30 AM - 11:59 PM	1990	1990	Water source heat pump, gas fired boilers, DOAS AHUs	Water source heat pump	Gas Fired	Miscellaneous heat pumps have been replaced and renovations have added air handlers.
Skytop Office Building	Office	52,900	6:00 AM - 6:00 PM M-F	1972	2018	Gas Fired Boilers	Rooftop	Gas Fired	Recently renovated with RTU's and VAV boxes.
Ski Lodge	Restaurant/ Bar	9,342	11 AM - 12 AM	1948	1948	Gas Fired Steam	Ductless Split	Gas fired	Building lacks makeup air for kitchen hoods.
480 Winding Ridge (Typical Apartment Building)	Apartment	6,257	24/7	1972	1997	Electric Resistance	None	Electric Resistance	Baseboard electric heat.
460 Winding Ridge (Typical Large Apartment Building)	Apartment	9,356	24/7	1972	1997	Electric Resistance	None	Electric Resistance	Baseboard electric heat.

2.4 623 Skytop Data Center

This 12,073 square foot building is a data center, connected to the adjacent 621 Skytop office building. The data center supports the Syracuse University campus, operating 24 hours per day, 365 days per year. The central plant systems are shared between the two buildings, and thus the utility information must be combined to get an accurate assessment of the overall facility. Previously, a combination of natural gas microturbines and absorption chillers provided electricity and chilled water to the facility but were taken offline in 2018. The baseline utility data shows natural gas load in the early months of the data, but it has been adjusted to eliminate that load.

The Commercial Building Energy Consumption Survey (CBECS) that is aggregated by Energy Star® indicates the national average Power Usage Effectiveness (PUE) for a data center is a ratio of 1.82. For a data center which requires 100 tons of cooling—assuming that it follows a ASHRAE 90.1-2016 computer data room schedule—translates to roughly 990 thousand Bristish thermal units per square feet (kBtu/sf). The adjusted Energy Utilization Index (EUI) of the existing building is 925.1 kBtu/sf, which suggests an energy efficient building. However, some of the cooling energy is relegated to the adjacent office building and is not included in the building utility data.

It is clear from the trend data that the data center is consistently used throughout the year, and not greatly affected by the time of year.

Figure 1. 623 Skytop–Utility Consumption

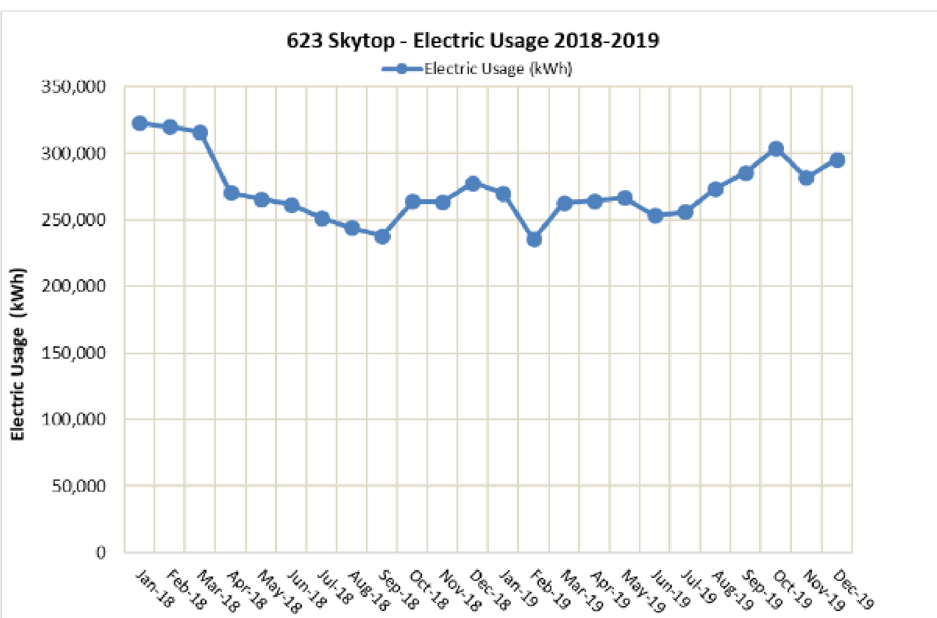


Figure 1 continued

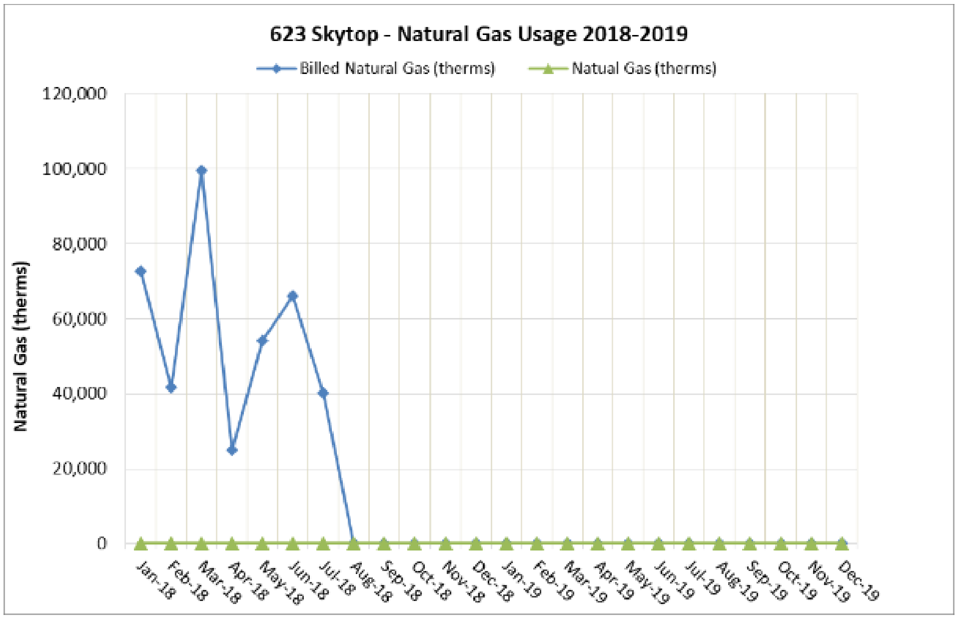


Table 2. 623 Skytop–Utility Bills

623 Skytop Road–Data Center												
Statement Date	Electricity			Natural Gas			Adjusted Natural Gas		Total Energy			
	Usage (kWh)	Cost ($)	Rate ($/kWh)	Usage (therm)	Cost ($)	Rate ($/therm)	Usage (therm)	Cost ($)	Usage (mmBtu)	Cost ($)	Carbon Emissions (lb CO_2e)	EUI (kBtu/sf)
Jan-18	322,834	$13,394	$0.041	72,542	$27,522	$0.379	*0*	*$0*	1,102	$13,394	74,994	91.3
Feb-18	319,942	$11,130	$0.035	41,582	$15,839	$0.381	*0*	*$0*	1,092	$11,130	74,323	90.4
Mar-18	316,257	$12,363	$0.039	99,681	$38,248	$0.384	*0*	*$0*	1,079	$12,363	73,467	89.4
Apr-18	270,337	$10,835	$0.040	24,976	$12,785	$0.512	*0*	*$0*	923	$10,835	62,799	76.4
May-18	265,728	$10,393	$0.039	54,209	$20,645	$0.381	*0*	*$0*	907	$10,393	61,728	75.1
Jun-18	261,547	$9,199	$0.035	66,151	$25,548	$0.386	*0*	*$0*	893	$9,199	60,757	73.9
Jul-18	251,431	$12,316	$0.049	40,142	$16,175	$0.403	*0*	*$0*	858	$12,316	58,407	71.1
Aug-18	244,170	$16,009	$0.066	0	$149	--	0	*$0*	833	$16,009	56,721	69.0
Sep-18	238,014	$15,541	$0.065	0	$149	--	0	*$0*	812	$15,541	55,291	67.3
Oct-18	263,947	$17,689	$0.067	0	$149	--	0	*$0*	901	$17,689	61,315	74.6
Nov-18	263,616	$17,815	$0.068	0	$149	--	0	*$0*	900	$17,815	61,238	74.5
Dec-18	277,692	$18,435	$0.066	0	$149	--	0	*$0*	948	$18,435	64,508	78.5
Jan-19	269,811	$17,409	$0.065	0	$0	--	0	$0	921	$17,409	62,677	76.3
Feb-19	235,414	$15,292	$0.065	0	$0	--	0	$0	803	$15,292	54,687	66.6
Mar-19	262,992	$17,455	$0.066	0	$0	--	0	$0	898	$17,455	61,093	74.3
Apr-19	264,138	$18,401	$0.070	0	$0	--	0	$0	902	$18,401	61,359	74.7
May-19	266,902	$18,314	$0.069	0	$0	--	0	$0	911	$18,314	62,001	75.5
Jun-19	253,427	$17,293	$0.068	0	$0	--	0	$0	865	$17,293	58,871	71.6
Jul-19	256,104	$18,189	$0.071	0	$0	--	0	$0	874	$18,189	59,493	72.4
Aug-19	273,616	$14,882	$0.054	0	$0	--	0	$0	934	$14,882	63,561	77.4
Sep-19	285,662	$12,999	$0.046	0	$0	--	0	$0	975	$12,999	66,359	80.8
Oct-19	304,152	$13,677	$0.045	0	$0	--	0	$0	1,038	$13,677	70,655	86.0
Nov-19	281,837	$14,082	$0.050	0	$0	--	0	$0	962	$14,082	65,471	79.7
Dec-19	295,377	$14,863	$0.050	0	$0	--	0	$0	1,008	$14,863	68,616	83.5
2018 Total	3,295,515	$165,119	$0.050	399,283	$157,510	$0.394	0	$0	11,248	$165,119	765,548	931.6
2019 Total	3,249,432	$192,856	$0.059	0	$0	--	0	$0	11,090	$192,856	754,843	918.6
2-year Average	**3,272,473**	**$178,988**	**$0.055**	**199,642**	**$78,755**	**$0.394**	**0**	**$0**	**11,169**	**$178,988**	**760,196**	**925.1**

* ***Red italic text*** indicates adjusted or assumed utility data as described.

2.5 621 Skytop Office Building

Connected to the 623 Skytop Data Center, this 95,800 square foot office building contains offices, labs, conference rooms, classrooms, etc. As an office building, it operates weekdays 7:00 a.m.–6:00 p.m., with reduced summer hours. It shares a central plant with the data center. When the absorption chillers were taken offline and replaced with traditional systems, the electricity consumption moderately increased to account for the additional load on the central plant. Thus, the utility data has been adjusted to increase the electricity data at the beginning of 2018 as well.

Energy Star indicates that a typical office building has an EUI of 52.9 kBtu/sf (per the CBECS). Moreover, ASHRAE 100 suggests an energy goal of 56 EUI for an office building in the Syracuse, NY climate zone (5A). This building shows an overall EUI of 162.0 kBtu/sf. The high rating suggests an inefficient building. However, the calculation includes some cooling energy for the data center, which creates a misleading statistic.

Like the data center, the electricity usage in this building is fairly flat throughout the year, with some increased usage in the summer months. This further shows that the data center, which has a consistent cooling load regardless of time of year, has a significant impact on the building, and drives up the energy consumption. Conversely, the natural gas usage follows typical weather patterns—peaks in winter and summer, as expected for an office building.

Figure 2. 621 Skytop–Utility Consumption

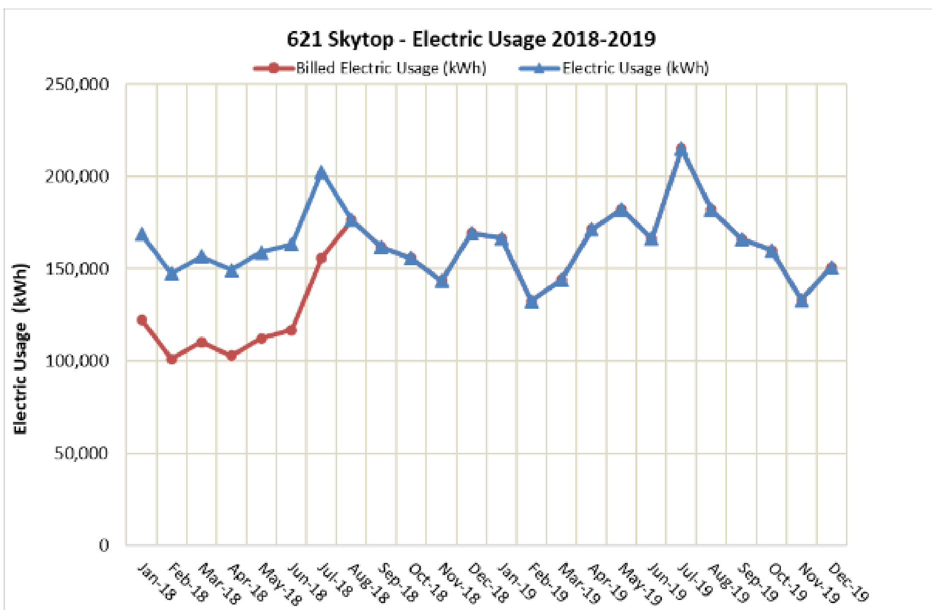


Figure 2 continued

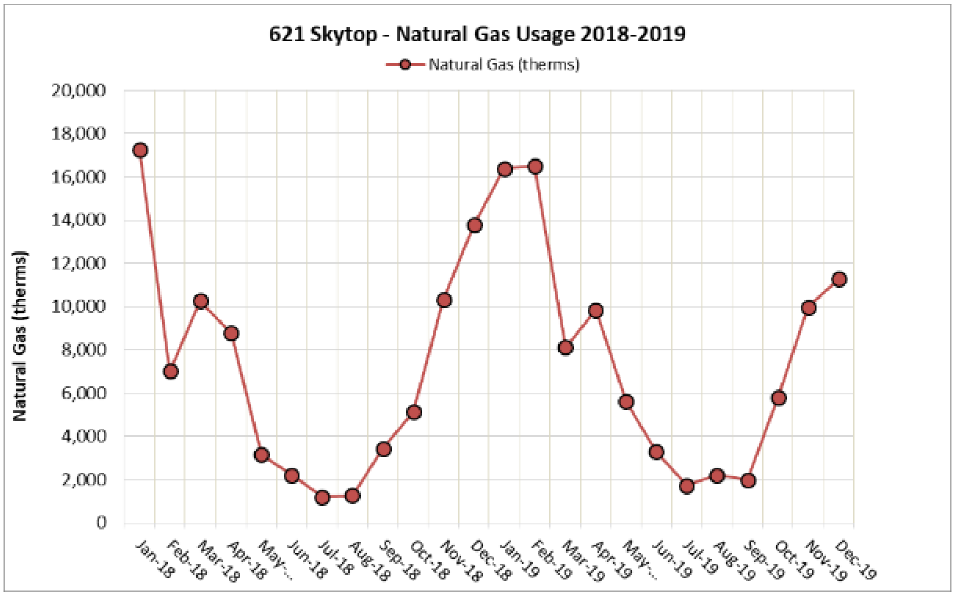


Table 3. 621 Skytop–Utility Bills

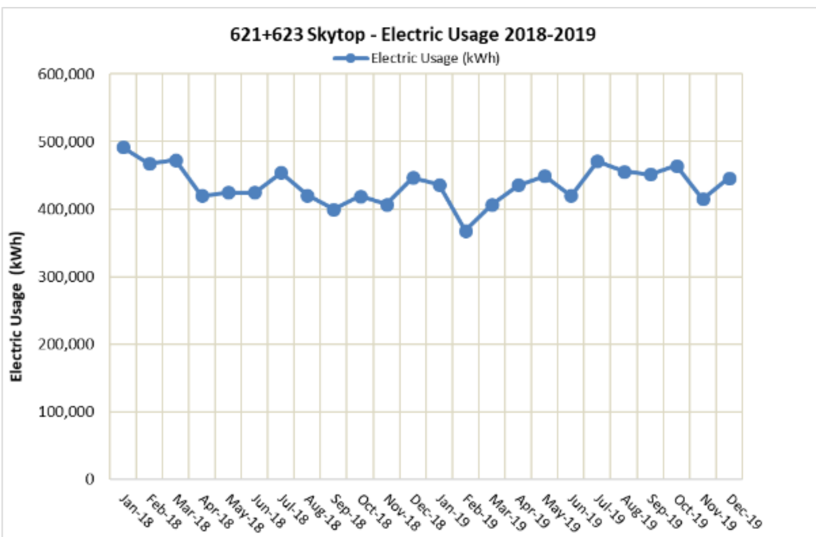
621 Skytop Road–Office Building														
Statement Date	Electricity				Adjusted Electricity		Natural Gas			Total Energy				
	Usage (kWh)	Demand (kW)	Cost ($)	Rate ($/kWh)	Usage (kWh)	Cost ($)	Usage (therm)	Cost ($)	Rate ($/therm)	Usage (mmBtu)	Cost ($)	Carbon Emissions (lb CO_2e)	EUI (kBtu/sf)
Jan-18	122,451	267.6	$5,081	$0.041	*169,007*	*$7,012*	17,251	$7,666	$0.444	2,302	$14,678	230,243	24.0
Feb-18	101,112	309.6	$3,517	$0.035	*147,668*	*$5,137*	7,006	$3,339	$0.477	1,205	$8,476	105,442	12.6
Mar-18	110,242	283.4	$4,309	$0.039	*156,798*	*$6,129*	10,268	$4,613	$0.449	1,562	$10,743	145,721	16.3
Apr-18	102,887	314.8	$4,124	$0.040	*149,443*	*$5,990*	8,771	$4,989	$0.569	1,387	$10,978	126,501	14.5
May-18	112,361	335.9	$4,395	$0.039	*158,917*	*$6,216*	3,142	$1,708	$0.544	857	$7,924	62,856	8.9
Jun-18	116,805	391.7	$4,108	$0.035	*163,361*	*$5,745*	2,211	$1,125	$0.509	779	$6,871	52,997	8.1
Jul-18	156,002	394.6	$7,642	$0.049	*202,558*	*$9,922*	1,201	$792	$0.660	811	$10,714	50,288	8.5
Aug-18	176,595	436.5	$11,579	$0.066	176,595	$11,579	1,274	$797	$0.626	730	$12,376	55,926	7.6
Sep-18	161,892	400.8	$10,570	$0.065	161,892	$10,570	3,433	$1,722	$0.501	896	$12,292	77,766	9.4
Oct-18	155,612	395.3	$10,429	$0.067	155,612	$10,429	5,116	$2,556	$0.500	1,043	$12,984	95,994	10.9
Nov-18	143,484	425.1	$9,697	$0.068	143,484	$9,697	10,317	$5,332	$0.517	1,521	$15,029	154,017	15.9
Dec-18	169,292	430.1	$11,239	$0.066	169,292	$11,239	13,778	$9,418	$0.684	1,956	$20,657	200,498	20.4
Jan-19	166,656	409.6	$10,753	$0.065	166,656	$10,753	16,381	$9,194	$0.561	2,207	$19,947	230,334	23.0
Feb-19	132,544	361.3	$8,610	$0.065	132,544	$8,610	16,489	$8,424	$0.511	2,101	$17,033	223,674	21.9
Mar-19	144,047	377.1	$9,561	$0.066	144,047	$9,561	8,119	$4,061	$0.500	1,304	$13,621	128,436	13.6
Apr-19	171,313	347.3	$11,934	$0.070	171,313	$11,934	9,847	$5,361	$0.544	1,569	$17,295	154,983	16.4
May-19	182,252	413.0	$12,506	$0.069	182,252	$12,506	5,606	$3,021	$0.539	1,183	$15,526	107,915	12.3
Jun-19	166,234	452.3	$11,343	$0.068	166,234	$11,343	3,278	$1,814	$0.553	895	$13,157	76,961	9.3
Jul-19	215,000	480.0	$15,269	$0.071	215,000	$15,269	1,723	$1,215	$0.705	906	$16,484	70,100	9.5
Aug-19	182,000	480.0	$9,899	$0.054	182,000	$9,899	2,207	$1,444	$0.654	842	$11,343	68,095	8.8
Sep-19	166,000	478.0	$7,554	$0.046	166,000	$7,554	1,993	$1,287	$0.646	766	$8,841	61,875	8.0
Oct-19	160,000	399.0	$7,195	$0.045	160,000	$7,195	5,793	$2,813	$0.486	1,125	$10,008	104,933	11.7
Nov-19	133,000	385.0	$6,645	$0.050	133,000	$6,645	9,969	$4,872	$0.489	1,451	$11,517	147,510	15.1
Dec-19	151,000	400.0	$7,598	$0.050	151,000	$7,598	11,276	$5,231	$0.464	1,643	$12,829	166,981	17.1
2018 Total	1,628,735	436.5	$86,689	$0.053	1,954,629	$99,665	83,768	$44,057	$0.526	15,048	$143,722	1,358,249	157.1
2019 Total	1,970,046	480.0	$118,867	$0.060	1,970,046	$118,867	92,681	$48,736	$0.526	15,992	$167,603	1,541,797	166.9
2-year Average	**1,799,391**	**458.2**	**$102,778**	**$0.057**	**1,962,338**	**$109,266**	**88,225**	**$46,397**	**$0.526**	**15,520**	**$155,663**	**1,450,023**	**162.0**

* *Red italic text* indicates adjusted or assumed utility data as described.

2.6 621 and 623 Skytop (combined)

Since 621 and 623 Skytop share a central plant, it is important to look at both buildings together. Using the CBECS/Energy Star benchmarks, weighted by square footage, a typical building would use 157.8 kBtu/sf. The adjusted utility data shows an overall EUI for both buildings combined is 247.4 EUI, suggesting that the combined buildings are not energy efficient. This is not a surprising result, since the main heating, ventilation, and air conditioning (HVAC) system in the office building dates from 1968 and is a constant volume dual duct system, which utilizes simultaneous heating and cooling. In addition, there are labs in the office space, which have a typical EUI of 115.3 and tend to increase energy consumption. However, some of the disparity in the EUI may be based upon differing assumptions in the data center EUI calculation, as the PUE utilizes additional data when calculating.

Figure 3. 621 and 623 Skytop–Utility Consumption



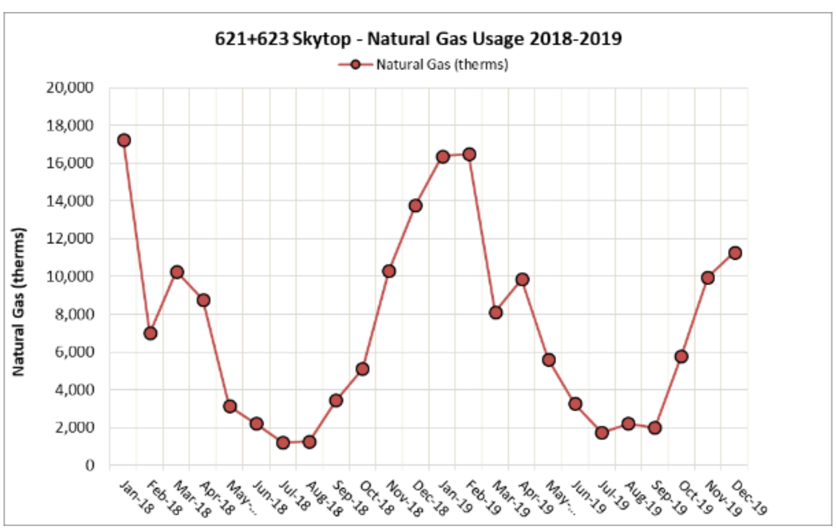


Table 4. 621 and 623 Skytop–Utility Bills

621 and 623 Skytop Road (Combined)										
Statement Date	Adjusted Electricity			Adjusted Natural Gas			Total Energy			
	Usage (kWh)	Cost ($)	Rate ($/kWh)	Usage (therm)	Cost ($)	Rate ($/therm)	Usage (mmBtu)	Cost ($)	Carbon Emissions (lb CO_2e)	EUI (kBtu/sf)
Jan-18	491,841	$20,407	$0.041	17,251	$7,666	$0.444	3,404	$28,072	316,052	31.6
Feb-18	467,610	$16,267	$0.035	7,006	$3,339	$0.477	2,297	$19,605	190,580	21.3
Mar-18	473,055	$18,492	$0.039	10,268	$4,613	$0.449	2,641	$23,105	230,003	24.5
Apr-18	419,780	$16,825	$0.040	8,771	$4,989	$0.569	2,310	$21,814	200,116	21.4
May-18	424,645	$16,609	$0.039	3,142	$1,708	$0.544	1,764	$18,317	135,399	16.3
Jun-18	424,908	$14,944	$0.035	2,211	$1,125	$0.509	1,671	$16,069	124,570	15.5
Jul-18	453,989	$22,238	$0.049	1,201	$792	$0.660	1,670	$23,030	119,511	15.5
Aug-18	420,765	$27,588	$0.066	1,274	$797	$0.626	1,563	$28,385	112,647	14.5
Sep-18	399,906	$26,111	$0.065	3,433	$1,722	$0.501	1,708	$27,833	133,056	15.8
Oct-18	419,559	$28,117	$0.067	5,116	$2,556	$0.500	1,944	$30,673	157,309	18.0
Nov-18	407,100	$27,512	$0.068	10,317	$5,332	$0.517	2,421	$32,844	215,255	22.4
Dec-18	446,984	$29,674	$0.066	13,778	$9,418	$0.684	2,903	$39,093	265,005	26.9
Jan-19	436,467	$28,162	$0.065	16,381	$9,194	$0.561	3,128	$37,356	293,012	29.0
Feb-19	367,958	$23,901	$0.065	16,489	$8,424	$0.511	2,905	$32,325	278,360	26.9
Mar-19	407,039	$27,016	$0.066	8,119	$4,061	$0.500	2,201	$31,077	189,529	20.4
Apr-19	435,451	$30,335	$0.070	9,847	$5,361	$0.544	2,471	$35,696	216,343	22.9
May-19	449,154	$30,820	$0.069	5,606	$3,021	$0.539	2,094	$33,841	169,916	19.4
Jun-19	419,661	$28,637	$0.068	3,278	$1,814	$0.553	1,760	$30,451	135,832	16.3
Jul-19	471,104	$33,458	$0.071	1,723	$1,215	$0.705	1,780	$34,673	129,593	16.5
Aug-19	455,616	$24,781	$0.054	2,207	$1,444	$0.654	1,776	$26,225	131,656	16.5
Sep-19	451,662	$20,553	$0.046	1,993	$1,287	$0.646	1,741	$21,840	128,235	16.1
Oct-19	464,152	$20,872	$0.045	5,793	$2,813	$0.486	2,163	$23,685	175,587	20.1
Nov-19	414,837	$20,727	$0.050	9,969	$4,872	$0.489	2,413	$25,599	212,981	22.4
Dec-19	446,377	$22,461	$0.050	11,276	$5,231	$0.464	2,651	$27,692	235,597	24.6
2018 Total	5,250,144	$264,784	$0.050	83,768	$44,057	$0.526	26,296	$308,841	2,199,502	243.8
2019 Total	5,219,478	$311,724	$0.060	92,681	$48,736	$0.526	27,082	$360,459	2,296,641	251.1
2-year Average	**5,234,811**	**$288,254**	**$0.055**	**88,225**	**$46,397**	**$0.526**	**26,689**	**$334,650**	**2,248,072**	**247.4**

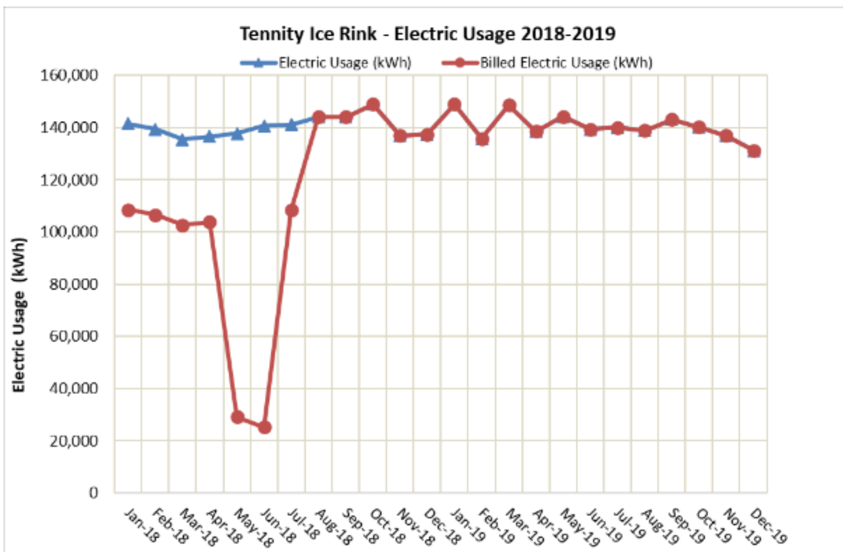
2.7 Tennity Ice Skating Pavilion

The 47,823 square foot Tennity Ice Pavilion contains two ice rinks, as well as some minimal support space. It is available 24 hours per day, 7 days per week, and is generally operational all year round. In summer 2018, the chilled water plant was updated, which is reflected in the utility data by higher energy consumption starting in late 2018. Thus, the utility data has been adjusted to increase the electricity data at the beginning of 2018 as well.

An ice rink is not directly addressed in by Energy Star or the CBECS; instead, it is classified as the more generic "recreation." A recreation building has an average EUI of 50.8 kBtu/sf, and the ice rink building utilizes 170.5 kBtu/sf. However, this encompasses buildings such as bowling alleys, fitness centers, roller rinks, pools, as well as ice rinks. A 2009 ASHRAE Journal article cites an average of 1,500,000 kilowatt hours (kWh) for a standard rink. At an adjusted annual consumption of 1,684,902 kWh, Tennity Ice Rink uses 12 percent more than average, which suggests a building of standard efficiency.

Because the building must maintain ice temperatures throughout the year, the electric trend data shows a flat yearly demand profile. Conversely, the natural gas usage follows typical weather patterns, which peaks in winter and minimal gas for dehumidification in the summer months.

Figure 4. Tennity Ice Rink–Utility Consumption



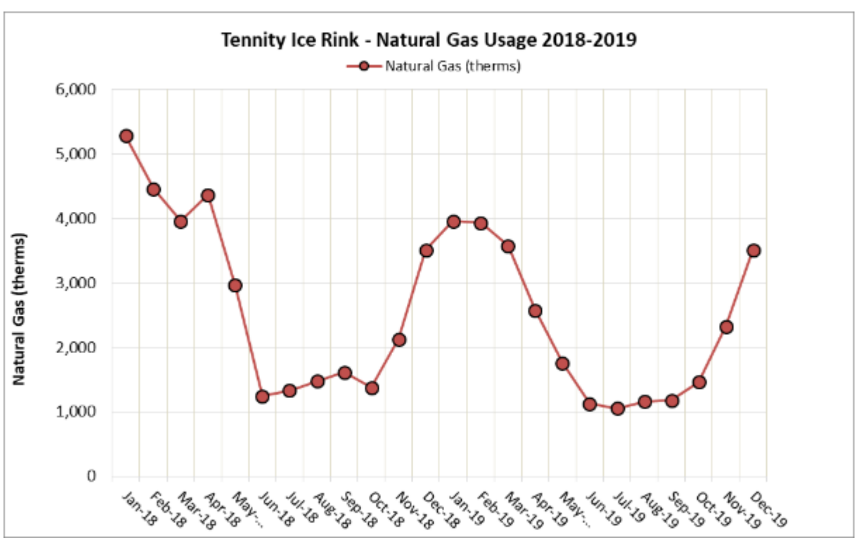


Table 5. Tennity Ice Rink–Utility Bills

Tennity Ice Rink													
Statement Date	Electricity			Adjusted Electricity		Natural Gas			Total Energy				
	Usage (kWh)	Cost ($)	Rate ($/kWh)	Usage (kWh)	Cost ($)	Usage (therm)	Cost ($)	Rate ($/therm)	Usage (mmBtu)	Cost ($)	Carbon Emissions (lb CO2e)	EUI (kBtu/sf)
Jan-18	108,600	$4,506	$0.041	*141,406*	*$5,867*	5,280	$2,547	$0.482	899	$7,053	86,992	18.8
Feb-18	106,600	$3,708	$0.035	*139,406*	*$4,850*	4,458	$2,187	$0.490	810	$5,895	76,912	16.9
Mar-18	102,700	$4,015	$0.039	*135,506*	*$5,297*	3,959	$2,043	$0.516	746	$6,058	70,168	15.6
Apr-18	103,800	$4,160	$0.040	*136,606*	*$5,475*	4,364	$2,261	$0.518	791	$6,422	75,162	16.5
May-18	29,100	$1,138	$0.039	*137,772*	*$5,389*	2,966	$1,439	$0.485	396	$2,577	41,455	8.3
Jun-18	25,200	$886	$0.035	*140,613*	*$4,945*	1,246	$685	$0.550	211	$1,571	20,429	4.4
Jul-18	108,398	$5,310	$0.049	*141,204*	*$6,917*	1,330	$711	$0.534	503	$6,020	40,739	10.5
Aug-18	144,031	$9,444	$0.066	144,031	$9,444	1,477	$779	$0.527	639	$10,223	50,736	13.4
Sep-18	144,089	$9,408	$0.065	144,089	$9,408	1,616	$837	$0.518	653	$10,245	52,375	13.7
Oct-18	149,023	$9,987	$0.067	149,023	$9,987	1,375	$751	$0.546	646	$10,738	50,702	13.5
Nov-18	136,966	$9,256	$0.068	136,966	$9,256	2,124	$1,111	$0.523	680	$10,367	56,663	14.2
Dec-18	137,379	$9,120	$0.066	137,379	$9,120	3,508	$2,048	$0.584	820	$11,168	72,949	17.1
Jan-19	148,953	$9,611	$0.065	148,953	$9,611	3,954	$2,629	$0.665	904	$12,239	80,855	18.9
Feb-19	135,753	$8,818	$0.065	135,753	$8,818	3,929	$2,221	$0.565	856	$11,039	77,496	17.9
Mar-19	148,645	$9,866	$0.066	148,645	$9,866	3,573	$1,803	$0.505	865	$11,669	76,326	18.1
Apr-19	138,623	$9,657	$0.070	138,623	$9,657	2,573	$1,448	$0.563	730	$11,105	62,300	15.3
May-19	144,202	$9,895	$0.069	144,202	$9,895	1,760	$1,008	$0.573	668	$10,903	54,086	14.0
Jun-19	139,301	$9,506	$0.068	139,301	$9,506	1,123	$677	$0.603	588	$10,182	45,496	12.3
Jul-19	139,945	$9,939	$0.071	139,945	$9,939	1,051	$702	$0.668	583	$10,641	44,804	12.2
Aug-19	138,940	$7,557	$0.054	138,940	$7,557	1,157	$837	$0.724	590	$8,394	45,810	12.3
Sep-19	143,128	$6,513	$0.046	143,128	$6,513	1,178	$833	$0.707	606	$7,346	47,029	12.7
Oct-19	140,155	$6,302	$0.045	140,155	$6,302	1,460	$905	$0.620	624	$7,207	49,637	13.1
Nov-19	136,916	$6,841	$0.050	136,916	$6,841	2,325	$1,265	$0.544	700	$8,106	59,003	14.6
Dec-19	131,243	$6,604	$0.050	131,243	$6,604	3,509	$1,824	$0.520	799	$8,428	71,535	16.7
2018 Total	1,295,886	$70,938	$0.055	1,683,999	$85,954	33,703	$17,398	$0.516	7,793	$88,336	695,282	163.0
2019 Total	1,685,804	$101,109	$0.060	1,685,804	$101,109	27,592	16,152	$0.585	8,513	$117,261	714,376	178.0
2-year Average	**1,490,845**	**$86,023**	**$0.058**	**1,684,902**	**$93,531**	**30,648**	**$16,775**	**$0.547**	**8,153**	**$102,799**	**704,829**	**170.5**

* *Red italic text* indicates adjusted or assumed utility data as described.

2.8 Goldstein Student Center

Goldstein Student Center is a 43,888 square foot community building, containing dining, laundry facilities, meeting rooms, and offices. It is available for use from 6:30 a.m. to midnight, 7 days per week. During the summer months, the building remains open for use, but is utilized less frequently.

This building utilizes a high amount of energy. Energy Star indicates that the average social/meeting hall building consumes 56.1 kBtu/sf. The Goldstein Student Center utilizes 226.5 kBtu/sf, much greater than average for a generic building of this type. However, the student center incorporates several different space types: fast food restaurant (402.7 EUI), laundromat, office (52.9 EUI), convenience store (231.4 EUI), and meeting hall. Weighted by space type, you may expect the building to use roughly 186.8 kBtu/sf. This suggests some inefficiencies in the building and/or heavy utilization.

For electricity use, the building follows expected occupancy and weather trends. It begins to rise in the spring, then drops off significantly during summer break. As expected, in the fall months, electricity use increases when occupancy returns, only to fall somewhat when the weather cools. Natural gas peaks in winter and is low during the summer months, which suggests minimal summer-time occupancy.

Figure 5. Goldstein Student Center–Utility Consumption

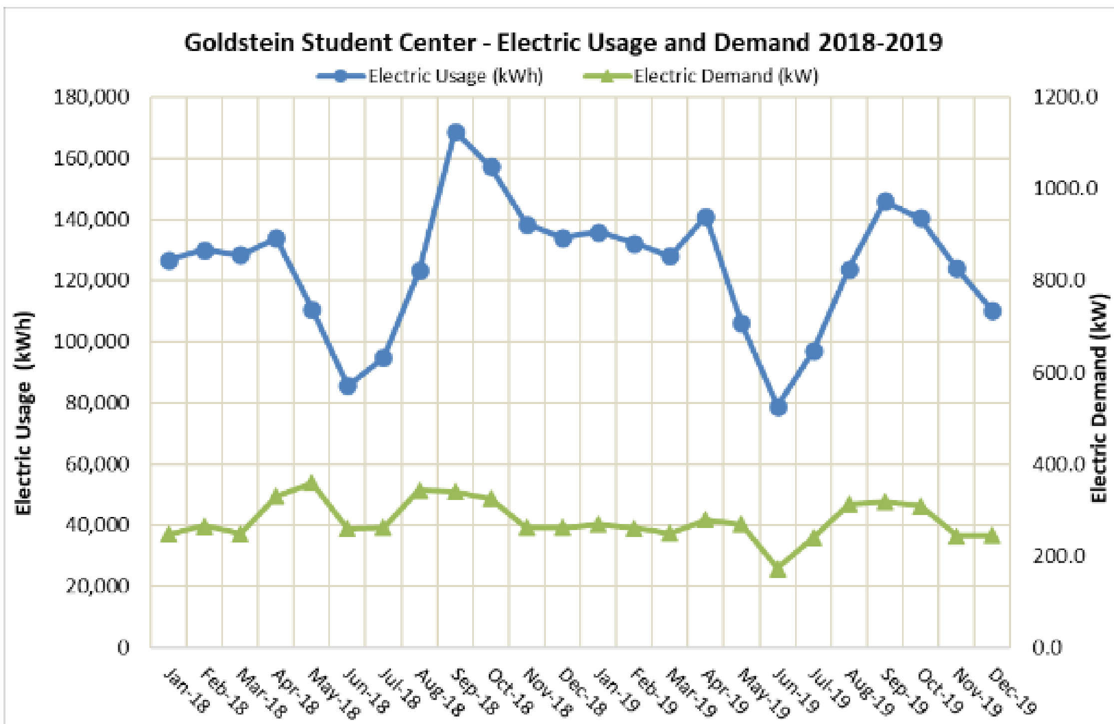


Figure 5 continued

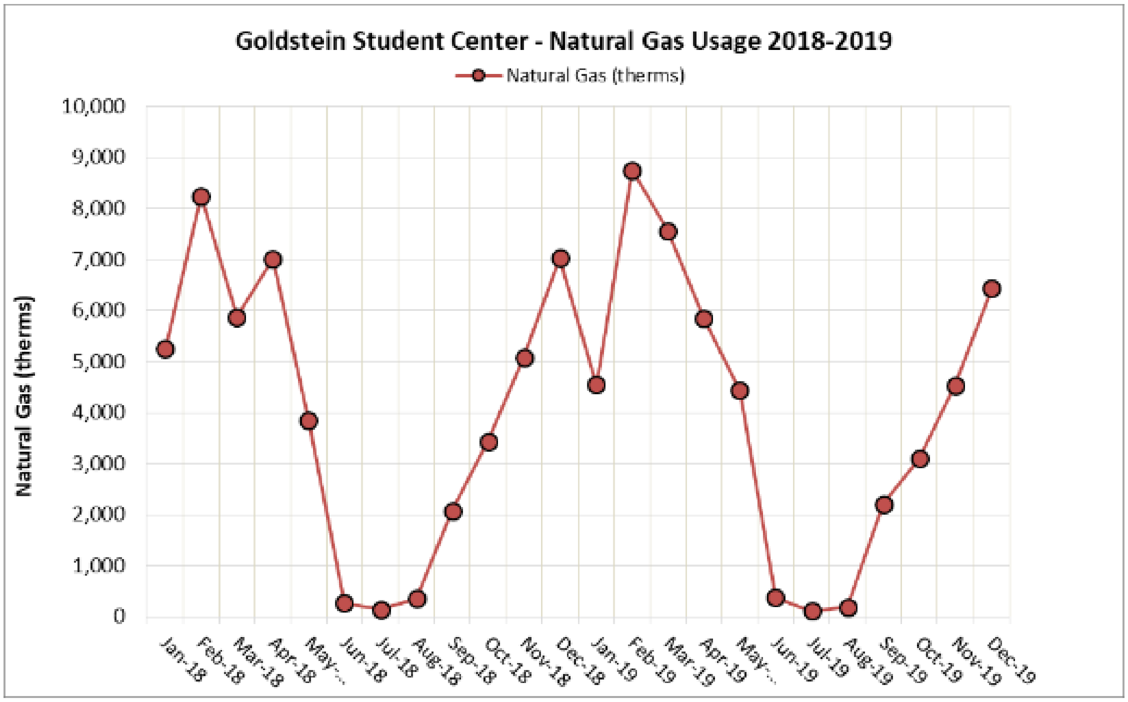


Table 6. Goldstein Student Center–Utility Bills

Goldstein Student Center											
Statement Date	Electricity				Natural Gas			Total Energy			
	Usage (kWh)	Demand (kW)	Cost ($)	Rate ($/kWh)	Usage (therm)	Cost ($)	Rate ($/therm)	Usage (mmBtu)	Cost ($)	Carbon Emissions (lb CO_2e)	EUI (kBtu/sf)
Jan-18	126,791	246.8	$5,261	$0.041	5,241	$2,533	$0.483	957	$7,794	61,365	21.8
Feb-18	130,087	265.6	$4,525	$0.035	8,237	$3,541	$0.430	1,268	$8,066	96,416	28.9
Mar-18	128,447	248.3	$5,021	$0.039	5,874	$2,757	$0.469	1,026	$7,779	68,770	23.4
Apr-18	133,840	330.1	$5,364	$0.040	7,010	$3,514	$0.501	1,158	$8,878	82,078	26.4
May-18	110,704	359.5	$4,330	$0.039	3,840	$1,846	$0.481	762	$6,175	45,003	17.4
Jun-18	85,580	259.7	$3,010	$0.035	269	$197	$0.731	319	$3,206	3,207	7.3
Jul-18	94,739	261.7	$4,641	$0.049	144	$112	$0.778	338	$4,753	1,745	7.7
Aug-18	123,277	342.9	$8,083	$0.066	350	$229	$0.655	456	$8,312	4,174	10.4
Sep-18	168,713	339.5	$11,016	$0.065	2,076	$1,058	$0.510	783	$12,074	24,363	17.9
Oct-18	157,249	325.5	$10,538	$0.067	3,438	$1,791	$0.521	880	$12,329	40,292	20.1
Nov-18	138,386	261.4	$9,352	$0.068	5,085	$2,627	$0.517	981	$11,980	59,544	22.3
Dec-18	134,052	262.4	$8,899	$0.066	7,025	$3,966	$0.565	1,160	$12,865	82,237	26.4
Jan-19	135,867	268.8	$8,766	$0.065	4,540	$3,010	$0.663	918	$11,776	53,170	20.9
Feb-19	132,209	260.8	$8,588	$0.065	8,744	$4,390	$0.502	1,326	$12,977	102,345	30.2
Mar-19	127,987	249.8	$8,495	$0.066	7,548	$3,539	$0.469	1,192	$12,034	88,352	27.2
Apr-19	140,967	278.6	$9,820	$0.070	5,838	$3,037	$0.520	1,065	$12,858	68,356	24.3
May-19	106,167	268.6	$7,285	$0.069	4,431	$2,444	$0.552	805	$9,729	51,895	18.4
Jun-19	78,952	172.6	$5,388	$0.068	372	$265	$0.713	307	$5,653	4,392	7.0
Jul-19	96,959	240.2	$6,886	$0.071	112	$107	$0.953	342	$6,993	1,366	7.8
Aug-19	123,834	313.2	$6,735	$0.054	193	$179	$0.928	442	$6,914	2,330	10.1
Sep-19	146,023	317.4	$6,645	$0.046	2,208	$1,507	$0.683	719	$8,152	25,902	16.4
Oct-19	140,444	308.7	$6,315	$0.045	3,091	$1,850	$0.598	788	$8,165	36,229	18.0
Nov-19	123,938	243.8	$6,193	$0.050	4,535	$2,407	$0.531	877	$8,600	53,106	20.0
Dec-19	110,050	244.3	$5,538	$0.050	6,427	$3,197	$0.497	1,018	$8,734	75,238	23.2
2018 Total	1,531,865	359.5	$80,040	$0.052	48,589	$24,171	$0.497	10,087	$104,211	568,464	229.8
2019 Total	1,463,397	317.4	$86,654	$0.059	48,039	$25,931	$0.540	9,798	$112,585	562,020	223.3
2-year Average	**1,497,631**	**338.4**	**$83,347**	**$0.056**	**48,314**	**$25,051**	**$0.519**	**9,943**	**$108,398**	**565,242**	**226.5**

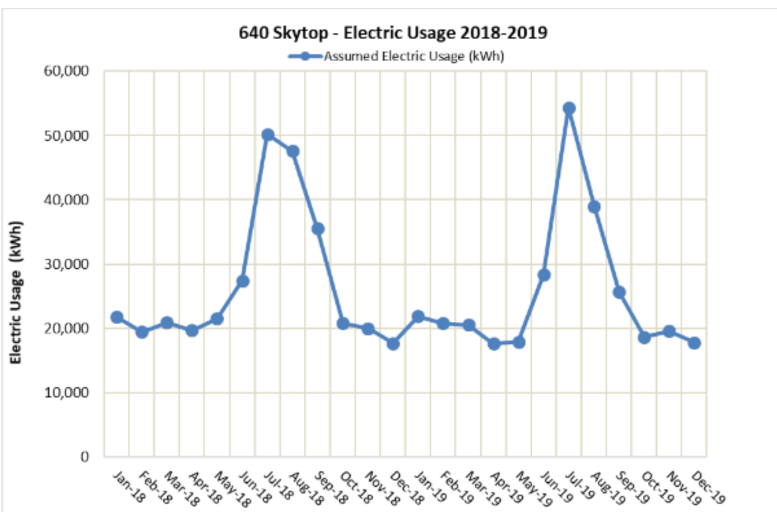
2.9 Skytop Office Building

The 52,900 square foot office building located at 640 Skytop Road is a two-story building, open 6:00 a.m. to 6:00 p.m., Monday through Friday. Containing the Comptroller's Office and Human Resources, it is primarily open office space. Note that the original data indicated a building area of 78,301 square feet.

Electricity data was not available for this building. Data was estimated based on weather and occupancy data, as well as an assumed electricity EUI. The building was recently renovated in 2018, so the ASHRAE 100 electricity target for an existing professional office of 18 EUI was utilized. The provided natural gas EUI is 18 percent less than the target fossil fuel EUI, so the assumed electricity has been reduced accordingly.

Similarly, natural gas was available for only one year, due to a building renovation. Since trend data shows that the consumption follows weather patterns as expected for a heating system, an additional year was assumed, following 2019 weather patterns. Combined, the overall building is estimated to have a EUI of 44.5 kBtu/sf. Energy Star indicates that the average office building is 52.9 kBtu/sf, suggesting that the Skytop Office building runs relatively efficiently.

Figure 6. 640 Skytop–Utility Consumption



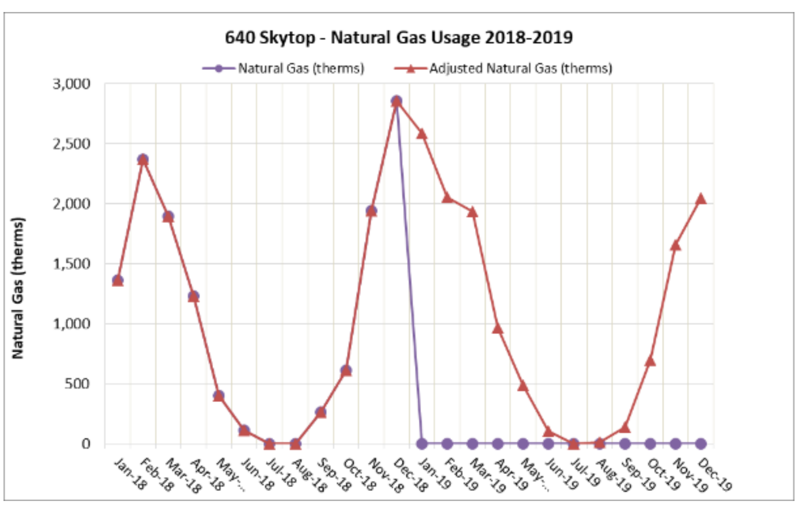


Table 7. 640 Skytop–Utility Bills

640 Skytop Office Building											
Statement Date	Assumed Electricity		Natural Gas			Adjusted Natural Gas		Total Energy			
	Usage (kWh)	Cost ($)	Usage (therm)	Cost ($)	Rate ($/therm)	Usage (therm)	Cost ($)	Usage (mmBtu)	Cost ($)	Carbon Emissions (lb CO_2e)	EUI (kBtu/sf)
Jan-18	*21,774*	*$1,244*	1,365	$821	$0.601	1,365	$821	211	$2,065	21,025	4.0
Feb-18	*19,464*	*$1,112*	2,367	$1,171	$0.495	2,367	1,171	303	$2,283	32,210	5.7
Mar-18	*20,931*	*$1,196*	1,893	$951	$0.502	1,893	$951	261	$2,146	27,006	4.9
Apr-18	*19,671*	*$1,124*	1,231	$686	$0.557	1,231	$686	190	$1,809	18,969	3.6
May-18	*21,533*	*$1,230*	403	$325	$0.806	403	$325	114	$1,555	9,716	2.2
Jun-18	*27,410*	*$1,566*	111	$198	$1.783	111	$198	105	$1,764	7,666	2.0
Jul-18	*50,184*	*$2,866*	0	$149	--	0	$149	171	$3,016	11,658	3.2
Aug-18	*47,567*	*$2,717*	0	$149	--	0	$149	162	$2,866	11,050	3.1
Sep-18	*35,514*	*$2,029*	264	$282	$1.068	264	$282	148	$2,310	11,338	2.8
Oct-18	*20,773*	*$1,187*	611	$373	$0.610	611	$373	132	$1,559	11,973	2.5
Nov-18	*19,967*	*$1,140*	1,939	$954	$0.492	1,939	$954	262	$2,095	27,320	5.0
Dec-18	*17,702*	*$1,011*	2,857	$1,219	$0.427	2,857	$1,219	346	$2,230	37,533	6.5
Jan-19	*21,881*	*$1,250*	0	$–	--	*2,586*	*$1,443*	333	$2,693	5,083	6.3
Feb-19	*20,759*	*$1,186*	0	$–	--	*2,052*	*$1,145*	276	$2,331	4,822	5.2
Mar-19	*20,538*	*$1,173*	0	$–	--	*1,932*	*$1,078*	263	$2,251	4,771	5.0
Apr-19	*17,636*	*$1,007*	0	$–	--	*970*	*$541*	157	$1,549	4,097	3.0
May-19	*17,949*	*$1,025*	0	$–	--	*488*	*$272*	110	$1,297	4,169	2.1
Jun-19	*28,346*	*$1,619*	0	$–	--	*102*	*$57*	107	$1,676	6,585	2.0
Jul-19	*54,336*	*$3,104*	0	$–	--	*0*	*$–*	185	$3,104	12,622	3.5
Aug-19	*39,000*	*$2,228*	0	$–	--	*10*	*$5*	134	$2,233	9,060	2.5
Sep-19	*25,675*	*$1,467*	0	$–	--	*136*	*$76*	101	$1,543	5,964	1.9
Oct-19	*18,659*	*$1,066*	0	$–	--	*699*	*$390*	134	$1,456	4,334	2.5
Nov-19	*19,557*	*$1,117*	0	$–	--	*1,660*	*$926*	233	$2,043	4,543	4.4
Dec-19	*17,776*	*$1,015*	0	$–	--	*2,046*	*$1,142*	265	$2,157	4,129	5.0
2018 Total	*322,490*	*$18,420*	13,041	$7,277	$0.558	13,041	$7,277	2,405	$7,277	227,464	45.5
2019 Total	*302,112*	*$17,256*	0	$–	--	12,680	$7,076	2,299	$–	70,181	43.5
2-year Average	***312,301***	***$17,838***	**6,521**	**$3,639**	**$0.558**	**12,860**	**$7,177**	**2,352**	**$3,639**	**148,822**	**44.5**

* *Red italic text* indicates adjusted or assumed utility data as described.

2.10 Ski Lodge

The Inn Complete, also known as the Ski Lodge, is a 9,342 square foot bar and restaurant. The building is open 11:00 a.m. to midnight, two days per week. It is a lightly used facility that includes conference space as well.

Only six months of electricity data is available for the facility for the end of 2019. The known usage has been combined with weather and occupancy data to create a projected two-year load profile. The usage is exceptionally low and indicates a sparsely occupied building; however, the gas load is high compared to the electric consumption. Typically, this space type is 38 percent electric. The low usage and high gas load suggests a very inefficient heating system, as well as likely high infiltration—all of which is not surprising, since the building and HVAC systems date from 1948.

The national average EUI for a bar/nightclub is 130.7 kBtu/sf, and this facility utilizes 130.1 kBtu/sf. However, the electric load is minimal, and virtually all the energy is natural gas, which follows very closely to weather data. These results suggest that HVAC setback controls and/or envelope improvements would be a significant benefit to the building.

Figure 7. Ski Lodge–Utility Consumption

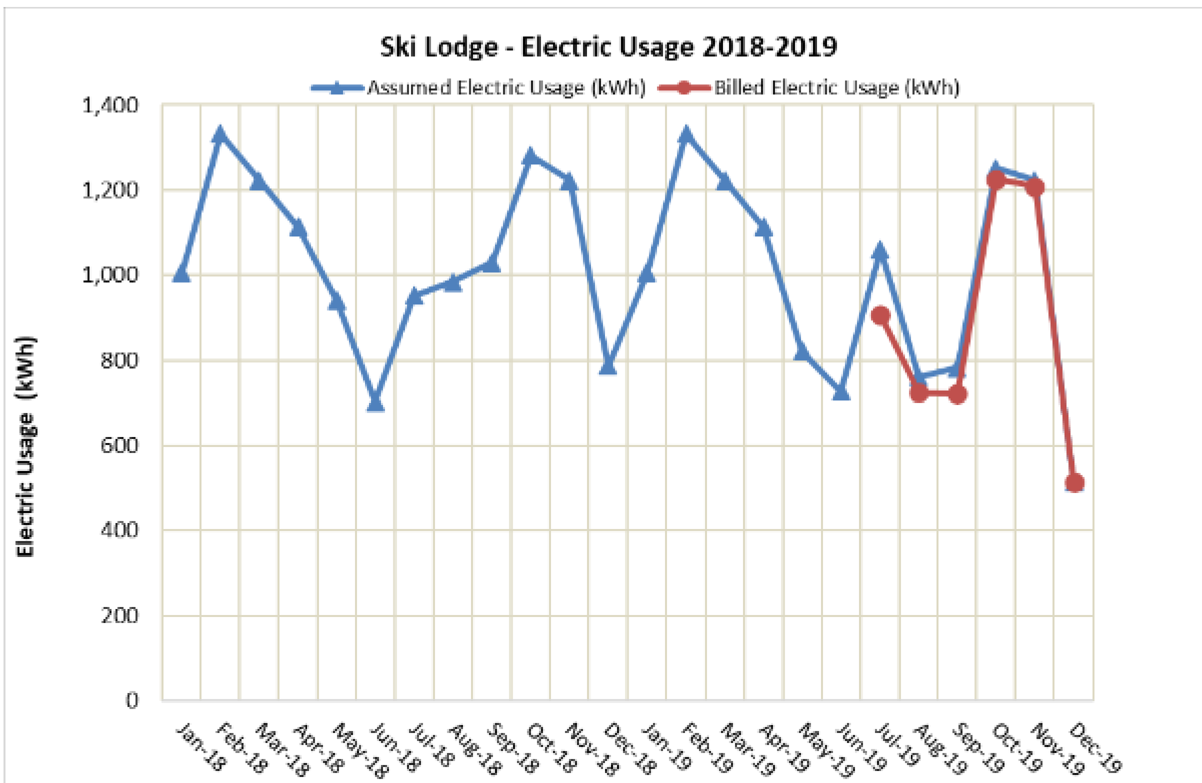


Figure 7 Continued

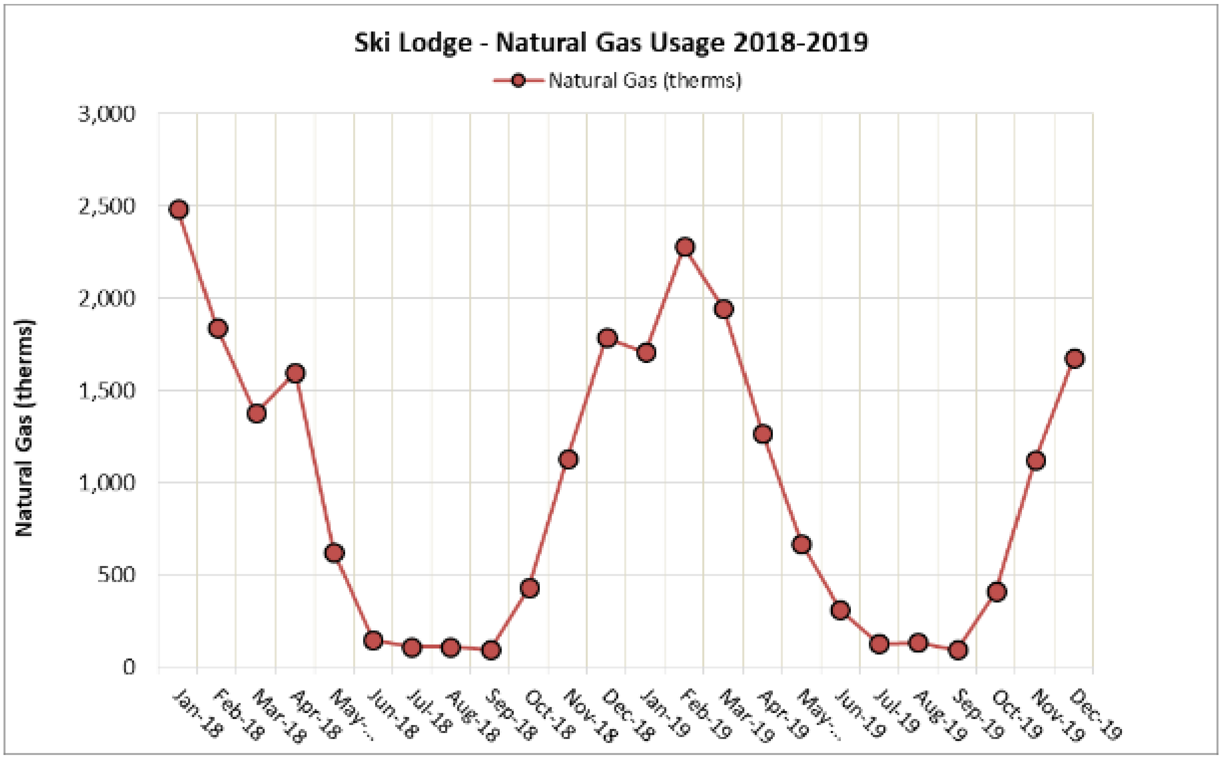


Table 8. Ski Lodge–Utility Bills

Ski Lodge												
Statement Date	**Electricity**			**Projected Electricity**		**Natural Gas**			**Total Energy**			
	Usage (kWh)	**Cost ($)**	**Rate ($/kWh)**	**Usage (kWh)**	**Cost ($)**	**Usage (therm)**	**Cost ($)**	**Rate ($/therm)**	**Usage (mmBtu)**	**Cost ($)**	**Carbon Emissions (lb CO_2e)**	**EUI (kBtu/sf)**
Jan-18	--	$–	--	*1,005*	*$53*	2,483	$1,195	$0.481	252	$1,248	29,279	26.9
Feb-18	--	$–	--	*1,332*	*$70*	1,843	$938	$0.509	189	$1,008	21,868	20.2
Mar-18	--	$–	--	*1,223*	*$64*	1,378	$749	$0.544	142	$813	16,404	15.2
Apr-18	--	$–	--	*1,114*	*$58*	1,598	$865	$0.541	164	$924	18,952	17.5
May-18	--	$–	--	*942*	*$49*	622	$348	$0.560	65	$398	7,495	7.0
Jun-18	--	$–	--	*703*	*$37*	146	$117	$0.803	17	$154	1,871	1.8
Jul-18	--	$–	--	*951*	*$50*	112	$92	$0.824	14	$142	1,531	1.5
Aug-18	--	$–	--	*984*	*$52*	110	$91	$0.825	14	$142	1,515	1.5
Sep-18	--	$–	--	*1,030*	*$54*	96	$82	$0.850	13	$136	1,362	1.4
Oct-18	--	$–	--	*1,281*	*$67*	430	$275	$0.640	47	$342	5,328	5.1
Nov-18	--	$–	--	*1,223*	*$64*	1,131	$619	$0.547	117	$683	13,514	12.6
Dec-18	--	$–	--	*787*	*$41*	1,787	$1,072	$0.600	181	$1,113	21,087	19.4
Jan-19	--	$–	--	*1,005*	*$53*	1,709	$1,170	$0.684	174	$1,222	20,225	18.7
Feb-19	--	$–	--	*1,332*	*$70*	2,281	$1,314	$0.576	233	$1,384	26,992	24.9
Mar-19	--	$–	--	*1,223*	*$64*	1,944	$1,008	$0.518	199	$1,072	23,024	21.3
Apr-19	--	$–	--	*1,114*	*$58*	1,266	$743	$0.587	130	$801	15,068	14.0
May-19	--	$–	--	*821*	*$43*	671	$422	$0.629	70	$465	8,040	7.5
Jun-19	--	$–	--	*727*	*$38*	312	$232	$0.745	34	$271	3,819	3.6
Jul-19	906	$64	$0.071	*1,059*	*$56*	126	$117	$0.930	16	$173	1,720	1.7
Aug-19	724	$39	$0.054	*761*	*$40*	134	$131	$0.980	16	$171	1,744	1.7
Sep-19	721	$33	$0.046	*783*	*$41*	94	$98	$1.038	12	$139	1,281	1.3
Oct-19	1,225	$55	$0.045	*1,252*	*$66*	412	$300	$0.728	45	$365	5,110	4.9
Nov-19	1,208	$60	$0.050	*1,223*	*$64*	1,123	$642	$0.572	116	$706	13,421	12.5
Dec-19	515	$26	$0.050	*514*	*$27*	1,676	$903	$0.539	169	$930	19,725	18.1
2018 Total	0	$–	--	*12,574*	*$659*	11,736	$6,444	$0.549	1,217	$7,103	140,205	130.2
2019 Total	5,298	$278	$0.052	*11,813*	*$619*	11,748	$7,080	$0.603	1,215	$7,358	140,169	130.1
2-year Average	**2,649**	**$139**	**$0.052**	***12,194***	***$639***	**11,742**	**$6,762**	**$0.576**	**1,216**	**$6,901**	**140,187**	**130.1**

* ***Red italic text*** indicates adjusted or assumed utility data as described.

2.11 480 Winding Ridge Apartments

The 8-unit apartment building at 480 Winding Ridge, totaling of 6,257 square feet, is occupied all year, although some tenants leave during summer break. The all-electric building does not include cooling or consistent ventilation.

The electricity usage available is low for the square footage and suggests that the meter tracks only a portion of the building. A typical residential building, according to Energy Star, is 57.6 kBtu/sf, and the utility data shows 12.4 kBtu/sf. Thus, the utility data has been adjusted to reflect whole building consumption, adjusted for this building, for a revised EUI of 49.7.

The energy usage follows weather data closely. Since there is no cooling, energy consumption in the summer is very stable. During the winter months, the usage peaks as the temperature drops.

Figure 8. 480 Winding Ridge–Utility Consumption

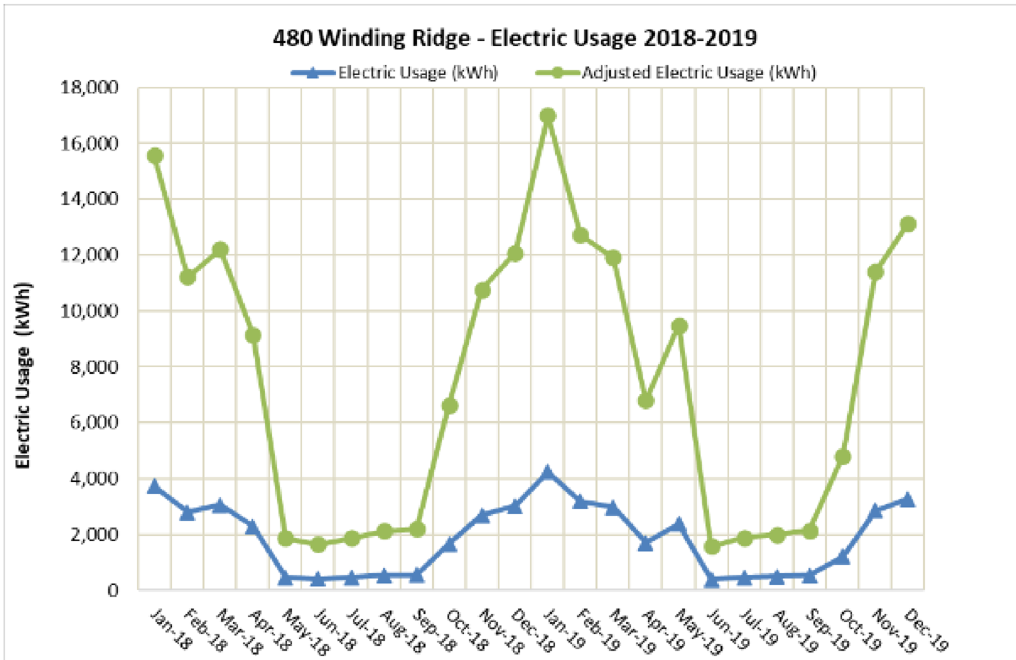


Table 9. 480 Winding Ridge–Utility Bills

480 Winding Ridge Apartments										
Statement Date	Electricity				Adjusted Electricity		Total Energy			
	Usage (kWh)	Demand (kW)	Cost ($)	Rate ($/kWh)	Usage (kWh)	Cost ($)	Usage (mmBtu)	Cost ($)	Carbon Emissions (lb CO_2e)	EUI (kBtu/sf)
Jan-18	3,731	8.5	$315	$0.085	*15,575*	*$1,373*	53	$1,373	3,618	8.5
Feb-18	2,805	8.5	$238	$0.085	*11,220*	*$989*	38	$989	2,606	6.1
Mar-18	3,054	8.5	$257	$0.084	*12,216*	*$1,077*	42	$1,077	2,838	6.7
Apr-18	2,288	8.4	$195	$0.085	*9,152*	*$807*	31	$807	2,126	5.0
May-18	467	8.2	$61	$0.130	*1,868*	*$165*	6	$165	434	1.0
Jun-18	411	1.0	$71	$0.174	*1,644*	*$145*	6	$145	382	0.9
Jul-18	467	1.3	$72	$0.155	*1,868*	*$165*	6	$165	434	1.0
Aug-18	532	1.4	$76	$0.142	*2,128*	*$188*	7	$188	494	1.2
Sep-18	550	8.4	$64	$0.116	*2,200*	*$194*	8	$194	511	1.2
Oct-18	1,659	8.5	$149	$0.090	*6,636*	*$585*	23	$585	1,542	3.6
Nov-18	2,689	8.4	$229	$0.085	*10,756*	*$948*	37	$948	2,499	5.9
Dec-18	3,022	8.5	$261	$0.086	*12,088*	*$1,066*	41	$1,066	2,808	6.6
Jan-19	4,248	9.9	$347	$0.082	*16,992*	*$1,498*	58	$1,498	3,947	9.3
Feb-19	3,178	8.4	$264	$0.083	*12,712*	*$1,121*	43	$1,121	2,953	6.9
Mar-19	2,977	10.6	$254	$0.085	*11,908*	*$1,050*	41	$1,050	2,766	6.5
Apr-19	1,701	8.8	$156	$0.092	*6,804*	*$600*	23	$600	1,581	3.7
May-19	2,373	8.2	$255	$0.107	*9,492*	*$837*	32	$837	2,205	5.2
Jun-19	393	1.0	$61	$0.154	*1,572*	*$139*	5	$139	365	0.9
Jul-19	470	1.0	$65	$0.139	*1,880*	*$166*	6	$166	437	1.0
Aug-19	500	1.0	$62	$0.124	*2,000*	*$176*	7	$176	465	1.1
Sep-19	536	2.3	$50	$0.093	*2,144*	*$189*	7	$189	498	1.2
Oct-19	1,204	8.4	$83	$0.069	*4,816*	*$425*	16	$425	1,119	2.6
Nov-19	2,851	9.6	$188	$0.066	*11,404*	*$1,006*	39	$1,006	2,649	6.2
Dec-19	3,283	9.6	$229	$0.070	*13,132*	*$1,158*	45	$1,158	3,051	7.2
2018 Total	21,675	8.5	$1,989	$0.092	*87,351*	*$7,703*	298	$7,703	20,292	47.6
2019 Total	23,714	10.6	$2,014	$0.085	*94,856*	*$8,364*	324	$2,014	22,035	51.7
2-year Average	**22,695**	**9.6**	**$2,001**	**$0.088**	***91,103***	***$8,033***	**311**	**$2,001**	**21,163**	**49.7**

* *Red italic text* indicates adjusted or assumed utility data as described.

2.12 460 Winding Ridge Apartments

The apartment building at 460 Winding Ridge is 12 units and has the same apartment layout and systems as 480 Winding Ridge. The buildings are adjacent in the same complex. The only significant difference is the extra four apartments and the building orientation.

No utility data was available for this building; however, since the building is so similar to 480 Winding Ridge, utility data can be utilized and scaled for the larger building. Again, Energy Star indicates that residential buildings have an average of 57.9 kBtu/sf, and this building is projected at 49.7 kBtu/sf.

Figure 9. 460 Winding Ridge–Utility Consumption

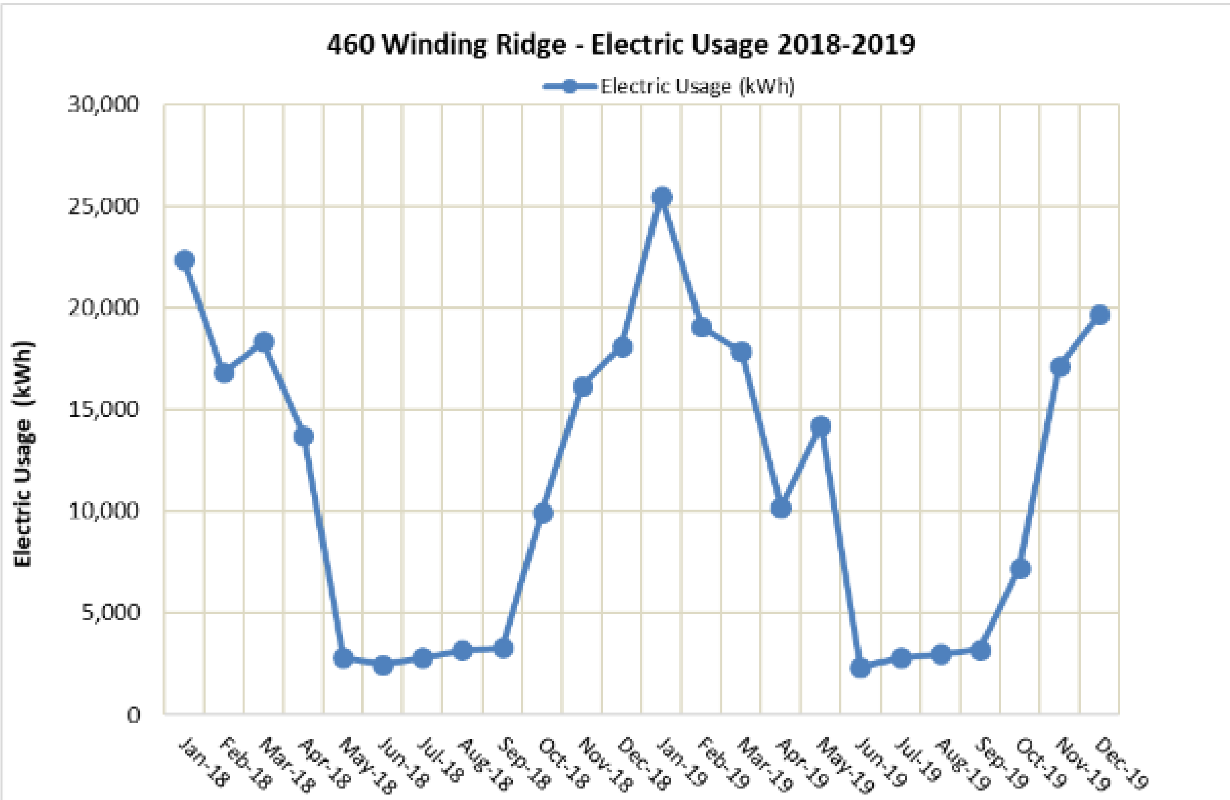


Table 10. 460 Winding Ridge–Utility Bills

460 Winding Ridge Apartments							
	Assumed Electricity			Total Energy			
Statement Date	Usage (kWh)	Cost ($)	Rate ($/kWh)	Usage (mmBtu)	Cost ($)	Carbon Emissions (lb CO_2e)	EUI (kBtu/sf)
Jan-18	*22,386*	*$1,893*	$0.085	76	$1,893	440	8.2
Feb-18	*16,830*	*$1,428*	$0.085	57	$1,428	332	6.1
Mar-18	*18,324*	*$1,543*	$0.084	63	$1,543	358	6.7
Apr-18	*13,728*	*$1,173*	$0.085	47	$1,173	272	5.0
May-18	*2,802*	*$366*	$0.130	10	$366	85	1.0
Jun-18	*2,466*	*$429*	$0.174	8	$429	100	0.9
Jul-18	*2,802*	*$435*	$0.155	10	$435	101	1.0
Aug-18	*3,192*	*$454*	$0.142	11	$454	105	1.2
Sep-18	*3,300*	*$383*	$0.116	11	$383	89	1.2
Oct-18	*9,954*	*$891*	$0.090	34	$891	207	3.6
Nov-18	*16,134*	*$1,376*	$0.085	55	$1,376	320	5.9
Dec-18	*18,132*	*$1,564*	$0.086	62	$1,564	363	6.6
Jan-19	*25,488*	*$2,079*	$0.082	87	$2,079	483	9.3
Feb-19	*19,068*	*$1,585*	$0.083	65	$1,585	368	7.0
Mar-19	*17,862*	*$1,522*	$0.085	61	$1,522	354	6.5
Apr-19	*10,206*	*$936*	$0.092	35	$936	217	3.7
May-19	*14,238*	*$1,529*	$0.107	49	$1,529	355	5.2
Jun-19	*2,358*	*$363*	$0.154	8	$363	84	0.9
Jul-19	*2,820*	*$393*	$0.139	10	$393	91	1.0
Aug-19	*3,000*	*$371*	$0.124	10	$371	86	1.1
Sep-19	*3,216*	*$300*	$0.093	11	$300	70	1.2
Oct-19	*7,224*	*$500*	$0.069	25	$500	116	2.6
Nov-19	*17,106*	*$1,129*	$0.066	58	$1,129	262	6.2
Dec-19	*19,698*	*$1,374*	$0.070	67	$1,374	319	7.2
2018 Total	*130,050*	*$11,933*	$0.092	444	$11,933	2,772	47.4
2019 Total	*142,284*	*$12,081*	$0.085	486	$12,081	2,806	51.9
2-year Average	***136,167***	***$12,007***	**$0.088**	465	$12,007	**2,789**	**49.7**

* *Red italic text* indicates adjusted or assumed utility data as described.

3 Existing Conditions: Energy Profile

3.1 Developing An Energy Profile

Each of the buildings in this study were 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 10 percent of the annual consumption of each utility. Building data was gathered through a combination of building drawings, discussions with the owner, utility bill evaluation, and typical assumptions. Known and assumed building conditions have been indicated. The summarized modeling results are shown below.

Table 11. 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
623 Skytop Data Center	3,272,473	0	11,169	760,196	$178,988	3,225,477	2,441	11,253	777,832	$177,380	-1.4%	--
621 Skytop Office Building	1,962,338	88,225	15,520	1,487,876	$158,482	1,710,014	89,963	14,833	1,449,598	$144,984	-12.9%	2.0%
Tennity Ice Skating Pavilion	1,684,902	30,648	8,815	749,908	$113,996	1,643,578	29,196	8,529	723,330	$110,817	-2.5%	-4.7%
Goldstein Student Center	1,497,631	48,314	9,943	913,063	$108,398	1,191,176	53,750	9,440	905,462	$94,162	-20.5%	11.3%
Skytop Office Building	312,301	12,860	2,352	222,985	$24,258	285,863	13,295	2,305	221,927	$23,054	-8.5%	3.4%
Ski Lodge	12,194	11,742	1,216	140,187	$7,401	21,632	10,745	1,148	130,717	$7,322	77.4%	-8.5%
480 Winding Ridge Apartments	91,103	0	311	21,163	$8,033	84,801	0	289	19,699	$7,478	-6.9%	--
460 Winding Ridge Apartments	136,655	0	466	31,745	$12,050	129,187	0	441	30,010	$11,392	-5.5%	--

3.2 623 Skytop Data Center

Built in 2009, the 623 Skytop Data Center is a data center containing an estimated 100 tons of server equipment. The data center itself is conditioned through a subfloor system, which incorporates both chilled water (CHW) computer room air conditioning (CRAC) units and in-rack cooling. Minimal heat is required in ancillary spaces, utilizing hot water (HW) from the neighboring building. The loops are variable flow with variable speed pumping. Additional ancillary air conditioning (AC) units and fan coils units are provided in conjunction with an energy recovery unit for ventilation. Instantaneous electric hot water heater provides handwashing water for the lavatory.

The cooling load is driven mainly by the server consumption, and energy efficiency measures have already been included in the server room cooling. Additional energy savings can be found mainly with a higher efficiency chilled water generator, such as a geothermal heat pump.

Table 12. 623 Skytop–Existing Conditions

Existing Conditions		
623 Skytop Data Center	Building Type	Data Center
	Square Footage	12073
	Year Built	2009
	Number of Floors	1,P
	Exterior Walls	Metal panel, 2" rigid, 8" CMU
	Roof	2" deck, built up roof (R-30 assumed)
	Window-Wall Ratio	2%
	Window Type	Equal to ASHRAE 90.1-2007 curtainwall (U-0.55, SHGC-0.4)
	HVAC System	Boiler/WC chiller, CHW CRAC, FCUs
	HVAC Efficiencies	70% boiler (621), 0.59 kW/ton chiller, 73% ERU
	Lighting	30% better than ASHRAE 90.1-2007

Table 13. 623 Skytop–Baseline Modeling

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
623 Skytop Data Center	3,272,473	0	11,169	760,196	$178,988	3,225,477	2,441	11,253	777,832	$177,380	-1.4%	--

3.3 621 Skytop Office Building

The office building at 621 Skytop is a sprawling one-story building with two mechanical penthouses. It houses offices as well as laboratories, classrooms, and conference rooms. The bulk of the building was constructed in 1968 and has not undergone a major HVAC renovation since. Thus, the building systems remain the same—a constant volume, dual-duct air handling system with chilled water and steam heat. An air cooled chiller and steam boiler condition the building loops, utilizing variable speed pumping for the CHW loops. The west addition has variable air volume (VAV) packaged air handling units (AHU) with direct exapansion (DX) cooling and a furnace, combined with hot water reheat at the terminal units. A steam-to-water heat exchanger provides domestic hot water.

The building at 621 Skytop has very high energy consumption for an office/lab building, due in large part to the constant volume dual duct HVAC system. This type of system requires simultaneous heating and cooling throughout the year and is generally inefficient. Additionally, the existing systems may require more outdoor air than is required for the current configuration of the building, as it was set up to include many fume hoods in the laboratories. The modeling of the building includes high internal loads combined with high fan power which drives up electricity usage. In addition to replacing the central plants with high-efficiency systems for more efficient building loops, the HVAC systems should be updated with variable airflow units. The controls should be evaluated, and additional control points provided to ensure the building is operated as required for the current occupants. Furthermore, as an older building, it is likely that during construction no exterior insulation or infiltration was considered. When a building retrofit is planned, the energy consumption of this building could be significantly reduced.

Table 14. 621 Skytop–Existing Conditions

Existing Conditions		
621 Skytop Office Building	Building Type	Office
	Square Footage	95800
	Year Built	1968
	Number of Floors	1,P
	Exterior Walls	4" brick, 8" CMU
	Roof	2" deck, built up roof (R-30 assumed)
	Window-Wall Ratio	9%
	Window Type	Metal framed, double, no thermal break (U-0.9, SHGC-0.57)
	HVAC System	Boiler/chiller with dual duct AHUs, DX/gas RTUs
	HVAC Efficiencies	70% boiler, 5.6 COP chiller, 12.1 EER and 80% RTU
	Lighting	Approximately equal to 2007 ECCCNYS

Table 15. 621 Skytop–Baseline Modeling

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
621 Skytop Office Building	1,962,338	88,225	15,520	1,487,876	$158,482	1,710,014	89,963	14,833	1,449,598	$144,984	-12.9%	2.0%

3.4 621 and 623 Skytop (combined)

Since 621 and 623 Skytop share central plants, both buildings should be evaluated together. As known from the utility analysis, some of the cooling load in 623 is provided by building 621. Thus, the modeled electricity in 623 is somewhat low, but when taken together with 621, the buildings fall within calibration parameters.

Table 16. 621 and 623 Skytop (Combined)–Baseline Modeling

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
621+623 Skytop (Combined)	5,234,811	88,225	26,689	2,248,072	$337,470	4,935,491	92,404	26,085	2,227,430	$322,364	-5.7%	4.7%

3.5 Tennity Ice Skating Pavilion

Recreational ice-skating is available at the Tennity Ice Skating Pavilion with its two rinks that make up roughly 22,700 square feet of ice. The ice skating rink is cooled with a 2014 water cooled chiller, with a gas fired dehumidification unit. Heat is recovered from the chiller and utilized for under-slab heating and snow pile melting. Support spaces utilized a packaged VAV rooftop unit with gas heating and energy recovery, as well as some ancillary gas fired unit heaters. Domestic water is provided by a natural gas storage unit, which also provides reheat for the VAV terminal units.

This building has cooling available all year round, and capitalizes on this to capture rejected heat. Some of the effectiveness of converting to geothermal may be lost, since free heat is already being utilized.

Table 17. Tennity Ice Rink–Existing Conditions

Existing Conditions		
Tennity Ice Skating Pavilion	Building Type	Ice Rink
	Square Footage	47823
	Year Built	2000
	Number of Floors	1
	Exterior Walls	Metal panel walls, R-19 batt insulations
	Roof	Metal deck (R-30 assumed)
	Window-Wall Ratio	2%
	Window Type	Metal framed, double, no thermal break (U-0.9, SHGC-0.57)
	HVAC System	Gas fired DOAS, ice rink WC chiller
	HVAC Efficiencies	80% heating, 4.1 COP chiller, 11.3 EER VAV, 52% ERW
	Lighting	Approximately equal to 2007 ECCCNYS

Table 18. Tennity Ice Rink–Baseline Modeling

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
Tennity Ice Skating Pavilion	1,684,902	30,648	8,815	749,908	$113,996	1,643,578	29,196	8,529	723,330	$110,817	-2.5%	-4.7%

3.6 Goldstein Student Center

The two-story student activities center, Goldstein Student Center, contains a convenience store, dining area, laundromat, computer lab, conference space, and offices.

Water source heat pump (WSHP) units condition most of the building, utilizing a high-efficiency gas fired boiler and cooling tower in conjunction with energy recovery units to capture waste heat from the kitchen and laundry areas. Air handling units with water cooled DX cooling and hot water heat have been added to the building during upgrades (assumed 15 percent of the floor area). Hot water is provided by gas fired storage type heaters.

The building has a very high energy utilization, which suggests occupancy dependent equipment use, or some other substantial process load. The model was unable to reach the desired calibration levels, since the variable in question is process load and utilization schedules, and the steep drop off during summer months makes it difficult to understand the base loads. However, for the purposes of this study, the increased process load does not substantially alter the heating and cooling impact. Prior to implementing any system upgrades, a thorough assessment of the building loads should be undertaken to ensure that all relevant loads are accounted for.

Table 19. Goldstein Student Center–Existing Conditions

Existing Conditions		
Goldstein Student Center	Building Type	Student Center
	Square Footage	43888
	Year Built	1990
	Number of Floors	B,1,2,A
	Exterior Walls	Metal stud walls, R-13 insulation
	Roof	2" concrete deck, built up roof (R-20 assumed)
	Window-Wall Ratio	40%
	Window Type	Metal framed, double, no thermal break (U-0.9, SHGC-0.57)
	HVAC System	WSHP, HW boiler, DOAS
	HVAC Efficiencies	93% boiler, 9.3+12 EER and 3.3+4.2 COP HP. 52%+60% ERU
	Lighting	Approximately equal to 2007 ECCCNYS

Table 20. Goldstein Student Center–Baseline Modeling

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
Goldstein Student Center	1,497,631	48,314	9,943	913,063	$108,398	1,191,176	53,750	9,440	905,462	$94,162	-20.5%	11.3%

3.7 Skytop Office Building

In 2018, the office building at 640 Skytop underwent a major renovation, including the HVAC systems and additional insulation. Variable air volume rooftop units with DX cooling and hot water reheat condition the space, which is entirely office space in a primarily open area. A condensing boiler with a variable flow loop supplies the reheat coils, snowmelt, and a limited number of unit heaters. Domestic water is provided by the boiler via heat exchanger.

The building at 640 Skytop has all new systems and is generally energy efficient. However, there are energy savings to be captured via a high-efficiency system, such as a geothermal heat pump system.

Table 21. Skytop Office Building–Existing Conditions

Existing Conditions		
Skytop Office Building	Building Type	Office
	Square Footage	52900
	Year Built	1972
	Number of Floors	1,2
	Exterior Walls	8" concrete, R-13.6 in furring
	Roof	Concrete deck, built up roof (R-30 assumed)
	Window-Wall Ratio	29%
	Window Type	Metal framed, double, no thermal break (U-0.9, SHGC-0.57)
	HVAC System	RTUS, HW boiler
	HVAC Efficiencies	93% boiler, 11.3 EER RTUs
	Lighting	30% better than ASHRAE 90.1-2013

Table 22. Skytop Office Building–Baseline Modeling

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
Skytop Office Building	312,301	12,860	2,352	222,985	$24,258	285,863	13,295	2,305	221,927	$23,054	-8.5%	3.4%

3.8 Ski Lodge

The Ski Lodge is a sparsely occupied restaurant/lounge building adjacent to the ski slopes. Built in 1948, the original steam system is still in place. Split system air conditioning is provided for the main seating area and kitchen in conjunction with unit heaters throughout the building. The building lacks both ventilation and makeup air, other than infiltration. Domestic hot water for the kitchen is provided by natural gas storage-type heaters.

Utility data provided for this facility indicates very low electric consumption, which poses difficulties for model calibration. Although the electric portion indicates a wide disparity, it represents only 3 percent of the overall building energy usage.

When considering renovation for this facility, it will be important to ensure that the building is brought up to current ventilation codes. As a 1948-era building with a stone basement, it is likely that there is a significant quantity of air infiltration used to provide fresh air to the facility. Air leakage should be sealed, and mechanical ventilation provided to ensure a high-functioning building.

Table 23. Ski Lodge–Existing Conditions

Existing Conditions		
Ski Lodge	Building Type	Restaurant/Bar
	Square Footage	9342
	Year Built	1948
	Number of Floors	B,1,2
	Exterior Walls	Stud walls, R-11 insulation
	Roof	Peaked roof, wood deck, R-26 at deck
	Window-Wall Ratio	11%
	Window Type	Metal framed, double, no thermal break (U-0.9, SHGC-0.57)
	HVAC System	Steam boiler, DX cooling
	HVAC Efficiencies	70% boiler, 10 SEER split systems
	Lighting	Approximately equal to 2007 ECCCNYS

Table 24. Ski Lodge–Baseline Modeling

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
Ski Lodge	12,194	11,742	1,216	140,187	$7,401	21,632	10,745	1,148	130,717	$7,322	77.4%	-8.5%

3.9 480 Winding Ridge Apartments

Part of the larger Winding Ridge Apartment Complex, the 8-unit building at 480 is a typical one of many 8-unit buildings in the complex. Each unit is all-electric, utilizing electric resistance baseboard heat and electric water heaters in lieu of any natural gas. No cooling is provided for the apartments. The buildings are simple, with no common space in the building and the same layout for each unit.

In an all-electric building such as the Winding Ridge Apartments, each unit has the capacity to switch to a heat pump system. However, for a one-for-one replacement, a separate water-to-water heat pump would be required. In this case, it may make sense to replace the baseboard with a forced air unit, which would have the added benefit of ventilation in the dwelling unit.

Table 25. 480 Winding Ridge–Existing Conditions

Existing Conditions		
480 Winding Ridge Apartments	Building Type	Apartment
	Square Footage	6257
	Year Built	1972
	Number of Floors	1,2
	Exterior Walls	Stud walls, R-11 insulation
	Roof	Wood deck, built up roof (R-20 assumed)
	Window-Wall Ratio	22%
	Window Type	Metal framed, double, no thermal break (U-0.9, SHGC-0.57)
	HVAC System	Electric resistance
	HVAC Efficiencies	100% resistance heating
	Lighting	1.1 W/sf dwelling units

Table 26. 480 Winding Ridge–Baseline Modeling

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
480 Winding Ridge Apartments	91,103	0	311	21,163	$8,033	84,801	0	289	19,699	$7,478	-6.9%	--

3.10 460 Winding Ridge Apartments

With 12-units, the apartment building at 460 Winding Ridge is virtually the same as 480 Winding Ridge, but 50 percent larger. It uses the same electric resistance building systems and identical apartment layouts. The challenges and advantages will be the same among the two buildings, and likely most of the Winding Ridge Apartment Complex buildings as well.

Table 27. 460 Winding Ridge–Existing Conditions

Existing Conditions		
460 Winding Ridge Apartments	Building Type	Apartment
	Square Footage	9356
	Year Built	1972
	Number of Floors	1,2
	Exterior Walls	Stud walls, R-11 insulation
	Roof	Wood deck, built up roof (R-20 assumed)
	Window-Wall Ratio	23%
	Window Type	Metal framed, double, no thermal break (U-0.9, SHGC-0.57)
	HVAC System	Electric resistance
	HVAC Efficiencies	100% resistance heating
	Lighting	1.1 W/sf dwelling units

Table 28. 460 Winding Ridge–Baseline Modeling

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
460 Winding Ridge Apartments	136,655	0	466	31,745	$12,050	129,187	0	441	30,010	$11,392	-5.5%	--

3.11 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 be reduced due to this phenomenon.

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

When multiple buildings can share a HVAC system, the overall equipment size can be reduced by considering the peak of the additive hourly loads, since every building typically peaks at a different time.

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 is only part of the equation for the wellfield. Nevertheless, when the heating and cooling peaks offset each other during the course of the year, they are further reduced.

The differences in the building peaks are noted in the following table:

Table 29. Combined Load Profile

Sum of Peaks (Baseline)			Individual GSHP Loop Peaks (Code-Compliant)		Combined Building Peaks			
					GSHP Loop Peak		Peak with Cooling Tower (Proposed)	
Heating (tons)	Cooling (tons)	DHW (tons)	Heating (tons)	Cooling (tons)	Heating (tons)	Cooling (tons)	Heating (tons)	Cooling (tons)
785	623	34	726	659	667	617	667	521

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. 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).

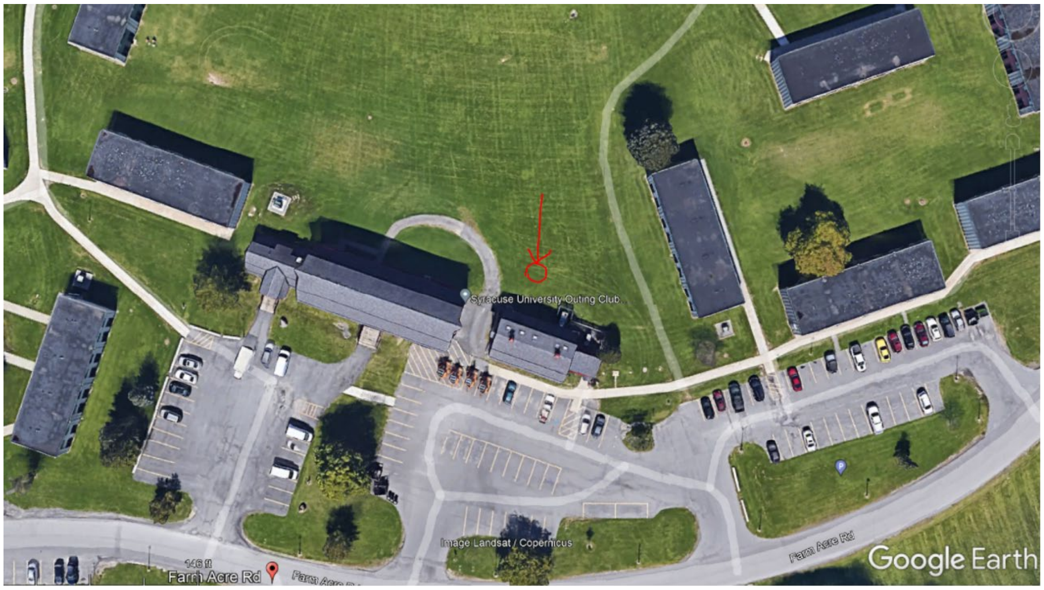
The well was drilled behind the Carriage House on Farm Acres Road, north of the proposed building cluster.

Nothnagle Drilling, Inc. performed the drilling and thermal conductivity testing. The test well drilled is as follows:

- Single vertical well
- 5.75 inches diameter bore
- 1 1/4 inches SR11 HDPE pipe
- 400 feet deep
- U-Bend
- Geo-clips (to space tubes apart)
- High performance grout (1.2 Btu/h*ft*°F)
- 36-hour test
- 5 day "rest" period prior to testing to equalize temperature

Thermal conductivity was calculated to be 1.54 Btu/h*ft*°F with a thermal diffusivity of 1.02 ft^2/day. See appendix for complete test well results.

Figure 10. Test Well Location



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 by 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 a location north of the buildings. However, this location does not have sufficient open area to accommodate all the wells required. Instead, the overflow parking lot near the south athletic has space available to accommodate all wells together. Although there is a utility easement with overhead power lines running through the lot, it is generally clear of underground utilities. Alternatively, there are several smaller lawn areas throughout the site that may be appropriate for satellite wellfield locations. However, pumping would likely need to be distributed as well, or the campus loop would require larger primary-only pumps. Should future expansion of the district systems be desired, the existing test well would work well in a satellite wellfield location serving the surrounding residences.

The wellfield will consist of 210 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. The manifold will be in a large utility vault located at the head end of the wellfield where the branches will be combined into a main 12-inch pipe header for distribution throughout the campus. The 12-inch main will be routed to the data center, where dedicated variable speed wellfield pumps will control the flow in the wellfield. Secondary variable flow distribution pumps will pump the heat pump loop water throughout the campus, and individual branch lines will bring the loop to each building. Each building will have another set of tertiary loop pumps to move the condenser water throughout the building, through heat pumps, and back to the main campus loop.

The total building cluster as modeled requires 352 wells to provide sufficient capacity for all the buildings and to ensure that the wellfield can maintain the water temperatures desired. However, the cluster is unbalanced, and has more cooling load than heating, due in large part to the data center. This high cooling load is an advantage when combined with buildings with high heat loads, but in this case, there is excess cooling on the loop. For a more cost-effective solution, the cooling tower in the data center should be maintained to cool the loop in the hottest months. For the purposes of this study, it is assumed that the cooling tower will handle the heat rejection from the data center in the months of June, July, August, and September. With a more balanced loop, the wellfield is significantly downsized. A robust control system will permit the cooling tower to operate based on loop temperatures to ensure that the wellfield is balanced and the earth surrounding the wellfield does not continue to increase in temperature over time. Note that the proposed wellfield as sized is insufficient to keep the wellfield balanced, and without the cooling tower, the ground temperatures will continue to creep up over time and decrease the available heat rejection capacity of the wellfield.

To further maximize the wellfield potential, oversized piping and an oversized utility vault could be installed. This will allow future wells to be installed and additional buildings to be brought online. Additionally, since the heat pump loop is cooling dominated, more heating-dominated buildings could be added to the loop for little impact on the wellfield size. For example, most residential buildings in this climate have weather dependent loads and therefore are heating dominated. There are a substantial number of residences on the South Campus in close proximity, and additional buildings can be brought online with minimal cost.

Proposed Equipment:

- 210 wells (400 ft, 20 x 20) as described in the "Test Well" section of this report.
- 4-inch circuit pipe headers, 12-inch campus loop piping.
- Wellfield circulation pumps (x4, n+1 redundant) with variable frequency drive (VFD) (50 horsepower (HP)).
- Campus ground loop distribution pumps (x4, n+1 redundant) with VFD (75 HP).

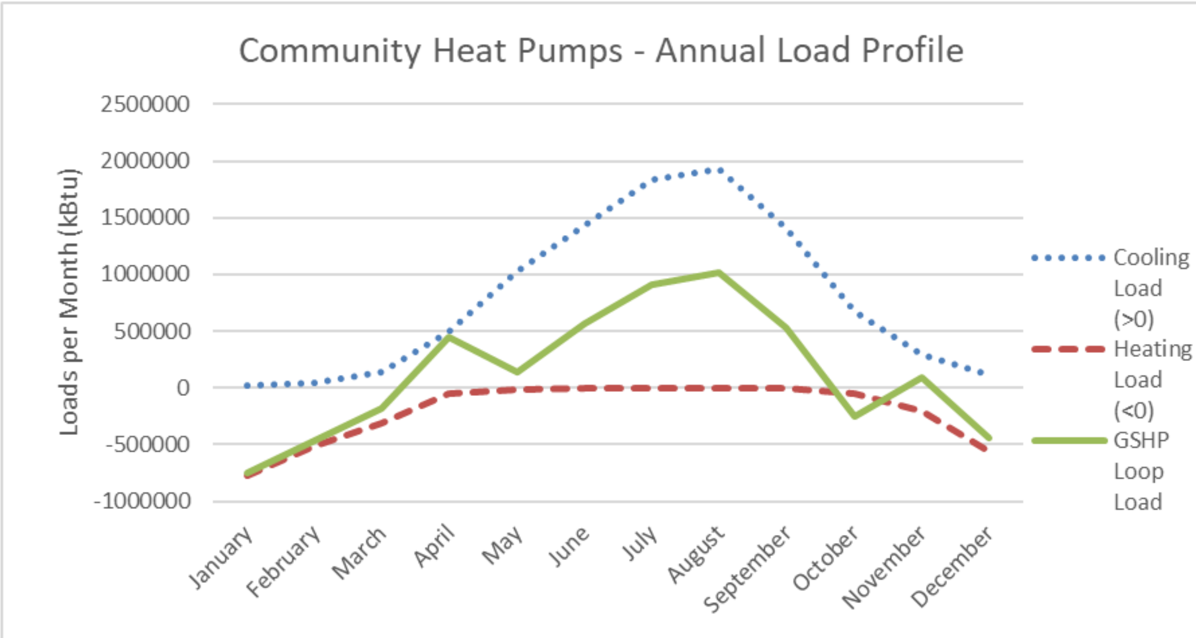
Table 30. Estimated Overall Savings

Building Name	Modeled Option	Modeled Consumption						Savings vs. Baseline					
		Electric (kWh)	Demand (kW)	Natural Gas (therm)	Energy (mmBtu)	Carbon (lb CO2e)	Cost ($)	Energy (mmBtu)	Energy (%)	Carbon (lb CO2e)	Carbon (%)	Cost ($)	Cost (%)
Entire Eight Building Cluster	Existing Baseline	8,291,728	1,871	199,390	48,239	4,258,576	$576,589	--	--	--	--	--	--
	Community Heat Pumps	9,384,267	2,723	11,889	33,217	2,319,039	$536,322	15,021	31%	1,939,536	46%	$40,267	7%

Figure 11. Community Wellfield Layout

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

Figure 12. Overall Annual Load Profile



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

4.4 623 Skytop Data Center

When the Skytop Data Center was built in 2009, it was designed as a "green" data center, utilizing energy efficient systems, including energy recovery, displacement underfloor air systems, and in-rack cooling. It is recommended that these systems are maintained, and only the chiller be upgraded for a geothermal system.

Instead of utilizing a traditional chiller, a water-to-water heat pump is recommended. In this building, since the primary load is cooling with minimal heat load, the heat pump will function much like a traditional chiller but can accommodate the low water temperatures of the geothermal condenser loop. The condenser loop will recover the rejected heat from the compressors and add it to the community-wide geothermal loop to be used in other buildings.

The combined energy profile of the buildings show that the community system is cooling-dominated, due in part to the data center and high internal loads of other buildings. To lower the cooling load on the geothermal loop, the existing closed-circuit cooling tower is recommended to be tied into the geothermal loop to provide an additional mechanism for heat rejection. This allows the wellfield to be downsized to better balance the heating and cooling system. However, there is some efficiency loss, due to the power required for cooling tower fans and pumps. To optimize the wellfield size, the calculations assume that the cooling tower will provide the heat rejection for the data center cooling load in only the months of June through August.

The existing pumping systems are variable flow/variable speed and are efficient. These can be maintained and reused for the chilled water loop. The existing hot water loop is fed from the adjacent building and will remain. However, the hot water is provided via fossil fuel boiler, and until the 621 Skytop Office building undergoes renovation to convert the hot water to an electrified source, the data center will not be fully electrified.

The chiller in this building has been newly replaced, so it may not be cost-effective to replace this chiller at once. Instead, the chiller can utilize economizer cooling with the geothermal loop when conditions permit. Economizer cooling bypasses the chiller compressor and utilizes the cold condenser water (from the geothermal loop) to cool the chilled water directly. This arrangement will limit the ability of the campus loop to recover heat from the data center but will provide energy savings via compressor-less cooling. However, the proposed chiller is intended to be utilized to provide hot water for the adjacent building at 621 Skytop, so supplementary heating may be required in the building until the chiller can be upgraded.

The heat pump change in the data center itself does not require an electrical service upgrade, since the load will not differ greatly from the existing chiller. Additionally, the data center was designed with spare capacity for up to two more chillers. However, the installation of the campus ground loop pumps adds a significant load, which requires a service upgrade, from an estimated 1000 amperage (A) service to a 1600A. The previous removal of the microturbines and designation of future chiller space provides ample room for heat pump related equipment installation.

Equipment to be removed:

- 250-ton water cooled chiller.
- Primary chiller pumps (7.5 HP).

Proposed Equipment:

- Modular 250-ton ground source water-to-water heat pump, 18.2 EER cooling, 3.4 COP heating.
- Ground source heat pump loop pump with VFD (10 HP).
- Chilled water primary pumps with VFD (7.5 HP).
- Campus ground loop equipment as noted in the section "Proposed Central Wellfield" of this report.

The expected energy savings are as follows:

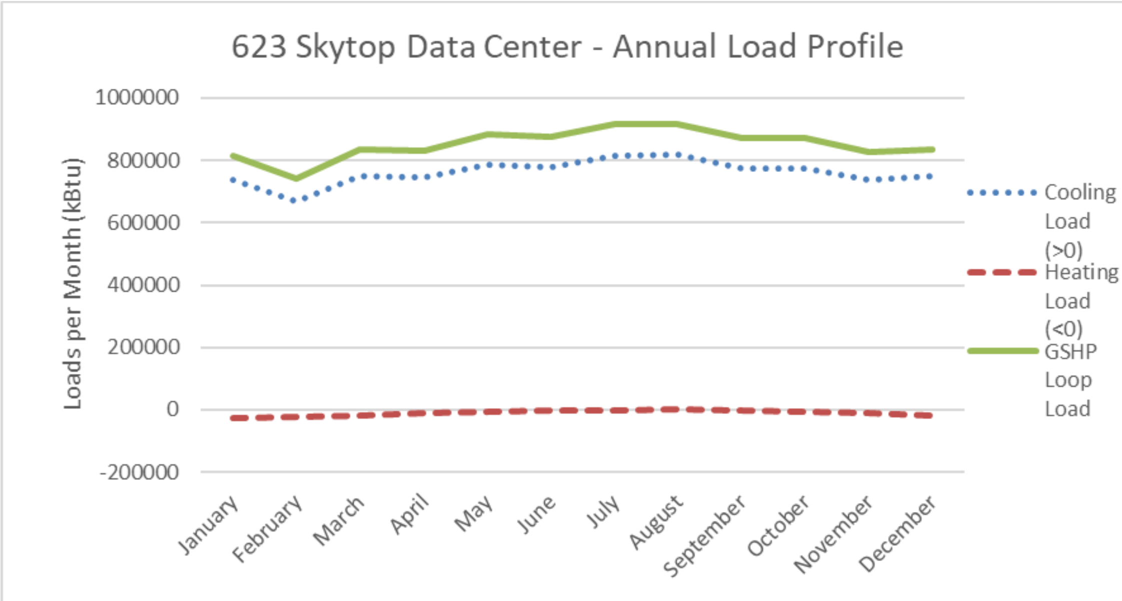
Table 31. 623 Skytop–Estimated Savings

Building Name	Modeled Option	Modeled Consumption						Savings vs. 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 (%)
623 Skytop Data Center	Existing Baseline	3,225,477	375	2,441	11,253	777,832	$177,380	--	--	--	--	--	--
	Code-Compliant Heat Pumps	3,452,622	523	0	11,784	802,044	$188,841	-531	-5%	-24,212	-3%	-$11,461	-6%
	Community Heat Pumps	3,327,950	762	0	11,358	773,083	$182,022	-106	-1%	4,750	1%	-$4,642	-3%

The energy consumption actually increases with the community heat pump system, thanks to the installation of the wellfield pumps in this facility. However, even with the increased pump load, the community heat pump system still demonstrates carbon savings.

The annual load profile:

Figure 13. 623 Skytop–Annual Load Profile



Note that the GSHP load is more than the cooling load because it includes the heat of the heat pump compressor, which the geothermal loop must alleviate.

4.5 621 Skytop Office Building

The primary HVAC system in the 621 Skytop Office Building is a dual-duct constant volume system. This system is original to the building and inefficient. Any renovation of this building should include a replacement of the air handling units.

The proposed system will replace the existing steam boilers and air cooled chiller with a modular water-to-water heat pump. The heat pump will be tied into the geothermal loop to maximize efficiency, and both the chilled water and hot water loops will be tied into adjacent data center to share hot and chilled water. The main large air handling unit will be removed in its entirety and replaced with a VAV unit with hot and chilled water coils, the dual-duct terminal units will be replaced with variable air volume units with reheat as required, the hot supply duct will be removed, and the cool supply duct will remain. All pumps will be replaced with premium efficient pumps with variable speed drives. Existing DX/natural gas rooftop units will be removed and replaced with units with hot and chilled water coils. Any steam unit heaters will be replaced with hot water heaters, and the stand-alone AC units will be replaced with chilled water fan coil units. New reheat piping will be routed throughout the building for the VAV units as well.

A smaller additional dedicated domestic hot water heat pump (tied into the ground loop) will be provided for service water heating, combined with a domestic water storage tank.

An alternative solution for this building is to remove the centralized air handler altogether and replace the dual-duct terminal units with water-to-air ground source heat pumps. A dedicated outdoor air system (DOAS) with energy recovery would be necessary to supply ventilation air. This arrangement would likely save fan power, but the distributed heat pumps would require additional maintenance when compared to the more centralized water-to-water heat pumps.

Utilizing a water-to-water heat pump system to produce hot and chilled water leaves open opportunities for additional energy efficient systems. For example, the VAV boxes can be eliminated, and decoupled fan coils or even chilled beams employed in conjunction with a DOAS system.

Additional electric capacity is expected to be required for the new geothermal heat pumps. The building was designed with capacity for a future chiller and cooling towers, and there is likely spare capacity. However, the heat pumps, especially during the dead of winter, have a significant electrical demand. The service is expected to require an increase from 1200A to 1400A. The removal of the existing boilers and chiller as well as designation of space for future boiler and chiller provides ample space for the installation of the heat pumps in the mechanical penthouse.

Equipment to be removed:

- 76,000 cubic feet per minute (cfm) air handling unit
- DX/Gas VAV rooftop units
- 450-ton air cooled chiller
- 3000 mbh steam boilers x2
- Heat exchanger
- Chilled water pump (40 HP)
- Hot water distribution pumps (1 1/2 HP x2)
- Dual duct terminal boxes
- Steam unit heaters
- AC units
- Domestic water heaters

Proposed Equipment:

- VAV air handling units and an energy recovery unit (CHW/HW)
- Modular 250-ton ground source water-to-water heat pump, 18.2 EER cooling, 3.4 COP heating
- Ground source heat pump loop with VFD (10 HP)
- Chilled water primary pumps with VFD (7.5 HP)
- Hot water primary pumps with VFD (5 HP)
- Chilled water distribution pumps with VFD (40 HP)
- Hot water distribution pumps with VFD (25 HP)
- VAV terminal boxes with hot water
- HW unit heaters
- AC units
- Ground source water-to-water heat pump water heater (5 ton), 2.9 COP heating
- Domestic hot water storage tank

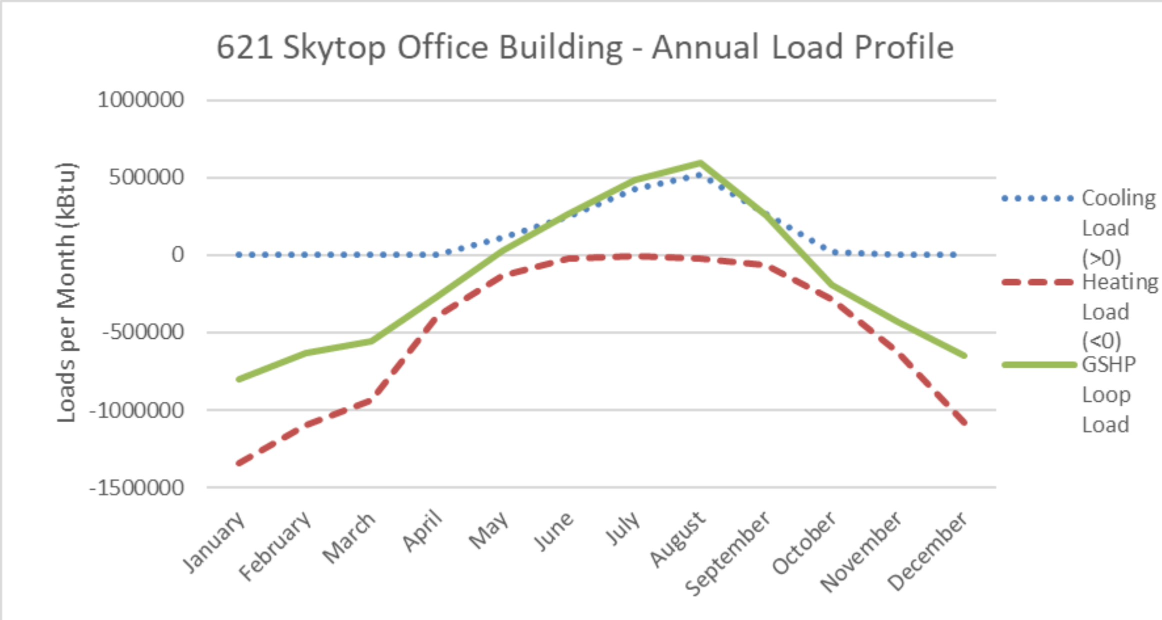
The expected energy savings are as follows:

Table 32. 621 Skytop–Estimated Savings

Building Name	Modeled Option	Modeled Consumption						Savings vs. 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 (%)
621 Skytop Office Building	Existing Baseline	1,710,014	610	89,963	14,833	1,449,598	$144,984	--	--	--	--	--	--
	Code-Compliant Heat Pumps	2,032,382	1,065	0	6,937	472,122	$116,086	7,896	53%	977,475	67%	$28,898	20%
	Community Heat Pumps	1,810,176	870	0	6,178	420,504	$103,394	8,654	58%	1,029,094	71%	$41,590	29%

The annual load profile:

Figure 14. 621 Skytop–Annual Load Profile



4.6 Tennity Ice Skating Pavilion

The main energy consumer at Tennity Ice Skating Pavilion is the equipment associated with ice making. In 2014, this system was replaced with a high-efficiency system with heat recovery. Since this is a modern, high-efficiency system and the free heat is already being utilized in the rinks themselves, adding the ice-skating rink to the geothermal system is not recommended. Furthermore, as a process cooling system, the needs of the rinks are unique and extreme, and benefit from a dedicated system to maintain proper control. Instead, only the space conditioning systems are recommended to be upgraded to a geothermal system.

In this building, a new water-to-water heat pump is recommended to be used for hot water generation. The hot water will be distributed to unit heaters and fan coil units (in lieu of gas unit heaters and furnaces), as well as VAV reheat. The desiccant unit is nearing the end of its useful life and is recommended to be replaced with a unit containing energy recovery, as well as with hot water coils instead of natural gas heaters. The VAV rooftop unit will be replaced with a water cooled heat pump unit as well, but the VAV boxes will remain.

A smaller additional dedicated domestic hot water heat pump (tied into the ground loop) will be provided for service water heating, combined with a domestic water storage tank. The hot water pumps will be replaced to accommodate the additional load and provided with a VFD.

A service line upgrade may be required to accommodate the new heat pumps. No electric chiller is being replaced to mitigate the load impact of the heat pumps. The load increase is estimated to be ~100 kilowatts (kW), which would upsize the service from an estimated 800A service to 1000A. Space for the heat pump is sparse as well. The domestic water system can be installed in the mechanical room where the existing domestic hot water (DHW) system is located in the addition. The larger hot water generator may fit in the mechanical room with the existing furnaces but if space is limited, may require taking a section of the adjacent equipment room instead.

A potential difficulty in this building is the large open ice rink area that any hot water piping must cross to get between the original office area and the addition. Piping should not be routed directly above the ice rink, to reduce the risk of condensation, and should be installed with additional insulation to mitigate the effects of the ice rink temperatures.

Equipment to be removed:

- VAV rooftop unit
- Desiccant dehumidifier
- Heat exchanger
- Gas unit heaters
- Gas furnaces
- Domestic water heaters

Proposed Equipment:

- VAV air handling unit (CHW/HW)
- Desiccant dehumidifier (HW)
- Modular 150-ton ground source water-to-water heat pump, 18.2 EER cooling, 3.4 COP heating
- Ground source heat pump loop pumps with VFD (5 HP)
- Hot water primary pumps with VFD (3 HP)
- Hot water distribution pumps with VFD (7.5 HP)
- Chilled water pumps with VFD (1 HP)
- Hot water unit heaters
- Hot water fan coil units
- Ground source water-to-water heat pump water heater (10 ton), 2.9 COP heating
- Domestic hot water storage tanks

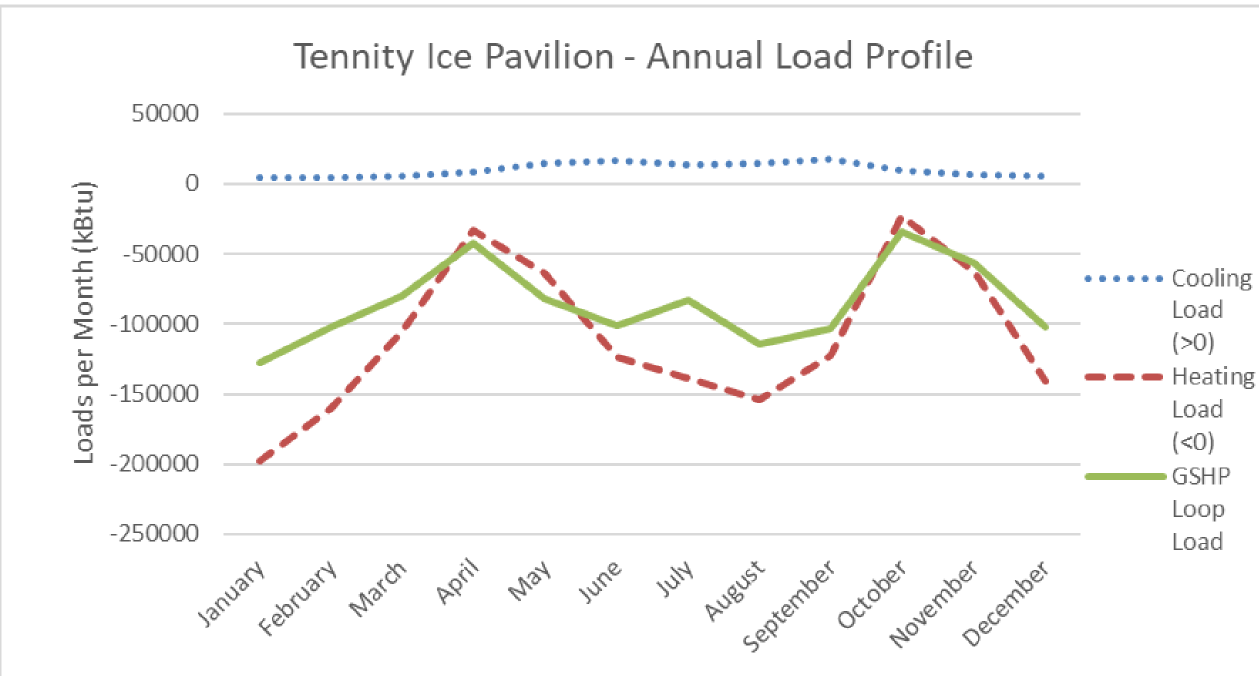
The expected energy savings are as follows:

Table 33. Tennity Ice Rink–Estimated Savings

Building Name	Modeled Option	Modeled Consumption						Savings vs. 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 (%)
Tennity Ice Skating Pavilion	Existing Baseline	1,643,578	279	29,196	8,529	723,330	$110,817	--	--	--	--	--	--
	Code-Compliant Heat Pumps	2,033,466	380	0	6,940	472,374	$117,333	1,589	19%	250,955	35%	-$6,516	-6%
	Community Heat Pumps	1,979,395	338	0	6,756	459,813	$114,213	1,773	21%	263,516	36%	-$3,396	-3%

The annual load profile:

Figure 15. Tennity Ice Rink–Annual Load Profile



Note the load profile does not include the cooling for the ice.

4.7 Goldstein Student Center

Much of the existing building at the Goldstein Student Center is already serviced by water source heat pumps. However, typical WSHPs are not rated for the low temperatures of a ground source loop, and the units must be replaced for a geothermal system. Since this building has distributed systems, the air handling units will be replaced with water cooled heat pump units as well.

The existing boiler and cooling tower attached to the water loop will be removed and the existing loop will instead be tied into the campus geothermal loop. A new water-to-water heat pump will be provided for the existing hot water loop. The loop pumps will be upsized as required to accommodate the new AHUs and provided with VFDs.

A smaller additional dedicated domestic hot water heat pump (tied into the ground loop) will be provided for service water heating, combined with domestic water storage tanks.

A service line upgrade may be required to accommodate the new, large air handler heat pumps. The load increase is estimated to be ~125 kW, which would upsize the service from an estimated 400A service to 600A. The new central heat pump equipment will be located in the boiler room, located in the place of the existing boilers.

Equipment to be removed:

- Standard water source heat pumps
- Air handling units
- Boilers (1000 mbh x2)
- Cooling tower (515 gallons per minute (gpm))
- Hot water loop pumps (10 HP)
- Heat pump loop pumps (20 HP)
- Domestic water heaters

Proposed Equipment:

- Water-to-air ground source heat pumps, 16.9-20.3 EER cooling, 3.7-4.4 COP heating (19.3 EER and 4 COP used in model)
- Energy recovery units (HW)
- Water cooled heat pump air handling units
- Modular 100-ton ground source water-to-water heat pump, 18.2 EER cooling, 3.4 COP heating
- Ground source heat pump loop pumps with VFD (20 HP)
- Hot water primary pumps with VFD (3 HP)
- Hot water distribution pumps with VFD (10 HP)
- Ground source water-to-water heat pump water heater (20 ton), 2.9 COP heating
- Domestic hot water storage tanks

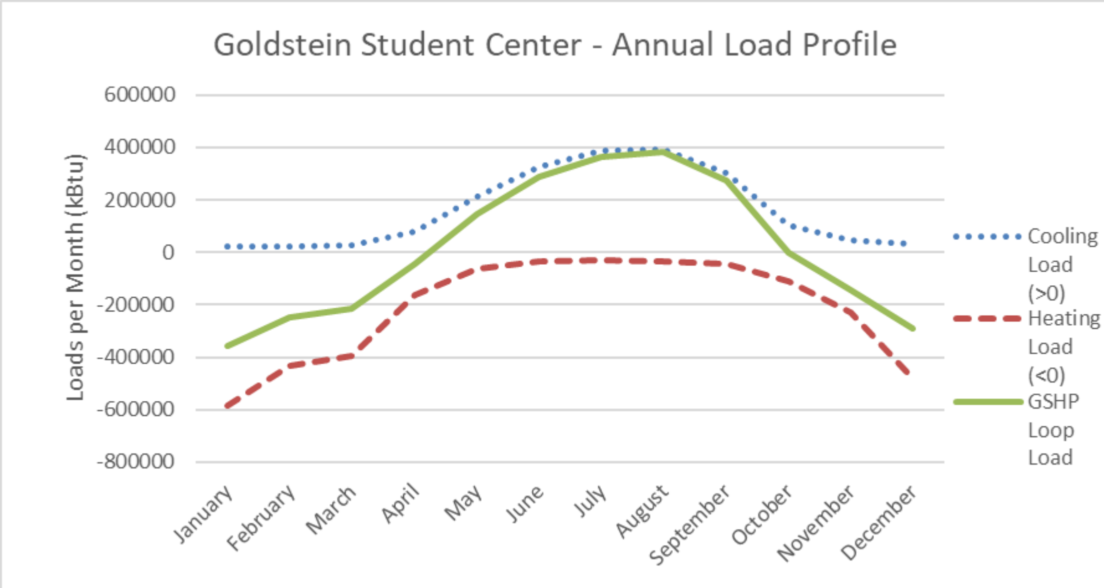
The expected energy savings are as follows:

Table 34. Goldstein Student Center–Estimated Savings

Building Name	Modeled Option	Modeled Consumption						Savings vs. 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 (%)
Goldstein Student Center	Existing Baseline	1,191,176	355	53,750	9,440	905,462	$94,162	--	--	--	--	--	--
	Code-Compliant Heat Pumps	1,700,100	548	11,522	6,955	529,714	$100,589	2,486	26%	375,748	41%	-$6,427	-7%
	Community Heat Pumps	1,618,895	463	11,522	6,677	510,850	$96,070	2,763	29%	394,612	44%	-$1,908	-2%

The annual load profile:

Figure 16. Goldstein Student Center–Annual Load Profile



4.8 Skytop Office Building

Recently renovated, the Skytop Office Building utilizes VAV systems with hot water throughout. To maintain the updated systems and the updated office space, a water-to-water heat pump is recommended for this building. Hot water systems will be maintained, and distributed DX systems will be replaced with chilled water.

The new heat pump will provide both chilled and hot water, and the existing boiler will be removed. New chilled water piping will be circulated through the building, and all rooftop units will be removed and replaced with air handling units with hot and chilled water coils. Stand-alone AC units will be replaced with chilled water fan coil units. New primary and secondary chilled water pumps will be provided, as well as a new primary HW loop pump and a GSHP condenser water loop pump; all will have VFDs.

A smaller additional dedicated domestic hot water heat pump (tied into the ground loop) will be provided for service water heating, combined with a domestic water storage tank.

A service line upgrade is likely required to accommodate the new heat pumps. The increase is mitigated somewhat due to the presence of DX coils; however, especially with the snowmelt load, the electricity needed for peak heating exceeds what is currently needed for cooling. The load increase is estimated to be ~90 kW, which would upsize the service from an estimated 400A service to 600A. The removal of the existing boilers is expected to provide sufficient space for the installation of the heat pumps in the boiler room.

Equipment to be removed:

- Boilers (1200 thousand British thermal units per hour (mbh))
- Boiler pumps (3/4 HP)
- DX/HW rooftop units
- AC units
- Domestic water heater

Proposed Equipment:

- Modular 200-ton ground source water-to-water heat pump, 18.2 EER cooling, 3.4 COP heating
- VAV air handling units (CHW/HW)
- Ground source heat pump loop pumps with VFD (5 HP)
- Chilled water primary pumps with VFD (3 HP)
- Hot water primary pumps with VFD (3 HP)
- Chilled water distribution pumps with VFD (7.5 HP)
- GSHP pumps + VFD (10 HP)
- AC Units (CHW)
- Ground source water-to-water heat pump water heater (10 ton), 2.9 COP heating
- Domestic hot water storage tank

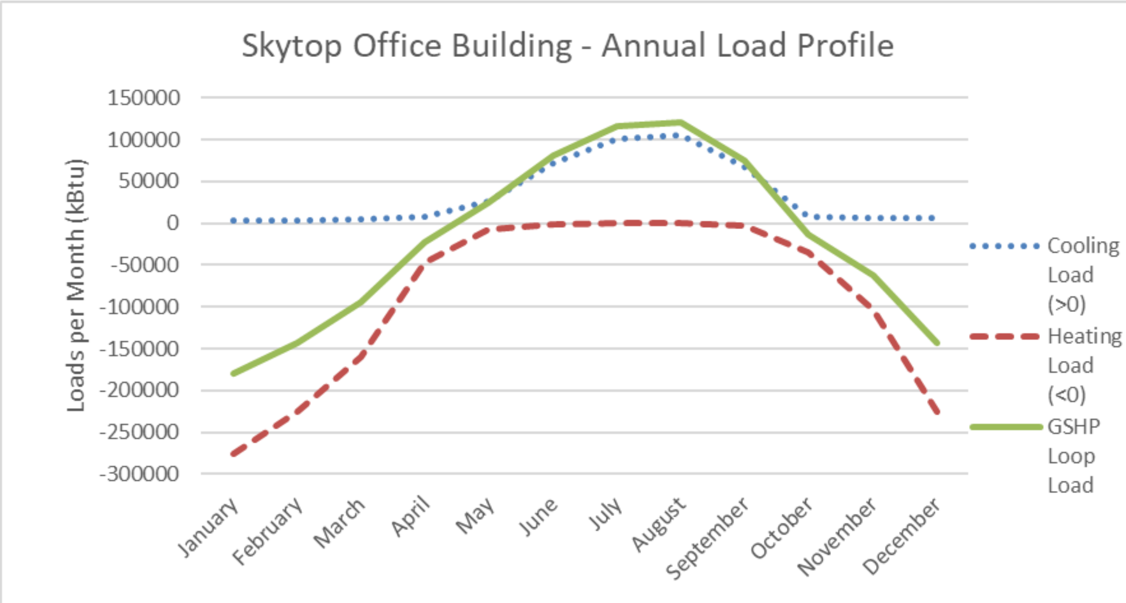
The expected energy savings are as follows:

Table 35. Skytop Office Building–Estimated Savings

Building Name	Modeled Option	Modeled Consumption						Savings vs. 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 (%)
Skytop Office Building	Existing Baseline	285,863	126	13,295	2,305	221,927	$23,054	--	--	--	--	--	--
	Code-Compliant Heat Pumps	476,243	228	0	1,625	110,631	$26,048	680	29%	111,296	50%	-$2,994	-13%
	Community Heat Pumps	427,902	199	0	1,460	99,402	$23,404	845	37%	122,525	55%	-$350	-2%

The annual load profile:

Figure 17. Skytop Office Building–Annual Load Profile



4.9 Ski Lodge

The equipment at Ski Lodge is very old and in need of replacement. Much of the building is heating only, as it is ancillary space, with the main dining area and kitchen cooled. To minimize extraneous HVAC noise in the seating area, fan coil units are recommended, since they do not have compressors. High-wall fan coil units, located where the split system air-conditioning units are now, will provide both heating and cooling in this space in conjunction with new hot water convectors.

The kitchen will have ceiling mounted fan coil units, and the remainder of the space will utilize convectors and unit heaters. As a restaurant, the domestic hot water load is significant, so a ground source heat pump hot water heater with storage is required. The chilled and hot water produced by the heat pump unit will be circulated with primary-only pumping with variable speed drives.

A service line upgrade may be required to accommodate the new heat pumps. The load increase is estimated to be ~25 kW, which would upsize the service from an estimated 400A service to 600A. There is ample storage space, and in conjunction with the removal of the existing boilers, there is sufficient clearance for installation in the basement of this facility.

Energy savings include increased insulation and envelope sealing, recommended to save energy and downsize equipment. It is also recommended irrespective of the option selected, so costs associated with envelope modifications have not been included in the cost estimate.

Equipment to be removed:

- Steam unit heaters
- Steam convectors
- Steam boiler (~400 mbh)
- Gas domestic water heater
- AC units

Proposed Equipment:

- Fan coils
- Hot water unit heaters
- Hot water convectors
- Modular 15-ton ground source water-to-water heat pump, 18.2 EER cooling, 3.4 COP heating
- Ground source heat pump loop pumps with VFD (5 HP)
- Chilled water distribution pumps with VFD (3 HP)
- Hot water distribution pumps with VFD (1.5 HP)
- Ground source water-to-water heat pump water heater (10 ton), 2.9 COP heating
- Domestic hot water storage tank

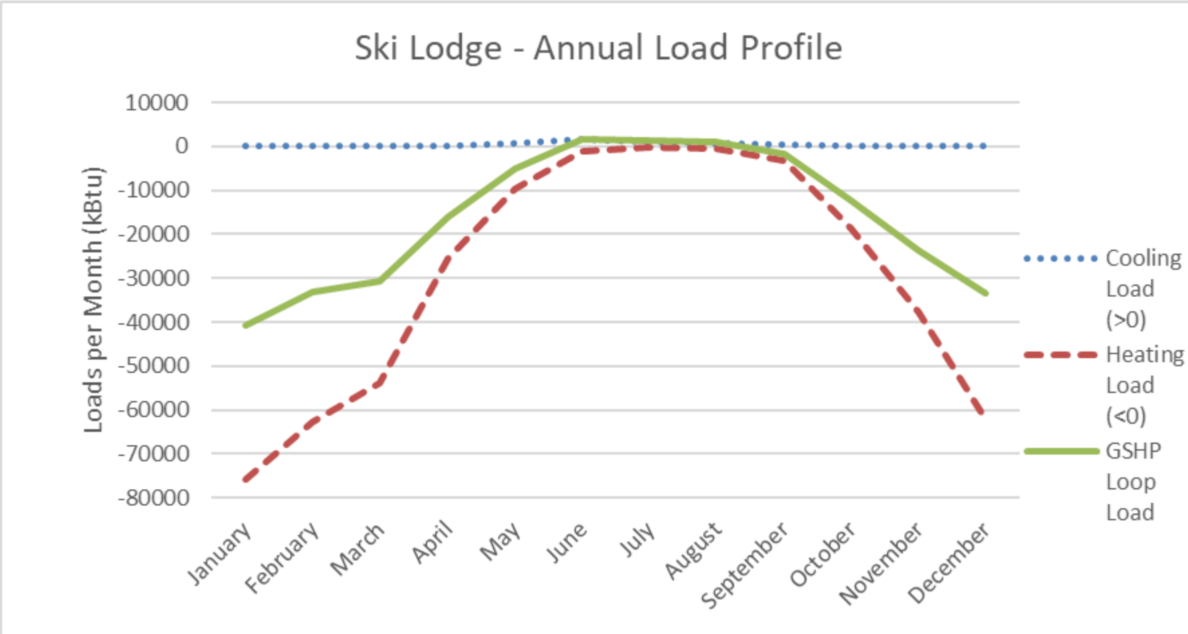
The expected energy savings are as follows:

Table 36. Ski Lodge–Estimated Savings

Building Name	Modeled Option	Modeled Consumption						Savings vs. 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 (%)
Ski Lodge	Existing Baseline	21,632	15	10,745	1,148	130,717	$7,322	--	--	--	--	--	--
	Code-Compliant Heat Pumps	72,958	44	367	286	21,241	$4,037	863	75%	109,476	84%	$3,285	45%
	Community Heat Pumps	66,821	40	367	265	19,816	$3,716	884	77%	110,901	85%	$3,607	49%

The annual load profile:

Figure 18. Ski Lodge–Annual Load Profile



4.10 480 Winding Ridge Apartments

The apartments at Winding Ridge are simple systems, which utilize electric resistance. To replace the existing systems with geothermal, a hydronic system would be required. Since the system requires the baseboard be replaced in its entirety, an upgrade to an air-side system to add cooling and provide increased comfort conditions is recommended.

An option for residential units is a combined geothermal heat pump with domestic water generation as one packaged unit. It is primarily a water-to-air heat pump, with domestic hot water as a value-add. This eliminates the need for a separate water heater and provides on-demand hot water. Due to the small size of the apartments, the in-unit hot water generation is expected to be sufficient alone for the needs of the dwelling unit. Additional ductwork will be required to accommodate the air-side system. The ground loop water will be circulated with variable flow pumping.

Because the existing system is resistance heating, and heat pumps use significantly less energy, an electrical service upgrade is not expected to be required. The new heat pumps will be placed in the individual unit mechanical rooms, which previously housed electric furnaces.

Equipment to be removed:

- Electric baseboard
- Electric water heater

Proposed Equipment:

- Ground source water-to-air heat pumps with domestic hot water generation (1.5 tons).
- Ground source heat pump loop pumps with VFD (2 HP).

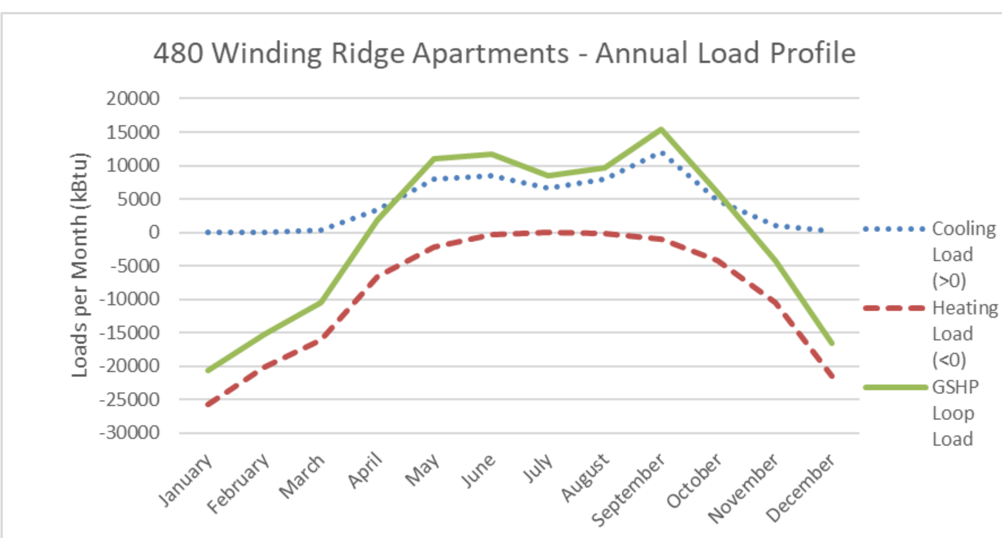
The expected energy savings are as follows:

Table 37. 480 Winding Ridge–Estimated Savings

Building Name	Modeled Option	Modeled Consumption						Savings vs. 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 (%)
480 Winding Ridge Apartments	Existing Baseline	84,801	44	0	289	19,699	$7,478	--	--	--	--	--	--
	Code-Compliant Heat Pumps	63,795	21	0	218	14,820	$5,625	72	25%	4,880	25%	$1,852	25%
	Community Heat Pumps	60,498	20	0	206	14,054	$5,335	83	29%	5,646	29%	$2,143	29%

The annual load profile is shown below:

Figure 19. 480 Winding Ridge–Annual Load Profile



4.11 460 Winding Ridge Apartments

Since 460 Winding Ridge is identical to 480, except in the number of units, the proposed systems are identical. This proposed system can likely be repeated throughout the entire Winding Ridge Apartment, should the wellfield be sized for the additional buildings.

Equipment to be removed:

- Electric baseboard
- Electric water heater

Proposed Equipment:

- Ground source water-to-air heat pumps with domestic hot water generation (1.5 tons).
- Ground source heat pump loop pumps with VFD (2 HP).

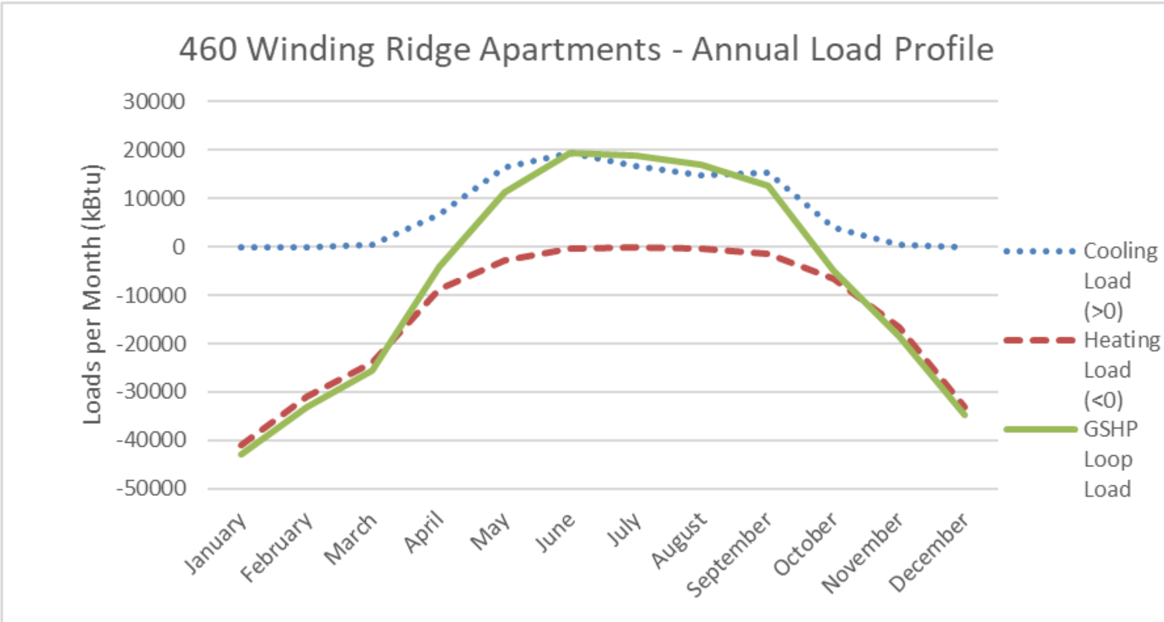
The expected energy savings are as follows:

Table 38. 460 Winding Ridge–Estimated Savings

Building Name	Modeled Option	Modeled Consumption						Savings vs. 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 (%)
460 Winding Ridge Apartments	Existing Baseline	129,187	67	0	441	30,010	$11,392	--	--	--	--	--	--
	Code-Compliant Heat Pumps	98,043	32	0	335	22,775	$8,645	106	24%	7,235	24%	$2,746	24%
	Community Heat Pumps	92,630	30	0	316	21,518	$8,168	125	28%	8,492	28%	$3,224	28%

The annual load profile is shown below:

Figure 20. 460 Winding Ridge–Annual Load Profile



4.12 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 as well. For this option, all buildings are assumed to have individual wellfields, with individual wellfield pumps. Where the size of the wellfield indicates it, a piping manifold for the wellfield piping is included. Additionally, the heat pumps in the buildings have been modeled with code-minimum efficiencies.

Note that for the purposes of this alternative, 621 and 623 Skytop are part of the same wellfield system, as their systems are intertwined. Additionally, to keep the calculations consistent, the data center cooling tower utilization during the summer months has been included in this option as well to reduce the number of wells. The data center, although contributing greatly to the district geothermal system, is unbalanced on its own and requires a large wellfield to function.

All other items are the same between both options.

Excluded Equipment (versus Proposed System)

- 210 wells (400 ft, 20 x 20) as described in the "Test Well" section of this report.
- 4-inch circuit pipe headers, 12-inch campus loop piping.
- Wellfield circulation pumps (x4, n+1 redundant) with VFD (50 HP).
- Campus ground loop distribution pumps (x4, n+1 redundant) with VFD (75 HP).

Code-Compliant System Equipment

- 315 wells (400 ft, 20 x 20) as described in "Test Well"
- 621+623 Skytop: Wellfield Pumps with VFD (25 HP)
- Tennity: Wellfield Pumps with VFD (7.5 HP)
- Goldstein: Wellfield Pumps with VFD (20 HP)
- 640 Skytop: Wellfield Pumps with VFD (10 HP)
- Ski Lodge: Wellfield Pumps with VFD (2 HP)
- 480 Winding: Wellfield Pumps with VFD (3/4 HP)
- 460 Winding: Wellfield Pumps with VFD (1 HP)

Table 39. Code-Compliant Load Profile

Sum of Individual Buildings (Code-Compliant System)				Combined Building Loads Peak (Proposed Community System)			
Heating Peak (tons)	Cooling Peak (tons)	Number of Wells	Number of Wells with CT	Heating Peak (tons)	Cooling Peak (tons)	Number of Wells	Number of Wells with CT
726	659	474	315	667	617	352	210

Table 40. Code-Compliant Estimated Savings

Building Name	Modeled Option	Modeled Consumption						Savings vs. 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 (%)
Entire Eight Building Cluster	Code-Compliant Heat Pumps	9,929,609	2,842	11,889	35,079	2,445,722	$378,365	--	--	--	--	--	--
	Community Heat Pumps	9,384,267	2,723	11,889	33,217	2,319,039	$354,300	1,861	5%	126,683	5%	$24,065	6%

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 the appendix for a detailed breakdown of the installation and maintenance costs of each system.

Table 41. Economic Summary

Economic Summary							
Design Option	**Construction Cost**	**Estimated Incentives**	**Total First Cost**	**Annual Mainten ance**	**Annual Energy Costs**	**Total Annual Costs**	**Annual Carbon (lb CO_2e)**
Baseline System: Replace systems in kind	$4,918,071	$0	**$4,918,071**	$72,218	$576,589	**$648,807**	**4,258,576**
Code-Compliant System: Individual building heat pumps	$17,719,877	$789,601	**$16,930,276**	$57,679	$567,206	**$624,885**	**2,445,722**
Proposed System: Community heat pumps	$17,628,502	$5,201,701	**$12,426,801**	$58,127	$536,322	**$594,449**	**2,319,039**
Economic Savings vs. Baseline							
Design Option	**First Cost ($)**	**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	-12,012,205	-244%	23,922	4%	502	1,812,853	43%
Proposed System: Community heat pumps	-7,508,730	-153%	54,358	9%	138	1,939,536	46%

Compared to the existing systems, and maintaining the status quo, the geothermal wellfield does not provide a reasonable simple payback. 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 Syracuse University, 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.

Although the costs of the proposed option are high, the carbon emission reductions with the community heat pump system is remarkable—saving almost 50 percent 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, Upstate New York has an emissions factor of 232.3-pound carbon dioxide per megawatt hour (pounds CO_2/MWh) of electricity. For comparison, the Midwest has a factor almost seven times as high, 1584.4-pound 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 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 15–20 years. The expected lifespan of the installed equipment is as follows:

Table 42. Equipment Expected Useful Lifespan

Expected Useful Lifespan			
Equipment Description	Years	Equipment Description	Years
Air cooled chiller	15	Natural gas DWH	15
Water cooled chiller	20	Electric DWH	13
Cooling tower	15	Air handling unit	20
Natural gas boiler	25	Rooftop unit	15
Geothermal W-W heat pump	25	Rooftop WSHP	20
Geothermal W-A heat pump	25	Unitary AC	15
Geothermal GSHP DWH	20	Fan coil unit	25
Pumps	15	Gas fired unit heater	15
Controls	15	Hydronic unit heater	25

When considering the lifecycle 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 43. 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 (LCCA) 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	($4,918,071)	($576,589)	($72,218)	20	($17,310,608)	--
Code-Compliant System: Individual Building Geothermal Heat Pumps	2	($16,930,276)	($567,206)	($58,127)	25	($30,466,790)	($13,156,182)
Proposed System: Community Geothermal Heat Pumps	3	($12,426,801)	($536,322)	($57,679)	25	($24,376,589)	($7,065,981)

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 $4,000,000 more than the individual building systems. This indicates that although the community system is a large financial outlay, it is prudent to act 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 44. Estimated Incentives

Possible 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)	$1,201,701	$789,601	Yes	Assumes only 75% of calculated energy savings is eligible for incentive
NYSERDA New Construction	$554,878	$554,878	No	Only available for gut rehabs, project may not be eligible. Program currently closed but expected to reopen in a different form.
Total	**$6,256,579**	**$1,344,479**		

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, Syracuse University 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 below:

5.4.1 NYSERDA Programs

5.4.1.1 NYSERDA Community Heat Pump Systems PON 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 percent of costs for a more focused design study for implementation.
- Category C: Award of up to $4,000,000 or a maximum of ~50 percent of costs for the implementation of the community wellfield design project.
- For more information about the program: 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 upon 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 percent 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 square feet.

- 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 square feet.

- Financial Support:
  - Compliance Path A:
    - Energy Performance Incentive of 15 percent AND No Fossil Fuel use on site = **$2.00/Square foot** 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/Square foot** 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: 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 NY 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: 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/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: 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/kWh saved (non-lighting), $0.13/kWh (custom lighting), and $1.00/therm saved, up to 50 percent of incremental cost of project (compared to code minimum equipment).
- For more information: https://www.nationalgridus.com/Upstate-NY-Business/Energy-Saving-Programs/

5.4.2.3 National Grid Make-Ready Program

- Will fund up to 50 percent (or 90 percent if made available to the public) of the electric infrastructure costs associated with new vehicle charging stations.
- For more information: 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:
    - 30 percent bonus rate for geothermal systems based on total system cost.
    - Additional 10 percent 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.
    - 100 percent bonus depreciation 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 percent of the cost of the solar photovoltaic system.
- For additional information: www.energy.gov/eere/solar

5.4.3.3 NYS 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: 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 and including 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: 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 Syracuse University, since they are knowledgeable about how their buildings operate and have a robust maintenance staff with the necessary expertise to operate and maintain their 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, Syracuse University 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 suppler 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 Syracuse University 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 since 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 percent 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 photovoltaics (PV) provide an additional opportunity to reduce the energy consumption and operation cost of the community. PV systems harvest the 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 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.

All of the buildings considered are low-rise buildings, many of which have flat roofs to provide ample roof area for roof-mounted panels. The campus is a fairly dense area, and much of the lawn space is shaded by buildings or utilized for athletic fields, which limits the installation area for additional ground mounted solar panels. However, there may be lawn space behind the 621 Skytop building and parking lot as well as along Skytop Road. Solar panels can also be installed above the 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 as well.

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 percent of the electricity (to understand what area would be required), the roof area 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 as follows:

Table 45. Solar Panel Array–Estimated Savings

Solar Panel Array									
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)
800	10% of proposed electric use	43896	940196	10%	$53,390	$1,600,000	$120,000	$1,480,000	27.7
880	Consumption differential	48285	1034215	11%	$58,729	$1,760,000	$132,000	$1,628,000	27.7
1700	Roof area available	93278	1997916	21%	$113,455	$3,400,000	$255,000	$3,145,000	27.7
2000	25% of proposed electric use	109739	2350489	25%	$133,476	$4,000,000	$300,000	$3,700,000	27.7
8000	100% of proposed electric use	438957	9401957	100%	$533,904	$16,000,000	$1,200,000	$14,800,000	27.7

** 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 requirements of the Interconnection Tariff (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. Despite the urban setting, the site is not in an underground secondary network area, which can cause connection complications for the utility. In 2020, Syracuse University successfully installed a 50-kW solar array at Shine Student Center. Note that a distributed solar field system (i.e., on many roofs) 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 this facility, it is imperative to include the utility at early planning stages.

An alternative to site-installed solar panels is utilizing Community Distributed Generation (CDG), 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; however, it does not require a significant financial outlay, construction coordination, or maintenance responsibilities.

6.2 Electric Vehicle Charging

According to the EPA, the transportation sector is responsible for the majority of carbon emissions in this country. At Syracuse University, 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: Level 1–slow charging, Level 2–typical chargers, and Level 3–DC fast charging (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 Level 1 but is generally more useful for public use. Level 3 fast charging 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 ~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 encourage EV usage on campus. In lieu of a survey, NYStretch Energy Code suggests a total of 5 percent 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 recouple installation and energy costs. With current volatile prices of energy, it is recommended to offer paid charging.

The energy and cost implications of the EV charging stations are as follows:

Table 46. Electric Vehicle Charging–Estimated Savings

Electric Vehicle Charging											
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)**
621/623 Skytop	281	14	$142,100	$52,500	$89,600	0.5	134.4	41,104	$2,283	$9,013	13
Tennity	44	2	$20,300	$7,500	$12,800	0.5	19.2	5,872	$339	$1,302	13
Goldstein	67	4	$40,600	$15,000	$25,600	2	38.4	46,976	$2,614	$10,306	3
640 Skytop	184	10	$101,500	$37,500	$64,000	0.5	96.0	29,360	$1,606	$6,409	13
Ski Lodge	44	2	$20,300	$7,500	$12,800	0.5	19.2	5,872	$308	$1,267	13
Winding Ridge	51	2	$20,300	$7,500	$12,800	0.5	19.2	5,872	$518	$1,508	13
Total	**671**	**34**	**$345,100**	**$127,500**	**$217,600**		**326.4**	**135,055**	**$7,667**	**$29,805**	10

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

Annual EV Carbon Emissions						
Electric			**Gasoline**		**Savings vs. 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 percent less carbon emissions when compared to gasoline vehicles, and 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 the 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 photovoltaics, 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 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-3 (for customers with less than 2,000 kW demand) is $11.38, and when eliminated, can show significant savings. Three scenarios are analyzed for sizing purposes: (1) batteries sized per building based upon evening out the peak of the demand day, (2) sized to match the existing building peak, and (3) sized for 4-hour standby power instead of a gas generator. The results are summarized as follows:

Table 47. Battery Charging: Demand Day–Estimated Savings

Battery Charging–Sized Based on Demand Day Needs									
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)
623 Skytop Data	111	0	681	578	49.0	588	$6,693	$175,469	26
621 Skytop Data	284	1055	913	649	231.7	2780	$31,640	$446,611	14
Tennity	30	111	341	313	27.8	334	$3,796	$47,072	12
Goldstein	97	363	479	388	90.7	1088	$12,380	$153,534	12
640 Skytop	57	213	210	157	48.8	586	$6,664	$90,358	14
Ski Lodge	10	41	40	30	7.3	87	$995	$16,202	16
480 Winding Ridge	5	19	20	16	4.2	50	$568	$8,034	14
460 Winding Ridge	8	29	31	24	6.4	77	$877	$12,136	14
Total	**603**	**1831**	**2715**	**2154**	**466**	**5590**	**$63,614**	**$949,416**	**15**

Table 48. Battery Charging: Existing Peaks–Estimated Savings

Battery Charging–Sized to Match Existing Peaks									
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)
623 Skytop Data	329	622	681	526	54.9	659	$7,502	$518,508	69
621 Skytop Data	326	1213	913	610	249.1	2989	$34,014	$513,386	15
Tennity	66	246	341	299	49.4	593	$6,750	$104,287	15
Goldstein	133	496	479	355	118.6	1423	$16,192	$209,931	13
640 Skytop	91	320	210	130	56.5	678	$7,710	$142,585	18
Ski Lodge	27	57	40	26	7.7	93	$1,054	$42,181	40
480 Winding Ridge	0	0	20	20	0.0	0	$0	$0	--
460 Winding Ridge	0	0	31	31	0.0	0	$0	$0	--
Total	**972**	**2954**	**2715**	**1997**	**536**	**6434**	**$73,222**	**$1,530,877**	**21**

Table 49. Battery Charging: Emergency Generation–Estimated Savings

Battery Charging–Sized for Emergency Generation												
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)
623 Skytop Data	370	1481	379	$150	185	$10	4393	99%	$583,281	$166,652	$416,629	2988
621 Skytop Data	529	2116	542	$214	265	$15	6275	99%	$833,175	$238,050	$595,125	2997
Tennity	204	817	209	$83	102	$6	2424	99%	$321,847	$91,956	$229,891	3000
Goldstein	287	1150	294	$116	144	$8	3409	99%	$452,616	$129,319	$323,297	2991
640 Skytop	126	504	129	$51	63	$3	1496	99%	$198,632	$56,752	$141,880	2988
Ski Lodge	24	96	25	$10	12	$1	284	99%	$37,712	$10,775	$26,937	2979
480 Winding Ridge	12	49	13	$5	6	$1	145	99%	$19,258	$5,502	$13,755	3127
460 Winding Ridge	18	74	19	$7	9	$1	219	99%	$29,081	$8,309	$20,772	3127
Total	**1572**	**6287**	**1609**	**$635**	**786**	**$45**	**18643**	99%	**$2,475,602**	**$707,315**	**$1,768,287**	**2996**

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 Community Distributed Generator 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 Value of Distributed Energy Resources 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 South Campus site at Syracuse University is located in two townships: a portion in the City of Syracuse and a portion in the Town of Onondaga. Therefore, building permit applications will need to be submitted to both AHJs, and can be expected to take between two to six weeks, depending on the available bandwidth of the building departments. Some extra coordination may be required to ensure that the concerns of both AHJs are adequately addressed; however, the only item that crosses townships is distribution piping, so significant delay is unlikely.

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. This form was already filled out and submitted for the construction of the test well (see appendix). Due to the size of the wellfield, the site will also likely have a Stormwater Pollution Protection Plan. However, all the site trenching will be backfilled and graded, and returned back to their 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 photovoltaics 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 and roadways and most of the surrounding infrastructure are owned and maintained by Syracuse University. Therefore, right-of-way permits will not be required. However, there are a number of utility easements including an easement for overhead electrical transmission running above the proposed wellfield. No wells are proposed for installation within the easement, but several geothermal distribution lines will cross the easement. The utility rights franchise agreement will need to be consulted, along with the plans approved by the town engineering department; however, it is not unusual for other site utilities to cross utility easements and it is not expected to pose a problem. Additionally, the existing transmission lines are overhead and are unlikely to require the use of the underground space in the easement.

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 Syracuse University 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 Analysis

8.1 Site Considerations

This study encompassed eight buildings on the Syracuse University South Campus as previously described. The building cluster contains many different building types, including office, food service, data center, ice rink, and community 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 wellfields required for the buildings to operate.

Syracuse University is the only member in the proposed community and is the sole arbiter of this project moving forward. This 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 should include the wellfield and distribution network, bringing the piping into the data center. Upgrades to the data center and 621 Skytop should follow, since the wellfield pumps are located in the data center, and the large cooling loads are necessary to offset heat loads in the district system. The 621 Skytop building, which shares HVAC systems with the data center, is old and in need of renovation. It will provide the greatest energy savings from the onset.

In the next phase, the upgrades should be performed at Tennity. The data center heavily skews the thermal network to cooling, and Tennity requires the most heat, thanks to the desiccant dehumidification system and the ice rink (which is not connected to the geothermal system). Tennity can be paired with the apartments at Winding Ridge and the Ski Lodge, as they have older systems in need of replacement and are relatively easily implemented once the wellfield is in place.

Lastly, 640 Skytop and Goldstein remain. Goldstein should be the last installed because it has a significant cooling load due to the restaurant and community spaces. A second phase of wells could be installed with these buildings as well.

The site lends itself well to a community geothermal system. Although primarily located in the city of Syracuse, it is relatively flat with a fair amount of open land as well as parking lots. However, as with most communities, there are underground utilities throughout, which requires careful coordination during installation, though wells can be installed around them as feasible. The proposed location of the wellfield has no utilities and has ample room for both this community wellfield and future capacity. The smaller lawn or parking areas can be utilized as locations for satellite wellfields as well. 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. In fact, there are a large number of heating-dominated residences on campus, which would pair nicely with the cooling load of the data center and may not even require additional wells. If needed, additional satellite wellfields can tie directly into the geothermal loop.

8.2 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, with some water-to-air units in select locations. Generally, high-efficient equipment was selected and was 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 wellfield is not well balanced. In fact, the data center cooling is the vast majority of the load on the loop. To maintain a better balance and to achieve longevity in the wellfield operation, the existing cooling tower at the data center is recommended to remain, providing additional cooling to the loop.

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 photovoltaics 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.

8.3 Analytical Methods

Every building was modeled utilizing the eQuest 3.65 simulation program, and simulated for a period of one year, with Syracuse NY TMY2 Typical Meteorological Year 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 90.1-2016 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 United States Environmental Protection Agency, United States Department of Energy, NYSERDA, PV Watts, ASHRAE standards, and others as noted.

A test well was drilled during the study to determine the thermal properties of the earth 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 Syracuse University, 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.

8.4 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. The only exception is 621 Skytop, which has a constant volume dual duct system that is in need of replacement.

With that in mind, all of the buildings have an existing heating loop of some kind for unit heaters and/or radiation. To maintain similar systems, heat generation is required; once there is a heat pump in place, it makes sense to utilize it for cooling as well. In Goldstein, where there are already water-to-air water source heat pumps, they are replaced directly with ground source heat pump units. Water-to-air heat pumps were considered and evaluated for Tennity, Ski Lodge, and 621 Skytop, but ultimately, the hot water/chilled water systems were more 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. The campus expressed uneasiness with this equipment, and 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 efficient 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 function well in the Syracuse 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 commercially viable, so a boiler and storage tank system is required. However, this takes up a fair amount of floor space. Because of the cooling-dominated nature of the wellfield loop, GSHP domestic water heaters have been recommended for the buildings. However, until a more practical storage-type unit becomes available, the buildings may be better served with gas storage water heaters, and the cooling load balanced with alternative heat sources (i.e., additional buildings).

Phasing may also be a challenge within buildings to minimize disruption to the building occupants. The heat pumps require the floor space that the boilers are currently occupying for installation. Where possible, the proposed main heat pumps will swap in for the existing equipment, but in many cases, the air distribution systems need to be replaced, as they won't function with the geothermal system without upgrades.

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 functions somewhat as additional wells by tempering water temperatures in the loop.

8.5 Business Model

Since Syracuse University 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.

8.6 System Impact

The difference in the number of geothermal wells required in the individual building scenario in contrast to the district wellfield is great: 315 versus 210. However, much of the initial cost savings of the community well system is eliminated due to the infrastructure required to connect the buildings. The energy and carbon savings is improved in the district energy system, although not by a great amount, saving 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 makes up the majority of the difference between the individual system and the community system, should the project be awarded this incentive. This is a competitive incentive and is not guaranteed to be awarded for this project. 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 50. Options Summary

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	$4,918,071	$0	**$4,918,071**	$72,218	$576,589	**$648,807**	**4,258,576**	($17,310,608)
Code-Compliant System: Individual building heat pumps	$17,719,877	$789,601	**$16,930,276**	$57,679	$567,206	**$624,885**	**2,445,722**	($30,466,790)
Proposed System: Community heat pumps	$17,628,502	$5,201,701	**$12,426,801**	$58,127	$536,322	**$594,449**	**2,319,039**	($24,376,589)

Table 51. Savings over Existing Systems

Options Savings vs. Baseline									
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	($12,012,205)	-244%	$23,922	4%	502	1,812,853	43%	$13,156,182	-76%
Proposed System: Community heat pumps	($7,508,730)	-153%	$54,358	9%	138	1,939,536	46%	$7,065,981	-41%

Table 52. Savings over Code-Compliant System

Comparison of Heat Pump Systems vs. 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	$4,503,475	27%	$30,436	5%	148	126,683	5%	$6,090,201	-25%

8.7 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 Syracuse University 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 Syracuse University to their goal of carbon-neutrality by 2040.

Appendix A. Supplemental Information

A.1 Project Contacts

A.1.1 Site Owner

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A.2 Modeling Program Outputs

A.2.1 Baseline Models

A.2.1.1 623 Skytop Data Center

623 Skytop Data DOE-2.3-50h 7/16/2022 16:23:05 BDL RUN 3

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	33509.	0.	2709998.	0.	394611.	0.	40936.	46403.	0.	0.	0.	0.	3225477.
FM1 NATURAL-GAS THERM	0.	0.	0.	2441.	0.	0.	0.	0.	0.	0.	0.	0.	2441.

A.2.1.2 621 Skytop Office Building

621 Skytop Office DOE-2.3-50h 7/16/2022 17:41:19 BDL RUN 3

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	297226.	0.	502912.	0.	158876.	1043.	44297.	699979.	0.	0.	0.	5682.	1710014.
FM1 NATURAL-GAS THERM	0.	0.	0.	88789.	0.	0.	0.	0.	0.	0.	1175.	0.	89963.

A.2.1.3 Tennity Ice Skating Pavilion

Tennity Ice Rink DOE-2.2-47h2 7/16/2022 22:28:33 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	410217.	0.	34850.	12291.	848137.	24170.	233513.	80400.	0.	0.	0.	0.	1643578.
FM1 NATURAL-GAS THERM	0.	0.	0.	11469.	12054.	0.	0.	0.	0.	0.	5673.	0.	29196.

A.2.1.4 Goldstein Student Center

Goldstein Student Center DOE-2.3-50h 7/17/2022 11:18:32 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	249336.	0.	480809.	19581.	157231.	2440.	79018.	199539.	0.	0.	0.	3223.	1191176.
FM1 NATURAL-GAS THERM	0.	0.	11522.	34799.	0.	0.	0.	0.	0.	0.	7430.	0.	53750.

A.2.1.5 Skytop Office Building

640 Skytop Office DOE-2.3-50h 7/17/2022 17:05:59 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	99969.	0.	131699.	1000.	38248.	0.	1773.	9804.	0.	0.	0.	3369.	285863.
FM1 NATURAL-GAS THERM	0.	0.	2214.	10480.	0.	0.	0.	0.	0.	0.	601.	0.	13295.

A.2.1.6 Ski Lodge

SkiLodge DOE-2.3-50h 12/16/2021 1:00:51 BDL RUN 5

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	10473.	0.	2808.	0.	1414.	0.	2465.	4472.	0.	0.	0.	0.	21632.
FM1 NATURAL-GAS THERM	0.	0.	367.	10112.	0.	0.	0.	0.	0.	0.	266.	0.	10745.

A.2.1.7 480 Winding Ridge

480 Winding Ridge DOE-2.3-50h 12/16/2021 1:27:08 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	11154.	0.	18679.	42893.	0.	0.	0.	0.	0.	0.	7822.	4254.	84801.
FM1 NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

A.2.1.8 460 Winding Ridge Apartments

460 Winding Ridge DOE-2.3-50h 12/16/2021 1:29:58 BDL RUN 9

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	16730.	0.	28019.	66331.	0.	0.	0.	0.	0.	0.	11726.	6381.	129187.
FM1	NATURAL-GAS													
	THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

A.2.2 Proposed Model

A.2.2.1 623 Skytop Data Center

623 Skytop Data DOE-2.3-50h 7/22/2022 6:46:47 BDL RUN 11

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	33509.	0.	2709998.	16212.	374154.	9992.	62363.	46402.	0.	0.	0.	0.	3252652.
FM1	NATURAL-GAS													
	THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

With Cooling Tower

623 Skytop Data DOE-2.3-50h 7/22/2022 6:47:06 BDL RUN 11

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	33509.	0.	2709998.	16419.	313992.	0.	57706.	46402.	0.	0.	0.	0.	3178046.
FM1	NATURAL-GAS													
	THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Without Cooling Tower

A.2.2.2 621 Skytop Office Building

621 Skytop Office DOE-2.3-50h 7/22/2022 13:43:43 BDL RUN 6

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	297226.	0.	502912.	825250.	100198.	0.	54656.	212319.	0.	0.	34139.	5682.	2032382.
FM1 NATURAL-GAS													
THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

A.2.2.3 Tennity Ice Skating Pavilion

Tennity Ice Rink DOE-2.2-47h2 7/22/2022 15:07:27 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	410217.	0.	34850.	109523.	906335.	24979.	278886.	75703.	0.	0.	122266.	0.	1962757.
FM1 NATURAL-GAS													
THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

A.2.2.4 Goldstein Student Center

Goldstein Student Center DOE-2.3-50h 7/22/2022 14:16:56 BDL RUN 10

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	249336.	0.	480809.	279830.	111367.	0.	120448.	136311.	0.	0.	186924.	3223.	1568248.
FM1 NATURAL-GAS													
THERM	0.	0.	11522.	0.	0.	0.	0.	0.	0.	0.	0.	0.	11522.

A.2.2.5 Skytop Office Building

640 Skytop Office DOE-2.3-50h 7/22/2022 13:59:55 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	99969.	0.	147605.	108032.	20286.	0.	19933.	8605.	0.	0.	17277.	3369.	425076.
FM1 NATURAL-GAS													
THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

A.2.2.6 Ski Lodge

SkiLodge DOE-2.3-50h 7/22/2022 14:40:52 BDL RUN 12

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	10473.	0.	2808.	43870.	260.	0.	3678.	3450.	0.	0.	1557.	0.	66097.
FM1	NATURAL-GAS THERM	0.	0.	367.	0.	0.	0.	0.	0.	0.	0.	0.	0.	367.

A.2.2.7 480 Winding Ridge

480 Winding Ridge DOE-2.3-50h 7/22/2022 13:33:46 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	11154.	0.	18679.	10924.	1479.	0.	4332.	2084.	0.	0.	4663.	4254.	57568.
FM1	NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

A.2.2.8 460 Winding Ridge Apartments

460 Winding Ridge DOE-2.3-50h 7/22/2022 13:25:46 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	16730.	0.	28019.	17064.	2642.	0.	6868.	3538.	0.	0.	7010.	6381.	88251.
FM1	NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

A.2.5 Code-Compliant Model

A.2.5.1 623 Skytop Data Center

623 Skytop Data DOE-2.3-50h 7/22/2022 6:47:38 BDL RUN 12

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	33509.	0.	2709998.	27409.	561579.	10606.	63098.	46402.	0.	0.	0.	0.	3452622.
FM1	NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

With Cooling Tower

623 Skytop Data DOE-2.3-50h 7/22/2022 6:47:59 BDL RUN 12

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	33509.	0.	2709998.	27908.	470095.	0.	58798.	46402.	0.	0.	0.	0.	3346730.
FM1 NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Without Cooling Tower

A.2.5.2 621 Skytop Office Building

621 Skytop Office DOE-2.3-50h 7/22/2022 13:43:43 BDL RUN 6

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	297226.	0.	502912.	825250.	100198.	0.	54656.	212319.	0.	0.	34139.	5682.	2032382.
FM1 NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

A.2.5.3 Tennity Ice Skating Pavilion

Tennity Ice Rink DOE-2.2-47h2 7/22/2022 15:07:36 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	410217.	0.	34850.	147368.	918859.	24979.	305207.	75703.	0.	0.	125584.	0.	2042767.
FM1 NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

A.2.5.4 Goldstein Student Center

Goldstein Student Center DOE-2.3-50h 7/22/2022 14:18:44 BDL RUN 10

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	249336.	0.	480809.	357454.	100787.	0.	155356.	136304.	0.	0.	216832.	3223.	1700100.
FM1 NATURAL-GAS THERM	0.	0.	11522.	0.	0.	0.	0.	0.	0.	0.	0.	0.	11522.

A.2.5.5 Skytop Office Building

640 Skytop Office — DOE-2.3-50h 7/22/2022 14:01:27 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	99969.	0.	150187.	142047.	29066.	0.	22959.	8605.	0.	0.	20041.	3369.	476243.
FM1	NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

A.2.5.6 Ski Lodge

SkiLodge — DOE-2.3-50h 7/22/2022 14:41:27 BDL RUN 12

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	10473.	0.	2808.	49701.	330.	0.	4512.	3450.	0.	0.	1684.	0.	72958.
FM1	NATURAL-GAS THERM	0.	0.	367.	0.	0.	0.	0.	0.	0.	0.	0.	0.	367.

A.2.5.7 480 Winding Ridge

480 Winding Ridge — DOE-2.3-50h 7/22/2022 13:34:04 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	11154.	0.	18679.	12172.	2821.	0.	7969.	2084.	0.	0.	4663.	4254.	63795.
FM1	NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

A.2.5.8 460 Winding Ridge Apartments

460 Winding Ridge — DOE-2.3-50h 7/22/2022 13:26:20 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	16730.	0.	28019.	18986.	5040.	0.	12339.	3538.	0.	0.	7010.	6381.	98043.
FM1	NATURAL-GAS THERM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

A.3 Test Well Results

NOTHNAGLE DRILLING, INC.

1821 Scottsville-Mumford Road
Scottsville, New York 14546
(585) 538-2328
FAX(585) 538-2357
www.nothnagledrilling.com
Well Completion Report

Job Location: Syracuse University
161 Farm Acre Rd.
Syracuse, NY 13210

Contact: Jason Plumpton
Phone: 315-447-0916

Customer: M/E Engineering, P.C.
Suite 320, 60 Lakefront Blvd.
Buffalo, NY 14202

Contact: Melanie G. Stachowiak, PE
Phone No.: 716-845-5092
Email Address: mgstachowiak@meengineering.com

Well Coordinates/Number: Test Well

Start Well Date 3/15/22 **Finished Well Date** 3/16/22 **Driller(s)** Duane Saunders

Hole Size: 5.75" **Rig #** VD-1 **Pipe Size** 1.25" loop **Material** HDPE SR11

Overburden Depth:	61' **Description:** Silt and sand with some layers of weathered shale
Casing Depth:	64' **Total Casing Used:** 66'
Description of Rock:	64'-400' Gray shale
	125' 2 gpm water zone
	350' 2-3 gpm water zone
Static Water Level:	

Grouting Material and Conductivity: Baroid Max Yield TCM/HP 1.20 btu/hour ft.-F

Remarks: Loop spacers were placed approx. every 10' on loop.

Ground Loop Design
Thermal Conductivity Report - 4/1/2022

Project Name:	**Syracuse University Thermal Conductivity Test**		
Project Address:	161 Farm Acre Road		
City:	Syracuse	**State:** NY	**Zip:** 13210
Prepared By:	Bob Dowd		
Email:	redowd1862@gmail.com	**Phone:**	315-246-8724
Drill Date	3/16/2022		
TC Test Date(s)	3/29/2022	>>	3/31/2022
Client Name:	**Nothnagle Drilling, Inc.**		
Address Line 1:	1821 Scottsville-Mumford Road		
Address Line 2:			
City:	Scottsville	**Phone:**	585-538-2328
State:	NY	**Fax:**	595-538-2357
Zip:	14546	**Email:**	jmt@nothnagledrilling.com

Calculation Results

Thermal Conductivity (Btu/(h*ft*°F)) :	**1.54**	
Thermal Diffusivity (est.) (ft^2/day) :	**1.02**	
Average Heat Flux (W/ft) :	**18.6**	
BH Thermal Resist (BTR) (h*ft*°F/Btu) :	**0.19**	
Average Flow Rate (gpm) :	**8.93**	
Test Duration (hr) :	**36**	
Calculation Interval :	**12.0 - 48.0 Hours**	

Borehole Input Parameters

Undisturbed Ground Temperature (°F) :	**52.0**	(User-Estimated)
Depth (ft) :	**400.0**	
Borehole Diameter (in) :	**5.75**	
Pipe Size:	**1 1/4 in. (32 mm)**	
Grout Thermal Conductivity (Btu/(h*ft*°F)) :	**1.20**	
Drilling Method :	**Standard**	
Drilling Time (hr) :	**8.0**	

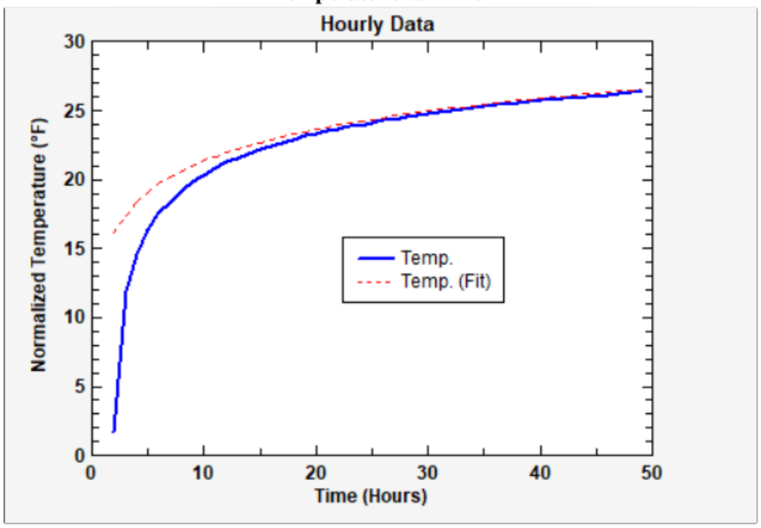
Diffusivity Input Parameters

Soil/Rock Specific Heat - Dry (Btu/(°F*lbm)) :	**N/A**
Soil/Rock Density - Dry (lb/ft^3) :	**N/A**
Moisture (0-100) (%) :	**N/A**

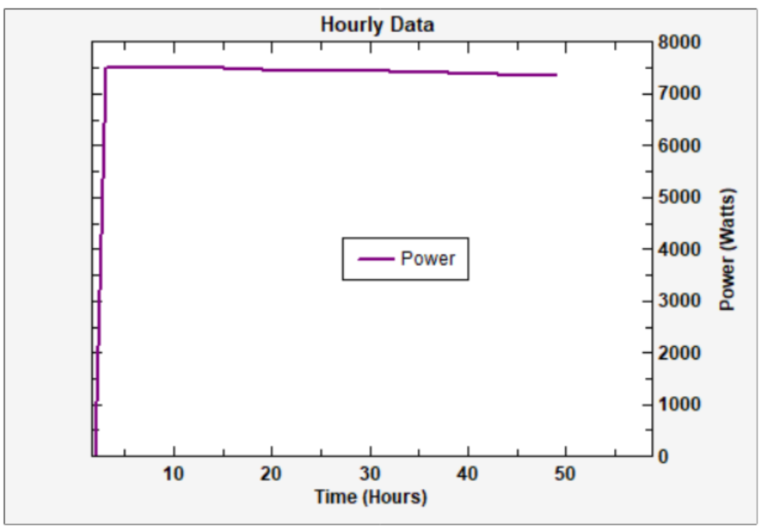
Flow Rate Input Parameters

TC Unit Model Name	**GeoCube Standard**

Temperature vs Time

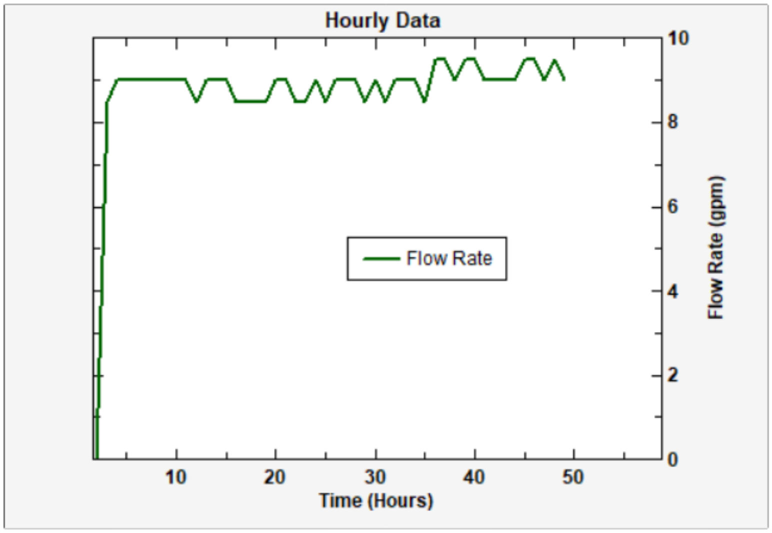


Power vs Time



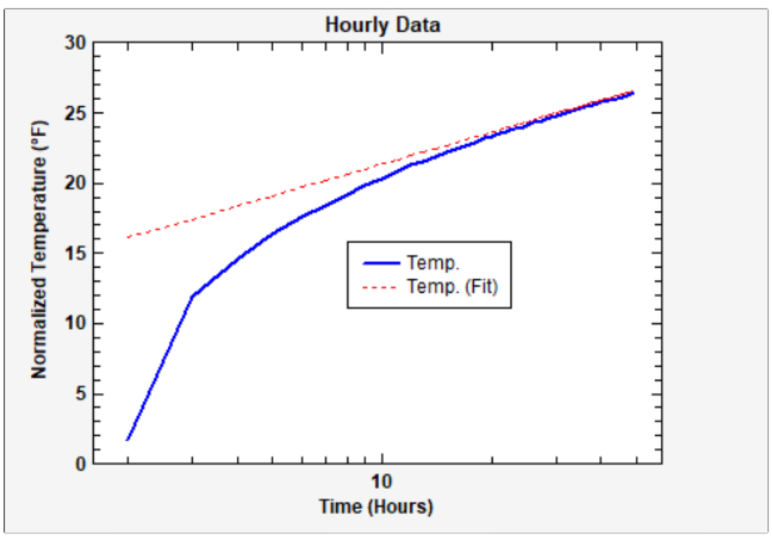
Average Power 7429.5 Watts

Flow Rate vs Time



Average Flow Rate 8.93

Temperature vs ln(Time)



Slope :	**3.27**
Calculation Interval :	**12.0 - 48.0 Hours**

Data Quality

		Threshold			Threshold
Power Standard Deviation :	**Pass**	**0.50 %**	Flow Rate :	**Pass**	**3.60 %**
Power Variation :	**Pass**	**1.25 %**	Slope Stability :	**Pass**	**3.00 %**
Temperature :	**Pass**	**0.30 %**	Water Flow Test :	**Pass**	**1.25 %**

Comments

Straight forward test.

Thermal Conductivity Test Overview

The thermal conductivity, or thermal response, test is a way to determine ground thermal properties that are critical for ground source heat pump system design. The test is performed by injecting a known and constant heat power into a borehole heat exchanger and then measuring the temperature response. A competent test can provide the undisturbed formation ground temperature, the calculated thermal conductivity, the calculated borehole thermal resistance and an estimate of the thermal diffusivity. These values, critical for the optimal design of a geothermal system, can be used in a geothermal design program to design an optimized, cost effective system.

Undisturbed Ground Temperature Determination

The undisturbed ground temperature is the constant temperature of the formation. Typically, this temperature is measured before starting the active thermal conductivity test. The TC module automatically estimates this value from the first few temperature measurements collected via the TC test unit data logger. The organization that performs the test also has the option of manually estimating this value with temperature probes or the like. If the TC test is initiated too soon after the installation of the test bore, the undisturbed ground temperature may be inaccurate. In general, it is recommended that the testing company waits a minimum of 3-5 days after installing the borehole before initiating the test so as to ensure that the ground has returned to its native and undisturbed temperature state.

Thermal Conductivity Calculation

Because thermal conductivity cannot be measured directly, The Ground Loop Design Thermal Conductivity Module uses the line source heat transfer model to calculate the required results. The line source model, which assumes an infinitely thin heat source in a homogeneous medium, is very broadly-referenced in the published literature and is considered to be the standard analysis methodology. To analyze test data, the average temperature of the water entering and exiting the heat exchanger is plotted versus the natural log of time. Using regression analysis, a best-fit line is plotted to match the empirical data and the slope of the line is used to calculate the thermal conductivity of the formation. Typically, the data analysis procedure may be repeated several times for several different time intervals to ensure the closest fit between the empirical data and the derived best-fit line. In addition, approximately the first 10 hours of temperature data are not included in the analysis so as to ensure that the conductivity value is determined from steady state rather than transient heat conduction processes.

Borehole Thermal Resistance Calculation

The borehole thermal resistance cannot be measured directly but can be calculated from the recorded in-situ measurements. After determining the thermal conductivity, the resultant value can be used in the line-source equation to calculate the borehole thermal resistance. Note that the calculated borehole thermal resistance is representative of the entire test bore configuration including the pipe type, pipe spacing, grout resistance and borehole diameter, etc. The empirically derived borehole thermal resistance may be entered into a design program such as Ground Loop Design for final loopfield design assuming the parameters for the boreholes in the final installation are equivalent to those in the test bore. Details pertaining to the general equation used for the calculation can be found in the research literature (Mattison, et al., 2007 for example).

Thermal Diffusivity Estimation

Thermal Diffusivity may be estimated from a combination of the calculated thermal conductivity value (which is directly related to the diffusivity) in conjunction with estimates of the specific heat, density and moisture content of the test bore. The thermal diffusivity reflects the rate of conductive heat transfer in the soil and helps determine the impact of neighboring borehole interactions on the final geothermal loopfield design.

Test Procedure Recommendations

The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) offers a set of procedural recommendations for in-situ thermal conductivity/thermal response tests. These can be found in the ASHRAE 2007 HVAC Applications Handbook. Several of the key recommended procedures are as follows:

A) Time between test bore installation and start of TC test: A 5 day minimum wait time is recommended.

B) Undisturbed ground temperature measurement: The undisturbed ground temperature should be recorded prior to test start up.

C)Test Duration: Test duration typically should be for 48 hours or longer.

D) Power Quality: The power standard deviation should be equal to or less than 1.5% of the average power and the maximum power variation should be less than 10% of the average power. The average heat flux should fall within the 15 W/ft to 25 W/ft range to best simulate the expected peak loads in the borehole.

A.4 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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Oklahoma City, OK 73179
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Water Source HP
ANSI/AHRI/ASHRAE/ISO13256

LC1030
Rev. : 9/29/21

Tranquility® 22 Ultra High Efficiency (TZ) Series

Models TZH/V024 -060 60Hz - HFC 410A

The Tranquility® High Efficiency (TZ) Series offers high efficient two-stage operation in a simple cabinet design. The Tranquility® High Efficiency Series also offers options that allow for application flexibility. Available options include hot water generator, enhanced iGate® controls, coated air coils, extended range insulation, UltraQuiet package, vFlow® internal variable water flow, and internal secondary circulator.

Advantages of the High Efficiency TZ Series:

- Advanced Controls - iGate® communicating control provides advanced unit functionality and comprehensive configuration, monitoring and diagnostic capabilities through digital communication links with the variable-speed fan motor, variable-speed source pump (or modulating valve) and communicating thermostat or configuration/diagnostic tool
- Internal Variable Water Flow - Industry-first, Built-in vFlow® replaces a traditionally inefficient, external component of the geothermal system (water circulation) with an ultra-high-efficient, variable speed, internal water flow system consisting of an internal variable speed circulator or an internal modulating motorized water valve
- Sound absorbing glass fiber insulation
- Unique double isolation compressor mounting for quiet operation
- Insulated divider and separate compressor/air handler compartments
- Field convertible discharge air arrangement for horizontal units
- Variable speed ECM fan motor
- Eight safeties standard
- Extended range (20 to 120°F, -6.7 to 48.9°C) capable

Unit Size

Vertical Upflow Model		A Width	B Depth	C Height
024 - 030	in. cm	22.4 56.9	22.4 56.9	40.0 101.6
036 - 042	in. cm	22.4 56.9	25.4 64.5	45.0 114.3
048 - 060	in. cm	25.4 64.5	29.1 73.9	50.5 128.3

Horizontal Model		A Width	B Length	C Height
024 - 030	in cm	22.4 56.9	48.3 122.7	18.3 46.5
036 - 042	in. cm	22.4 56.9	53.1 134.9	21.0 53.3
048 - 060	in. cm	25.4 64.5	68.0 172.7	21.0 53.3

Physical Data

Model	024	030	036	042	048	060
Compressor (1 Each)	Scroll					
Factory Charge HFC-410A (oz)	51	48	54	70	80	80
ECM Fan Motor & Blower						
Fan Motor (hp)	1/2	1/2	1/2	3/4	3/4	1
Blower Wheel Size (dia x w) - (in)	9X7	9X7	9X8	9X8	10X10	11X10
Water Connection Size						
FPT(in)	3/4"	3/4"	3/4"	3/4"	1"	1"
Coax Volume (gallons)	0.323	0.323	0.738	0.89	0.738	0.939
HWG Connection Size						
FPT(in)	1/2"					
Vertical Upflow						
Air Coil Dimensions (h x w) - (in)	20 X 17.25	20 X 17.25	24 X 21.75	24 X 21.75	28.75 X 24	28.75 X 24
Standard Filter - 1" [25.4mm] Throwaway, qty (in)	20x20	20x20	24x24	24x24	28x28	28x28
Weight - Operating, (lbs)	216	224	249	260	315	330
Weight - Packaged, (lbs)	221	229	255	266	322	337
Horizontal						
Air Coil Dimensions (h x w) - (in)	16 X 22	16 X 22	20 X 25	20 X 25	20 X 35	20 X 35
Standard Filter - 1" [25.4mm] Throwaway, qty (in)	18x25	18x25	20x28 or 2-20x14	20x28 or 2-20x14	1-20x24, 1-20x14	1-20x24, 1-20x14
Weight - Operating, (lbs)	208	208	233	244	299	314
Weight - Packaged, (lbs)	213	213	239	250	306	321

Tested To ASHRAE/AHRI/ISO 13256-1 English Units

Model	Water Loop Heat Pump				Ground Water Heat Pump				Ground Loop Heat Pump			
	Cooling 86°F		Heating 68°F		Cooling 59°F		Heating 50°F		Full Cool 77°F Part Cool 68°F		Full Heat 32°F Part Heat 41°F	
	Capacity Btuh	EER Btuh/W	Capacity Btuh	COP	Capacity Btuh	EER Btuh/W	Capacity Btuh	COP	Capacity Btuh	EER Btuh/W	Capacity Btuh	COP
TZ*024 Part	18,100	16.1	20,600	5.2	20,300	27.2	16,700	4.4	19,400	22.2	14,700	4.0
TZ*024 Full	23,700	14.3	28,000	4.6	26,500	21.7	23,000	4.1	24,600	16.0	17,800	3.6
TZ*030 Part	21,900	15.2	26,300	5.0	24,900	24.8	22,000	4.3	24,200	20.9	19,400	3.9
TZ*030 Full	28,500	14.0	35,800	4.6	32,300	20.7	30,000	4.2	29,900	15.7	23,800	3.6
TZ*036 Part	25,800	17.2	29,900	5.3	29,000	29.4	24,900	4.6	27,300	23.4	21,500	4.0
TZ*036 Full	34,300	15.1	42,000	4.6	38,200	22.3	35,100	4.3	35,200	16.7	27,300	3.6
TZ*042 Part	31,000	15.8	36,800	5.1	35,200	26.4	30,500	4.3	34,000	22.0	26,900	3.8
TZ*042 Full	41,100	14.3	50,200	4.6	46,300	21.3	42,300	4.1	43,100	16.1	33,300	3.4
TZ*048 Part	34,100	15.2	39,500	5.5	39,200	26.8	32,600	4.6	37,600	21.2	29,200	4.1
TZ*048 Full	45,900	14.0	53,800	4.9	51,800	20.9	45,000	4.4	48,100	15.5	35,600	3.7
TZ*060 Part	45,500	17.7	49,000	5.3	50,400	28.9	39,800	4.5	48,600	23.7	34,800	4.0
TZ*060 Full	61,700	15.7	67,500	4.8	68,000	22.7	55,400	4.3	63,200	17.3	43,700	3.6

Cooling capacities based upon 80.6°F DB, 66.2°F WB entering air temperature
Heating capacities based upon 68°F DB, 59°F WB entering air temperature

All rating based upon operation at lower voltage of dual voltage rated models
* Includes vertical and horizontal configurations

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Oklahoma City, OK 73179
Phone: 405-745-6000
climatemaster.com

LC1041
Rev.: 07/08/21

Tranquility® Rooftop (TRE) Series

Models TRE036 - 240 60Hz - HFC - 410A

The Rooftop (TRE) Series provides an economical solution for today's HVAC challenges. The TRE product line offers the option of introducing a fixed amount of outside air year-round or a modulating Economizer to provide free cooling when outdoor conditions are favorable. TRE units are designed for an extended range of source water temperatures, making it suitable for closed-loop, or ground source closed-loop systems. With high efficiency scroll compressors and belt drive motors, the TRE product line offers 13+ EER and 4+ COP. Also available is an optional Unitized Energy Recovery Ventilator for outside air.

Advantages of the Rooftop TRE Series:

- EarthPure® (HFC-410A) zero ozone depletion refrigerant
- Exceeds ASHRAE 90.1 efficiencies (40% better than standard rooftop units!)
- Galvanized steel construction and powder coat paint on all units
- Copeland Scroll compressors (dual circuited on sizes 096 and larger)
- Microprocessor controls standard (optional DXM and/or DDC controls)
- Bi-directional, balanced port expansion valve refrigerant metering device standard
- Extended range operation package standard
- Double wall construction for access doors and non-corrosive hardware
- Belt-drive blowers with various configurations for RPM/ESP settings
- High/low pressure switches and electronic condensate overflow sensor standard
- Eight safeties standard
- Handles up to 100% outside air when used with Rx ERV unit
- Optional ClimaDry® modulating dedicated dehumidification mode
- Curb options include knock down, welded, and vibration isolation

Unit Size

Model		W	D*	H
036 - 072	in.	43.2	80.1	39.4
	cm	109.7	203.5	100.1
096 - 144	in.	49.2	90.1	45.4
	cm	125.0	228.9	115.3
168 - 240	in.	87.1	90.1	50.6
	cm	221.2	228.9	128.5

* Does not include optional rain hood

Physical Data

Model	036	048	060	072	096	120	144	168	240
Compressor (qty)	Scroll (1)				Scroll (2)				
Factory Charge HFC-410A - (oz) [kg] per circuit	64 [1.81]	84 [2.38]	120 [3.40]	132 [3.74]	108 [3.06]	120 [3.4]	130 [3.69]	192 [5.44]	300 [8.50]
Blower Motor									
Motor Quantity	1								
Standard Motor (hp) [kW]	1 [.75]	1 [.75]	1 [.75]	1.5 [1.12]	2 [1.49]	3 [2.24]	3 [2.24]	3 [2.24]	5 [3.73]
Large Motor (hp) [kW]	N/A	1.5 [1.12]	1.5 [1.12]	2 [1.49]	3 [2.24]	5 [3.73]	5 [3.73]	5 [3.73]	7.5 [5.60]
Blower(s)									
Number of Blowers	1							2	
Blower Wheel Size (dia x w) - (in) [cm]	10 x 6 [25.4 x 15.2]		12 x 12 [30.5 x 30.5]		15 x 11 [38.1 x 38.1]		15 x 15 [38.1 x 38.1]	15 x 11 [38.1 x 38.1]	
V-belt size, Std drive	A29	A30	A32	AX33	B40	BX42	BX46	B39	BX40
Water Connection Size									
FPT (in) [cm]	3/4" [19.05]		1" [25.4]	1-1/4" [31.75]	1-1/2" [38.1]			2" [50.8]	
Coax Volume									
Volume (US Gallons) [liters]	0.61 [2.29]	0.77 [2.90]	1.11 [4.21]	1.30 [4.93]	1.69 [6.49]	2.29 [8.69]	2.68 [10.13]	3.83 [14.50]	4.77 [18.04]
Condensate Connection Size									
FPT (in)	1" [25.4]								
Air Coil Data									
Air Coil Total Face Area (ft²) [m²]	5 [.465]		7 [.65]		9.33 [.867]	10.5 [.975]		20 [1.86]	
Internal Secondary Pump/ClimaDry® Pump									
No. of Pumps	1								
Standard Motor (hp) [kW]	1/6 [.124]				1/2 [.373]			3/4 [.556]	1-1/2 [1.12]
Connection Size (in) [cm]	3/4" [19.05]		1" [25.4]		1-1/2" [38.1]				2" [1.86]
Hydronic Coil Data									
Air Coil Dimensions H x W (in) [cm]	32 x 20 [81.3 x 50.8]		32 x 28 [81.3 x 71.1]		38 x 32 [96.5 x 81.3]	38 x 36 [96.5 x 91.4]		76 x 36 [193.0 x 91.4]	
Air Coil Total Face Area (ft²) [m²]	4.44 [.413]		6.22 [.578]		8.44 [.784]	9.5 [.883]		19 [1.77]	
Air Coil Tube Size (in) [cm]	3/8 [0.953]								
Air Coil Fin Spacing (fpi) [fins per min]	11 [4.3]								
Air Coil Number of Rows	2								

Tested To ASHRAE/AHRI/ISO 13256-1 English Units

Model	Water Loop Heat Pump				Ground Water Heat Pump				Ground Loop Heat Pump			
	Cooling 86°F		Heating 68°F		Cooling 59°F		Heating 50°F		Cooling 77°F		Heating 32°F	
	Capacity BTUH	EER BTUH/W	Capacity BTUH	COP	Capacity BTUH	EER BTUH/W	Capacity BTUH	COP	Capacity BTUH	EER BTUH/W	Capacity BTUH	COP
TRE036	35,000	14.2	42,700	5.0	39,800	21.7	35,400	4.4	35,000	16.5	28,100	3.6
TRE048	48,500	14.4	59,700	4.7	54,800	21.1	48,500	4.1	50,000	16.0	37,800	3.4
TRE060	61,100	15.7	72,800	5.1	69,800	23.5	60,100	4.5	62,100	17.6	45,600	3.6
TRE072	71,000	15.0	88,500	5.0	79,000	23.0	72,000	4.4	71,000	16.2	55,000	3.6
TRE096	97,000	14.0	110,600	4.4	108,600	20.6	91,700	3.9	101,000	15.6	74,000	3.2
TRE120	122,500	13.9	149,400	4.4	135,000	20.6	122,700	3.9	129,000	15.6	98,000	3.2
TRE144	141,000	13.8	180,000	4.5	158,000	20.0	145,000	4.0	144,000	15.2	113,000	3.3
TRE168	175,000	15.0	206,700	5.0	187,000	20.9	168,000	4.5	177,500	16.5	129,500	3.7
TRE240	241,000	13.6	287,000	4.8	276,000	19.3	230,000	4.2	249,500	15.0	182,400	3.4

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RP966

A.5 Cost Estimates

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

Budget Pricing Cost Estimate	
PROJECT NAME: SYRACUSE UNIVERSITY	
NYSERDA COMMUNITY HEAT PUMP PROGRAM	
M/E REFERENCE: 201362	DATE: 7/22/2022
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	**623 Skytop Data Center**			**$49,095**	**$178,640**	**$227,735**
5	Water-cooled chiller (250 ton)	1	LS	$34,275	$122,725	$157,000
6	Chiller primary pumps + VFD (7.5 HP)	2	LS	$7,410	$24,150	$63,120
7	Demolition	1	LS	$0	$7,615	$7,615
8						
9	**621 Skytop Office Building**			**$353,675**	**$875,555**	**$1,229,230**
10	Air-handling Unit - Dual Duct (76,000 cfm)	1	LS	$46,900	$134,000	$180,900
11	Air-handling Unit - CHW/Steam	1	EA	$9,975	$27,100	$37,075
12	Heat Recovery Unit	1	EA	$14,000	$39,200	$53,200
13	DX/Gas VAV Rooftop Unit	2	LS	$9,050	$22,900	$63,900
14	Air-cooled chiller (225 tons)	1	EA	$34,275	$122,725	$157,000
15	Steam Boilers (3000 mbh)	2	EA	$36,300	$67,000	$206,600
16	Heat Exchanger (1620 mbh)	1	EA	$16,000	$28,700	$44,700
17	Chilled Water Pump + VFD (40 HP)	1	EA	$15,400	$61,825	$77,225
18	Hot Water Distribution Pumps (1 1/2 HP)	2	EA	$2,488	$7,850	$20,675
19	Dual Duct Terminal Boxes	85	EA	$1,105	$2,150	$276,675
20	Steam Unit Heaters	5	EA	$1,925	$3,400	$26,625
21	A/C Units	2	EA	$6,525	$10,000	$33,050
22	Domestic Water Heaters	2	EA	$2,425	$7,650	$20,150
23	Demolition	1	LS	$0	$31,455	$31,455
24						
25	**Tennity Ice Skating Pavilion**			**$50,075**	**$165,981**	**$216,056**
26	VAV Rooftop Unit + Energy Recovery (4000 cfm)	1	EA	$11,900	$43,100	$55,000
27	Dessicant Dehumidifier (10,000 cfm)	1	EA	$20,525	$81,425	$101,950
28	Heat Exchanger (100 mbh)	1	EA	$4,425	$8,600	$13,025
29	Gas Unit Heaters	3	EA	$1,675	$2,625	$12,900
30	Gas Furnaces	3	EA	$1,925	$3,625	$16,650
31	Domestic Water Heater	1	EA	$2,425	$7,650	$10,075
32	Demolition	1	LS	$0	$6,456	$6,456
33						

34	**Goldstein Student Center**			**$377,973**	**$840,838**	**$1,218,812**
35	Heat Pumps	52	EA	$3,735	$5,325	$471,120
36	Energy Recovery Units (~5000 cfm)	3	EA	$14,000	$39,200	$159,600
37	DX/Gas VAV Rooftop Unit	4	EA	$9,050	$22,900	$127,800
38	Boilers (1000 mbh)	2	EA	$21,875	$41,375	$126,500
39	Cooling Towers (515 gpm)	1	EA	$13,300	$33,600	$46,900
40	HW Loop Pumps (10 HP)	2	EA	$9,010	$29,825	$77,670
41	HP Loop Pumps (20 HP)	2	EA	$11,988	$42,300	$108,575
42	Boiler Pumps (1/3 HP)	2	EA	$829	$2,617	$6,892
43	Domestic Water Heater	2	EA	$2,425	$7,650	$20,150
44	Demolition	1	LS	$0	$73,605	$73,605
45						
46	**Skytop Office Building**			**$110,313**	**$325,693**	**$436,006**
47	Boilers (1200 mbh)	2	EA	$25,375	$45,438	$141,625
48	DX/HW Rooftop Units	4	EA	$10,400	$46,800	$228,800
49	Boiler Pumps (3/4 HP)	2	EA	$1,244	$3,925	$10,338
50	A/C Units	2	EA	$6,525	$10,000	$33,050
51	Domestic Water Heater	1	EA	$2,425	$7,650	$10,075
52	Demolition	1	LS	$0	$12,118	$12,118
53						
54	**Ski Lodge**			**$85,150**	**$127,104**	**$212,254**
55	DX A/C Units	4	EA	$6,525	$10,000	$66,100
56	Steam Unit Heaters	9	EA	$1,700	$2,475	$37,575
57	Steam Convectors	13	EA	$1,500	$1,000	$32,500
58	Steam Boiler (~400 mbh)	1	EA	$19,400	$29,200	$48,600
59	Gas Domestic Water Heater	2	EA	$2,425	$7,650	$20,150
60	Demolition	1	LS	$0	$7,329	$7,329
61						
62	**480 Winding Ridge Apartments**			**$6,835**	**$25,719**	**$32,553**
63	Electric Baseboard	276	LF	$10	$18	$7,866
64	Electric Water Heater	8	EA	$505	$1,950	$19,640
65	Demolition	1	LS	$0	$5,047	$5,047
66						
67	**460 Winding Ridge Apartments**			**$10,252**	**$38,578**	**$48,830**
68	Electric Baseboard	414	LF	$10	$18	$11,799
69	Electric Water Heater	12	EA	$505	$1,950	$29,460
70	Demolition	1	LS	$0	$7,571	$7,571
	BASELINE SYSTEM SUBTOTAL			**$1,043,367**	**$2,578,108**	**$3,621,475**
	Overhead (Labor x 10%)					$104,337
	Profit (Labor Incl. OH + Material x 10%)					$372,581
	Design Contingency (Subtotal+OHP x 10%)					$409,839
	Construction Contingency (Subtotal+OHP x 10%)					$409,839
	BASELINE SYSTEM TOTAL					**$4,918,071**

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: SYRACUSE UNIVERSITY	
NYSERDA COMMUNITY HEAT PUMP PROGRAM	
M/E REFERENCE: 201362	DATE: 7/22/2022
DIVISION: **HVAC**	BY: AES

ITEM	DESCRIPTION	QTY.	UNIT	LABOR COST	MATERIAL COST	TOTAL ITEM COST
PROPOSED SYSTEM: COMMUNITY GEOTHERMAL HEAT PUMPS						
1	**Campus System**			$3,087,810	$2,418,160	$5,505,970
2	Geothermal Wellfield (400 ft wells)	210	EA	$10,000	$5,000	$3,150,000
3	Wellfield Pumps + VFD (50 HP)	4	EA	$24,450	$49,150	$294,400
4	Campus Distribution Pumps + VFD (75 HP)	4	EA	$27,375	$67,200	$378,300
5	Distribution Piping + Earthwork	9000	LF	$44	$34	$696,780
6	Well piping	12000	LF	$20	$11	$372,840
7	Piping manifold	1	LS	$25,440	$74,800	$100,240
8	Repaving	171	kSF	$510	$2,200	$463,410
9	Controls	1	LS	$30,000	$20,000	$50,000
10						
11	**623 Skytop Data Center**			$233,545	$623,465	$857,010
12	Modular water-to-water heat pump (50 ton)	5	LS	$32,700	$79,125	$559,125
13	GSHP Loop pumps + VFD (10 HP)	2	LS	$10,975	$35,850	$93,650
14	CHW primary pumps + VFD (7.5 HP)	2	LS	$9,010	$29,825	$77,670
15	Electrical Upgrade	1	LS	$30,075	$88,875	$118,950
16	Demolition	1	LS	$0	$7,615	$7,615
17						
18	**621 Skytop Office Building**			$419,910	$1,216,460	$1,636,369
19	VAV air-handling unit (76,000 cfm)	1	EA	$46,900	$134,000	$180,900
20	VAV air-handling unit (small)	3	EA	$9,975	$27,100	$111,225
21	Heat recovery unit	1	EA	$14,000	$39,200	$53,200
22	Modular water-to-water heat pump (50 ton)	5	EA	$32,700	$79,125	$559,125
23	GSHP Loop Pumps + VFD (10 HP)	2	EA	$10,975	$35,850	$93,650
24	CHW primary pumps + VFD (7.5 HP)	2	EA	$9,010	$29,825	$77,670
25	HW primary pumps + VFD (5 HP)	2	EA	$6,240	$21,150	$54,780
26	Chilled Water Distribution Pumps + VFD (40 HP)	2	EA	$15,400	$61,825	$154,450
27	Hot Water Distribution Pumps + VFD (25 HP)	2	EA	$13,375	$48,625	$124,000
28	VAV Terminal Boxes	1	EA	$1,112	$2,325	$3,437
29	HW Unit Heaters	2	EA	$1,925	$3,400	$10,650
30	A/C Units (CHW)	3	EA	$2,600	$5,125	$23,175
31	Water-to-Water Heat Pump Water Heater (5 ton)	1	EA	$8,663	$14,555	$23,217
32	DHW Storage Tank	1	EA	$1,010	$4,525	$5,535
33	Electrical Upgrade	1	LS	$33,150	$96,750	$129,900
34	Demolition	1	LS	$0	$31,455	$31,455
35						
36	**Tennity Ice Skating Pavilion**			$272,262	$682,762	$955,024
37	CHW/HW VAV RTU + Energy Recovery (4000 cfm)	1	EA	$11,900	$33,000	$44,900

38	Dessicant Dehumidifier (10,000 cfm)	1	EA	$22,050	$84,400	$106,450
39	Modular water-to-water heat pump (50 ton)	3	EA	$32,700	$79,125	$335,475
40	GSHP Loop Pumps + VFD (5 HP)	2	EA	$6,240	$21,150	$54,780
41	HW primary pumps + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
42	Hot Water Distribution Pumps + VFD (7.5 HP)	2	EA	$7,410	$24,150	$63,120
43	CHW Pumps + VFD (1 HP)	2	EA	$1,863	$5,842	$15,410
44	HW Unit Heaters	3	EA	$1,925	$3,400	$15,975
45	HW Furnaces	3	EA	$2,325	$4,300	$19,875
46	Water-to-Water Heat Pump Water Heater (10 ton)	2	EA	$9,525	$26,344	$71,738
47	DHW Storage Tank	2	EA	$1,010	$4,525	$11,070
48	Piping (interior) + insulation	1200	LF	$33	$36	$83,220
49	Electrical Upgrade	1	LS	$24,525	$55,800	$80,325
50	Demolition	1	LS	$0	$6,456	$6,456
51						
52	**Goldstein Student Center**			**$522,372**	**$1,153,791**	**$1,676,163**
53	Heat Pumps	52	EA	$4,669	$6,656	$588,900
54	Energy Recovery Units (~5000 cfm)	2	EA	$14,000	$39,200	$106,400
55	GSHP VAV AHU	1	EA	$15,150	$44,250	$59,400
56	Modular water-to-water heat pump (50 ton)	2	EA	$32,700	$79,125	$223,650
57	HW primary pumps + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
58	Hot Water Distribution Pumps + VFD (10 HP)	2	EA	$9,010	$29,825	$77,670
59	GSHP Loop Pumps + VFD (20 HP)	2	EA	$11,988	$42,300	$108,575
60	Water-to-Water Heat Pump Water Heater (20 ton)	2	EA	$19,050	$52,688	$143,475
61	DHW Storage Tank	2	EA	$1,010	$3,900	$9,820
62	Piping (interior) + insulation	790	LF	$60	$91	$119,488
63	Electrical Upgrade	1	LS	$30,075	$88,875	$118,950
64	Demolition	1	LS	$0	$73,605	$73,605
65						
66	**Skytop Office Building**			**$293,945**	**$903,679**	**$1,197,623**
67	Modular water-to-water heat pump (50 ton)	4	EA	$32,700	$79,125	$447,300
68	CHW/HW VAV RTU (~10,000 cfm)	4	EA	$14,500	$82,000	$386,000
69	CHW Primary Pumps + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
70	HW primary pumps + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
71	Chilled Water Distribution Pumps + VFD (7.5 HP)	2	EA	$7,410	$24,150	$63,120
72	GSHP Loop Pumps + VFD (5 HP)	2	EA	$6,240	$21,150	$54,780
73	A/C Units (CHW)	2	EA	$2,600	$5,125	$15,450
74	Water-to-Water Heat Pump Water Heater (10 ton)	1	EA	$9,525	$26,344	$35,869
75	DHW Storage Tank	1	EA	$1,010	$3,900	$4,910
76	Piping (interior) + insulation	590	LF	$33	$36	$40,917
77	Electrical Upgrade	1	LS	$20,250	$24,450	$44,700
78	Demolition	1	LS	$0	$12,118	$12,118
79						

80	**Ski Lodge**			**$163,542**	**$312,591**	**$476,133**
81	Fan Coils (3 tons)	3	EA	$3,375	$4,775	$24,450
82	Fan Coils (1.5 ton)	2	EA	$3,050	$2,650	$11,400
83	HW Unit Heaters	9	EA	$1,700	$2,475	$37,575
84	HW Convectors	13	EA	$1,500	$1,000	$32,500
85	Modular water-to-water heat pump (15 ton)	2	EA	$19,050	$52,688	$143,475
86	Water-to-Water Heat Pump Water Heater (10 ton)	1	EA	$9,525	$26,344	$35,869
87	DHW Storage Tank	1	EA	$1,010	$4,525	$5,535
88	Chilled Water Distribution Pumps + VFD (1 HP)	2	EA	$1,863	$5,842	$15,410
89	Hot Water Distribution Pumps + VFD (1 1/2 HP)	2	EA	$2,795	$8,763	$23,115
90	GSHP Loop Pumps + VFD (3 HP)	2	LS	$5,590	$17,525	$46,230
91	Piping (interior) + insulation	700	LF	$33	$36	$48,545
92	Electrical Upgrade	1	LS	$20,250	$24,450	$44,700
93	Demolition	1	LS	$0	$7,329	$7,329
94						
95	**480 Winding Ridge Apartments**			**$65,838**	**$150,402**	**$216,240**
96	Water-to-Air Heat Pumps with DHW (1.5 tons)	8	EA	$5,260	$12,141	$139,205
97	Ductwork Package	8	EA	$825	$2,250	$24,600
98	GSHP Pumps + VFD (1 1/2 HP)	2	EA	$2,795	$8,763	$23,115
99	Piping (interior) + insulation	350	LF	$33	$36	$24,273
100	Demolition	1	LS	$0	$5,047	$5,047
101						
102	**460 Winding Ridge Apartments**			**$96,998**	**$221,775**	**$318,773**
103	Water-to-Air Heat Pumps with DHW (1.5 tons)	12	EA	$5,260	$12,141	$208,808
104	Ductwork Package	12	EA	$825	$2,250	$36,900
105	GSHP Pumps (2 HP)	2	EA	$3,727	$11,683	$30,820
106	Piping (interior) + insulation	500	LF	$33	$36	$34,675
107	Demolition	1	LS	$0	$7,571	$7,571
	PROPOSED SYSTEM SUBTOTAL			**$5,156,220**	**$7,683,084**	**$12,839,304**
	Overhead (Labor x 10%)					$515,622
	Profit (Labor Incl. OH + Material x 10%)					$1,335,493
	Design Contingency (Subtotal+OHP x 10%)					$1,469,042
	Construction Contingency (Subtotal+OHP x 10%)					$1,469,042
	PROPOSED SYSTEM TOTAL					**$17,628,502**

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

ENGINEERING

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

Budget Pricing Cost Estimate	
PROJECT NAME: SYRACUSE UNIVERSITY	
NYSERDA COMMUNITY HEAT PUMP PROGRAM	
M/E REFERENCE: 201362	DATE: 7/22/2022
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**			**$3,719,140**	**$2,282,707**	**$6,001,846**
2	Geothermal Wellfield (400 ft wells)	315	EA	$10,000	$5,000	$4,725,000
3	621+623 Skytop: Wellfield Pumps + VFD (25 HP)	2	EA	$13,375	$48,625	$124,000
4	Tennity: Wellfield Pumps + VFD (7.5 HP)	2	EA	$7,410	$24,150	$63,120
5	Goldstein: Wellfield Pumps + VFD (20 HP)	2	EA	$11,988	$42,300	$108,575
6	640 Skytop: Wellfield Pumps + VFD (10 HP)	2	EA	$9,010	$29,825	$77,670
7	Ski Lodge: Wellfield Pumps + VFD (2 HP)	2	EA	$3,727	$11,683	$30,820
8	480 Winding: Wellfield Pumps + VFD (3/4 HP)	2	EA	$1,398	$4,381	$11,558
9	460 Winding: Wellfield Pumps + VFD (1 HP)	2	EA	$1,863	$5,842	$15,410
10	Piping manifolds	1	LS	$29,185	$88,500	$117,685
11	Grade restoration	255	kSF	$86	$198	$72,535
12	Well piping	18200	LF	$20	$11	$565,474
13	Controls	1	LS	$50,000	$40,000	$90,000
14						
15	**623 Skytop Data Center**			**$203,470**	**$455,465**	**$658,935**
16	Modular water-to-water heat pump (50 ton)	5	LS	$32,700	$63,300	$480,000
17	GSHP Loop pumps + VFD (10 HP)	2	LS	$10,975	$35,850	$93,650
18	CHW primary pumps + VFD (7.5 HP)	2	LS	$9,010	$29,825	$77,670
19	Demolition	1	LS	$0	$7,615	$7,615
20						

21	**621 Skytop Office Building**			**$439,409**	**$1,155,841**	**$1,595,250**
22	VAV air-handling unit (76,000 cfm)	1	EA	$46,900	$134,000	$180,900
23	VAV air-handling unit (small)	3	EA	$9,975	$27,100	$111,225
24	Heat recovery unit	1	EA	$14,000	$39,200	$53,200
25	Modular water-to-water heat pump (50 ton)	5	EA	$32,700	$63,300	$480,000
26	GSHP Loop Pumps + VFD (10 HP)	2	EA	$10,975	$35,850	$93,650
27	CHW primary pumps + VFD (7.5 HP)	2	EA	$9,010	$29,825	$77,670
28	HW primary pumps + VFD (5 HP)	2	EA	$6,240	$21,150	$54,780
29	Chilled Water Distribution Pumps + VFD (40 HP)	2	EA	$15,400	$61,825	$154,450
30	Hot Water Distribution Pumps + VFD (25 HP)	2	EA	$13,375	$48,625	$124,000
31	VAV Terminal Boxes	1	EA	$1,112	$2,325	$3,437
32	HW Unit Heaters	2	EA	$1,925	$3,400	$10,650
33	A/C Units (CHW)	3	EA	$2,600	$5,125	$23,175
34	Water-to-Water Heat Pump Water Heater (5 ton)	1	EA	$8,663	$11,644	$20,306
35	DHW Storage Tank	1	EA	$1,010	$4,525	$5,535
36	Piping (interior) + insulation	590	LF	$33	$36	$40,917
37	Electrical Upgrade	1	LS	$33,150	$96,750	$129,900
38	Demolition	1	LS	$0	$31,455	$31,455
39						
40	**Tennity Ice Skating Pavilion**			**$272,262**	**$624,749**	**$897,011**
41	CHW/HW VAV RTU + Energy Recovery (4000 cfm)	1	EA	$11,900	$33,000	$44,900
42	Dessicant Dehumidifier (10,000 cfm)	1	EA	$22,050	$84,400	$106,450
43	Modular water-to-water heat pump (50 ton)	3	EA	$32,700	$63,300	$288,000
44	GSHP Loop Pumps + VFD (5 HP)	2	EA	$6,240	$21,150	$54,780
45	HW primary pumps + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
46	Hot Water Distribution Pumps + VFD (7.5 HP)	2	EA	$7,410	$24,150	$63,120
47	CHW Pumps + VFD (1 HP)	2	EA	$1,863	$5,842	$15,410
48	HW Unit Heaters	3	EA	$1,925	$3,400	$15,975
49	HW Furnaces	3	EA	$2,325	$4,300	$19,875
50	Water-to-Water Heat Pump Water Heater (10 ton)	2	EA	$9,525	$21,075	$61,200
51	DHW Storage Tank	2	EA	$1,010	$4,525	$11,070
52	Piping (interior) + insulation	1200	LF	$33	$36	$83,220
53	Electrical Upgrade	1	LS	$24,525	$55,800	$80,325
54	Demolition	1	LS	$0	$6,456	$6,456
55						
56	**Goldstein Student Center**			**$522,372**	**$1,101,066**	**$1,623,438**
57	Heat Pumps	52	EA	$4,669	$6,656	$588,900
58	Energy Recovery Units (~5000 cfm)	2	EA	$14,000	$39,200	$106,400
59	GSHP VAV AHU	1	EA	$15,150	$44,250	$59,400
60	Modular water-to-water heat pump (50 ton)	2	EA	$32,700	$63,300	$192,000
61	HW primary pumps + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
62	Hot Water Distribution Pumps + VFD (10 HP)	2	EA	$9,010	$29,825	$77,670
63	GSHP Loop Pumps + VFD (20 HP)	2	EA	$11,988	$42,300	$108,575
64	Water-to-Water Heat Pump Water Heater (20 ton)	2	EA	$19,050	$42,150	$122,400
65	DHW Storage Tank	2	EA	$1,010	$3,900	$9,820
66	Piping (interior) + insulation	790	LF	$60	$91	$119,488
67	Electrical Upgrade	1	LS	$30,075	$88,875	$118,950
68	Demolition	1	LS	$0	$73,605	$73,605
69						

70	**Skytop Office Building**			**$303,120**	**$856,453**	**$1,159,573**
71	Modular water-to-water heat pump (50 ton)	4	EA	$32,700	$63,300	$384,000
72	CHW/HW VAV RTU (~10,000 cfm)	4	EA	$14,500	$82,000	$386,000
73	CHW Primary Pumps + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
74	HW primary pumps + VFD (3 HP)	2	EA	$5,590	$17,525	$46,230
75	Chilled Water Distribution Pumps + VFD (7.5 HP)	2	EA	$7,410	$24,150	$63,120
76	GSHP Pumps + VFD (10 HP)	2	EA	$9,010	$29,825	$77,670
77	A/C Units (CHW)	2	EA	$2,600	$5,125	$15,450
78	Water-to-Water Heat Pump Water Heater (10 ton)	1	EA	$9,525	$21,075	$30,600
79	DHW Storage Tank	1	EA	$1,010	$3,900	$4,910
80	Piping (interior) + insulation	700	LF	$33	$36	$48,545
81	Electrical Upgrade	1	LS	$20,250	$24,450	$44,700
82	Demolition	1	LS	$0	$12,118	$12,118
83						
84	**Ski Lodge**			**$151,817**	**$272,387**	**$424,204**
85	Fan Coils (3 tons)	3	EA	$3,375	$4,775	$24,450
86	Fan Coils (1.5 ton)	2	EA	$3,050	$2,650	$11,400
87	HW Unit Heaters	9	EA	$1,700	$2,475	$37,575
88	HW Convectors	13	EA	$1,500	$1,000	$32,500
89	Modular water-to-water heat pump (15 ton)	2	EA	$19,050	$42,150	$122,400
90	Water-to-Water Heat Pump Water Heater (10 ton)	1	EA	$9,525	$21,075	$30,600
91	DHW Storage Tank	1	EA	$1,010	$4,525	$5,535
92	Chilled Water Distribution Pumps + VFD (1 HP)	2	EA	$1,863	$5,842	$15,410
93	Hot Water Distribution Pumps + VFD (1 1/2 HP)	2	EA	$2,795	$8,763	$23,115
94	GSHP Loop Pumps + VFD (3 HP)	2	LS	$5,590	$17,525	$46,230
95	Piping (interior) + insulation	700	LF	$16	$17	$22,960
96	Electrical Upgrade	1	LS	$20,250	$24,450	$44,700
97	Demolition	1	LS	$0	$7,329	$7,329
98						
99	**480 Winding Ridge Apartments**			**$65,838**	**$130,977**	**$196,815**
100	Water-to-Air Heat Pumps with DHW (1.5 tons)	8	EA	$5,260	$9,713	$119,780
101	Ductwork Package	8	EA	$825	$2,250	$24,600
102	GSHP Pumps + VFD (1 1/2 HP)	2	EA	$2,795	$8,763	$23,115
103	Piping (interior) + insulation	350	LF	$33	$36	$24,273
104	Demolition	1	LS	$0	$5,047	$5,047
105						
106	**460 Winding Ridge Apartments**			**$96,998**	**$192,637**	**$289,636**
107	Water-to-Air Heat Pumps with DHW (1.5 tons)	12	EA	$5,260	$9,713	$179,670
108	Ductwork Package	12	EA	$825	$2,250	$36,900
109	GSHP Pumps (2 HP)	2	EA	$3,727	$11,683	$30,820
110	Piping (interior) + insulation	500	LF	$33	$36	$34,675
111	Demolition	1	LS	$0	$7,571	$7,571
	CODE-COMPLIANT SYSTEM SUBTOTAL			**$5,774,424**	**$7,072,282**	**$12,846,707**
	Overhead (Labor x 10%)					$577,442
	Profit (Labor Incl. OH + Material x 10%)					$1,342,415
	Design Contingency (Subtotal+OHP x 10%)					$1,476,656
	Construction Contingency (Subtotal+OHP x 10%)					$1,476,656
	CODE-COMPLIANT SYSTEM TOTAL					**$17,719,877**

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

ENGINEERING

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

Annual Maintenance Cost Estimate			
PROJECT NAME: SYRACUSE UNIVERSITY			
NYSERDA COMMUNITY HEAT PUMP PROGRAM			
M/E REFERENCE: 201362		DATE:	7/22/2022
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	**623 Skytop Data Center**			**$2,411**	**$111**	**$2,522**
5	Water-cooled chiller (250 ton)	1	LS	$2,275	$87	$2,362
6	Chiller primary pumps + VFD (7.5 HP)	2	LS	$68	$12	$160
7						
8	**621 Skytop Office Building**			**$11,268**	**$3,299**	**$14,567**
9	Air-handling Unit - Dual Duct (76,000 cfm)	1	LS	$187	$395	$582
10	Air-handling Unit - CHW/Steam	1	EA	$111	$375	$486
11	Heat Recovery Unit	1	EA	$187	$395	$582
12	DX/Gas VAV Rooftop Unit	2	LS	$164	$175	$678
13	Air-cooled chiller (225 tons)	1	EA	$880	$91	$971
14	Steam Boilers (3000 mbh)	2	EA	$1,525	$88	$3,226
15	Heat Exchanger (1620 mbh)	1	EA	$53	$23	$76
16	Chilled Water Pump + VFD (40 HP)	1	EA	$68	$12	$80
17	Hot Water Distribution Pumps (1 1/2 HP)	2	EA	$68	$12	$160
18	Dual Duct Terminal Boxes	85	EA	$64	$10	$6,290
19	Steam Unit Heaters	5	EA	$48	$48	$480
20	A/C Units	2	EA	$195	$126	$642
21	Domestic Water Heaters	2	EA	$99	$58	$314
22						
23	**Tennity Ice Skating Pavilion**			**$1,802**	**$948**	**$2,750**
24	VAV Rooftop Unit + Energy Recovery (4000 cfm)	1	EA	$164	$175	$339
25	Dessicant Dehumidifier (10,000 cfm)	1	EA	$187	$395	$582
26	Heat Exchanger (100 mbh)	1	EA	$53	$23	$76
27	Gas Unit Heaters	3	EA	$48	$48	$288
28	Gas Furnaces	3	EA	$385	$51	$1,308
29	Domestic Water Heater	1	EA	$99	$58	$157
30						

31	**Goldstein Student Center**			**$18,613**	**$9,997**	**$28,610**
32	Heat Pumps	52	EA	$243	$158	$20,852
33	Energy Recovery Units (~5000 cfm)	3	EA	$395	$187	$1,746
34	DX/Gas VAV Rooftop Unit	4	EA	$164	$175	$1,356
35	Boilers (1000 mbh)	2	EA	$1,425	$88	$3,026
36	Cooling Towers (515 gpm)	1	EA	$680	$156	$836
37	HW Loop Pumps (10 HP)	2	EA	$68	$12	$160
38	HP Loop Pumps (20 HP)	2	EA	$68	$12	$160
39	Boiler Pumps (1/3 HP)	2	EA	$68	$12	$160
40	Domestic Water Heater	2	EA	$99	$58	$314
41						
42	**Skytop Office Building**			**$4,269**	**$1,308**	**$5,577**
43	Boilers (1200 mbh)	2	EA	$1,525	$88	$3,226
44	DX/HW Rooftop Units	4	EA	$164	$175	$1,356
45	Boiler Pumps (3/4 HP)	2	EA	$68	$12	$160
46	A/C Units	2	EA	$164	$175	$678
47	Domestic Water Heater	1	EA	$99	$58	$157
48						
49	**Ski Lodge**			**$3,340**	**$1,362**	**$4,702**
50	DX A/C Units	4	EA	$164	$175	$1,356
51	Steam Unit Heaters	9	EA	$48	$48	$864
52	Steam Convectors	13	EA	$58	$2	$780
53	Steam Boiler (~400 mbh)	1	EA	$1,300	$88	$1,388
54	Gas Domestic Water Heater	2	EA	$99	$58	$314
55						
56	**480 Winding Ridge Apartments**			**$4,794**	**$602**	**$5,396**
57	Electric Baseboard	276	LF	$15	$1	$4,140
58	Electric Water Heater	8	EA	$99	$58	$1,256
59						
60	**460 Winding Ridge Apartments**			**$7,191**	**$903**	**$8,094**
61	Electric Baseboard	414	LF	$15	$1	$6,210
62	Electric Water Heater	12	EA	$99	$58	$1,884
	BASELINE SYSTEM TOTAL			**$53,688**	**$18,530**	**$72,218**

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: SYRACUSE UNIVERSITY			
NYSERDA COMMUNITY HEAT PUMP PROGRAM			
M/E REFERENCE: 201362		DATE:	7/22/2022
DIVISION:	**HVAC**	BY:	AES

ITEM	DESCRIPTION	QTY.	UNIT	LABOR COST	MATERIAL COST	TOTAL ITEM COST
PROPOSED SYSTEM: COMMUNITY GEOTHERMAL HEAT PUMPS						
1	**Campus System**			**$715**	**$158**	**$873**
2	Wellfield Pumps + VFD (50 HP)	4	EA	$73	$11	$336
3	Campus Distribution Pumps + VFD (75 HP)	4	EA	$73	$11	$336
4	Controls	1	LS	$131	$70	$201
5						
6	**623 Skytop Data Center**			**$1,377**	**$838**	**$2,215**
7	Modular water-to-water heat pump (50 ton)	5	LS	$221	$158	$1,895
8	GSHP Loop pumps + VFD (10 HP)	2	LS	$68	$12	$160
9	CHW primary pumps + VFD (7.5 HP)	2	LS	$68	$12	$160
10						
11	**621 Skytop Office Building**			**$3,504**	**$3,427**	**$6,931**
12	VAV air-handling unit (76,000 cfm)	1	EA	$187	$395	$582
13	VAV air-handling unit (small)	3	EA	$111	$375	$1,458
14	Heat recovery unit	1	EA	$187	$395	$582
15	Modular water-to-water heat pump (50 ton)	5	EA	$221	$158	$1,895
16	GSHP Loop Pumps + VFD (10 HP)	2	EA	$68	$12	$160
17	CHW primary pumps + VFD (7.5 HP)	2	EA	$68	$12	$160
18	HW primary pumps + VFD (5 HP)	2	EA	$68	$12	$160
19	Chilled Water Distribution Pumps + VFD (40 HP)	2	EA	$68	$12	$160
20	Hot Water Distribution Pumps + VFD (25 HP)	2	EA	$68	$12	$160
21	VAV Terminal Boxes	1	EA	$64	$10	$74
22	HW Unit Heaters	2	EA	$48	$48	$192
23	A/C Units (CHW)	3	EA	$191	$112	$909
24	Water-to-Water Heat Pump Water Heater (5 ton)	1	EA	$221	$158	$379
25	DHW Storage Tank	1	EA	$58	$2	$60
26						

27	**Tennity Ice Skating Pavilion**			**$3,415**	**$1,757**	**$5,172**
28	CHW/HW VAV RTU + Energy Recovery (4000 cfm)	1	EA	$164	$175	$339
29	Dessicant Dehumidifier (10,000 cfm)	1	EA	$187	$395	$582
30	Modular water-to-water heat pump (50 ton)	3	EA	$221	$158	$1,137
31	GSHP Loop Pumps + VFD (5 HP)	2	EA	$68	$12	$160
32	HW primary pumps + VFD (3 HP)	2	EA	$68	$12	$160
33	Hot Water Distribution Pumps + VFD (7.5 HP)	2	EA	$68	$12	$160
34	CHW Pumps + VFD (1 HP)	2	EA	$68	$12	$160
35	HW Unit Heaters	3	EA	$48	$48	$288
36	HW Furnaces	3	EA	$385	$51	$1,308
37	Water-to-Water Heat Pump Water Heater (10 ton)	2	EA	$221	$158	$758
38	DHW Storage Tank	2	EA	$58	$2	$120
39						
40	**Goldstein Student Center**			**$14,998**	**$9,473**	**$24,471**
41	Heat Pumps	52	EA	$243	$158	$20,852
42	Energy Recovery Units (~5000 cfm)	2	EA	$395	$187	$1,164
43	GSHP VAV AHU	1	EA	$164	$175	$339
44	Modular water-to-water heat pump (50 ton)	2	EA	$221	$158	$758
45	HW primary pumps + VFD (3 HP)	2	EA	$68	$12	$160
46	Hot Water Distribution Pumps + VFD (10 HP)	2	EA	$68	$12	$160
47	GSHP Loop Pumps + VFD (20 HP)	2	EA	$68	$12	$160
48	Water-to-Water Heat Pump Water Heater (20 ton)	2	EA	$221	$158	$758
49	DHW Storage Tank	2	EA	$58	$2	$120
50						
51	**Skytop Office Building**			**$2,771**	**$2,070**	**$4,841**
52	Modular water-to-water heat pump (50 ton)	4	EA	$221	$158	$1,516
53	CHW/HW VAV RTU (~10,000 cfm)	4	EA	$118	$222	$1,360
54	CHW Primary Pumps + VFD (3 HP)	2	EA	$68	$12	$160
55	HW primary pumps + VFD (3 HP)	2	EA	$68	$12	$160
56	Chilled Water Distribution Pumps + VFD (7.5 HP)	2	EA	$68	$12	$160
57	GSHP Pumps + VFD (10 HP)	2	EA	$68	$12	$160
58	A/C Units (CHW)	2	EA	$296	$147	$886
59	Water-to-Water Heat Pump Water Heater (10 ton)	1	EA	$221	$158	$379
60	DHW Storage Tank	1	EA	$58	$2	$60
61						
62	**Ski Lodge**			**$3,270**	**$1,566**	**$4,836**
63	Fan Coils (3 tons)	3	EA	$191	$112	$909
64	Fan Coils (1.5 ton)	2	EA	$191	$112	$606
65	HW Unit Heaters	9	EA	$48	$48	$864
66	HW Convectors	13	EA	$58	$2	$780
67	Modular water-to-water heat pump (15 ton)	2	EA	$221	$158	$758
68	Water-to-Water Heat Pump Water Heater (10 ton)	1	EA	$221	$158	$379
69	DHW Storage Tank	1	EA	$58	$2	$60
70	Chilled Water Distribution Pumps + VFD (1 HP)	2	EA	$68	$12	$160
71	Hot Water Distribution Pumps + VFD (1 1/2 HP)	2	EA	$68	$12	$160
72	GSHP Loop Pumps + VFD (3 HP)	2	LS	$68	$12	$160
73						
74	**480 Winding Ridge Apartments**			**$2,080**	**$1,288**	**$3,368**
75	Water-to-Air Heat Pumps with DHW (1.5 tons)	8	EA	$243	$158	$3,208
76	GSHP Pumps + VFD (1 1/2 HP)	2	EA	$68	$12	$160
77						

78	**460 Winding Ridge Apartments**			**$3,052**	**$1,920**	**$4,972**
79	Water-to-Air Heat Pumps with DHW (1.5 tons)	12	EA	$243	$158	$4,812
80	GSHP Pumps (2 HP)	2	EA	$68	$12	$160
	PROPOSED SYSTEM TOTAL			**$35,182**	**$22,497**	**$57,679**

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: SYRACUSE UNIVERSITY	
NYSERDA COMMUNITY HEAT PUMP PROGRAM	
M/E REFERENCE: 201362	DATE: 7/22/2022
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**			**$1,083**	**$238**	**$1,321**
1	621+623 Skytop: Wellfield Pumps + VFD (25 HP)	2	EA	$68	$12	$160
2	Tennity: Wellfield Pumps + VFD (7.5 HP)	2	EA	$68	$12	$160
3	Goldstein: Wellfield Pumps + VFD (7.5 HP)	2	EA	$68	$12	$160
4	640 Skytop: Wellfield Pumps + VFD (10 HP)	2	EA	$68	$12	$160
5	Ski Lodge: Wellfield Pumps + VFD (2 HP)	2	EA	$68	$12	$160
6	480 Winding: Wellfield Pumps + VFD (3/4 HP)	2	EA	$68	$12	$160
7	460 Winding: Wellfield Pumps + VFD (1 HP)	2	EA	$68	$12	$160
8	Controls	1	LS	$131	$70	$201
9						
10	**623 Skytop Data Center**			**$1,377**	**$838**	**$2,215**
11	Modular water-to-water heat pump (50 ton)	5	LS	$221	$158	$1,895
12	GSHP Loop pumps + VFD (10 HP)	2	LS	$68	$12	$160
13	CHW primary pumps + VFD (7.5 HP)	2	LS	$68	$12	$160
14						
15	**621 Skytop Office Building**			**$3,504**	**$3,427**	**$6,931**
16	VAV air-handling unit (76,000 cfm)	1	EA	$187	$395	$582
17	VAV air-handling unit (small)	3	EA	$111	$375	$1,458
18	Heat recovery unit	1	EA	$187	$395	$582
19	Modular water-to-water heat pump (50 ton)	5	EA	$221	$158	$1,895
20	GSHP Loop Pumps + VFD (10 HP)	2	EA	$68	$12	$160
21	CHW primary pumps + VFD (7.5 HP)	2	EA	$68	$12	$160
22	HW primary pumps + VFD (5 HP)	2	EA	$68	$12	$160
23	Chilled Water Distribution Pumps + VFD (40 HP)	2	EA	$68	$12	$160
24	Hot Water Distribution Pumps + VFD (25 HP)	2	EA	$68	$12	$160
25	VAV Terminal Boxes	1	EA	$64	$10	$74
26	HW Unit Heaters	2	EA	$48	$48	$192
27	A/C Units (CHW)	3	EA	$191	$112	$909
28	Water-to-Water Heat Pump Water Heater (5 ton)	1	EA	$221	$158	$379
29	DHW Storage Tank	1	EA	$58	$2	$60
30						

31	**Tennity Ice Skating Pavilion**			**$3,415**	**$1,757**	**$5,172**
32	CHW/HW VAV RTU + Energy Recovery (4000 cfm)	1	EA	$164	$175	$339
33	Dessicant Dehumidifier (10,000 cfm)	1	EA	$187	$395	$582
34	Modular water-to-water heat pump (50 ton)	3	EA	$221	$158	$1,137
35	GSHP Loop Pumps + VFD (5 HP)	2	EA	$68	$12	$160
36	HW primary pumps + VFD (3 HP)	2	EA	$68	$12	$160
37	Hot Water Distribution Pumps + VFD (7.5 HP)	2	EA	$68	$12	$160
38	CHW Pumps + VFD (1 HP)	2	EA	$68	$12	$160
39	HW Unit Heaters	3	EA	$48	$48	$288
40	HW Furnaces	3	EA	$385	$51	$1,308
41	Water-to-Water Heat Pump Water Heater (10 ton)	2	EA	$221	$158	$758
42	DHW Storage Tank	2	EA	$58	$2	$120
43						
44	**Goldstein Student Center**			**$14,998**	**$9,473**	**$24,471**
45	Heat Pumps	52	EA	$243	$158	$20,852
46	Energy Recovery Units (~5000 cfm)	2	EA	$395	$187	$1,164
47	GSHP VAV AHU	1	EA	$164	$175	$339
48	Modular water-to-water heat pump (50 ton)	2	EA	$221	$158	$758
49	HW primary pumps + VFD (3 HP)	2	EA	$68	$12	$160
49	Hot Water Distribution Pumps + VFD (10 HP)	2	EA	$68	$12	$160
50	GSHP Loop Pumps + VFD (20 HP)	2	EA	$68	$12	$160
51	Water-to-Water Heat Pump Water Heater (20 ton)	2	EA	$221	$158	$758
52	DHW Storage Tank	2	EA	$58	$2	$120
53						
54	**Skytop Office Building**			**$2,771**	**$2,070**	**$4,841**
55	Modular water-to-water heat pump (50 ton)	4	EA	$221	$158	$1,516
56	CHW/HW VAV RTU (~10,000 cfm)	4	EA	$118	$222	$1,360
57	CHW Primary Pumps + VFD (3 HP)	2	EA	$68	$12	$160
58	HW primary pumps + VFD (3 HP)	2	EA	$68	$12	$160
59	Chilled Water Distribution Pumps + VFD (7.5 HP)	2	EA	$68	$12	$160
60	GSHP Pumps + VFD (10 HP)	2	EA	$68	$12	$160
61	A/C Units (CHW)	2	EA	$296	$147	$886
62	Water-to-Water Heat Pump Water Heater (10 ton)	1	EA	$221	$158	$379
63	DHW Storage Tank	1	EA	$58	$2	$60
64						
65	**Ski Lodge**			**$3,270**	**$1,566**	**$4,836**
66	Fan Coils (3 tons)	3	EA	$191	$112	$909
67	Fan Coils (1.5 ton)	2	EA	$191	$112	$606
68	HW Unit Heaters	9	EA	$48	$48	$864
69	HW Convectors	13	EA	$58	$2	$780
70	Modular water-to-water heat pump (15 ton)	2	EA	$221	$158	$758
71	Water-to-Water Heat Pump Water Heater (10 ton)	1	EA	$221	$158	$379
72	DHW Storage Tank	1	EA	$58	$2	$60
73	Chilled Water Distribution Pumps + VFD (1 HP)	2	EA	$68	$12	$160
74	Hot Water Distribution Pumps + VFD (1 1/2 HP)	2	EA	$68	$12	$160
75	GSHP Loop Pumps + VFD (3 HP)	2	LS	$68	$12	$160
76						
77	**480 Winding Ridge Apartments**			**$2,080**	**$1,288**	**$3,368**
78	Water-to-Air Heat Pumps with DHW (1.5 tons)	8	EA	$243	$158	$3,208
79	GSHP Pumps + VFD (1 1/2 HP)	2	EA	$68	$12	$160
80						

81	**460 Winding Ridge Apartments**			**$3,052**	**$1,920**	**$4,972**
82	Water-to-Air Heat Pumps with DHW (1.5 tons)	12	EA	$243	$158	$4,812
83	GSHP Pumps (2 HP)	2	EA	$68	$12	$160
	CODE-COMPLIANT SYSTEM TOTAL			**$35,550**	**$22,577**	**$58,127**

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

A.6 Life Cycle Cost Analysis

A-1 Life Cycle Cost Analysis Summary

LIFE-CYCLE COST ANALYSIS

Project Information **Prepared by: M/E Engineering, P.C.**

Date:	July 22, 2022
Client Name:	Syracuse University
Project Name:	NYSERDA Community Heat Pump Program
Project Number:	201362
Project Address:	South Campus Syracuse, NY
Building Name:	Community Heat Pump Cluster
Construction Year:	2023
Project Objective:	Energy Objective

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 (LCCA) 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	($4,918,071)	($576,589)	($72,218)	20	($17,310,608)	--
Code-Compliant System: Individual Building Geothermal Heat Pumps	2	($16,930,276)	($567,206)	($58,127)	25	($30,466,790)	($13,156,182)
Proposed System: Community Geothermal Heat Pumps	3	($12,426,801)	($536,322)	($57,679)	25	($24,376,589)	($7,065,981)

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

A-2 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:	($4,918,071)	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	($470,858)	-490163	-510259.7	-531180.3	-552958.7	-575630	-599230.9	-623799.3	-649375.1
Natural Gas Cost:	0	($105,731)	-112709	-120148	-128078	-136531	-145542	-155148	-165387	-176303
Maintenance:	0	($72,218)	-74023	-75874	-77771	-79715	-81708	-83751	-85845	-87991
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:	-4918071	-648807	-676896	-706282	-737029	-769205	-802880	-838129	-875031	-913669
Present Value:	-4918071	-604948	-588474	-572514	-557052	-542070	-527554	-513488	-499856	-486646
Net Present Value:	-4918071	-5523019	-6111493	-6684007	-7241058	-7783128	-8310682	-8824170	-9324026	-9810672

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:	v0	0	0	-91918.11	0	-2568504	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:	-675999.5	-703715.4	-732567.8	-762603.1	-793869.8	-826418.4	-860301.6	-895574	-932292.5	-970516.5
Natural Gas Cost:	-187939	-200343	-213566	-227661	-242687	-258704	-275778	-293980	-313382	-334066
Maintenance:	-90190	-92445	-94756	-97125	-99553	-102042	-104593	-107208	-109888	-112635
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:	-954129	-996504	-1040890	-1179307	-1136110	-3755669	-1240673	-1296762	-1355563	-1417218
Present Value:	-473843	-461433	-449404	-474747	-426440	-1314401	-404856	-394554	-384564	-374876
Net Present Value:	-10284515	-10745948	-11195352	-11670099	- 12096539	-13410939	-13815796	- 14210349	-14594913	- 14969789

Project Year	20	21	22	23	24	25
Calendar Year	2043	2044	2045	2046	2047	2048
OPTION 1						
Investment Costs						
Project Cost:	-1132283	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:	-1010308	-1051730	-1094851	-1139740	-1186469	-1235115
Natural Gas Cost:	-356114	-379618	-404672	-431381	-459852	-490202
Maintenance:	-115451	-118338	-121296	-124328	-127437	-130623
Other Costs/Savings:	0	0	0	0	0	0
Salvage/Residual Value:	0	0	0	0	0	0
Total:	-2614156	-1549685	-1620820	-1695449	-1773758	-1855939
Present Value:	-644741	-356369	-347531	-338959	-330643	-322575
Net Present Value:	-15614530	-15970900	- 16318431	- 16657390	- 16988033	-17310608

A-3 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
OPTION 2										
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:	$(16,930,276)	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	($561,020)	-584022.2	-607967.1	-632893.7	-658842.4	-685854.9	-713975	-743247.9	-773721.1
Natural Gas Cost:	0	($6,186)	-6594	-7029	-7493	-7987	-8515	-9077	-9676	-10314
Maintenance:	0	($58,127)	-59580	-61070	-62596	-64161	-65765	-67409	-69095	-70822
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:	-16930276	-625333	-650196	-676066	-702983	-730991	-760135	-790461	-822018	-854857
Present Value:	-16930276	-583061	-565262	-548021	-531319	-515140	-499467	-484283	-469573	-455321
Net Present Value:	-16930276	-17513337	- 18078599	-18626620	- 19157939	- 19673080	- 20172547	- 20656830	- 21126403	-21581724

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 2										
Investment Costs										
Project Cost:	0	0	0	0	0	-5419793	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:	-805443.7	-838466.9	-872844	-908630.6	-945884.5	-984665.7	-1025037	-1067064	-1110813	-1156356
Natural Gas Cost:	-10995	-11721	-12494	-13319	-14198	-15135	-16134	-17199	-18334	-19544
Maintenance:	-72593	-74407	-76268	-78174	-80129	-82132	-84185	-86290	-88447	-90658
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:	-889031	-924595	-961606	-1000124	-1040211	-6501725	-1125356	-1170552	-1217594	-1266559
Present Value:	-441514	-428135	-415173	-402614	-390444	-2275459	-367226	-356153	-345423	-335025
Net Present Value:	-22023238	-22451373	- 22866547	-23269161	- 23659605	- 25935065	- 26302290	- 26658443	- 27003866	-27338891

Project Year	20	21	22	23	24	25
Calendar Year	2043	2044	2045	2046	2047	2048
OPTION 2						
Investment Costs						
Project Cost:	-5347268	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:	-1203767	-1253122	-1304500	-1357984	-1413661	-1471621
Natural Gas Cost:	-20834	-22209	-23675	-25237	-26903	-28678
Maintenance:	-92925	-95248	-97629	-100070	-102572	-105136
Other Costs/Savings:	0	0	0	0	0	0
Salvage/Residual Value:	0	0	0	0	0	0
Total:	-6664794	-1370578	-1425803	-1483291	-1543136	-1605436
Present Value:	-1643769	-315181	-305717	-296543	-287653	-279036
Net Present Value:	-28982659	-29297841	- 29603557	-29900101	- 30187754	- 30466790

A-4 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:	($12,426,801)	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	($530,136)	-551871.9	-574498.6	-598053	-622573.2	-648098.7	-674670.8	-702332.3	-731127.9
Natural Gas Cost:	0	($6,186)	-6593.831	-7029.024	-7492.939	-7987.474	-8514.647	-9076.613	-9675.67	-10314.26
Maintenance:	0	($57,679)	-59121	-60599	-62114	-63667	-65258	-66890	-68562	-70276
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:	-12426801	-594001	-617587	-642127	-667660	-694228	-721872	-750637	-780570	-811718
Present Value:	-12426801	-553847	-536912	-520510	-504622	-489233	-474325	-459885	-445896	-432344
Net Present Value:	-12426801	-12980648	-13517560	-14038069	-14542691	-15031924	-15506249	-15966134	-16412030	-16844374

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	-4371304	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:	-761104.1	-792309.4	-824794.1	-858610.6	-893813.7	-930460	-968608.9	-1008322	-1049663	-1092699
Natural Gas Cost:	-10995.01	-11720.68	-12494.24	-13318.86	-14197.91	-15134.97	-16133.87	-17198.71	-18333.83	-19543.86
Maintenance:	-72033	-73834	-75680	-77572	-79511	-81499	-83536	-85625	-87765	-89960
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:	-844132	-877864	-912968	-949501	-987523	-5398398	-1068279	-1111145	-1155762	-1202203
Present Value:	-419216	-406497	-394174	-382235	-370668	-1889319	-348600	-338078	-327882	-318001
Net Present Value:	-17263590	-17670087	-18064261	-18446496	-18817164	-20706483	-21055083	-21393161	-21721043	-22039044

Project Year	20	21	22	23	24	25
Calendar Year	2043	2044	2045	2046	2047	2048
OPTION 3						
Investment Costs						
Project Cost:	-2516089	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:	-1137500	-1184137	-1232687	-1283227	-1335840	-1390609
Natural Gas Cost:	-20833.75	-22208.78	-23674.56	-25237.08	-26902.73	-28678.31
Maintenance:	-92209	-94514	-96877	-99299	-101781	-104326
Other Costs/Savings:	0	0	0	0	0	0
Salvage/Residual Value:	0	0	0	0	0	0
Total:	-3766631	-1300860	-1353238	-1407763	-1464523	-1523613
Present Value:	-928981	-299149	-290157	-281444	-272999	-264815
Net Present Value:	-22968026	-23267175	-23557332	-23838776	-24111775	-24376589

A.7 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):
Syracuse University, 1700 Colvin St E, Syracuse NY 13244, Tax Parcel 057.-02-02.2 (project location - Grassy Area Behind 161 Farm Acre Road)

Brief Description of Proposed Action:
Drilling of a 6 inch diameter 400 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 Syracuse University through the NYSERDA Community Geothermal Heat Pump Program. We are studying the feasibility of connecting eight 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 Syracuse University Campus, in Syracuse, NY 13244. 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: M/E Engineering P.C on behalf of Syracuse University, Melanie Stachowiak PE - Partner	Telephone: 716-845-5092 x1207 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	☐	☑

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? 86.48 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 (Syracuse University)
☐ 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?	☐	☑
7. Is the site of the proposed action located in, or does it adjoin, a state listed Critical Environmental Area? If Yes, identify: ______	☑	☐
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?	☑	☐
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.	☐	☑
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.	☑	☐
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.	☑	☐
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?	☑	☐
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		
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? This location is in the vicinity of Bats listed as endangered or threatened, however the 6 inch diameter, 400 ft deep hole would not be expected to impact any potential bat habitat.	NO ☐	YES ☑
16. Is the project site located in the 100-year flood plan?	NO ☑	YES ☐
17. Will the proposed action create storm water discharge, either from point or non-point sources? If Yes,	NO ☑	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: We do not expect there to be a significant amount of water, however if the geo well is found to produce water while drilling in small volumes it may be run to a nearby storm drain. If a significant amount is found it will be controlled and manged (collected and removed from the site if needed).	☑	☐
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: If any water is collected, it will be a 1 time event and temporary (drilling expected to take no more than 2 days).	NO ☑	YES ☐
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:	NO ☑	YES ☐
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:	NO ☑	YES ☐

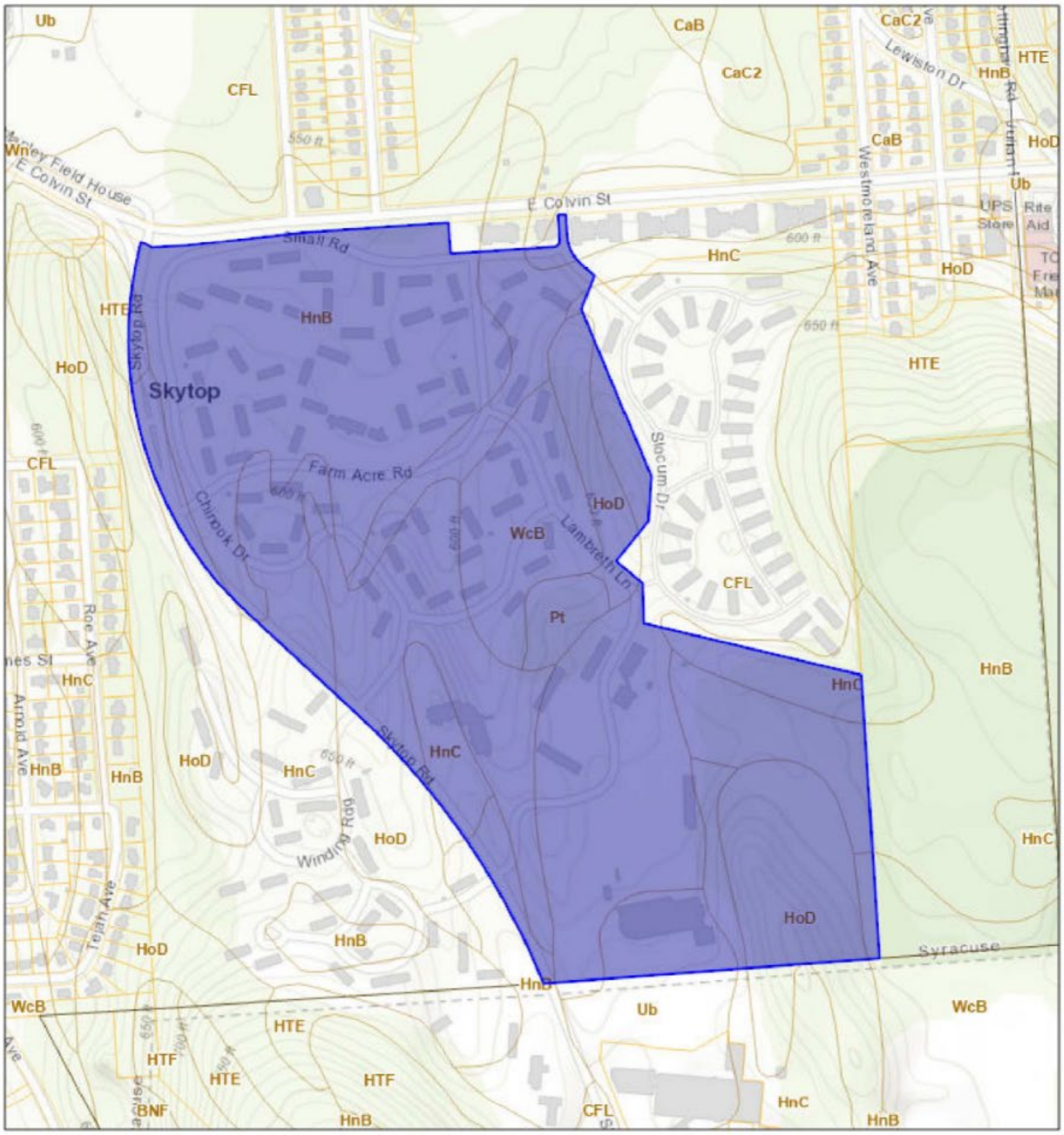
I CERTIFY THAT THE INFORMATION PROVIDED ABOVE IS TRUE AND ACCURATE TO THE BEST OF MY KNOWLEDGE

Applicant/sponsor/name: M/E Engineering, P.C., Melanie G. Stachowiak PE   Date: 03/04/2022

Signature: Digitally signed by Melanie G. Stachowiak PE, LEED AP BD+C, CMVP
Location: Buffalo NY
Date: 2022.03.04 01:49:21-05'00'   Title: Partner

PRINT FORM

Syracuse University, Skytop Building, 1700 Colvin St E, Syracuse NY 13244, Tax Parcel 057.-02-02.2



March 4, 2022

1:9,028

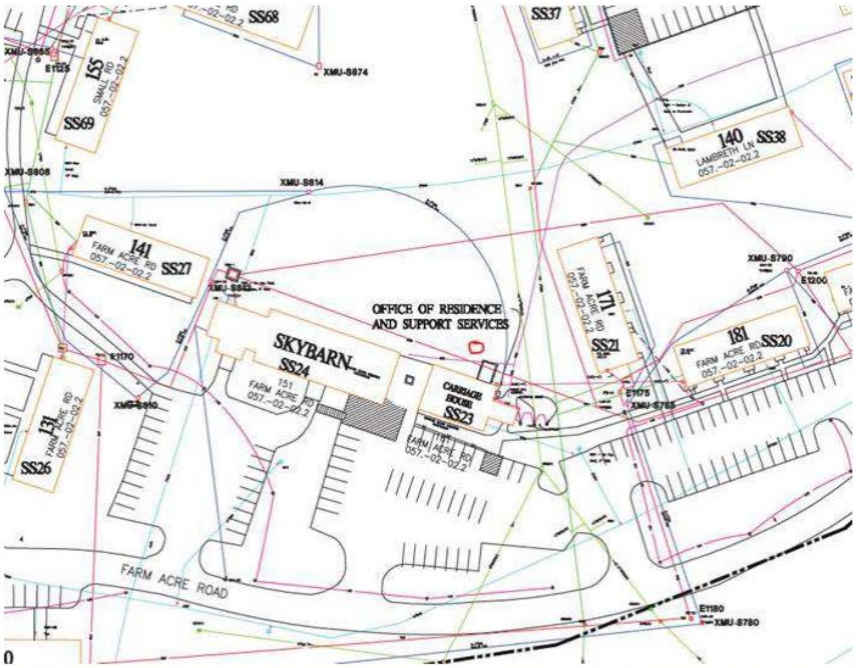
0 0.05 0.1 0.2 mi

0 0.07 0.15 0.3 km

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

EXHIBIT A

TEST WELL LOCATION



END OF SECTION

A.8 Kickoff Meeting Notes

TASK 0: PROJECT KICK-OFF MEETING

A. A preliminary meeting was convened virtually on August 4, 2021. Present at the meeting were:

Jason Plumpton - Syracuse University, Assistant Director Engineering and Utilities Campus Planning, Design and Construction
Lori Armstrong - NYSERDA, Project Manager
Ken Swan - M/E Engineering, Associate, Proposal Development and Kickoff
Melanie Stachowiak - M/E Engineering, Partner/ Project Manager

1. The purpose of this meeting was for introductions, determine pathways of communications, to discuss the project intent and schedule, and to determine what information is needed.

2. Items discussed were as follows:

    a. Introductions:

        - Lori Armstrong (NYSERDA) will be the NYSERDA Project Manager.
        - Melanie Stachowiak (M/E Engineering) will be managing this project.
        - Jason Plumpton (Syracuse University) will be contact from University.

    b. Copy of Agreement sent to Syracuse University

    c. Well drilling test - plan for weeks 14-23 if possible. Possibly winter/Christmas break. Concern over restoration, and insurance issues with hiring and performing work on Campus.

    d. Soil data is available if needed.

    e. Intern - currently Syracuse University does not have a candidate.

    f. The schedule and tasks are somewhat flexible with respect to Go / No-Go decisions. If it makes economic sense, M/E will move to next Task to prevent a lag in analysis.

    g. Information to be collected:

        - Drawings
        - Site Survey Work (Utility Plan)
        - Utility data (24 months)

    h. Information that M/E has:

        - Site plan
        - Aerial

    i. Official kickoff with project team to be held in the next couple of weeks.

B. A Project Kickoff meeting and virtual walkthrough took place September 1, 2021 at 2:00pm. Present at the virtual meeting were:

Jason Plumpton - Syracuse University, Assistant Director Engineering and Utilities Campus Planning, Design and Construction
Melanie Stachowiak - M/E Engineering, Partner/ Project Manager
Anna Szweda - M/E Engineering, Senior Energy Engineer
Thomas Gamer - M/E Engineering, Energy Engineer

1. The general project was discussed, including expectations and preliminary design concepts.

2. The mechanical systems of each building were reviewed, as well as the general age and condition of the buildings, and anything that may affect the building models.

3. Information received was reviewed:

    a. PDF of plans, base plans in CAD.

    b. Utility Information

4. Virtual Walkthrough

    a. Screen shots available if needed through CRI log-on (controls/operation)

    b. 623 Skytop - Green Data Center

        - HVAC: was micro turbines / absorption chillers with exhaust gas heat recovery
        - Under construction now: 1 water chiller (250 tons) primary/secondary), closed circuit cooling tower
        - Shares heating with 621 via heat exchanger for hot water. Steam boiler in 621, fire tube. Steam to water heat exchanger in 623.
        - Condenser only ever needs cooling
        - Data floor kW ~100 tons.
        - Ideas - Econ cooling? With geo-loop? HX on "future chiller loop"

    c. 621 Data Center

        - AC-1 & AC-2
        - Off chillers
        - Dual duct and mixing boxes at zone level, same throughout
        - Steam & CHW
        - T-8 flourescents
        - Hot & Cold Deck, 58 / 88.1 (reset) to 110
        - Single zone CV RTU / 100% OA for Vivarium and energy wheel, Single duct VAV w/ reheat
        - Daikin Rebel Gas/DX
        - Building D uses packaged RTU with VAV

d. Ice Rink

- Cooling in rink itself all year
- Chiller 2 zones
- Small and large rinks
- Constant source of heat off condenser loop, heats underfloor
- Brine CACL
- When on 16 degrees F
- Plus heat to prevent frost
- 70 deg F condenser water
- Heat - gas fired with desiccant, gas heater in reactivation Munters Unit.
- Bleachers - occupancy?
- Used for Women's hockey, rent to clubs and lessons on weekends
- Addition has RTU with VAV locker room

e. Goldstien Student Center

- All HP's, gas heat/CT (M/E - Rich/Evan)
- No water to water HPs
- Few AHU's for kitchen
- Small chiller and gas fired boiler
- 7am-1am occupancy
- Number of meals? Including takeout food

f. 640 Skytop Office

- 2 Stories
- 1 - Never renovated, electric heat an electric multizone
- 2- RTU DX with HW heat and reheat, gas boiler with glycol
- 3/4 LED, 1/4 T-8

g. Ski Lodge

- FCU's / CUH's
- Steam Boilers
- High wall mounted ductless splits

h. 480/460 Apartments

- Electric heat, no controls
- Vertical heat pumps?
- Used to be electric FCUs
- All one master meter at point of service

i. Big Picture

- 2 points of service
- MS7 service - all buildings (not at peak)

- All but 460/480, occasionally peaked when power goes out - spikes when electric heat comes back on.
- Need an expandable solution.
- Like VAV AHU's, OK with some HP's, OK with larger units, not particularly fond of VRF

5. Information Needed

   a. Number of meals cooked
   b. Number of Hockey Seats
   c. Kw data
   d. Building envelope data

6. Next Steps

   a. Will begin work on Task 1

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 Twitter, Facebook, YouTube, or Instagram.

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