City of Troy District Energy

Final Report | Report Number 23-13 | November 2021

NEW YORK STATE | NYSERDA

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City of Troy District Energy

Final Report

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Disclaimer

The report was prepared as part of the category A feasibility study portion of PON 4614 (Community Heat Pump Program). The study explores the feasibility and potential options for creating a fossil fuel free district energy system in Troy, NY. Portions of the system described will be submitted for further design and implementation; however, the final design and construction of any particular portion of the system will likely deviate from what is described within. Any potential customers described are included for analysis purpose and no commitments have been made at this time, financial or otherwise.

Abstract

This study explores the potential of a district heat pump system in Troy's downtown and waterfront areas. The project aims to establish a network ambient loop system for efficient heating and cooling of buildings. The system would reduce energy consumption by sharing energy, decreasing peak loads and improving equipment efficiencies. Phases 1A and 1B will cover buildings in the historic northern and southern downtown areas, including affordable housing projects. Phase 2 expands to other downtown buildings, while Phase 3 focuses on the waterfront redevelopment. The report provides a preliminary cost assessment and emphasizes Troy's commitment to sustainable development and economic revitalization.

Keywords

district energy, geothermal, ground source heat pumps, electrification

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Executive Summary

As Troy continues its economic resurgence, the city wishes to be a leader in implementing the Climate Leadership and Community Protection Act (CLCPA) just as they have historically led in economic development over the centuries. Troy's downtown area initially developed as a prosperous, vibrant city as a result of its success in manufacturing and the dominance of water-based transportation and energy. With the manufacturing decline, the downtown started to deteriorate and lose its vitality. Recent investments, including the restoration of heritage buildings and public realm improvements, are attracting new interest and activity including a cluster of computer technology and gaming businesses—many founded by Rensselaer Polytechnic Institute (RPI) alumni. An update to the city master development plan was completed by the city in 2018, with an emphasis on smart, sustainable redevelopment of the downtown area in general and the waterfront area in particular.

As part of that redevelopment plan, the City of Troy is pursuing a District Energy System project, which is the implementation of a district geothermal system. The purpose of this project is to provide a high-efficiency heating and cooling district energy utility option to buildings in the downtown and waterfront areas. The project team consists of Siemens, the project coordinator; CHA Consulting, the project engineer; and the City of Troy. Various additional community stakeholders have also been engaged as part of this project.

This district energy project has been identified as a major supplemental component of the City of Troy's Downtown Revitalization Initiative and an ongoing riverfront area redevelopment, including the proposed construction of the One Monument Square redevelopment project and the Riverfront Park redevelopment. The project will provide a clean energy source for the One Monument Square building as well as a number of the surrounding facilities, extending the benefit of this clean energy resource beyond the current scope of new building construction to reach the existing community.

The study revealed that a district energy system would reduce the community's future energy consumption due to decreasing community coincident peak loads that will become smaller than the sum of individual building peak loads, greater equipment efficiencies of larger equipment, and the reduction of mechanical heating and cooling requirements due to the use of a geothermal system.

The plan for the Troy District Energy project is to implement the proposed district geothermal system in three phases over the next 10 years. Phase 1 has been split into two parts: Phase 1A and Phase 1B. This proposal is for Phase 1A and covers nine potential buildings in the northern waterfront area: One Monument Square, the Arts Center, the Troy Atrium Complex, and existing mixed-used multifamily or office buildings. The potential buildings were chosen for the district geothermal system because of their geographical proximity to the new construction development project at the old Troy City Hall location on River Street in downtown Troy.

Phase 1B consists of 12 buildings on the southern part of downtown, centered around Russell Sage College. This phase also incorporates several affordable housing redevelopment projects that are planned for the area. Phase 2 consists of a further build-out of Phase 1 to include all the other buildings in the downtown area that would be large enough to see a significant benefit from a district geothermal system. Phase 3 consists of the future redevelopment of the Troy waterfront area referenced as the Riverside district in the Realize Troy Comprehensive Plan published in 2018.

The enclosed study characterizes the required heating and cooling loads for a potential project and provides a preliminary cost basis for each phase that can be pursued further. Several heat sources were considered, with vertical borehole ground heat exchangers as the primary sources of heating, supplemented with river, air, and/or wastewater resources.

1 Task 1. Establish Baseline Conditions

This section presents the approach and assumptions that were used to determine existing utility usages. Two key elements comprise baseline data–weather-related usage and non-weather-related usage. Building loads such as heating and cooling loads can be directly correlated to the local weather, however, building loads that originate from lighting systems or domestic hot water use may have little correlation to the local weather.

If the weather is less severe in a given year, resulting in an overall reduction in consumption, the energy savings from an implemented measure will be adjusted to determine the level of savings that would have been achieved under a typical year's weather conditions. A building's load characteristic may also drift because of changes in occupancy profile.

1.1 Thermal Model—Heating and Cooling loads

The table below shows the list of buildings that are included for the energy baseline development under phase 1A, 1B, 2 and 3 of the project. Phase 3 buildings are yet to be constructed.

Figure 1. Phase 1A Site Map–Building Area

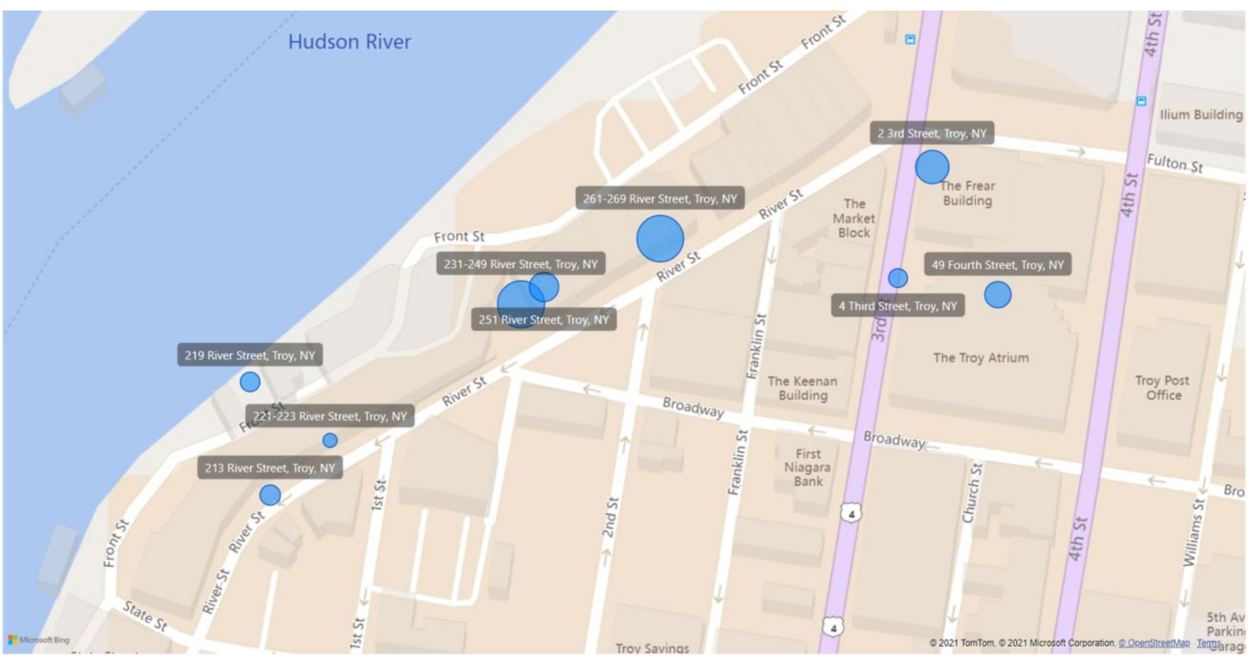


Table 1. List of Potential Buildings–Phase 1A

Building No.	Building Address	Building Type	Building SQFT
1	One Monument Square	Highrise Apartment	180,000
2	261–269 River Street	Midrise Apartment	63,000
3	2 3rd Street	Office and Retail	40,867
4	Third St	Office	16,720
5	Fourth St	Office	36,632
6	213 River St	Midrise Apartment	14,000
7	219 River St	Midrise Apartment	16,080
8	221–223 River Street	Midrise Apartment	3,450
9	251 River Street	Midrise Apartment	29,760
10	291 River Street	Midrise Apartment	14,000
		Total:	400,509

Figure 2. Phase 1B Site Map–Building Area

Table 2. List of Potential Buildings–Phase 1B

Building No.	Building Address	Building Type	Building SQFT
11	Taylor 1	Midrise Apartment	100,000
12	Taylor 2	Midrise Apartment	100,000
13	Taylor 3	Midrise Apartment	100,000
14	Taylor 4	Midrise Apartment	100,000
15	Cowee Hall	Classroom	23,313
16	Slingerland Alumnae House	Dormitory	5,208
17	Roy Courtyard	Classroom	7,757
18	Hart Hall	Classroom	21,552
19	Ricketts Hall	Classroom	34,191
20	Manning Hall	Dormitory	27,798
21	Esteves School of Education	Classroom	12,600
22	Plum Memorial	Classroom	9,794
		Total:	182,213

Figure 3. Phase 2 Site Map–Building Area

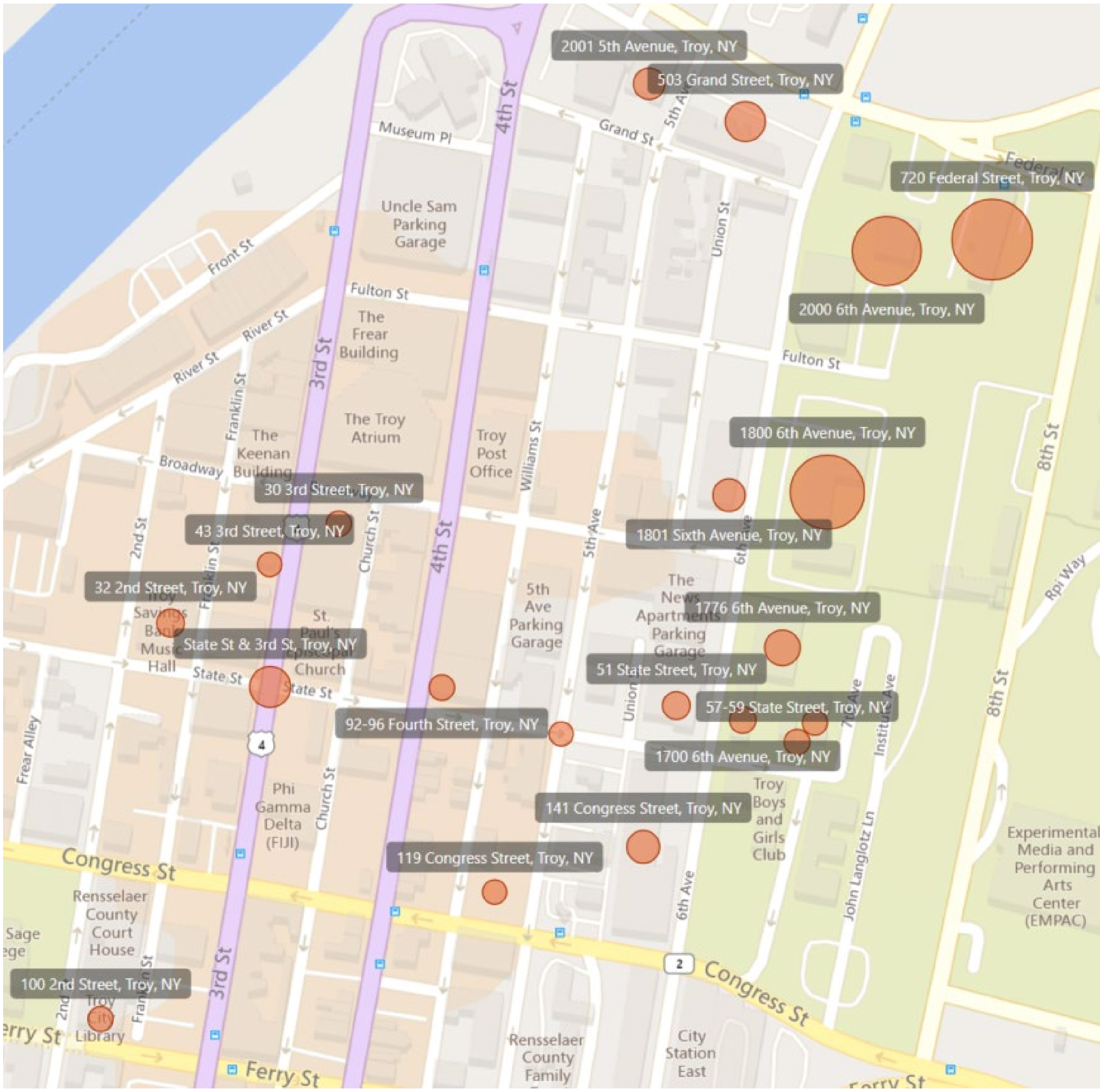


Table 3. List of Potential Buildings–Phase 2

Building No.	Building Address	Building Type	Building SQFT
23	100 2nd Street	Midrise Apartment	9,792
24	141 Congress Street	Midrise Apartment	66,508
25	1646 5th Avenue	Midrise Apartment	12,050
26	119 Congress Street	Midrise Apartment	13,158
27	51 State Street	Office	19,734
28	1700 6th Avenue	Office	15,250
29	57-59 State Street	Office	12,301
30	61 State Street	Office	10,124
31	State Street	Midrise Apartment	119,136
32	1776 6th Avenue	Office	47,958
33	1800 6th Avenue	Midrise Apartment	136,005
34	1801 6th Avenue	Office	36,886
35	2000 6th Avenue	Midrise Apartment	122,708
36	720 Federal Street	Midrise Apartment	152,874
37	503 Grand Street	Midrise Apartment	46,196
38	2001 5th Avenue	Office	33,085
39	92-96 Fourth Street	Office	11,844
40	30 3rd Street	Office	10,754
41	43 3rd Street	Midrise Apartment	5,147
42	32 2nd Street	Office	19,585
		Total:	901,095

Figure 4. Phase 3 Proposed Site Plan

Table 4. Phase 3 Potential Building List

Phase 3		
Building No.	**Building Type**	**Building SQFT**
43	Midrise Apartment	235,672
44	Midrise Apartment	353,323
45	Midrise Apartment	262,779
46	Midrise Apartment	248,046
47	Midrise Apartment	260,960
48	Midrise Apartment	428,797
49	Midrise Apartment	49,145
50	Midrise Apartment	32,745
51	Midrise Apartment	24,880
52	Midrise Apartment	30,720
53	Midrise Apartment	6,160
54	Midrise Apartment	46,100
55	Midrise Apartment	31,015
56	Midrise Apartment	364,990
57	Midrise Apartment	141,540
58	Office	27,091
59	Office	22,694
	Total:	2,566,657

Note: For modelling purpose, buildings greater than 10 floors are considered as Highrise, and the ones greater than 3 floors up to 10 are considered mid-rise.

Since no detailed utility bills were available for all the buildings to generate the baseline, an alternate method of estimating heating and cooling loads for the system was necessary. It was determined that the best approach for this study was to use models of reference buildings of various building types obtained from the DOE to estimate energy use per square foot. Building energy uses and model details are available for many different types of buildings and various American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) climate zones. Based on the potential end-user buildings that were considered for the project, as well as a plan for potential future development, most of the Troy buildings were placed into three main categories (or some combination of them): apartment/multifamily home, retail space, and office space.

It was also necessary to consider two different types (vintages) of building construction since the potential buildings in the system are either existing construction to be updated, or brand-new construction (specifically the buildings located in the future waterfront development to the south of the proposed centralized plant). In order to account for this, two sets of models were created: one for ASHRAE 90.1 new construction reference buildings for the new buildings and one for ASHRAE 90.1 existing reference buildings constructed before 1980 for the existing buildings. Descriptions of each of the three building types can be seen below, as well as some information showing the differences between the two construction types:

- Midrise Apartment—The midrise apartment is a four-floor multifamily residential building with each floor consisting of eight apartments and one corridor. On the ground floor: however, the apartment space in the southeast corner of the building is replaced with an office space. Each space has a floor-to-ceiling height of 10 ft.
- Medium Office—The medium office is a three-floor office building consisting of one core-zone on each floor surrounded by four perimeter zones in each direction with a depth of 15 ft. from the external wall. Each space has a floor-to-ceiling height of 9 ft. with a 4 ft. above-ceiling plenum.
- Strip mall Retail—The strip mall retail is a single floor building consisting of ten conditioned retail spaces, two large and eight small, with windows on the south (entrance) side only. Each space has a floor-to-ceiling height of 17 ft.
- High-rise Apartment—The high-rise apartment is a 10-floor multifamily residential building with each floor consisting of eight apartments and one corridor. On the ground floor, however, the apartment space in the southeast corner of the building is replaced with an office space. Each space has a floor-to-ceiling height of 10 ft.
- Sit-down Restaurant—The sit-down restaurant is a single floor non-residential building with a kitchen and dining space, as well as an unconditioned attic space over the entire floor area. Windows wrap around the outer walls of the dining space, while the kitchen has none. Both the dining and kitchen spaces have a ceiling-to-ceiling height of 10 ft, the attic has a pitched roof.

1.2 Develop Interval Profiles

After constructing the models in EnergyPlus, each model was simulated using weather data from the representative city for the 5A climate zone specified by ASHRAE 90.1. This was necessary to accurately match the energy end-uses of each model to the end-uses of the DOE reference buildings. Once each model was sufficiently close to the reference building, the weather data for that building was changed to Albany to accurately reflect Troy's local weather conditions. These Albany-based models were used as the base case data for comparison to the proposed system. Using these models, an 8,760-hour continuum heating, cooling and domestic hot water load was generated and used to build a load profile for each building.

Many of the buildings in the system fall into multiple building types, typically consisting of one ground floor retail space (sometimes an office) with multiple floors of apartments above. In order to account for this combination of building types, each building was given two building types, as well as a percentage of floor space represented by that type. For example, a building with one floor retail and three floors of apartments was given a space type of "Midrise Apartment" with a percentage of 75 percent, and a second space type of "Retail" with a percentage of 25 percent. Additionally, since each building is a different physical size than the reference model buildings, each space type was given a "Space Ratio" which was calculated as a ratio of the building's floor area compared to the floor area of the respective reference model.

This approach allowed for the ability to generate baseline load profiles at a granular level as shown in Table 2 and Table 3 below. Hourly loads for individual buildings were summed together to obtain an hourly baseline load for all of the buildings combined. The combined load was then used to determine monthly peaks and totals.

Table 5. Peak and Annual Heating Load for Phase 1A Buildings

Buildings	**One Monument Square**	**231–239 River Street**	**261–269 River Street**	**23rd Street**	**3rd Street**	**4th Street**	**213 River Street**	**219 River Street**	**221–223 River Street**	**251 River Street**	**Total**
Peak Heating (MMBtu/hr.)	1.15	1.66	1.30	0.22	0.48	0.41	0.41	0.24	0.22	0.95	**6.45**
Annual Heating (MMBtu/year)	2235	2693	1008	163	357	328	593	523	487	1253	**9,316**

Table 6. Peak and Annual Heating Load for Phase 1B Buildings

	Taylor–1	**Taylor–2**	**Taylor–3**	**Taylor–4**	**Cowee Hall**	**Slingerland Alumnae House**	**Roy Courtyard**	**Hart Hall**	**Ricketts Hall**	**Manning Hall**	**Esteves School of Education**	**Plum Memorial**	**Total**
Peak Heating (MMBtu/hr.)	1.81	1.81	1.81	1.81	0.72	0.09	0.2 4	0.67	1.06	0.50	0.39	0.30	**10.69**
Annual Heating (MMBtu/year)	4,380	4,380	4,380	4,380	443	228	147	409	649	1,218	239	186	**21,039**

Table 7. Peak and Annual Heating Load for Phase 2 Buildings

	100 2nd Street	141 Congress Street	1646 5th Avenue	119 Congress Street	51 State Street	1700 6th Avenue	57–59 State Street	61 State Street	State Street	1776 6th Avenue	1800 6th Avenue	1801 6th Avenue
Peak Heating (MMBtu/hr.)	0.13	0.53	0.1	0.1	0.26	0.2	0.16	0.13	0.95	0.63	2.46	0.49
Annual Heating (MMBtu/year)	96	1,264	229	250	193	149	120	99	2,265	468	5,967	360

Table 7 continued

	2000 6th Avenue	720 Federal Street	503 Grand Street	2001 5th Avenue	92–96 4th Street	30 3rd Street	43 3rd Street	32 2nd Street	Total
Peak Heating (MMBtu/hr.)	2.22	2.77	0.84	0.44	0.16	0.14	0.09	0.26	**12.08**
Annual Heating (MMBtu/year)	5,375	6,696	2,023	323	116	105	225	191	**26,504**

Table 8. Peak and Annual Heating Load for Phase 3 Buildings

	Building–1	Building–2	Building–3	Building–4	Building–5	Building–6	Building–7	Building–8
Peak Heating (MMBtu/hr.)	2.51	3.29	2.80	2.64	2.43	3.99	0.54	0.36
Annual Heating (MMBtu/year)	5172	7235	5766	5443	5344	8781	1094	729

Table 8 continued

	Building–9	Building–10	Building–11	Building–12	Building–13	Building–14	Building–15	Building–16	Building–17	Total
Peak Heating (MMBtu/hr.)	0.27	0.3 4	0.07	0.51	0.34	3.45	1.71	0.52	0.43	**52.37**
Annual Heating (MMBtu/year)	554	684	137	1027	691	7534	3291	738	601	**109,649**

Table 9. Peak and Annual Cooling Load for Phase 1A Buildings

Buildings	231–239 River Street	261–269 River Street	23rd Street	3rd Street	4th Street	213 River Street	219 River Street	221–223 River Street	251 River Street	Total
Peak Cooling (Tons.)	110.9	111.8	112.3	34.4	75.5	32	23.9	4.9	63.7	**557.87**
Annual Cooling (MMBtu/year)	1,763	505	790	374	820	125	175	33	288	**4,872**

Table 10. Peak and Annual Cooling Load for Phase 1B Buildings

	Taylor–1	Taylor–2	Taylor–3	Taylor–4	Cowee Hall	Slingerland Alumnae House	Roy Courtyard	Hart Hall	Ricketts Hall	Manning Hall	Esteves School of Education	Plum Memorial	Total
Peak Cooling (Tons.)	120.7	120.7	120.7	120.7	58.0	6.2	19.3	53.6	85	33.5	31.3	24.3	**769**
Annual Cooling (MMBtu/year)	525	525	525	525	311	27	103	288	456	146	168	131	**3,729**

Table 11. Peak and Annual Cooling Load for Phase 2 Buildings

	100 2nd Street	141 Congress Street	1646 5th Avenue	119 Congress Street	51 State Street	1700 6th Avenue	57–59 State Street	61 State Street	State Street	1776 6th Avenue	1800 6th Avenue	1801 6th Avenue
Peak Cooling (Tons.)	20.1	43.1	7.82	8.54	40.6	31.4	25.3	20.8	77.3	98.87	164	76.0
Annual Cooling (MMBtu/year)	219	827	149	163	441	341	275	226	1482	1072	713	825

Table 11 continued

	2000 6th Avenue	720 Federal Street	503 Grand Street	2001 5th Avenue	92–96 Fourth Street	30 3rd Street	43 3rd Street	32 2nd Street	Total
Peak Cooling (Tons.)	148.1	184.5	55.76	68.21	24.42	22.17	6.21	40.38	**1,156**
Annual Cooling (kWh)	644.0	802.3	242.4	740.1	264.9	240.5	27.01	438.1	**10,139**

Table 12. Peak and Annual Cooling Load for Phase 3 Buildings

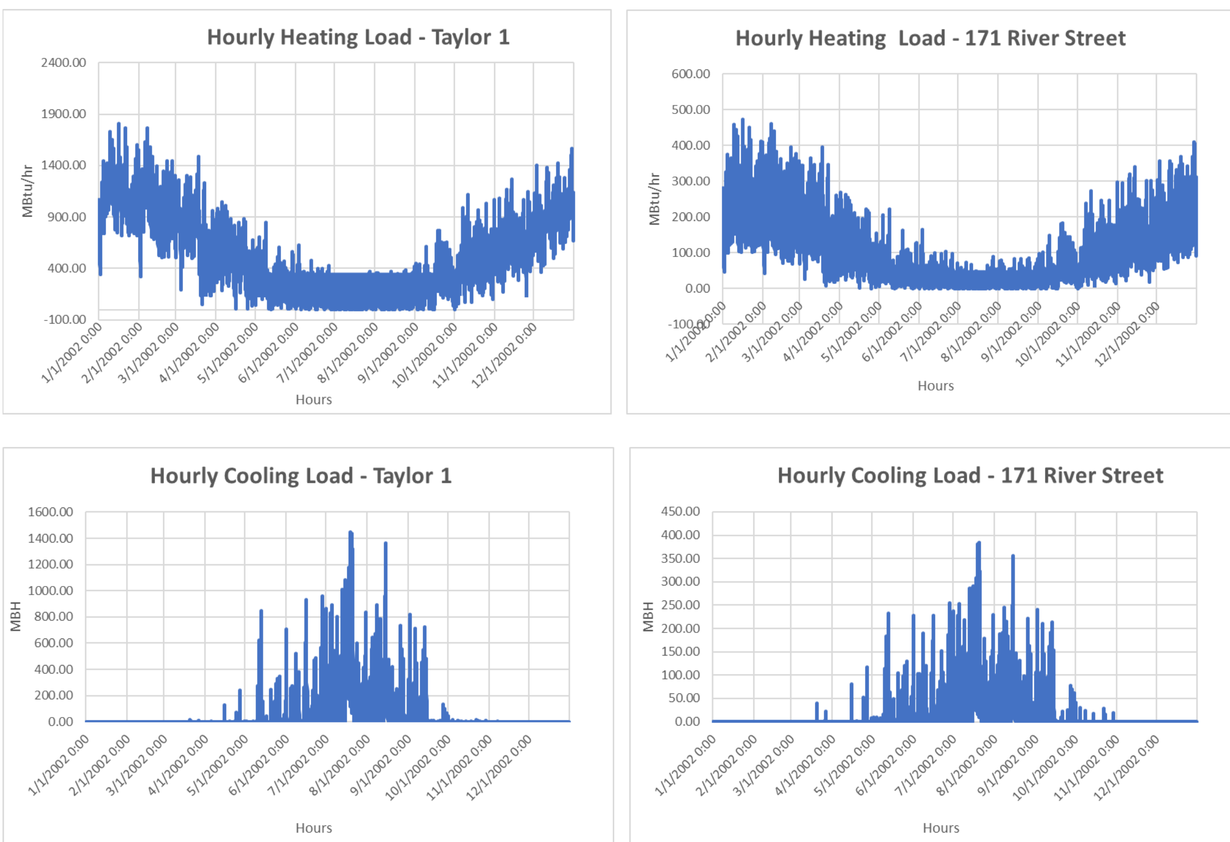
	Building–1	Building–2	Building–3	Building–4	Building–5	Building–6	Building–7	Building–8
Peak Cooling (Tons.)	191.3	255.8	213.3	201.3	188.9	310.5	40.90	27.25
Annual Cooling (kWh)	2,671	4,200	2,978	2,811	3,102	5,097	551	367

Table 12 continued

	Building–9	Building–10	Building–11	Building–12	Building–13	Building–14	Building–15	Building–16	Building–17	Total
Peak Cooling (Tons.)	20.71	25.57	5.13	38.37	25.81	267.3	126.4	58.76	53.83	**2,026**
Annual Cooling (kWh)	279	344	69	517	348	4,316	1,534	841	757	**30,780**

The graph below shows hourly load profiles for two sample buildings. Similar load profiles were generated for all buildings and phases.

Figure 5. Sample Modeled Hourly Load Profiles



The next step was to create models for each building type to represent the energy use when using the proposed heat pump system. This was done by replacing the original HVAC systems that were in each model with a new water source heat pump (WSHP) system. Models were simulated with new system types to generate new yearly energy end-use data that could be compared to the data associated with the original HVAC systems. The data for both the baseline conditions and the new proposed conditions can then be used to determine annual utility consumption. Factoring in the utility rates for electricity, natural gas, district cooling and district heating, the operational cost and energy cost savings associated with using a WSHP district energy system compared to the original systems can be calculated.

1.3 Monthly Load Profiles

The graphs below show monthly net load profiles for each phase. Noted that the graphs show positive values for heating dominant months and negative values for cooling dominant months. The coincident cooling and heating loads offset each other. These graphs indicate that Troy, NY is a heating dominant area. The geothermal loop needs to be designed with this in mind, as an annual imbalance in loads will affect the long term temperature of the surrounding ground, and the performance of the ground heat exchanger.

Figure 6. Phase 1A Monthly Load Profile

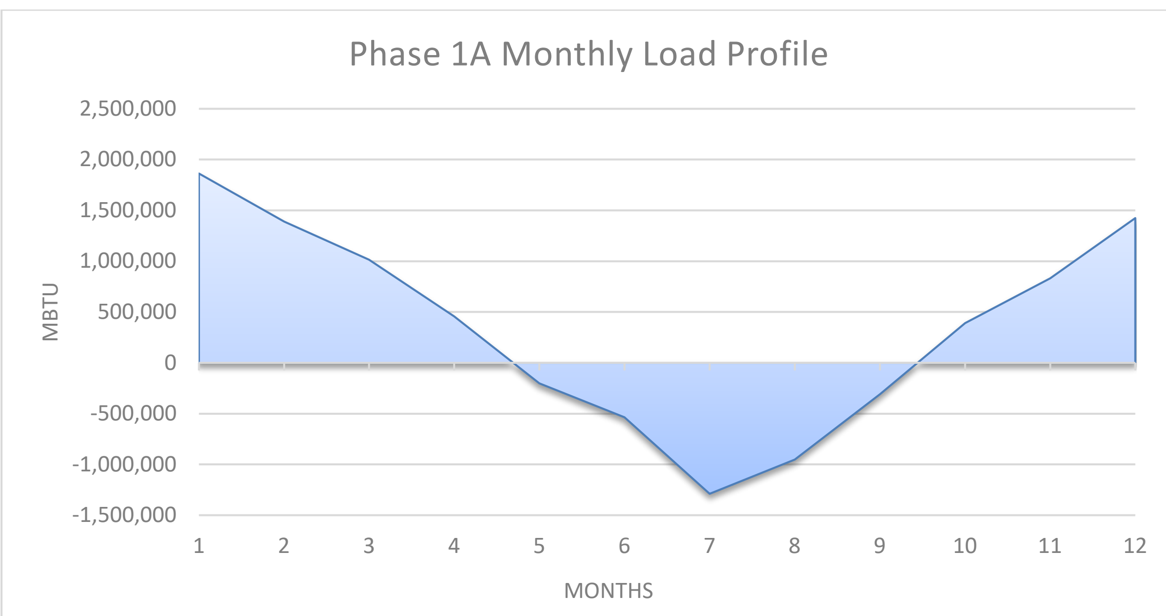


Figure 7. Phase 1B Monthly Load Profile

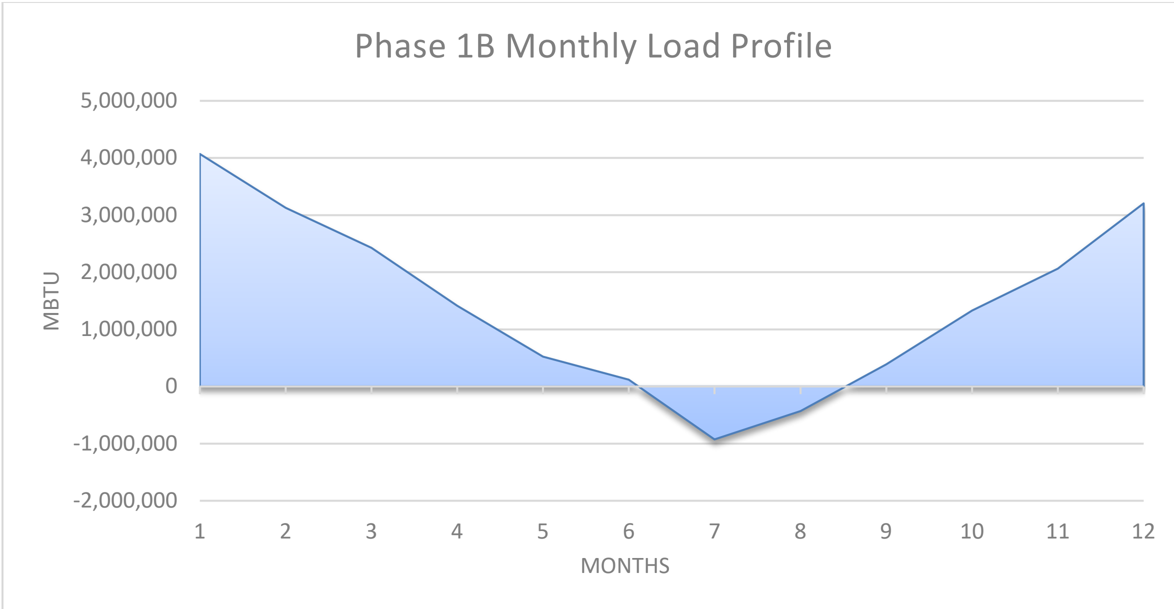


Figure 8. Phase 2 Monthly Load Profile

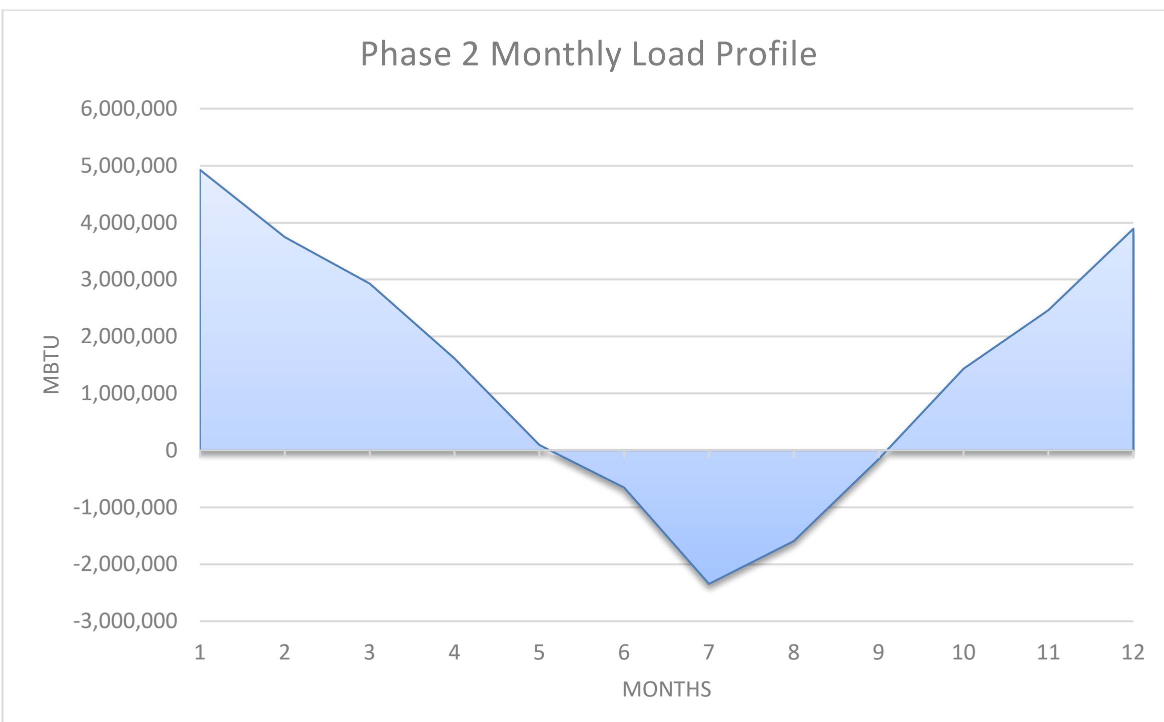
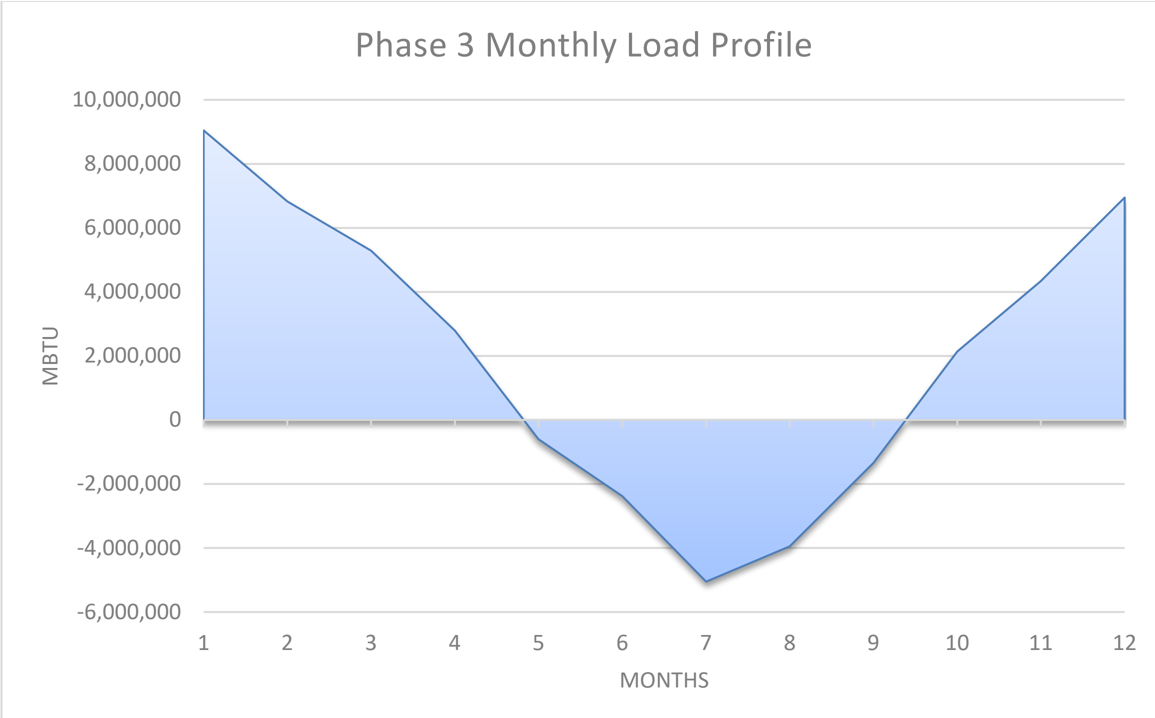


Figure 9. Phase 3 Monthly Load Profile



1.4 Hourly and Design Day Load Profiles

The graph below shows hourly load profiles for each phase. The peak loads noted here will be used to size the district system's peak capacity. It is to be noted that the heating dominated hours are shown as positive values in the graphs and the cooling dominant hours are shown as negative values in the graphs.

Figure 10. Phase 1A Hourly Load Profile

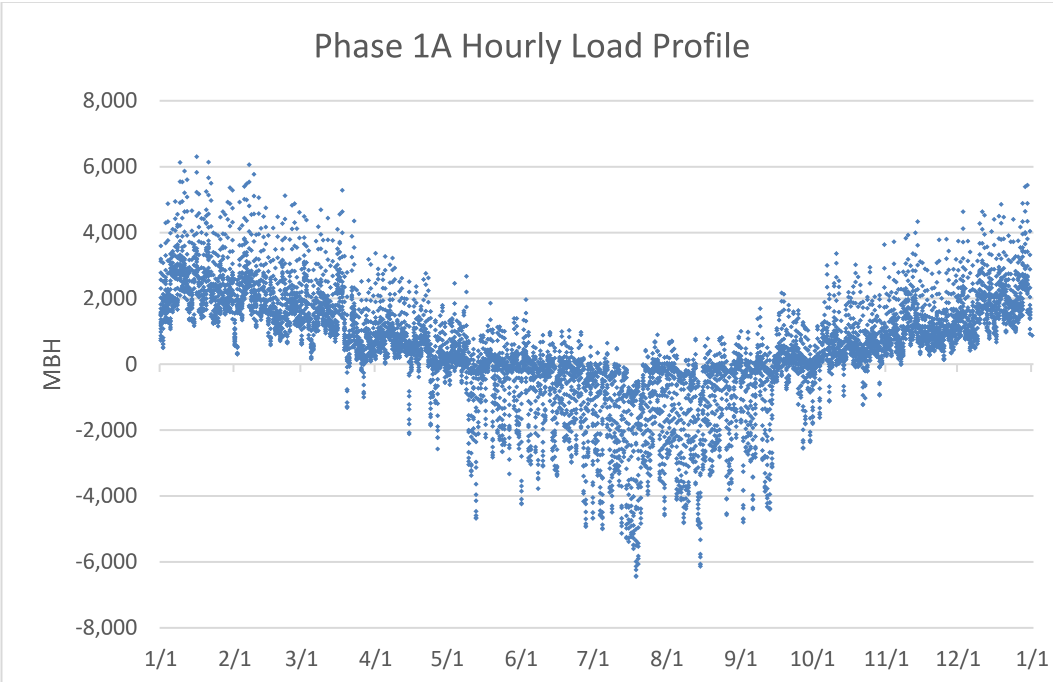


Figure 11. Phase 1A Design Day Heating Load

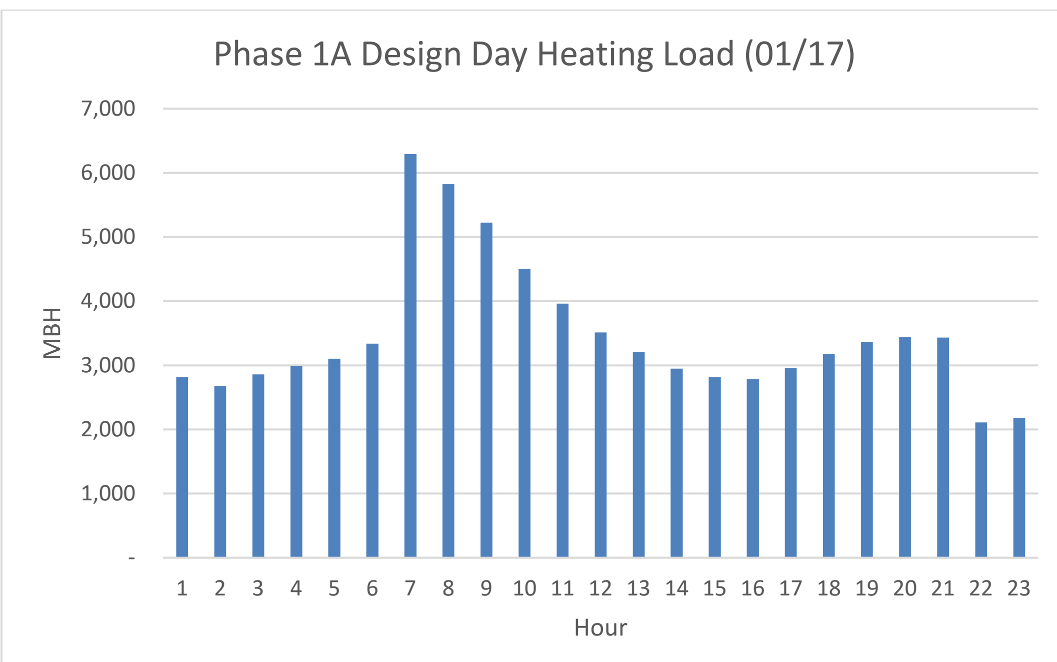


Figure 12. Phase 1A Design Day Cooling Load

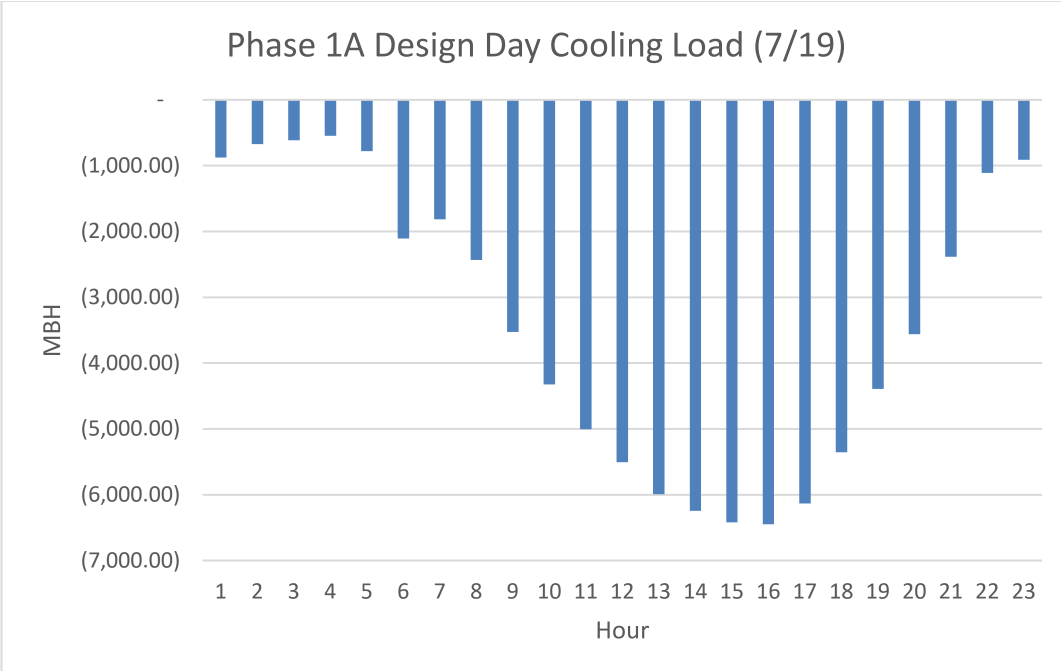


Figure 13. Phase 1B Hourly Load Profile

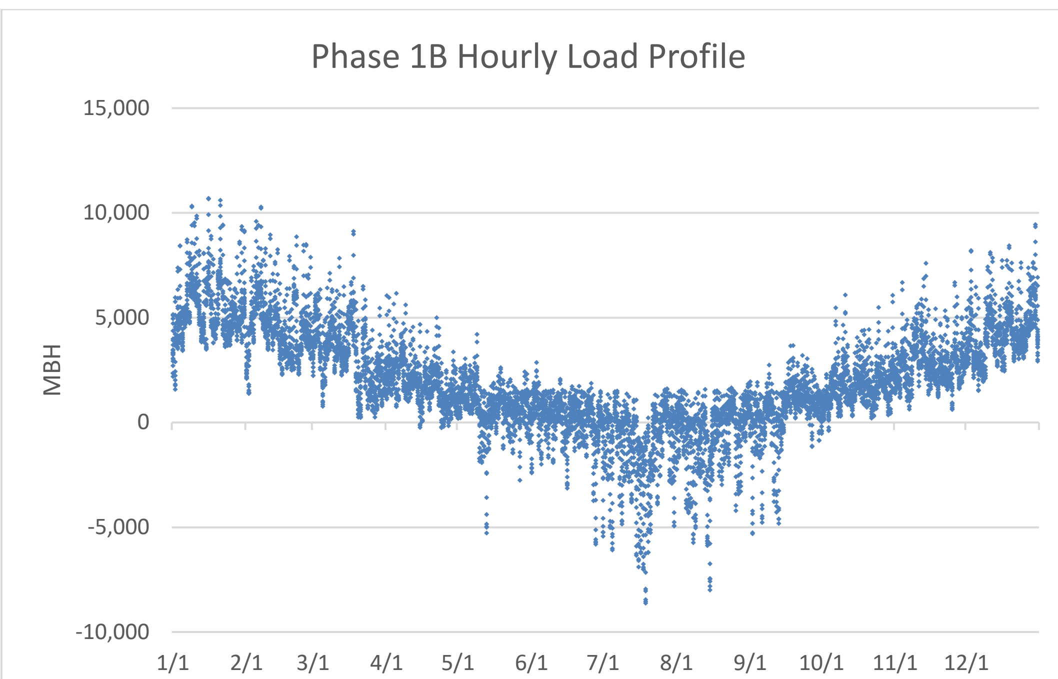


Figure 14. Phase 1B Design Day Heating Load

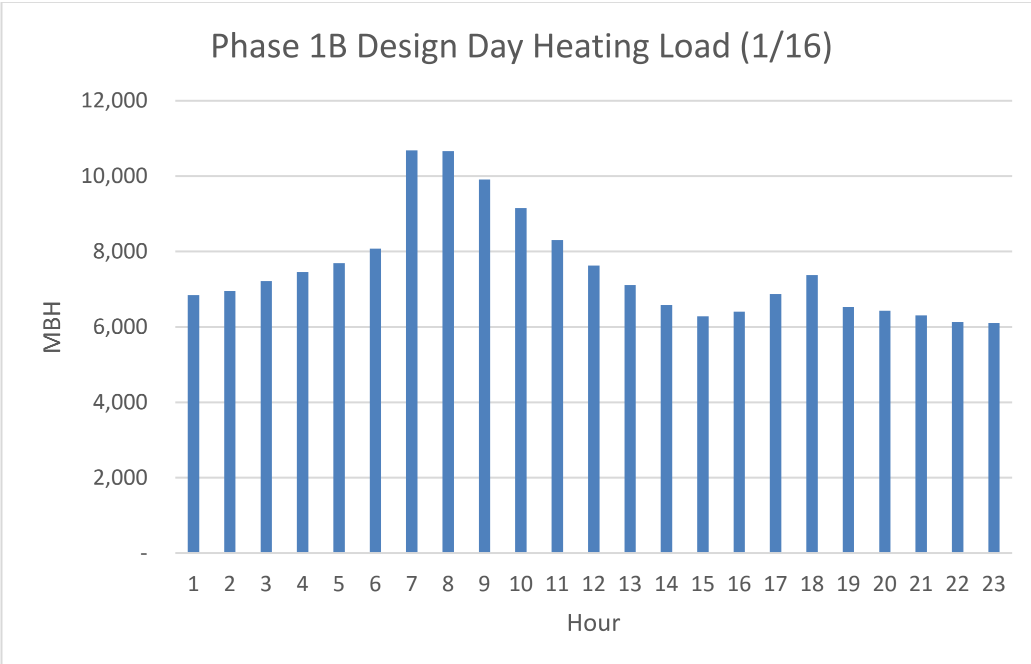


Figure 15. Phase 1B Design Day Cooling Load

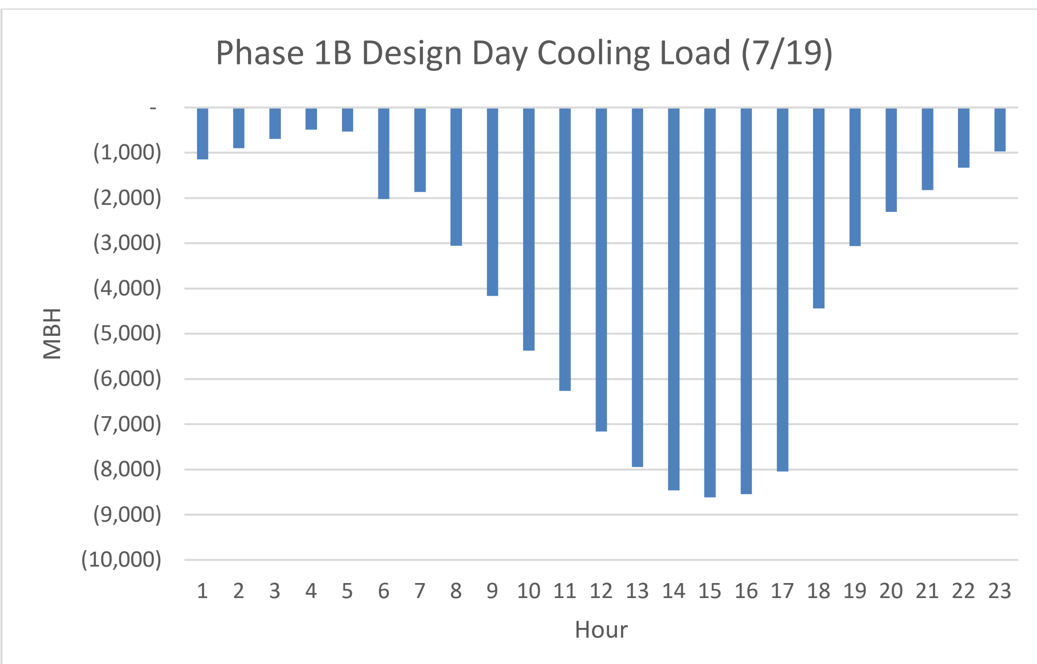


Figure 16. Phase 2 Hourly Load Profile

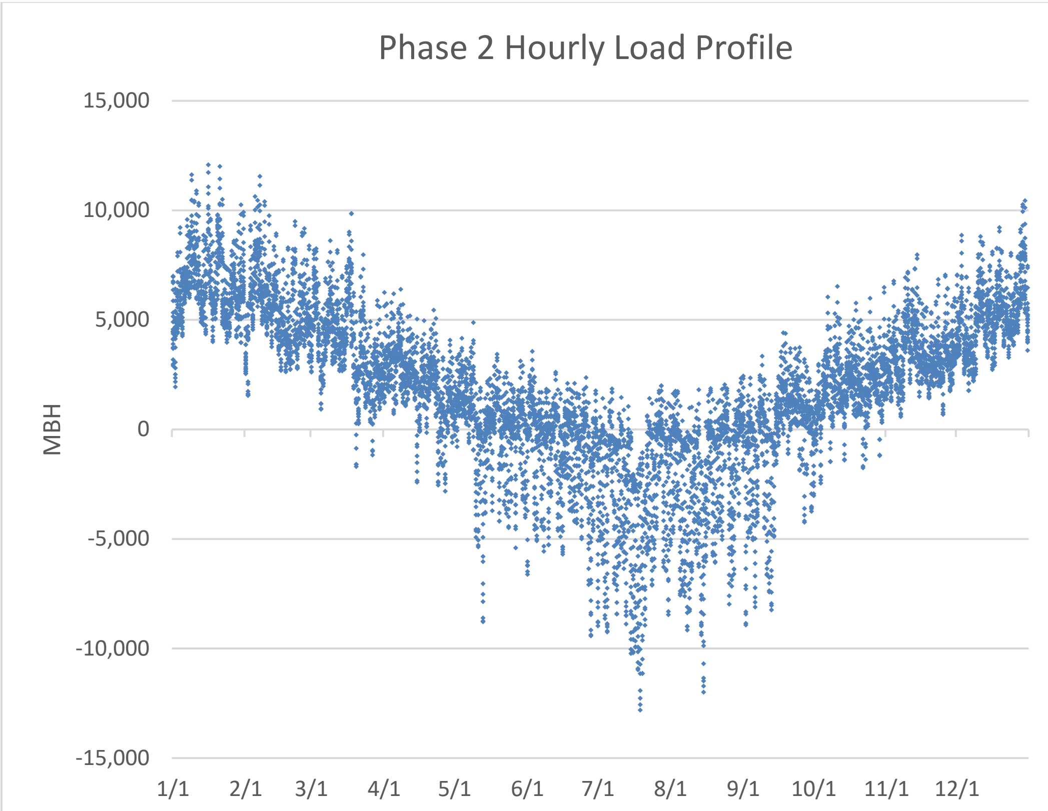


Figure 17. Phase 2 Design Day Heating Load

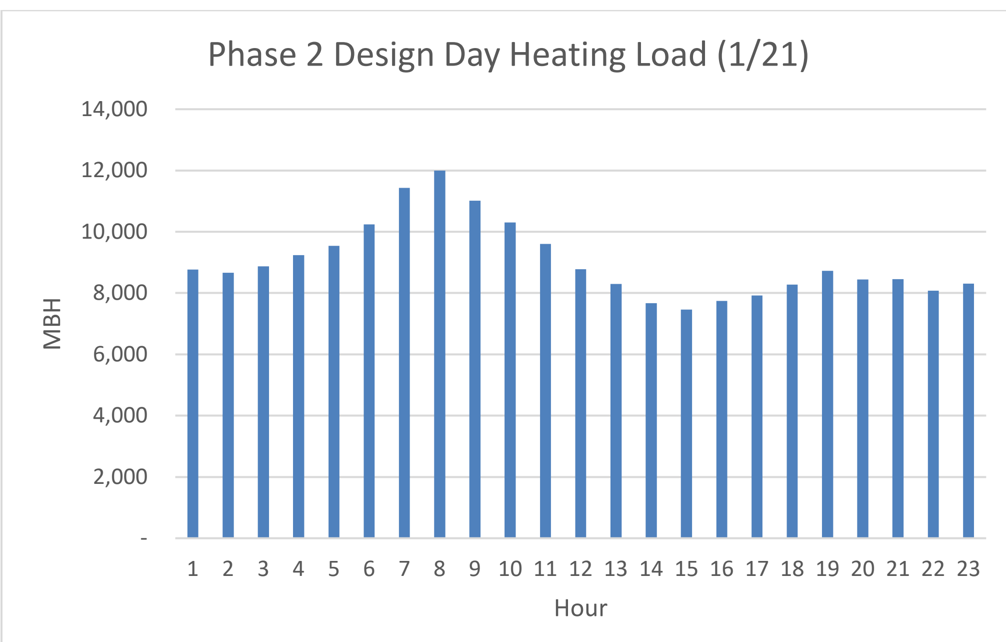


Figure 18. Phase 2 Design Day Cooling Load

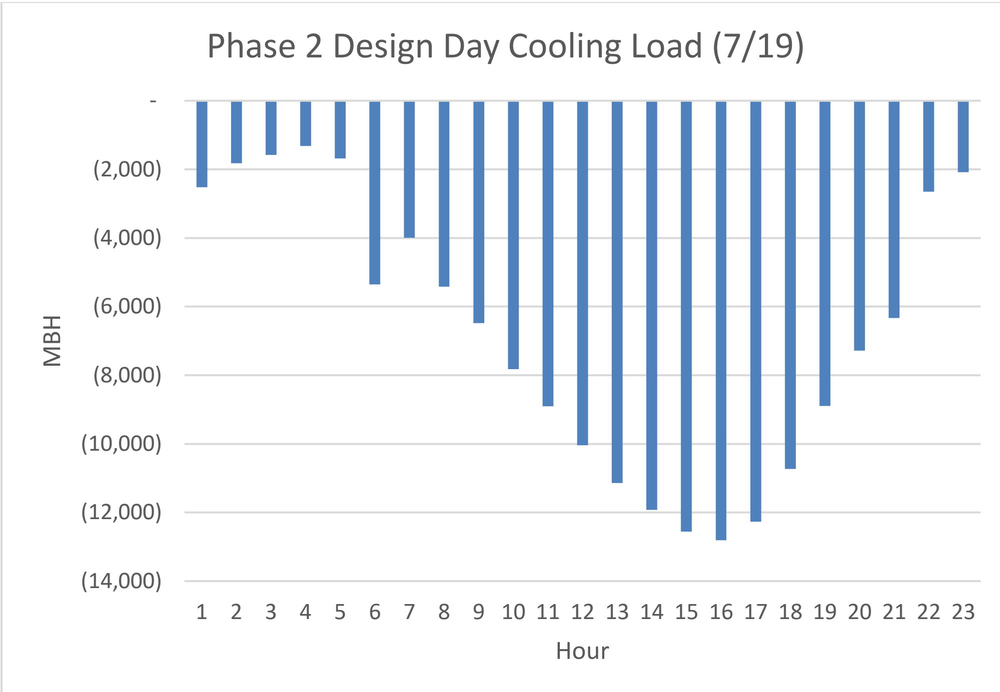


Figure 19. Phase 3 Hourly Load Profile

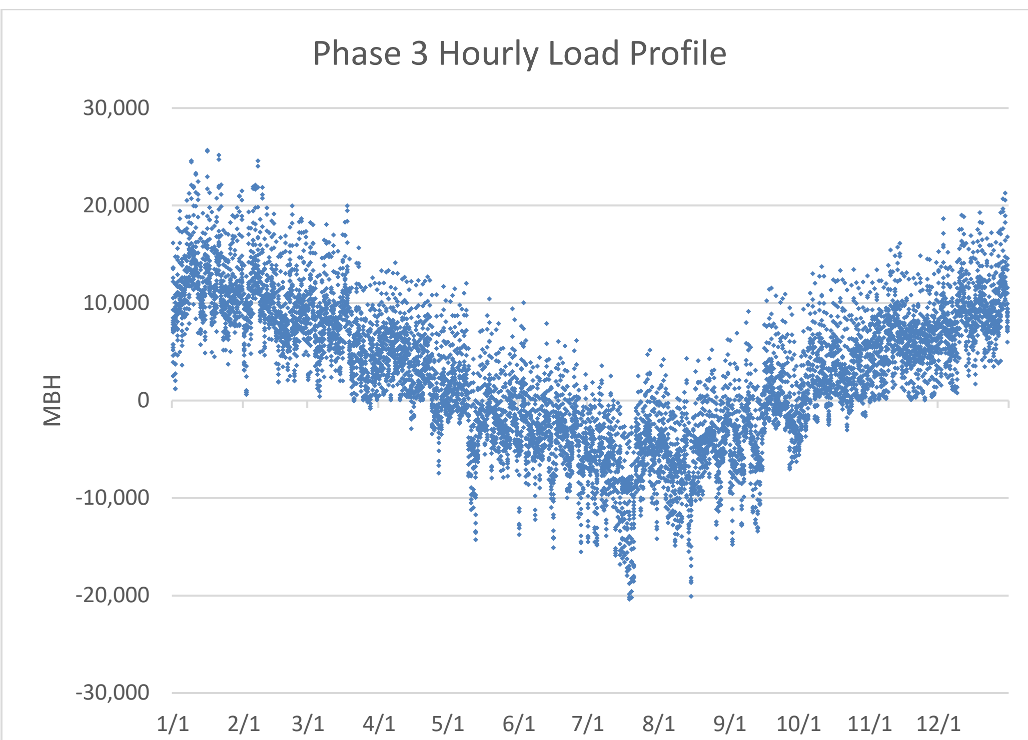


Figure 20. Phase 3 Design Day Heating Load

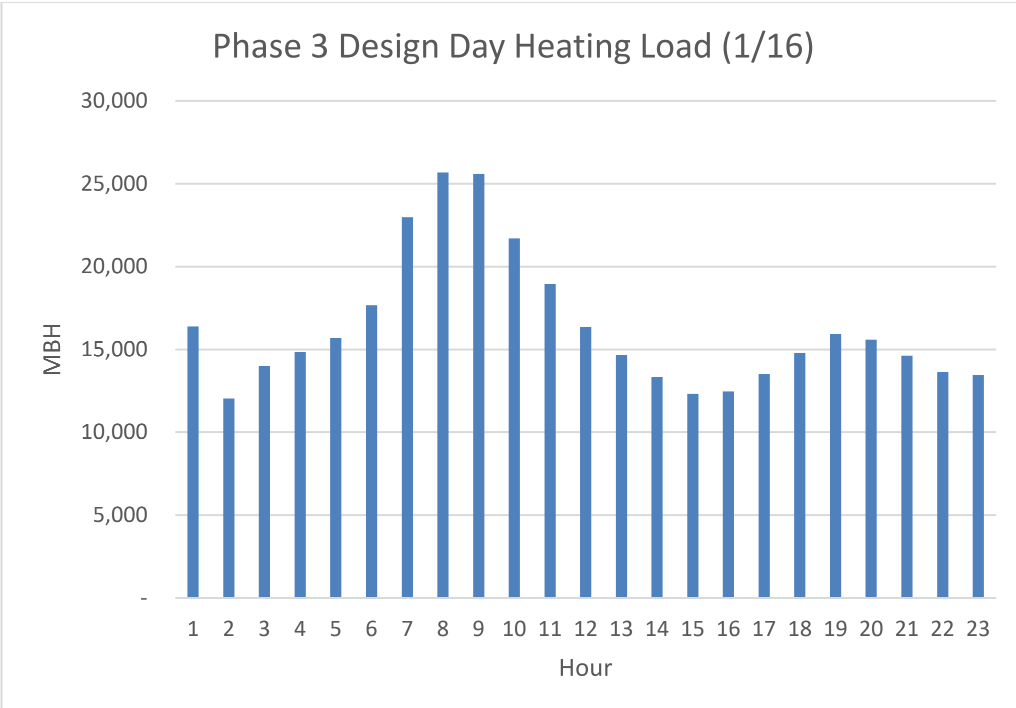
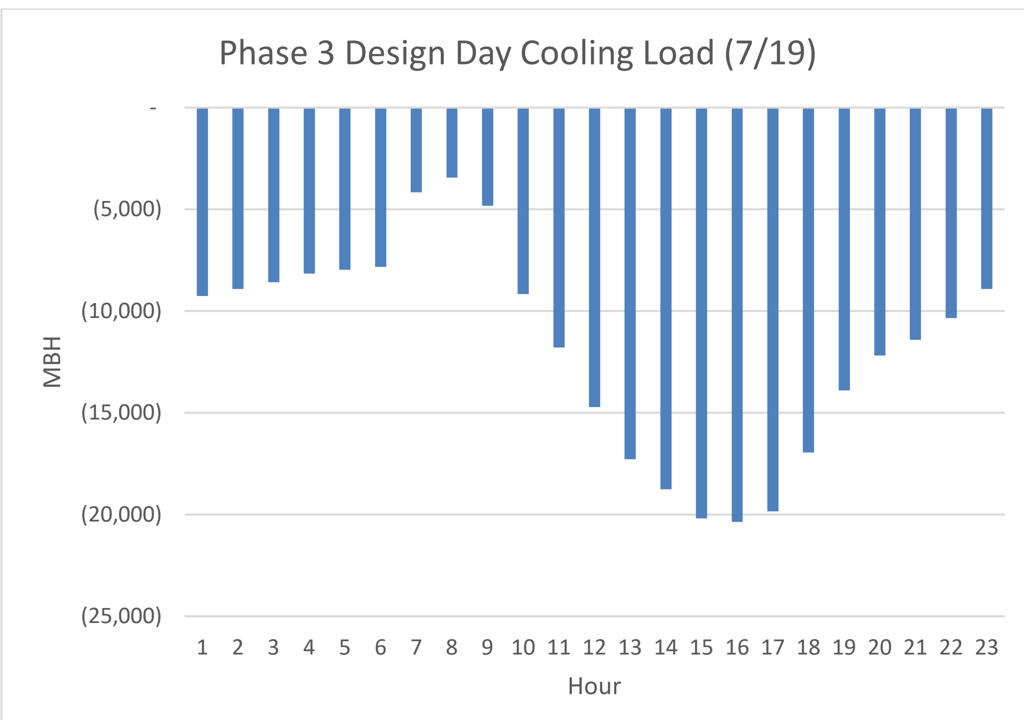


Figure 21. Phase 3 Design Day Cooling Load



1.5 Temporal Coincidence of Loads

Buildings were grouped into different phases based on type of building and location to optimize the energy load balance and the capital costs. Multifamily residential buildings generally have extended periods of heating in a year compared to cooling, whereas retail and office spaces see cooling requirements for extended periods of the year. This is because retail and office spaces see a lot of internal loads (equipment, people), which add heat to the space. A balanced mix of these building types have been considered to minimize energy imbalance. As seen in the tables above each phase has a mix of apartment buildings as well as retail and office spaces to help balance thermal loads. However, close consideration was given to proximity from the river and proposed borefield locations so that piping costs do not undermine the economics of the project.

Sizing of geothermal systems is most efficient when the cooling and heating energy required from the ground is equal. As important as it is to balance annual loads to ensure the geothermal loop doesn't extract too much heat from the ground, it is also important to increase efficiency of the loop by matching loads such that simultaneous cooling and heating is taken care of by the loop by shifting energy around, rather than by extracted more energy from the ground. Our 8760-model looked at hours where some buildings require cooling and others require heating where the loads could offset each other without required an outside energy source. This is also seen in our monthly load profiles above. Included in the analysis is this diversity factor which will increase as more buildings are added to the loop.

1.6 Preliminary Utility Usage

Tables 5 show the annual heating and cooling requirements for all included buildings. In the existing scenario, the existing system type is not known in every building, therefore assumptions were made based on the type of buildings, size, age and known characteristics of typical buildings of that profile. The heating plants are assumed be a form of natural gas combustion with a combined average overall fuel to heating efficiency of 76 percent and the baseline thermal usage is calculated using this value. The buildings at Russell Sage college are heated by cast iron sectional boilers. The heating system for the other buildings need to be surveyed. All buildings are assumed to be cooled by air cooled DX type systems, with the typically least expensive option of PTACs chosen. The overall cooling EER is assumed to be 10.2.

In the proposed scenario all buildings are assumed to be heated and cooled by a water source heat pump district energy system. The proposed system is expected to have a COP of 4.3 for heating and an average EER of 20.1 for cooling.

Table 13. Phase 1A: Existing and Proposed Systems Energy Usage

Phase 1A	Thermal Load	Existing Annual Heating	Existing Annual Cooling Load	Existing Annual Cooling	Proposed Annual Heating	Proposed Annual Cooling
Building	**MMBtu/yr.**	**Therms**	**MMBtu/yr.**	**kWh**	**kWh**	**kWh**
1 Monument-Sq 231-239 River St.	2236	29,421	1,763	50,481	152,402	25,708
261-269 River Street	2693	35,435	505	14,455	183,557	7,361
2 3rd Street	1008	13,267	790	22,630	68,726	11,525
Third St	163	2,147	374	10,710	11,124	5,454
Fourth St	358	4,705	820	23,465	24,371	11,950
213 River Street	594	7,812	125	3,567	40,469	1,816
219 River Street	524	6,891	175	5,018	35,694	2,556
221-223 River Street	487	6,408	33	941	33,195	479
251 River Street	1253	16,491	288	8,242	85,426	4,197
Totals:	**9,316**	**122,578**	**4,872**	**139,510**	**634,963**	**71,046**

Table 14. Phase 1B: Existing and Proposed Systems Energy Usage

Phase 1B	Thermal Load	Existing Annual Heating	Existing Annual Cooling Load	Existing Annual Cooling	Proposed Annual Heating	Proposed Annual Cooling
Building	**MMBtu/yr.**	**Therms**	**MMBtu/yr.**	**kWh**	**kWh**	**kWh**
Taylor-1	4,380	57,633	525	15,027	298,544	7,653
Taylor-2	4,380	57,633	525	15,027	298,544	7,653
Taylor-3	4,380	57,633	525	15,027	298,544	7,653
Taylor-4	4,380	57,633	525	15,027	298,544	7,653
Cowee Hall	443	5,823	311	8,905	30,161	4,535
Slingerland Alumnae House	228	3,002	27	783	15,548	399
Roy Courtyard	147	1,937	103	2,963	10,036	1,509
Hart Hall	409	5,383	288	8,232	27,883	4,192
Ricketts Hall	649	8,539	456	13,060	44,235	6,651
Manning Hall	1,218	16,021	146	4,177	82,989	2,127
Esteves School of Education	239	3,147	168	4,813	16,301	2,451
Plum Memorial	186	2,446	131	3,741	12,671	1,905
Totals:	**21,039**	**276,830**	**3,729**	**106,782**	**1,433,998**	**54,379**

Table 15. Phase 2: Existing and Proposed Systems Energy Usage

Phase 2	Thermal Load	Existing Annual Heating	Existing Annual Cooling Load	Existing Annual Cooling	Proposed Annual Heating	Proposed Annual Cooling
Building	**MMBtu/yr.**	**Therms**	**MMBtu/yr.**	**kWh**	**kWh**	**kWh**
100 2nd Street	96	1,258	219	6,272	6,515	3,194
141 Congress Street	1,264	16,637	828	23,694	86,182	12,066
1646 5th Avenue	229	3,014	150	4,293	15,615	2,186
119 Congress Street	250	3,292	164	4,688	17,050	2,387
51 State Street	193	2,535	441	12,641	13,129	6,438
1700 6th Avenue	149	1,959	341	9,769	10,146	4,975
57-59 State Street	120	1,580	275	7,880	8,184	4,013
61 State Street	99	1,300	226	6,485	6,736	3,303
State Street	2,265	29,802	1482	42,443	154,379	21,614
1776 6th Avenue	468	6,159	1073	30,721	31,906	15,645
1800 6th Avenue	5,957	78,384	714	20,438	406,034	10,408
1801 6th Avenue	360	4,737	825	23,628	24,540	12,033
2000 6th Avenue	5,375	70,720	644	18,440	366,337	9,391
720 Federal Street	6,696	88,106	802	22,973	456,396	11,699
503 Grand Street	2,023	26,624	242	6,942	137,915	3,535
2001 5th Avenue	323	4,249	740	21,193	22,011	10,793
92-96 Fourth Street	116	1,521	265	7,587	7,880	3,864
30 3rd Street	105	1,381	241	6,889	7,155	3,508
43 3rd Street	225	2,966	27	773	15,366	394
32 2nd Street	191	2,515	438	12,546	13,030	6,389
Totals:	**26,504**	**348,741**	**10,139**	**290,294**	**1,806,506**	**147,833**

Table 16. Phase 3: Existing and Proposed Systems Energy Usage

Phase 3	Thermal Load	Existing Annual Heating	Existing Annual Cooling Load	Existing Annual Cooling	Proposed Annual Heating	Proposed Annual Cooling
Building	MMBtu/yr.	Therms	MMBtu/yr.	kWh	kWh	kWh
Building–1	5,172	68,053	2,671	76,463	352,519	38,939
Building–2	7,236	95,206	4,200	120,254	493,172	61,240
Building–3	5,767	75,880	2,978	85,258	393,066	43,418
Building–4	5,444	71,626	2,811	80,478	371,029	40,984
Building–5	5,344	70,318	3,102	88,818	364,251	45,231
Building–6	8,781	115,543	5,097	145,942	598,520	74,321
Building–7	1,095	14,402	551	15,771	74,603	8,032
Building–8	729	9,596	367	10,508	49,708	5,351
Building–9	554	7,291	279	7,984	37,768	4,066
Building–10	684	9,003	344	9,858	46,634	5,020
Building–11	137	1,805	69	1,977	9,351	1,007
Building–12	1,027	13,510	517	14,794	69,981	7,534
Building–13	691	9,089	348	9,953	47,082	5,069
Building–14	7,534	99,132	4,316	123,580	513,513	62,934
Building–15	3,291	43,300	1,534	43,922	224,297	22,367
Building–16	738	9,712	841	24,073	50,309	12,259
Building–17	601	7,910	757	21,675	40,974	11,038
Totals:	**54,825**	**721,375**	**30,780**	**881,310**	**3,736,777**	**448,811**

1.7 Baseline Energy Use and Utility Costs

Based on available utility data from National Grid, the electricity rate in Troy, NY is estimated to vary from $0.8/kWh to $0.12/kWh, and natural gas price is estimated to vary from $7/MMBtu to $9/MMBtu. Average rates of $0.10/kWh and $8/MMBtu are therefore used for this report. The table below shows the utility cost of operating the existing heating and cooling system.

Table 17. Baseline Utility Usage and Cost

	Existing Annual Therms Usage	Existing Annual kWh Usage	Existing Annual Utility Cost
Phase 1A	122,578	139,510	$112,013
Phase 1B	276,830	106,782	$232,142
Phase 2	348,741	290,294	$308,022
Phase 3	721,375	881,310	$665,231
Total	**1,574,308**	**1,207,316**	**$1,317,408**

1.8 Life-Cycle Cost for Baseline

Life-cycle cost analyses (LCCA) provide the cost of ownership of the WSHP over the equipment life of the system. The costs that are incorporated into the life-cycle analysis are as follows:

- initial construction
- electricity and natural gas costs of system operation
- operation, maintenance, and repair
- replacement costs

It is to be noted that per the NYS DEC, State agencies are to use a social cost of carbon at \$123/ton CO_2. However, this was not included in the LCCA. A life cycle of 25 years was utilized in all LCCA models.

1.8.1 Initial Construction Costs

The table below shows the preliminary cost estimate of installing the baseline building system. The baseline building system includes boilers in each building to generate heating hot water for the building's heat, as well as packaged terminal air conditioner (PTAC) units in each room to provide cooling. The PTACs are assumed to have a hydronic coil to utilize heat from the heating hot water. In each case, it is assumed that the existing terminal equipment in these buildings is at their end of life, and that replacements are required in Year 1 of the LCCA. Since boilers last longer and we did not know the age of the existing equipment in each building, it was assumed that 10 percent of boiler infrastructure will be replaced from year 10 through year 19 in our LCCA.

For the proposed system, a ground source heat pump system is considered, with water to air water-source heat pumps in each building providing all of the heating and cooling. A central plant adjacent to the geothermal borefield site would house pumps, heat exchangers, controls, and any other ancillary equipment needed to send the condenser water out to the buildings. In the buildings, it is assumed that water-source heat pumps are installed. An allowance is included for distribution piping going to the water-source heat pumps in each building.

1.8.2 Electricity and Natural Gas Costs of System Operation

See previous section, "Preliminary Utility Usage," for discussion and results of the annual electricity and natural gas costs for all buildings. A National Institute of Standards and Technology (NIST) paper[1] was used to calculate the electricity and natural gas escalation rates. The model assumes that general economic inflation is set at 3 percent in the foreseeable future; the actual escalation rates for both electric and gas differ, with electric seeing a more rapid increase in unit cost. Please see the section on "Net Present Value Analysis" (NPV Analysis) in the Task 4 portion of this report for the escalation rates used for gas and electric.

Also, a system efficiency degradation of 0.25 percent per year was used in the analysis, for both existing and proposed systems.

1.8.3 Operation, Maintenance, and Repair Costs

The boilers in these buildings will be significantly more expensive to operate than the geothermal system with water-source heat pumps in the spaces. Initial estimates are that total baseline operations, maintenance, and repair costs will total about $4,500 per year per building. In comparison, only $4,500 per year is estimated for the proposed case for each central plant. An escalation rate for the O&M costs of 3 percent per year is used in the analysis.

1.8.4 Replacement Costs

According to ASHRAE, commercial water-source heat pumps (WSHPs) have a 19-year life cycle, whereas the baseline PTAC units only have a 15-year life cycle.

To account for these shorter life cycles in the LCCA, it is assumed that some WSHP's start failing 5 years before expected life and the last ones fail 5 years after the expected life. This results in 10 percent of the units failing from Year 14 through Year 23. The failure rate is assumed to drop to 5 percent for years 24 and 25 as most of the WSHP's would be new at that point.

1 Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis–2021
https://nvlpubs.nist.gov/nistpubs/ir/2021/NIST.IR.85-3273-36.pdf

For the PTAC units, the same is assumed; the first 10 percent of units would fail in year 10 and the last units would fail in year 19. In years 20 through 22, most of the units would be relatively new and the failure rate is assumed to drop to 5 percent for those years. In year 23, the oldest units begin to fail, and the rate goes back up to 10 percent.

1.8.5 Net Present Value Analysis (NPV) Results

Please refer to Task 4— "Perform economic analysis" for detailed results on the Net Present Value (NPV).

1.9 Environmental Footprint

The project will have a significant positive impact on the environment, hence there will be a reduction of emissions as shown below. The greenhouse gas emissions and CO_2 equivalence are calculated using DOE's greenhouse gas equivalencies calculator. A value of 200g CO_2 equivalent per kilowatt-hour of electricity (eq/kWh)was used for the grid electricity mix in New York State.[2] The social cost of carbon was taken as $123/ton based on a paper released by the DEC in the State.[3]

Table 18. Avoided Carbon Emissions

Phase	Annual Tons of CO_2 Emission Avoided	Annual Social Cost of Avoided Emissions
1A	440	$54,120
1B	1,224	$150,552
2	1,985	$244,155
3	3,102	$381,546

2 United States Environmental Protection Agency–Greenhouse Gas Equivalencies Calculator; https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

3 New York State Department of Environmental Conservation–Establishing a Value of Carbon; Guidelines for Use By State Agencies; https://www.dec.ny.gov/docs/administration_pdf/vocguidrev.pdf

2 Task 3. Determine Optimal Energy Source and Develop Conceptual Design

2.1 Vertical Bore Closed Loop System

Vertical boreholes provide a passive source of heat and heat rejection from the ground. A 495-foot deep bore is proposed, as closed loop geothermal boreholes in New York State are subject to additional regulations by the Department of Environmental Conservation (DEC) when drilled beyond 500 ft. Deeper wells are technically possible and have been attempted elsewhere: however, the current regulatory statues create a barrier to installation by treating them as oil and gas wells with additional permitting and escrow requirements. If the borefield is municipally owned, there may be relief available to the escrow requirements.

Borehole Layout

- Spacing of 20 ft. on center in a grid pattern for boreholes typically provides an optimal tradeoff between land area and performance. However, in this land constrained condition a staggard spacing—15 ft. on center with each row offset from the adjacent rows—is more effective at getting additional boreholes in the same fixed area, and still allows for an average 21 ft. spacing between boreholes.
  - Geology

    A thermal conductivity test has not been completed at this time; however, data was available from several structure bores in the vicinity. We expect loose gravel/fill until about 50 ft., then a formation of tight, wet, shale. The associated average thermal conductivity of the rock formations is taken to be 1.3 Btu/hr. ft. F and the thermal diffusivity for wet shale is 0.55 ft^2/day. Additionally, ground water was observed at 17–20 ft. below grade, which would coincide with the depth of the nearby sea wall.

    A building across the street from the 1 Monument square site also has a geothermal bore-field, and in interviews with the design team from that project, they did not report any issues with drilling in the immediate vicinity.
  - Grout

    A graphite enhanced bentonite will be utilized to provide a minimum thermal conductivity of 1.2 Btu/hr. ft. F.

2.2 Potential Ground Loop Heat Exchanger (GLHX) Site

The map below shows the location of the sites that are identified for the installation of the vertical bores. A total of seven land sites for vertical bores and one river water heat exchanger site were identified for buildings that are enlisted under Phases 1A and 1B. A total of 156,000 ft.[2] is available for borehole construction. The one borefield location is highlighted in yellow in Figure 22 and seven borefield locations are highlighted in yellow in Figures 23. The blue area outlined in Figure 23 is the boundary of Russell Sage College.

Figure 22. Site Locations for Phase 1A Buildings

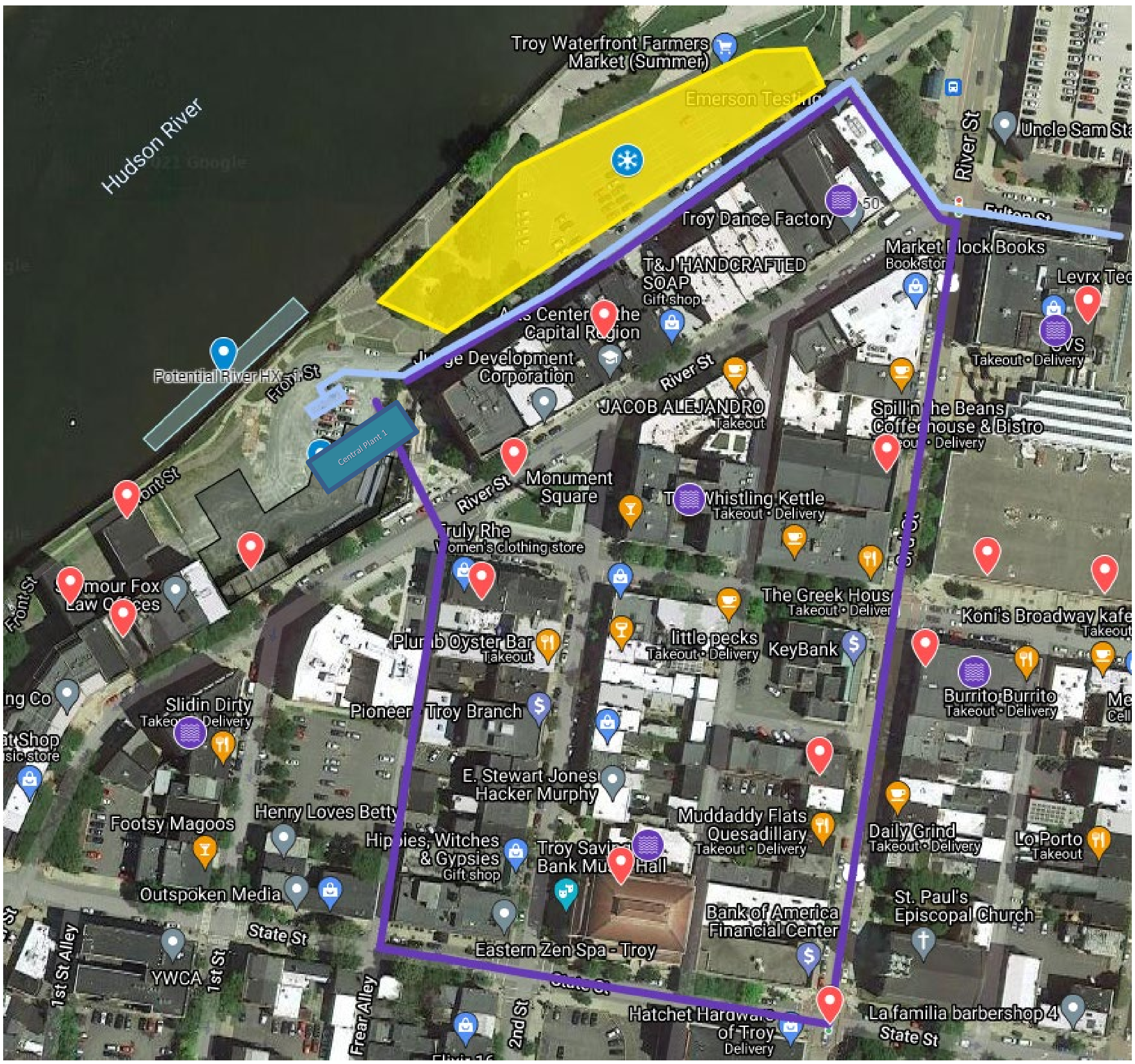


Figure 23. Potential Site Locations for Phase 1B Buildings

Figure 24. Potential Site Locations for Phase 2 Buildings

2.3 Centralized System Overview

There are two central plants for Phases 1A and 1B of the project, and the central plants are shown in Figures 4 and 5, highlighted in blue. The boreholes will utilize a ground loop heat exchanger (GHX) and the river water loop will utilize a river water heat exchanger (River HX) to connect to the central plant. The central plant will house the pumping system that will pump either water or a water/glycol mix to the end-user buildings via the central loop.

Table 19. Phases 1A and 1B

Phase	Proposed System	Total Heating Load on GHX (MMBtu)	Total Cooling Load on GHX (MMBtu)	Served By System	Area Available for Bores (sf)	Number of Boreholes	Borehole Grid Structure
1A	Central Plant - 1	7,044	4,872	Potential GHX Site 7, River HX 1	50,198	150	25 x 6
				Phase 1 A Totals	**50,198**	**150**	
1B	Central Plant - 2	15,908	3,729	Potential GHX Site 1	20,079	45	5 x 9
				Potential GHX Site 2	20,952	49	7 x7
				Phase 1BTotals	**41,031**	**94**	
1B Sage	Central Plant - 2	15,908	3,729	Potential GHX Site 3	15,278	75	5 x 15
				Potential GHX Site 4	8,730	27	9 x 3
				Potential GHX Site 5	23,571	48	8 x 6
				Potential GHX Site 6	17,460	40	5 x 8
				Phase 1B Sage Totals	**65,039**	**190**	

Table 20. Phase 2

Phase	Proposed System	Total Heating Load on GHX (MMBtu)	Total Cooling Load on GHX (MMBtu)	Served By System	Area Available for Bores (sf)	Number of Boreholes	Borehole Grid Structure
Phase 2	Central Plant 4, 5, and 6	20,040	10,139	Potential GHX Site - 8	26,190	55	11 x 5
				Potential GHX Site - 9	17,024	45	9 x 5
				Potential GHX Site - 10	17,024	40	5 x 8
				Potential GHX Site - 11	30,119	66	11 x 6
				Potential GHX Site - 13	8,730	24	6 x 4
				River HX - 2	-	-	-
					99,087	**230**	

Table 21. Phase 3

Building	Proposed System	Total Heating Load on GHX (MMBtu)	Total Cooling Load on GHX (MMBtu)	Served By System	Square-Feet Available for Bores	Number of Boreholes	Borehole Grid Structure
Phase 3	Central Plant - 3	41,453	30,780	Potential GHX Site 12	192,060	440	21 x 21

2.4 System Sizing

The heating degree days (HDD) and the cooling degree days (CDD) for this location were compared using a base temperature of 65°F. The HDD are significantly higher than the CDD; as a result, the buildings have a heating dominant load.

2.4.1 Heating Load

The tables below show the hourly and the annual heating load for different phases. The hourly GHX capacity for the sites is calculated based on a capacity of 2.3 tons/bore. The annual thermal energy available from the sites was obtained from a bin analysis. The annual heat loads for all buildings under each phase were added to obtain a combined hourly and annual value.

It is notable that on an annual basis, the GHX nearly meets or exceeds the heat load for Phases 1a and 1b; however, to meet the peak load of the buildings, we would need to add a river HX to supplement the GHX. For Phases 2 and 3 the GHX capacity falls short by 10 percent and 42 percent respectively. For these two phases as well, we would need to add either a river HX or wastewater heat recovery from the sewer system to supplement the GHX to meet the peak load.

During the design phase, adding more boreholes, increasing the size of the river heat exchanger or sewer wastewater heat recovery can be considered for all the phases based on the results of the conductivity test which is being performed on each site.

Table 22. GHX Heating Capacity–Phase 1A

Phase 1A	Hourly Peak Load	Annual Load
	MMBtu/hr.	MMBtu/yr.
Total Building Load	4.88	5,931
GHX Capacity	4.14	8,190
% Load Delivered by GHX	85%	138.1%
% Load Delivered by River HEX/Heat Recovery	15%	(38%)

Table 23. GHX Heating Capacity–Phase 1B

Phase 1B	Hourly Peak Load	Annual Load
	MMBtu/hr.	MMBtu/yr.
Total Building Load	10.69	15,908
GHX Capacity	7.84	15,506
% Load Delivered by GHX	73%	97.5%
% Load Delivered by River HEX/Heat Recovery	27%	2.5%

Table 24. GHX Heating Capacity–Phase 2

Phase 2	Hourly Peak Load	Annual Load
	MMBtu/hr.	MMBtu/yr.
Total Building Load	12.08	27,051
GHX Capacity	6.35	24,391
% Load Delivered by GHX	53%	90%
% Load Delivered by River HEX/Heat Recovery	47%	10%

Table 25. GHX Heating Capacity–Phase 3

Phase 3	Hourly Peak Load	Annual Load
	MMBtu/hr.	**MMBtu/yr.**
Total Building Load	19.42	41,453
GHX Capacity	12.14	24,023
% Load Delivered by GHX	63%	58.0%
% Load Delivered by River HEX/Heat Recovery	37%	42%

2.4.2 Cooling Load

The tables below show the peak hourly and the annual cooling load for different phases. Cooling loads for all buildings under each phase were added to obtain a combined hourly and annual value.

It is to be noted that on an annual basis, the GHX exceeds the annual cooling load requirement for all phases. However, to meet the peak cooling capacity, we would need to couple the GHX with a river HX or a sewer wastewater heat recovery system.

Table 26. GHX Cooling Capacity–Phase 1A

Phase 1A	Hourly Peak Load	Annual Load
	Tons	**MMBtu/yr.**
Total Building Load	558	4,872
GHX Capacity	345	8,190
% Load Delivered by GHX	62%	168.1%
% Load Delivered by River HEX/Heat Recovery	38%	

Table 27. GHX Cooling Capacity–Phase 1B

Phase 1B	Hourly Peak Load	Annual Load
	Tons	**MMBtu/yr.**
Total Building Load	769	3,729
GHX Capacity	653	15,506
% Load Delivered by GHX	85%	415.8%
% Load Delivered by River HEX/Heat Recovery	15%	

Table 28. GHX Cooling Capacity–Phase 2

Phase 2	Hourly Peak Load	Annual Load
	Tons	**MMBtu/yr.**
Total Building Load	1,156	10,139
GHX Capacity	529	27,051
% Load Delivered by GHX	46%	266.8%
% Load Delivered by River HEX/Heat Recovery	54%	

Table 29. GHX Cooling Capacity–Phase 3

Phase 3	Hourly Peak Load	Annual Load
	Tons	**MMBtu/yr.**
Total Building Load	2026	30,780
GHX Capacity	1012	41,453
% Load Delivered by GHX	50%	134.7%
% Load Delivered by River HEX/Heat Recovery	50%	

The remaining part of the load may be delivered by a combination of the following. A decision to be made during the design phase:

1. Include the river water heat exchanger (River HX).
2. Add another site to include more boreholes.
3. Potentially dig deeper boreholes.
4. Add wastewater heat recovery from a nearby wastewater source.
5. Add air source heat pumps.
6. Remove building load by installing hybrid systems in the end-user buildings.

2.5 Thermal Storage

Thermal storage was not analyzed in this task since the annual cooling loads for all buildings in all phases are being designed such that the ground loops, river heat exchanger, or the wastewater heat recovery could satisfy the cooling loads without any thermal storage.

2.6 Long-Term Thermal Imbalance

As observed in the previous graphs, the Troy, NY region is heating dominated and this means that more heat will need to be extracted from the ground during heating periods than will be put into the ground during cooling periods in a given year. The design challenge will be to balance the thermal loads such that there is minimal change to the ground temperature over a long period of time. This can be done in a few ways.

- Utilize the proposed river water heat exchanger and the proposed wastewater heat recovery opportunity in Troy to offset the majority of the thermal imbalance. We can use either the river water heat exchanger or the wastewater heat recovery as a primary loop and use the ground heat exchanger as a secondary loop. This will ensure lesser delta temperatures going in and out of the ground loop leading to balanced loads. The sizing and site-specific details of the river water heat exchanger and the wastewater heat recovery is mentioned in Task 3.
- During the design phase, borehole spacing and ground water movement will play a crucial role in the ability to absorb and dissipate heat. Close borehole spacing will restrict the ability of the borehole to dissipate heat, whereas good ground water movement will help carry the heat away.

Table 30. Annual HVAC Load Balance

Phase	Total Heating Load (MMBtu/year)	Total Cooling Load (MMBtu/year)
1A	5,931	3,369
1B	15,908	3,729
2	27,051	4,287
3	41,453	30,780

2.7 Ground Heat Exchanger (GHX) Site Locations

The potential GHX sites were chosen based on the location relative to the off-takers for each phase. Downtown Troy has multiple parking lots which could be used to drill the bore holes. Additional to the idea of having boreholes in parking lots, river heat exchangers can be utilized to add capacity to the loops. Currently, 14 potential GHX sites have been identified as shown in Figures 4, 5 and 6.

With the exception of the Riverfront Park area, all of the identified locations have third-party ownership, and a legal framework of how to lease the space underneath existing parking lots has yet to be determined.

2.8 River Heat Exchanger (HEX)

The site is adjacent to the Hudson River, which is accessed by other nearby sites for cooling water in an open system scheme. To simplify the regulatory process, a closed loop approach is instead proposed. Expansion of the system size would be possible from a modestly sized stainless steel heat exchanger. These heat exchangers can be used in series to supplement the temperature rise of the heat transfer fluid and can be sequenced as a secondary source of heat. The GHX will be used to meet the baseload and the river heat exchanger will be operational when additional capacity is needed.

The proposed River HEX system can help in increasing the efficiency of the system if the loop water is passed through the river HEX first and then through the ground loop. As part of the proposed design, heat pumps are being installed at central plants as a snow melt system for the sidewalks for the City of Troy. In extremely cold days when the return water temperature from the buildings is very low (around 28° F), we can pass that water through the river HEX where river water temperatures are expected to be higher (around 32° F), and we can extract heat from the water even at low temperatures by using those heat pumps in the central plant. Once that heat is recovered, we can further extract more heat from the ground loop as well enabling us to reduce the size of the equipment required to satisfy the peak heating load in the buildings.

2.9 Wastewater Heat Recovery

The city of Troy, like many northeast U.S. cities, has an aging combined storm sewer system. The E-W lines are owned by the city, and the N-S force mains are owned and operated by Rensselaer County. An 18 inch combined storm/sewer line goes though the 1 Monument Square site that can be accessed to provide supplemental heating capacity. A manhole is to be replaced as part of that project, which would allow the installation of a manhole with a wet well to allow for a submersible pump to pump the contents over to the central plant to be processed. Further filtration is needed by specialized equipment before it can be interfaced with the loop.

2.10 Air Source Heat Pump Chillers

Air source heat pump chillers are available from a limited number of manufacturers and provide heating to the loop. Since the loop would be at a low temperature in the winter, the leaving water temperature (LWT) of the heat pump would be near its minimum setting of 80°F and be able to operate fairly efficiently down to 5–10°F. Maximum equipment size is around 200–250 tons. VRF derivative heat pump chillers are also available that can function down to -15°F if peak winter heating is the limiting case. The units do require space and are noisy, which limits where they may be applied. However, this will be further investigated in the design phase of the project if the proposed supplemental systems such as river HEX and wastewater heat recovery from the sewers doesn't materialize due to permitting reasons.

2.11 Hybrid System

A hybrid system can be considered at the building level to satisfy the heating and cooling loads of the building.

In a hybrid cooling system, a cooling tower or a chiller can be installed (or an existing unit can be used where possible) in parallel to the building HEX. During the hotter days the tower/chiller will run at part or full load to supplement the building HEX.

In heating mode, a terminal unit that has electric resistance backup heat can be selected to meet the heat load during colder days. The electric resistance heat can be sequenced to serve as a secondary source of heat, and the heat pump will remain as the primary heat source.

3 Task 4. Perform Economic and Financial Analysis

3.1 Life-Cycle Cost for Baseline

Life-cycle cost analyses (LCCA) provides the cost of ownership of the water source heat pump (WSHP) over the equipment life of the system. The costs that are incorporated into the life-cycle analysis are shown below:

- initial construction costs
- electricity and natural gas costs of system operation
- operation, maintenance, and repair costs
- replacement costs

In this case, a life cycle of 25 years was utilized.

3.1.1 Initial Construction Costs

The table below shows the preliminary cost estimate of installing the baseline building system. The baseline building system includes boilers in each building to generate heating hot water for the building's heat, as well as PTAC units in each room to provide cooling. The PTACs are assumed to have a hydronic coil to utilize heat from the heating hot water. In each case, it is assumed that the existing equipment in these buildings is almost at end of life since site visits were not conducted on any of the buildings and that replacements are completed from Year 1 to Year 3 at the same rate in each year of the LCCA. Detailed line-by-line cost breakouts for each phase is provided in the appendix.

Table 31. Baseline Construction Cost

	Baseline Construction Cost ($)			
	Phase 1A	Phase 1B	Phase 2	Phase 3
Cost	$3,853,571	$5,150,597	$8,489,018	$10,417,023

For the proposed system, a geothermal heat pump system is considered, with water source heat pumps in each building providing all the heating and cooling. There would be a central plant adjacent to the geothermal borefield site that would have all the pumps, heat exchangers, controls, and any other ancillary equipment needed to send the condenser water out to the buildings. To supplement the heat l oad of the geothermal system, river heat exchanger and waste heat recovery from sewer lines are added to appropriate phases. In the buildings, it is assumed that water source heat pumps are installed. An allowance is included for some piping going to the water source heat pumps in each building. It is to be noted that although these costs include building level WSHP retrofit costs, they are for reference purposes only and will not be carried by the central plant owner and are supposed to be financed separately. The details of all the costs are available in appendix A.

Table 32. Proposed Construction Cost

	Proposed System Construction Cost ($)			
	Phase 1A	Phase 1B	Phase 2	Phase 3
Cost	$13,615,989	$20,538,540	$43,493,354	$34,649,333

3.1.2 Electricity and Natural Gas Costs of System Operation

The Table 37 shows the utility cost of operating the existing and proposed system, broken down by phases. All the assumptions for calculating these values are presented under "Preliminary Utility Usage" under Task 1. Also, a system efficiency degradation of 0.25 percent per year was used in the analysis, for both existing and proposed systems.

Table 33. Utility Costs

	First Year Utility Cost ($)			
	Phase 1A	Phase 1B	Phase 2	Phase 3
Existing - Therms	$98,063	$221,464	$366,923	$562,266
Existing - kWh	$13,951	$10,678	$11,506	$82,628
Proposed - kWh	$63,496	$143,399	$261,983	$436,764

3.1.3 Operation, Maintenance, and Repair Costs

The PTAC units along with boilers in these buildings will be significantly more expensive to operate than the geothermal system with water source heat pumps in the spaces. Initial estimates are that total baseline operations, maintenance, and repair costs will total about $4,500 per year for each building. This generally includes annual boiler cleaning and tuning, valve replacements, burner service, sensor replacement, pump service, and motor replacements.

In comparison, $4,500 per year is estimated for the proposed case for each central plant. The maintenance cost of the existing terminal PTAC units and the WSHP is expected to offset each other. An O&M escalation rate of 3 percent per year, in line with the assumed inflation rate of the economy, is used in the analysis.

3.1.4 Replacement Costs

Based on ASHRAE life expectancy, it is assumed that the boilers will last the full 25 years of the baseline life cycle; however, since we do not know the exact age of the existing boiler systems in the buildings, it is assumed that 10 percent of the boiler infrastructure will start to get replaced every year from year 10 through year 19. It is also assumed that all the geothermal infrastructures will last the full 25 years of the proposed life cycle. However, according to ASHRAE, commercial water source heat pumps (WSHPs) have a 19-year life cycle, whereas the baseline PTAC units only have a 15-year life cycle.

To account for these shorter life cycles in the LCCA, it is assumed that some WSHP's start failing 5 years before expected life and the last ones fail 5 years after the expected life. This results in 10 percent of the units failing in Year 14, 10 percent in Year 15, and so on, through Year 23. The failure rate is assumed to drop to 5 percent for years 24 and 25 as most of the WSHP's would be new at that point.

For the PTAC units, the same is assumed; the first 10 percent of units would fail in year 10 and the last units would fail in year 19. In years 20 through 22, most of the units would be relatively new and the failure rate is assumed to drop to 5 percent for those years. In year 23, the oldest units begin to fail, and the rate goes back up to 10 percent.

The LCA attached as an appendix to this report shows the LCCA on a year-by-year basis.

3.2 Life-Cycle Cost for District Energy System

The LCA attached as appendix A to this report shows the LCCA on a year-by-year basis.

3.3 Net Present Value (NPV) Analysis

3.3.1 Energy Escalation Rates

National Institute of Standards and Technology (NIST) publishes energy price indices and discount factors for life-cycle cost analysis. The energy escalation factors for electricity and natural gas as shown below was obtained from the NIST handbook and used in the analysis. These factors correspond to an overall inflation of 3 percent in the broader economy. The complete table for the factors is available in appendix B for reference.

Table 34. NIST Fuel Escalation Rates

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Electricity	1	1.05	1.09	1.14	1.19	1.24	1.3	1.35	1.4	1.43	1.48	1.52	1.59	1.65	1.71
Natural Gas	1	1.03	1.04	1.03	1.06	1.1	1.13	1.17	1.22	1.26	1.3	1.34	1.38	1.43	1.48

3.3.2 Discount Rate

The discount rate for future cash flows depends on the capital structure of an entity. Typically, a weighted average cost of capital is used to derive the present value of future cash flows. For municipal entities such as the City of Troy, the interest rate is typically lower because the income from these investments is free from federal income tax. In our analysis, we have used a discount rate of 5 percent and have included a sensitivity analysis of the NPV based on the discount rate.

3.3.3 NPV Summary

In the NPV analysis, using a 5 percent discount rate, the net present values of the investment in the more efficient water source heat pump units are shown in the table below. The analysis is broken down by phases. This indicates a positive return on investment for the project.

Table 35. Project Net Present Value Summary

	Phase 1A	Phase 1B	Phase 2	Phase 3
NPV without category C NYSERDA Aid	($6,746,839)	($10,796,029)	($27,364,455)	($19,560,824)
NPV with category C NYSERDA Aid	($3,116,205)	($7,165,395)	($23,769,767)	($15,966,136)

3.4 Results—Business Model

1. **Describe the customer contract offerings (e.g., ownership structure, membership rules, billing rates, terms/contractual relationships between project participants, organization and operational control) and rate of uptake of customers.**

The City of Troy will act as the lead applicant, in conjunction with co-applicant Troy Local Development Corporation (TLDC) to own and operate the system. Siemens will be the lead contractor for design and implementation for the turnkey project under NYS Article 9 Energy Performance Contract (EPC).

Under Siemens, the project is designed and engineered by CHA Consulting, Inc. (CHA) with additional geothermal design support from Karpinski Engineering. Siemens' implementation team will consist of CD Perry (Construction Services), Allied Well Drilling (Geothermal Wells), John W. Danforth (Mechanical Contractor), and Aztech Geothermal (Consulting).

The Siemens team also looked at other business models with the Article 9 EPC providing procurement, the most efficient and cost-effective model for this phase. The team looked at Energy-as-a-Service models for the project but determined this becomes more feasible once there is less speculation from off-takers, and when the future phases for district energy are adopted.

Billing Rates: Participants will be billed through the City of Troy Water Department as a separate service. The initial billing model will be a per square foot per month charge with a residential and commercial rate. This will minimize complexity for both the City and off-takers. Initial rates are being assessed at \$0.05 per square foot per month for residential and \$0.10 per month for commercial. Final rates and contract terms will be clarified once the final project cost and grant award allocation is determined.
The potential customers heating and cooling needs are greater than the system can produce. The list of off-takers to those will be near term projects and/or have signed letters of support. A variable rate was discussed and could be implemented, especially as the capacity is expanded in future phases.

Metered rates are being evaluated and documented for subsequent additional phases. During discussions with potential off-takers for this project, it was determined that a fixed rate pricing structure would be initially beneficial.

2. **Explain how the preferred ownership model unlocks value, such as desirable depreciation schedules of equipment, tax implications, etc.**

While there is no tax advantage for a Municipally owned system, the energy performance contracting (EPC) financial model will provide an opportunity for the City to create a needed additional revenue stream while helping achieve sustainability goals. As a municipally owned endeavor, this project can leverage funds from the recently awarded \$10 million (M) Downtown Revitalization Initiative (DRI), thereby offsetting some of the tax benefits allowed to a privately owned business.

3. **Explain how the project offers a value proposition to the various stakeholders.**

City of Troy—The City needs District Geothermal to meet the NYS Climate Act Passed in 2019 to reduce emissions by at least 85 percent by 2050. The City can also provide snow melt for key public areas to improve safety and salt wear on concrete/asphalt and contamination of the water table.

Troy Local Development Corporation (TLDC)—The TLDC will use this to attract new business and development. This will also be an opportunity for the City and the TLDC partnership to generate additional revenue to support future development.

Commercial/Residential Off-takers—Off-takers can take advantage of:

- Avoided infrastructure costs—No cooling towers, boiler, flue, chimney, and other initial capital investments.
- Lower maintenance cost—No cooling tower maintenance, chemical treatment, burner maintenance, etc.
- Improved equipment life cycle of WSHP versus Boiler and PTAC systems.
- Lower energy costs and fixed monthly heating/cooling costs for easy budget planning.

Workforce Development—The City of Troy, Siemens, RPI, Sage College, Hoboken Brownstone, and Future of Small Cities have been planning a Living Lab Space at One Monument Square who will be an off-taker. This Future of Cities and Urban Sustainability (FOCUS) Living Lab will be a dynamic, interactive exhibit space that showcases urban design and technology solutions for sustainable communities. District Geothermal will be showcased as "The Future of Equitable Energy Design in Small City Communities" and align with the green workforce development initiatives.

4. **Discuss the financial viability/net project benefits (and the impact of incentives), budget, potential sources of funds and proposed uses of funds, and implication of schedule.**

The full project proforma can be found in the appendix.

The Financial Model includes both commercial and residential off-takers that have Letters of Support for District Geothermal and have building projects in the next one to five years to take advantage of geothermal heating and cooling. As outlined previously, billing will be calculated by square footage. The initial group of off-takers have square footages outlined below.

The total square footage targeted for this project is 548,490 sq/ft.

- Commercial/Industrial—217,860 sq/ft
- Residential/Mixed Use—330,630 sq/ft

This will yield annual revenues of $459,810/year.

- For every 10,000 square foot of additional commercial off-takers that participate the annual revenue increases by $12,000.00.
- For every 10,000 square foot of additional residential off-takers that participate the annual revenue increases by $6,000.00.

The financial model includes annual mechanical services and measurement and verification to ensure that flow and btu/s requirements are being achieved.

The incentive is critical to the first tranche of the Troy District Energy plan as outline in the feasibility study. Maximizing the incentive will provide the most robust system and an acceptable ROI to the city and community.

5. **If the project was a public works project (e.g., for a municipal customer) please discuss compliance with public project requirements, and influence on the selected business model.**

The City of Troy has a previously awarded contract with Siemens for EPC contracting services. Under NYS Energy Law Article 9, Troy can leverage that contract to meet public project requirements with all of the partners outlined in the proposal.

3.5 Results—Impact

6. **Compare and contrast total project costs versus out-of-pocket costs (as a result of incentives, tax credits, etc.) for the community configuration and the individual smaller systems configuration, and highlight any awkward economic signals.**

One of the main drivers considered in terms of the district style geothermal system in this project was the location. Downtown Troy is dense with multiple buildings in close proximity without much open space with which private owners can use for geothermal. However, there is ample public space owned by the City of Troy which can be leveraged for a district style geothermal system.

The Phase 1A building–One Monument Square's ownership wanted to construct a geothermal system for the building as part of the new construction but could not find the required space to install the boreholes required to satisfy the majority of the modeled heating and cooling loads. This in fact kickstarted the conversation with the City of Troy and Siemens to consider the district style approach, where the city would own and operate the system and charge the off-takers a fee for use. This would not only bring down the first cost of construction for the One Monument Square ownership, it would improve the economics of the project immensely as well as lead to the construction of a green building.

The analysis for economic signals wasn't conducted in depth as the 58 buildings considered in this project would not be able to construct geothermal systems individually mainly due to space constraints in downtown Troy.

7. Community heat pump system compared to individual building electrification:

One of the main questions to analyze is how a community heat pump system is more efficient than installing standalone heat pumps in individual buildings.

Individual buildings were analyzed based on the modeling loads created. For each of the buildings, the heating and cooling loads were met by standard air source heat pumps (ASHPs) with electric back up. This was compared with a loop-wide geothermal analysis including pumping energy required for the loop from the central plant to the buildings.

The following curves were used for the coefficient of performance (COPs) of the individual building heat pumps.

Figure 25. Air Source HP Cooling Efficiency

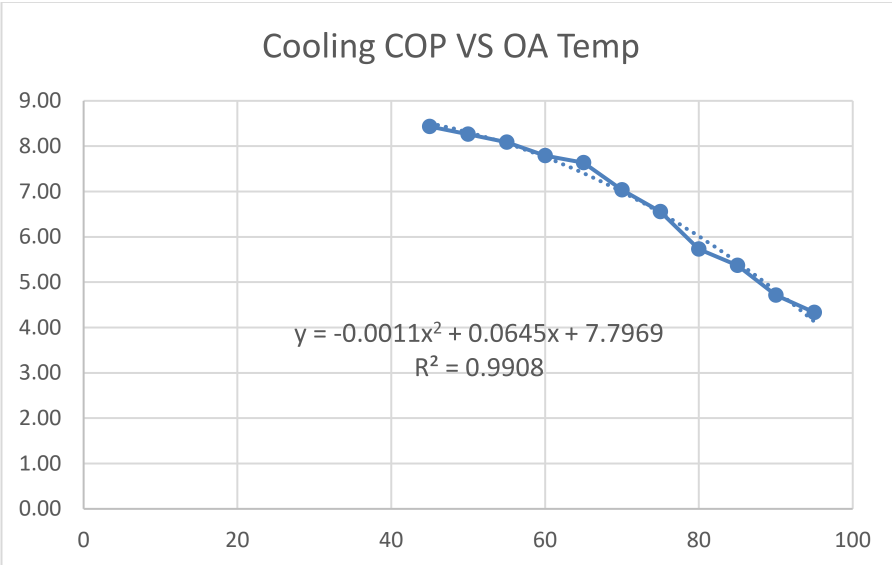
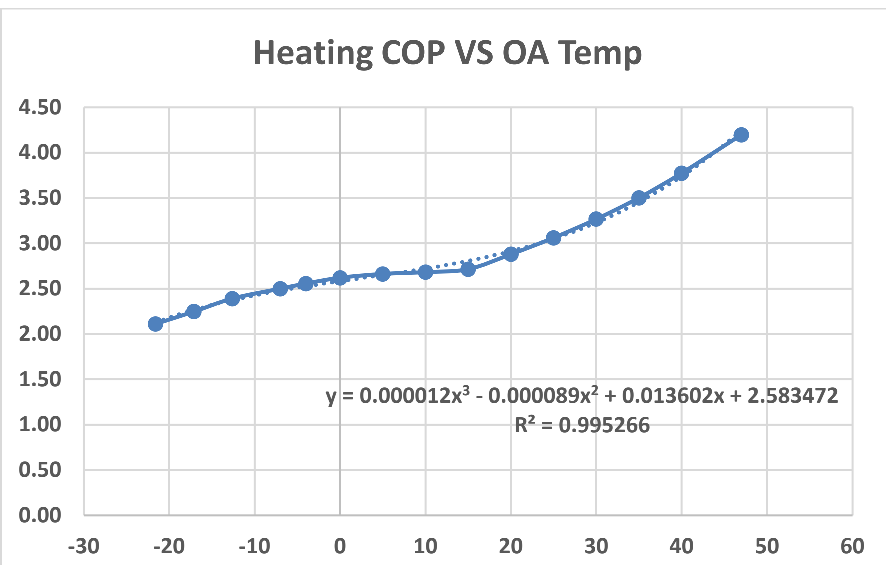


Figure 26. Air Source Heat Pump Heating Efficiency



From an 8760 analysis on each building, the following results were obtained for energy consumption for both scenarios in Phase 1A. The load profiles and the calculations are attached in the appendix.

Table 36. Energy Use–Individual Heat Pump Scenario

	Heating kW	Heating kWh	Cooling kW	Cooling kWh	Peak kW	Total kWh
231–249 River Street	89	117,081	78	60,695	89	177,776
261–269 River Street	129	169,895	82	18,914	129	188,809
2 3rd Street	103	67,935	87	39,593	103	107,528
Third St	18	11,427	26	18,519	26	29,946
Fourth St	39	25,036	57	40,574	57	65,609
213 River Street	32	37,669	20	4,988	32	42,657
219 River Street	19	31,772	17	6,351	19	38,123
221–223 River Street	4	7,397	3	1,106	4	8,503
251 River Street	74	79,956	48	12,098	74	92,054
Individual Building Total:	**506**	**548,167**	**420**	**202,837**	**533**	**751,004**

Table 37. Energy Use–District Loop Scenario

	Heating kW	Heating kWh	Cooling kW	Cooling kWh	Pumping kW	Pumping kWh	Peak kW	Total kWh
Geothermal Loop Totals	246	306,863	394	230,460	27	109,222	421	646,545
% Difference	51%	44%	6%	-14%			21%	14%

From the analysis we can see that the community geothermal system consumes 14 percent lesser energy than the individual ASHP systems including the loop pumping energies.

It is worth noting that the peak sizes of the systems have significant reduction in a community-based system compared to individual systems. With the electrification of the grid imminent in the near future, there is a need to reduce peak demand usage. We can see that the winter peaks in a community system is 51 percent lesser than the individual heat pump system and this contributes significantly to the health of the grid. It is also worth noting that the overall peak load is 21 percent lesser in the community system compared to the individual heat pump scenario.

4 Task 6. Conduct Permitting and Regulatory Review

The overall project will require compliance with the State Environmental Quality Review Act (SEQR) through the Department of Environmental Conservation (DEC). In New York State, most projects proposed by a State agency or unit of local government, and all discretionary approvals (permits) from a NYS agency or unit of local government, require an environmental impact assessment as prescribed by 6 NYCRR Part 617 SEQR.

Completion of the SEQR process will be required prior to any approvals, permitting, or funding on the part of State, regional, and local agencies. SEQR can be completed between conceptual layout and 30 percent completion of design plans, which will involve approvals from the City Council and the planning board. For this project, the timeline for SEQR approval can be between four and six months.

Based on the project's proximity to historic sites and districts, it is anticipated that the project will be progressed as a Type I Action and will require the preparation of a Full Environmental Assessment Form (FEAF) with the City of Troy serving as the Lead Agency. The FEAF is used when a state or local agency has determined that a SEQR review is necessary, and they have identified the project as being a Type I Action. Type I Actions are listed in SEQR (617.4) and described there as "...those actions and projects that are more likely to require the preparation of an Environmental Impact Statement (EIS) than Unlisted actions." It goes on to state "...the fact that an action or project has been listed as a Type I action carries with it the presumption that it is likely to have a significant adverse impact on the environment and may require an EIS."

The FEAF is designed specifically for Type I Actions. It has three parts. The first part (Part 1) is filled out by the applicant, or project sponsor. Part 2 and 3 are the responsibility of the lead agency.

Part 1 of the FEAF provides details that will help the reviewing agency understand the location, size, type, and characteristics of the proposed project. Part 1 can be completed by the applicant using information prepared as part of the approval submission along with maps, plats, or other studies that may have been conducted and by exploring the information and maps available through the links in this guide. The lead agency should also review the information provided by the applicant in Part 1 for basic accuracy and completeness.

Part 2 is used to help the reviewing agency identify potential impacts that may result from the project. In order to do this, the reviewing agency will evaluate information from Part 1, but may also ask the applicant for clarification of information provided in Part 1, or additional information.

Part 3 is used by the reviewing agency to determine if the potential adverse impacts identified in Part 2 are significant or not, and whether a draft environmental impact statement (DEIS) will be prepared. If the reviewing agency determines that a DEIS shall be required, Part 3 is also used to identify the scope (topics to be considered in more detail) for that evaluation. Part 3 is also used to help the reviewing agency identify whether the applicant has addressed the potential adverse impacts as part of the project design.

For this project, issuance of a Negative Declaration is anticipated. A Negative Declaration means one of the three scenarios applies: (1) there are no adverse environmental impacts identified, (2) the impacts identified will not be significant, or (3) any potential impacts are mitigated by project plans. In other words, there is nothing to be gained by further analysis, and the preparation of an EIS will not be needed.

Federal and State permitting will likely be limited to the installation of the heat exchanger within the Hudson River. The Hudson River is a federal and State Navigable waterway regulated by the U.S. Army Corps of Engineers (USACE) and the NYS Department of Environmental Conservation (NYSDEC). In addition, the NYS Office of General Services (NYSOGS) is responsible for the management of State lands underwater. Based on these jurisdictions and the nature of the project, the following permits and approvals are anticipated:

- Section 10 of the 1899 Rivers and Harbors Act and Section 404 of the Clean Water Act—Nationwide Permit(s)—USACE
- Section 401 Water Quality Certification (Blanket coverage may apply)—NYSDEC
- Article 15 Protection of Waters Permit—NYSDEC
- Authorization to occupy State lands underwater—NYSOGS

In addition to the above permits, it will be necessary to address the potential impact to the federal and State endangered species of fish in the Hudson River. According to the NOAA Fisheries Section 7 website,[4] there are two species listed under the Endangered Species Act (ESA) that occur or have the potential to occur in the proposed project area. These include the shortnose sturgeon (Acipenser

[4] National Oceanic and Atmospheric Administration/U.S. Department of Commerce; New England-Mid-Atlantic; https://www.greateratlantic.fisheries.noaa.gov/protected/section7/guidance/maps/index.html

brevirostrum) and Atlantic sturgeon (Acipenser oxyrinchus). CHA worked on a construction project at the Troy Seawall where a potential impact study was conducted to gage any possible adverse effect to these species due to construction near the seawall. The conclusion of the report stated that construction at the seawall will be insignificant and/or discountable and is likely not going to affect any of the species listed under the National Marine Fisheries Services' (NMFS) jurisdiction. A similar study will need to be performed for this project as well as a project in which river heat exchangers are proposed to be placed in the Hudson River.

Permitting can start with drawings at 60 percent design. The primary permitting effort will be the in-river work. Assuming this can be progressed as a Nationwide Permit or possibly a Letter of Permission from the Corps, approval for this step could take around eight months as coordination with NMFS would be required.

5 Task 7. Leverage Educational Opportunity of the Project

Several suitable educational institutions operate in the project area, including Russell Sage College, which is part of Phase 1B of the project. However, the current timeline of the project is not suitable for creating a dedicated internship or other partnership. CHA will work with the City of Troy in the design and implementation phase of the project to explore the opportunities available and provide a detailed recommendation on how to incorporate education in future phases.

Initial ideas include:

- Educational site visit to the borefield and central plants of the project for students interested in the subject.
- Educational sign boards near the Troy Seawall explaining the project and benefits of the project.
- Creating an elective subject in Russell Sage College to study and understand clean heating and cooling in more depth.
- Educational displays in each building involved in the project as an off-taker showing the environmental impacts of incorporating geothermal energy.

6 Lessons Learned

1. **Discuss observations of opportunities to improve the project value proposition to stakeholders.**

This project had a mix of new construction buildings, existing buildings with aging equipment and existing buildings with equipment that were relatively new. This mix created a different value proposition with each stakeholder. The phases for the project were created based on location and not on these factors. Going forward, both these factors must be weighted and considered to make it easier to bring off-takers on board. This will lead to more streamlined implementation.

2. **Discuss improvements to methods to recruit and select additional teammates to conduct subsequent work (e.g., an RFP to expand the team for conducting the next stage, if applicable)**

In this project, the City of Troy, Siemens, and CHA Consulting have well-defined project roles all the way through construction. Having a well-defined project team starting with a feasibility study and drilling a test bore hole has helped streamline the process and provide continuity. As the project progresses to construction the current design team will continue with enhancements where needed. Siemens will operate under the existing energy performance contract with the City of Troy, with CHA serving as a technical sub-consultant. The final construction documents will be publicly bid to provide competitive pricing. Once the system is operational, the goal would be to provide a framework were building owners could engage their chosen consultants and contractors to provide retrofit solutions that connect into the system.

Appendix A. City of Troy District Energy, Category A: Supporting Documents

Category A: Site-specific scoping study	Report Stage (Final Report for Category A Instructions part 2)

DISTRICT CHARACTERISTICS

Applicant:	City of Troy

CA1 Location & Site Area

District Street Address		City/Town, Zipcode	Troy, 12180
District site area (acres)		Latitude , Longitude	42.73,-73.69

CA2 Building Cluster Scale & Type	Indicate all that apply	CA3 Building Construction/Retrofit	Indicate all that apply	CA4 District System Construction/Retrofit	Indicate all that apply
a. SMALL e.g. a cluster of ten or more single-family houses		a. New Construction	x	a. New Construction	x
b. MEDIUM e.g. college campus or multifamily residential complex consisting of multiple buildings, an office or medical park, etc.	X	b. Major Retrofit of Existing Buildings	x	b. Retrofit of Existing District Energy Distribution System	
c. LARGE e.g. an urban core consisting of one or numerous city blocks.	x	c. If both, provide % Mix of New and Retrofit by conditioned area	20% retrofit, 80% new construction	c. If both, provide % Mix of New and Retrofit by conditioned area served	
OTHER - Specify		d. Replacement of Building Heating/Cooling System	x	Indicate present & proposed distribution system type (e.g., steam, High-temp hot water, etc.)	Present: No district level system. Proposed: Ambient loop system

CA5 Building Address, Type, Size, Conditioned Area, Age

Building Number	Street Address	Building Type *(select from drop down list)*	Building Size (square feet)	Conditioned Area to be Served - ***COOLING*** *(square feet)*	Conditioned Area to be Served - ***HEATING*** *(square feet)*	Type of Construction *(New Construction, Major Renovation, Retrofit of Heating and Cooling Systems)*	If Major Renovation or Retrofit Building Age *(years)*
Building 1	231-249 River Street, Troy, NY 12180	Other - Specify	110,000	110,000	110,000	New Construction	-
Building 2	261 - 269 River Street	Midrise Apartment	63,000	63,000	63,000	Retrofit of Heating and Cooling Systems	
Building 3	2 3rd Street	Office & Retail	40,867	40,867	40,867	Retrofit of Heating and Cooling Systems	
Building 4	Third St	Medium Office	16,720	16,720	16,720	Retrofit of Heating and Cooling Systems	
Building 5	Fourth St	Large Office	36,632	36,632	36,632	Retrofit of Heating and Cooling Systems	
Building 6	213 River St	Midrise Apartment	14,000	14,000	14,000	Retrofit of Heating and Cooling Systems	
Building 7	219 River St	Midrise Apartment	16,080	16,080	16,080	Retrofit of Heating and Cooling Systems	
Building 8	221 - 223 River Street	Midrise Apartment	3,450	3,450	3,450	Retrofit of Heating and Cooling Systems	
Building 9	251 River Street	Midrise Apartment	29,760	29,760	29,760	Retrofit of Heating and Cooling Systems	
Building 10	Cowee Hall, Russell Sage College, 71 1st St, Troy, NY 12180	Classroom	20,012	20,012	20,012	Retrofit of Heating and Cooling Systems	
Building 11	Slingerland Alumnae House, 69 First Street, Troy, NY 12180	Dormitory	5,208	5,208	5,208	Retrofit of Heating and Cooling Systems	
Building 12	Roy Courtyard, Russell Sage College, Troy, NY 12180	Other	7,757	7,757	7,757	Retrofit of Heating and Cooling Systems	
Building 13	Hart Hall, Russell Sage College, Troy, NY 12180	Classroom	21,552	21,552	21,552	Retrofit of Heating and Cooling Systems	
Building 14	Ricketts Hall, Russell Sage College, Troy, NY 12180	Classroom	34,191	34,191	34,191	Retrofit of Heating and Cooling Systems	
Building 15	Manning Hall, Russell Sage College, Troy, NY 12180	Dormitory	27,798	27,798	27,798	Retrofit of Heating and Cooling Systems	
Building 16	Esteves School of Education, Russell Sage College, Troy, NY 12180	Classroom	12,600	12,600	12,600	Retrofit of Heating and Cooling Systems	
Building 17	Plum Memorial, Russell Sage College, Troy, NY 12180	Classroom	9,794	9,794	9,794	Retrofit of Heating and Cooling Systems	
Building 18	Taylor 1, Troy, NY 12180	Highrise Apt	100,000	100,000	100,000	New Construction	-
Building 19	Taylor 2, Troy, NY 12180	Midrise Apt	100,000	100,000	100,000	New Construction	-
Building 20	Taylor 3, Troy, NY 12180	Midrise Apt	100,000	100,000	100,000	New Construction	-
Building 21	Taylor 4, Troy, NY 12180	Midrise Apt	100,000	100,000	100,000	New Construction	-
Building 22	100 2nd Street	Midrise Apartment	9,792	9,792	9,792	Retrofit of Heating and Cooling Systems	
Building 23	141 Congress Street	Midrise Apartment	66,508	66,508	66,508	Retrofit of Heating and Cooling Systems	
Building 24	1646 5th Avenue	Midrise Apartment	12,050	12,050	12,050	Retrofit of Heating and Cooling Systems	
Building 25	119 Congress Street	Midrise Apartment	13,158	13,158	13,158	Retrofit of Heating and Cooling Systems	
Building 26	51 State Street	Office	19,734	19,734	19,734	Retrofit of Heating and Cooling Systems	
Building 27	1700 6th Avenue	Office	15,250	15,250	15,250	Retrofit of Heating and Cooling Systems	
Building 28	57-59 State Street	Office	12,301	12,301	12,301	Retrofit of Heating and Cooling Systems	
Building 29	61 State Street	Office	10,124	10,124	10,124	Retrofit of Heating and Cooling Systems	
Building 30	State Street	Midrise Apartment	119,136	119,136	119,136	Retrofit of Heating and Cooling Systems	
Building 31	1776 6th Avenue	Office	47,958	47,958	47,958	Retrofit of Heating and Cooling Systems	
Building 32	1800 6th Avenue	Midrise Apartment	136,005	136,005	136,005	Retrofit of Heating and Cooling Systems	
Building 33	1801 Sixth Avenue	Office	36,886	36,886	36,886	Retrofit of Heating and Cooling Systems	
Building 34	2000 6th Avenue	Midrise Apartment	122,708	122,708	122,708	Retrofit of Heating and Cooling Systems	
Building 35	720 Federal Street	Midrise Apartment	152,874	152,874	152,874	Retrofit of Heating and Cooling Systems	
Building 36	503 Grand Street	Midrise Apartment	46,196	46,196	46,196	Retrofit of Heating and Cooling Systems	
Building 37	2001 5th Avenue	Office	33,085	33,085	33,085	Retrofit of Heating and Cooling Systems	
Building 38	92-96 Fourth Street	Office	11,844	11,844	11,844	Retrofit of Heating and Cooling Systems	
Building 39	30 3rd Street	Office	10,754	10,754	10,754	Retrofit of Heating and Cooling Systems	
Building 40	43 3rd Street	Midrise Apartment	5,147	5,147	5,147	Retrofit of Heating and Cooling Systems	
Building 41	32 2nd Street	Office	19,585	19,585	19,585	Retrofit of Heating and Cooling Systems	
Building 42	Phase 1C - Building 1	Midrise Apartment	235,672	235,672	235,672	New Construction	-
Building 43	Phase 1C - Building 2	Midrise Apartment	353,323	353,323	353,323	New Construction	-
Building 44	Phase 1C - Building 3	Midrise Apartment	262,779	262,779	262,779	New Construction	-
Building 45	Phase 1C - Building 4	Midrise Apartment	248,046	248,046	248,046	New Construction	-
Building 46	Phase 1C - Building 5	Midrise Apartment	260,960	260,960	260,960	New Construction	-
Building 47	Phase 1C - Building 6	Midrise Apartment	428,797	428,797	428,797	New Construction	-
Building 48	Phase 1C - Building 7	Midrise Apartment	49,145	49,145	49,145	New Construction	-
Building 49	Phase 1C - Building 8	Midrise Apartment	32,745	32,745	32,745	New Construction	-
Building 50	Phase 1C - Building 9	Midrise Apartment	24,880	24,880	24,880	New Construction	-
Building 51	Phase 1C - Building 10	Midrise Apartment	30,720	30,720	30,720	New Construction	-
Building 52	Phase 1C - Building 11	Midrise Apartment	6,160	6,160	6,160	New Construction	-
Building 53	Phase 1C - Building 12	Midrise Apartment	46,100	46,100	46,100	New Construction	-
Building 54	Phase 1C - Building 13	Midrise Apartment	31,015	31,015	31,015	New Construction	-
Building 55	Phase 1C - Building 14	Midrise Apartment	364,990	364,990	364,990	New Construction	-
Building 56	Phase 1C - Building 15	Midrise Apartment	141,540	141,540	141,540	New Construction	-
Building 57	Phase 1C - Building 16	Office	27,091	27,091	27,091	New Construction	-
Building 58	Phase 1C - Building 17	Office	22,694	22,694	22,694	New Construction	-
TOTALS							

CA6 Estimated Building Loads / **CA7 If Retrofit - Energy Systems of Existing Buildings**

Building Number	Summer Peak Total Cooling Load *(kBtu/hr)*	Winter Peak Total Heating Load *(kBtu/hr)*	Process Heating Load-Steam or Hot Water *(e.g. swimming pool, hotel, autoclaves, lab animal cage washing, Other-Specify) (MMBtu/hour)*	Process Cooling Load *(data centers, lasers etc) (tons)*	Domestic Hot Water *(gpm)*	Primary Energy Source Currently Used for Heating *(Oil, Gas, Propane, ConEd Steam, Electricity, Other)*	Primary Energy Source Currently Used for Cooling *(Electricity, Gas, ConEd Steam, Other)*	Annual Gas Consumption from Utility Bills *(MMBTU)*	Annual Fuel Oil Consumption from Utility Bills *(gal)*	Annual Electricity Consumption for cooling from Utility Bills *(kWh)*	Annual Electricity Consumption for heating from Utility Bills *(kWh)*	Are annual electricity use data metered for cooling and heating systems or are they estimated from building totals?	Existing Heating System (Steam, Hot water, *Forced air, Radiators, baseboard, hydronic, Other-specify)*	***Existing Cooling System*** (Window A/C, Central A/C, *Forced air, hydronic, Other-specify)*
Building 1	**1,763,061**	2,235,987				Gas	Electricity	2,942		50,481		Estimated from Building Loads	N/A	N/A
Building 2	**504,832**	2,693,071				Gas	Electricity	3,544		14,455		Estimated from Building Loads	HW	Rooftop DX
Building 3	**400,696**	1,008,316				Gas	Electricity	1,327		22,630		Estimated from Building Loads	WSHP	WSHP
Building 4	**55,210**	163,204				Gas	Electricity	215		10,710		Estimated from Building Loads	HW	PTAC
Building 5	**121,049**	357,566				Gas	Electricity	471		23,465		Estimated from Building Loads	HW	PTAC
Building 6	**124,571**	328,410				Gas	Electricity	781		3,567		Estimated from Building Loads	HW	PTAC
Building 7	**92,846**	255,268				Gas	Electricity	689		5,018		Estimated from Building Loads	HW	PTAC
Building 8	**19,481**	217,868				Gas	Electricity	641		941		Estimated from Building Loads	HW	PTAC
Building 9	**287,842**	748,250				Gas	Electricity	1,649		8,242		Estimated from Building Loads	HW	PTAC
Building 10	**310,000**	443,000				Gas	Electricity	5,823		8,905		Estimated from Building Loads	Hydronic baseboard	No cooling
Building 11	**27,000**	228,000				Gas	Electricity	3,002		783		Estimated from Building Loads	Hydronic baseboard	Air cooled chillers
Building 12	**103,000**	147,000				Gas	Electricity	1,937		2,963		Estimated from Building Loads	Hydronic baseboard	Air cooled chillers
Building 13	**287,000**	409,000				Gas	Electricity	5,383		8,232		Estimated from Building Loads	Hydronic baseboard	No cooling
Building 14	**456,000**	649,000				Gas	Electricity	8,539		13,060		Estimated from Building Loads	Hydronic baseboard	No cooling
Building 15	**145,000**	1,218,000				Gas	Electricity	16,021		4,177		Estimated from Building Loads	Hydronic baseboard	No cooling
Building 16	**168,000**	239,000				Gas	Electricity	3,147		4,813		Estimated from Building Loads	Hydronic baseboard	Air cooled chillers
Building 17	**130,000**	185,000				Gas	Electricity	2,446		3,741		Estimated from Building Loads	Hydronic baseboard	Air cooled chillers
Building 18	**525,000**	4,380,000												
Building 19	**525,000**	4,380,000												
Building 20	**525,000**	4,380,000												
Building 21	**525,000**	4,380,000												
Building 22	**219,000**	96,000				Gas	Electricity	125		6,272		Estimated from Building Loads	HW	PTAC
Building 23	**827,000**	1,264,000				Gas	Electricity	1,664		23,694		Estimated from Building Loads	HW	PTAC
Building 24	**149,000**	229,000				Gas	Electricity	301		4,293		Estimated from Building Loads	HW	PTAC
Building 25	**463,000**	250,000				Gas	Electricity	329		4,688		Estimated from Building Loads	HW	PTAC
Building 26	**441,000**	193,000				Gas	Electricity	254		12,641		Estimated from Building Loads	HW	PTAC
Building 27	**341,000**	149,000				Gas	Electricity	196		9,769		Estimated from Building Loads	HW	PTAC
Building 28	**275,000**	120,000				Gas	Electricity	158		7,880		Estimated from Building Loads	HW	PTAC
Building 29	**226,000**	99,000				Gas	Electricity	130		6,485		Estimated from Building Loads	HW	PTAC
Building 30	**1,482,000**	2,265,000				Gas	Electricity	2,980		42,443		Estimated from Building Loads	HW	PTAC
Building 31	**1,072,000**	468,000				Gas	Electricity	616		30,721		Estimated from Building Loads	HW	PTAC
Building 32	**713,000**	5,967,000				Gas	Electricity	7,835		20,438		Estimated from Building Loads	HW	PTAC
Building 33	**825,000**	360,000				Gas	Electricity	474		23,628		Estimated from Building Loads	HW	PTAC
Building 34	**644,000**	5,375,000				Gas	Electricity	7,072		18,440		Estimated from Building Loads	HW	PTAC
Building 35	**802,300**	6,696,000				Gas	Electricity	8,816		22,973		Estimated from Building Loads	HW	PTAC
Building 36	**242,400**	2,023,000				Gas	Electricity	2,662		6,942		Estimated from Building Loads	HW	PTAC
Building 37	**740,100**	323,000				Gas	Electricity	425		21,193		Estimated from Building Loads	HW	PTAC
Building 38	**264,900**	116,000				Gas	Electricity	152		7,587		Estimated from Building Loads	HW	PTAC
Building 39	**240,500**	105,000				Gas	Electricity	138		6,889		Estimated from Building Loads	HW	PTAC
Building 40	**27,010**	225,000				Gas	Electricity	297		773		Estimated from Building Loads	HW	PTAC
Building 41	**438,100**	191,000				Gas	Electricity	251		12,546		Estimated from Building Loads	HW	PTAC
Building 42	**2,671,000**	5,172,000												
Building 43	**4,200,000**	7,235,000												
Building 44	**2,978,000**	5,766,000												
Building 45	**2,811,000**	5,443,000												
Building 46	**3,102,000**	5,344,000												
Building 47	**5,097,000**	8,781,000												
Building 48	**551,000**	7,094,000												
Building 49	**367,000**	729,000												
Building 50	**279,000**	554,000												
Building 51	**344,000**	684,000												
Building 52	**69,000**	137,000												
Building 53	**517,000**	1,027,000												
Building 54	**348,000**	691,000												
Building 55	**4,316,000**	7,534,000												
Building 56	**1,534,000**	3,291,000												
Building 57	**841,000**	738,000												
Building 58	**757,000**	601,000												
TOTALS								**93,430**		**476,476**				

CA8 If Retrofit - Building Conversion Related Information

Building Number	Heat Pumps Currently Used? *(Y/N)*	Year HEATING System Last Installed or Replaced	Year COOLING System Last Installed or Replaced	Type of Fan Coil/Unit Ventilator systems in building *(2-pipe or 4-pipe?)*	Type of Connection to Distribution System *(active with pumps or passive with only HX?)*
Building 1	**No**				
Building 2	**Yes**				
Building 3	**Yes**				
Building 4	**No**				
Building 5	**No**				
Building 6	**No**				
Building 7	**No**				
Building 8	**No**				
Building 9	**No**				
Building 10	**No**				
Building 11	**No**				
Building 12	**No**				
Building 13	**No**				
Building 14	**No**				
Building 15	**No**				
Building 16	**No**				
Building 17	**No**				
Building 18	**No**				
Building 19	**No**				
Building 20	**No**				
Building 21	**No**				
Building 22	**No**				
Building 23	**No**				
Building 24	**No**				
Building 25	**No**				
Building 26	**No**				
Building 27	**No**				
Building 28	**No**				
Building 29	**No**				
Building 30	**No**				
Building 31	**No**				
Building 32	**No**				
Building 33	**No**				
Building 34	**No**				
Building 35	**No**				
Building 36	**No**				
Building 37	**No**				
Building 38	**No**				
Building 39	**No**				
Building 40	**No**				
Building 41	**No**				
Building 42	**No**				
Building 43	**No**				
Building 44	**No**				
Building 45	**No**				
Building 46	**No**				
Building 47	**No**				
Building 48	**No**				
Building 49	**No**				
Building 50	**No**				
Building 51	**No**				
Building 52	**No**				
Building 53	**No**				
Building 54	**No**				
Building 55	**No**				
Building 56	**No**				
Building 57	**No**				
Building 58					
TOTALS					

CA9 Energy Use from Existing Facilities

a. Total for All Buildings - Annual Gas Consumption from Utility Bills for Heating and Coolin	93,430
b. Total for All Buildings - Annual Oil Consumption from Utility Bills for Heating (gal)	0
c. Total for All Buildings - Annual Electricity Consumption from Utility Bills for Heating and (	476,476

CA10 Conditioned Space, Loads and Energy Use

a. Total for All Buildings -Conditioned Area Served - *Cooling* *(square feet)*	1,260,516
b. Total for All Buildings Conditioned Area Served - *Heating* *(square feet)*	1,260,516

Category A: Site-specific scoping study

Report Stage
(Final Report for Category A Instructions part 2)

SYSTEMS AND TECHNOLOGY

Applicant:	City of Troy

CA11 Proposed Thermal Capacity from Geothermal Resource

		Summer Peak	Winter Peak	Diversified District Summer Peak	Diversified District Winter Peak
Heating *(MBtu/hour)*			81590		65272
Cooling *(tons)*		4,509		2886	
Domestic Hot Water *(GPM)*					
Process Heating (*MBtu/hour)*					
Process Cooling *(tons)*					

CA12 Other Thermal Resources Proposed as a (% of Total Thermal Resource)

Solar thermal	
Sewer waste heat recovery	
Waste heat from Data Center	
Biomass	
Other - Specify	

CA13 Ground Heat Exchanger

Earth Coupling Method	
Closed loop *(horizontal or vertical) - (bores or energy piles)*	
Open loop *(dedicated injection well or seasonal reversal)*	
Standing column wells (specify design bleed %, if any)	
Surface water coupled *(lake/pond, river/stream, or marine)*	
Other - *specify*	
GHX Balancing	
Are seasonal GHX loads balanced?	Yes
Antifreeze used in GHX piping?	Yes
GHX Land Area	
Area needed for GHX	447,413
Percentage of property area	11%
Closed Loop Systems - vertical	
Number of bores (closed loop - vertical)	1104
Depth of closed-loop borehole heat exchangers (ft)	500
Closed-loop borehole heat exchanger grout thermal conductivity (W/m °K)	1.2
Closed-loop antifreeze design temperature (°F)	28
Thermal response test results - thermal conductivity (W/m°K)	TBD
Thermal response test results - thermal diffusivity (m^2/s)	TBD
CAPEX of closed-loop boreholes ($)	$52,145,006
Closed Loop Systems - horizontal	
Length of horizontal closed-loop heat exchanger trench (ft)	N/A
Horizontal closed-loop heat exchanger depth below grade (ft)	N/A
Horizontal closed-loop heat exchanger construction (e.g., slinky, # pipes per trench)	N/A
CAPEX of horizontal closed-loop heat exchanger ($)	N/A
Open-Loop Systems	
No. of open-loop wells	N/A
Depth of open-loop wells (ft)	N/A
Open-loop well borehole and screen diameter (in)	N/A
Design open-loop well extraction rate (gpm/well)	N/A
Design open-loop well injection rate (gpm/well)	N/A
Open -loop system configuration (ATES or dedicated injection well)	N/A
Open-loop well drilling method	N/A
Open-loop well screen length (ft)	N/A
CAPEX of open-loop well system ($)	N/A
Standing-Column Well Systems	
No. of standing column wells	N/A
Depth of standing column wells (ft)	N/A
Standing column well design bleed rate (%, gpm/well)	N/A
Standing column well design thermal diffusivity (m^2/s)	N/A
CAPEX of standing column wells ($/ft)	N/A

CA14 Heat Pumps

Heat Pump Configuration (centralized, distributed or both)	Distributed

For distributed heat pumps, complete for each type

Heat Pump Type	Make & Model	Number	Heating Capacity (MBtu/hr) Full/Part	Heating COP Full/Part	Heating COP EWT (°F)	Cooling Capacity (MBtu/hr) (tons) Full/Part	Cooling EER (Btu/wh) Full/Part	Cooling EER EWT (°F)	Refrigerant (R134A, NH3, CO2, Other - specify)

CA15 Pilot Borehole(s)

No. of pilot boreholes	N/A
Proposed pilot well use	N/A
Additional value / use of pilot well(s)	N/A
Ground surface elevation *(ft)*	N/A
Geophysical logging conducted?	N/A
Thermal response testing conducted?	N/A
Aquifer pumping test conducted?	N/A
Groundwater sampling conducted?	N/A
Soil or groundwater sampling conducted?	N/A
Measured ambient ground water temperature (° F)	N/A
Subsurface contamination potential?	N/A
Drilling method	N/A
Borehole Depth *(ft)*	N/A
Groundwater Depth *(ft)*	N/A
Borehole Diameter *(in)*	N/A
Geologic conditions in target formation *(bedrock, surficial/glacial, coastal plain)*	N/A

CA16 Onsite Electric Generation / Storage

Solar PV	N/A
Solar PV capacity (kW)	N/A
Wind Turbine	N/A
Wind turbine capacity (kW)	N/A
Battery Storage	N/A
Battery Storage Capacity (AH)	N/A

CA17 Community Distribution Piping Proposed

No. of distribution pipes (2 or 4)		
2 pipe		
Pipe Material	Pipe Diameter (inches)	Insulation Type

4 pipe		
Chilled Water		
Pipe Material	Pipe Diameter (inches)	Insulation Type
Hot Water		
Pipe Material	Pipe Diameter (inches)	Insulation Type

Category A: Site-specific scoping study	Report Stage (Final Report for Category A Instructions part 2)

BUSINESS MODEL

Applicant:	**City of Troy**

Ownership

C18 Building Ownership

Buildings all owned by a single entity	
Buildings having unrelated owners	X
Buildings owned by a cooperative or association	
Other - Specify	

C19 Proposed System Ownership & Operation

System owned/operated by a private entity	
System owned/operated by a public entity (municipality)	
System owned by a public entity and operated by a private entity	
System owned/operated by a utility	
System owned by a private or public entity and operated by another private entity	
System owned/operated by a public-private partnership.	X
Other - Specify	

C20 Key Assumptions used for 25 year NPV Life Cycle Cost Analysis

Economic Factors	*input values here - the values are examples*	
Economic Discount Rate or Hurdle Rate	5.0%	
General Inflation Rate	3.0%	/year
Electricity Escalation Rate	3.5%	/year
Useful life of Ground Heat Exchanger Loop	50	years
Useful life of GSHP	15	years

Geothermal Sizing Analysis

Tons/Bore
2.3

Building	Phase	Sq-ft	Peak Heating Load (MMBtu/hr)	Peak Cooling Load (Tons)	Base System	Proposed System (check map for locations)		Number of bore holes	Boreholes grid structure (20 ft o.c)	GPM	SQFT available for bores	GLHX Capacity (MMBtu/hr)	MMBtu/year Available from GHX	Total Heating Load (MMBtu)	Total Heating Load needed from GHX (MMBtu)	Peak Heating Load (MMBtu/hr)	Total Cooling Load (MMBtu)	Peak Cooling Load (Tons)
1 Monument - Sq 231 – 239 River St.	1A	180000	1.66	111.8	Boiler/PTAC HW	Central Plant - 1	Potential GHX Site - 7 AND River HX - 1	150	25 x 4	1500	50,198	4.14	8190	7,845	5,931	4.88	4,872	557.87
261 – 269 River Street	1A	63000	1.3	88.6	Boiler/PTAC HW													
2 3rd Street	1A	40867	0.22	12.7	Boiler/PTAC HW													
Third St	1A	16720	0.48	27.8	Boiler/PTAC HW													
Fourth St	1A	36632	0.41	27.5	Boiler/PTAC HW													
213 River Street	1A	14000	0.31	20.6	Boiler/PTAC HW													
219 River Street	1A	16080	0.07	4.3	Boiler/PTAC HW													
221-223 River Street	1A	3450	0.94	63.7	Boiler/PTAC HW													
251 River Street	1A	29760	1.15	110.9	Boiler/PTAC HW													
Taylor – 1	1B	10000	1.81	120.7	Boiler/PTAC HW	Central Plant - 2	Potential GHX Site - 1	45	5 x 9	675	20,079	7.84	15,506	21,039	15,908	10.69	3,729	768.86
Taylor - 2	1B	10000	1.81	120.7	Boiler/PTAC HW													
Taylor - 3	1B	10000	1.81	120.7	Boiler/PTAC HW		Potential GHX Site - 2	49	7 x7	735	20,952							
Taylor - 4	1B	10000	1.81	120.7	Boiler/PTAC HW													
Hart Hall	1B Sage	21,552	0.67	53.6	Boiler/PTAC HW		Potential GHX Site - 3	35	5 x 7	525	15,278							
Ricketts Hall	1B Sage	34,191	1.06	85	Boiler/PTAC HW													
Roy Courtyard	1B Sage	7,757	0.24	19.3	Boiler/PTAC HW		Potential GHX Site - 4	27	9 x 3	405	8,730							
Cowee Hall	1B Sage	23,313	0.72	58	Boiler/PTAC HW													
Slingerland Alumnae House	1B Sage	5,208	0.09	6.2	Boiler/PTAC HW		Potential GHX Site - 5	48	8 x 6	720	23,571							
Manning Hall	1B Sage	27,798	0.5	33.5	Boiler/PTAC HW													
Esteves School of Education	1B Sage	12,600	0.39	31.3	Boiler/PTAC HW		Potential GHX Site - 6	40	5 x 8	600	17,460							
Plum Memorial	1B Sage	9,794	0.3	24.3	Boiler/PTAC HW		River HX - 3											
100 2nd Street	2	9792	0.11	7.44	Boiler/PTAC HW	Central Plant 4 & Central Plant 5 & Central Plant 6						GLHX Capacity	24,391	35,777	27,051	12.08	10,139	1156.11
141 Congress Street	2	66508	1.21	80.27	Boiler/PTAC HW		Potential GHX Site - 8	55	11 x 5	825	26,190	6.35						
1646 5th Avenue	2	12050	0.22	14.54	Boiler/PTAC HW													
119 Congress Street	2	13158	0.24	15.88	Boiler/PTAC HW		Potential GHX Site - 9	45	9 x 5	675	17,024							
51 State Street	2	19734	0.22	14.99	Boiler/PTAC HW													
1700 6th Avenue	2	15250	0.17	11.58	Boiler/PTAC HW		Potential GHX Site - 10	40	5 x 8	600	17,024							
57-59 State Street	2	12301	0.14	9.34	Boiler/PTAC HW													
61 State Street	2	10124	0.12	7.69	Boiler/PTAC HW		Potential GHX Site - 11	66	11 x 6	990	30,119							
State Street	2	119136	2.16	143.7	Boiler/PTAC HW													
1776 6th Avenue	2	47958	0.55	36.42	Boiler/PTAC HW		Potential GHX Site - 13	24	6 x 4	360	8,730							
1800 6th Avenue	2	136005	2.46	164.1	Boiler/PTAC HW													
1801 6th Avenue	2	36886	0.42	28.01	Boiler/PTAC HW		River HX - 2					River HX-2 Capacity						
2000 6th Avenue	2	122708	2.22	148.1	Boiler/PTAC HW							5.73						
720 Federal Street	2	152874	2.77	184.5	Boiler/PTAC HW													
503 Grand Street	2	46196	0.84	55.76	Boiler/PTAC HW													
2001 5th Avenue	2	33085	0.38	25.12	Boiler/PTAC HW													
92-96 Fourth Street	2	11844	0.14	8.99	Boiler/PTAC HW													
30 3rd Street	2	10754	0.12	8.17	Boiler/PTAC HW													
43 3rd Street	2	5147	0.09	6.21	Boiler/PTAC HW													
32 2nd Street	2	19585	0.22	14.87	Boiler/PTAC HW													
Building – 1	3	235,672	2.51	191.3	Boiler/PTAC HW	Central Plant - 3	Potential GHX Site - 12	440	21 x 21	6,600	192,060	12.1	24,023	54,825	41,453	19.42	30,780	2,026
Building – 2	3	353,323	3.29	255.8	Boiler/PTAC HW													
Building – 3	3	262,779	2.8	213.3	Boiler/PTAC HW													
Building – 4	3	248,046	2.64	201.3	Boiler/PTAC HW													
Building – 5	3	260,960	2.43	188.9	Boiler/PTAC HW													
Building – 6	3	428,797	3.99	310.5	Boiler/PTAC HW													
Building – 7	3	49,145	0.54	40.9	Boiler/PTAC HW													
Building – 8	3	32,745	0.36	27.25	Boiler/PTAC HW													
Building – 9	3	24,880	0.27	20.71	Boiler/PTAC HW													
Building – 10	3	30,720	0.34	25.57	Boiler/PTAC HW													
Building – 11	3	6,160	0.07	5.13	Boiler/PTAC HW													
Building – 12	3	46,100	0.51	38.37	Boiler/PTAC HW													
Building – 13	3	31,015	0.34	25.81	Boiler/PTAC HW													
Building – 14	3	364,990	3.45	267.3	Boiler/PTAC HW													
Building – 15	3	141,540	1.71	126.4	Boiler/PTAC HW													
Building – 16	3	27,091	0.52	58.76	Boiler/PTAC HW													
Building – 17	3	22,694	0.43	53.83	Boiler/PTAC HW													

Phase 1A Savings Analysis

Baseline	Boiler Efficiency	76%
Baseline	PTAC EER	10.2
Proposed	Heating COP - WSHP	4.3
Proposed	Cooling EER - WSHP	20.1

			BASELINE			PROPOSED WSHP			
	Thermal Load	Cooling Load	Existing Systems	Existing HTG	Existing CLG	Proposed System	Thermal Load	Proposed HTG	Proposed CLG
Building	MMBtu/yr	MMBtu/yr		Baseline Therms	KWH		MMBtu/yr	KWH	KWH
1 Monument - Sq 231 – 239 River St.	2236	1,763	Boiler/PTAC HW	29,421	50,481	DES-WSHP	2236	152,402	25,708
261 – 269 River Street	2693	505	Boiler/PTAC HW	35,435	14,455	DES-WSHP	1008	183,557	7,361
2 3rd Street	1008	790	Boiler/PTAC HW	13,267	22,630	DES-WSHP	163	68,726	11,525
Third St	163	374	Boiler/PTAC HW	2,147	10,710	DES-WSHP	357	11,124	5,454
Fourth St	358	820	Boiler/PTAC HW	4,705	23,465	DES-WSHP	328	24,371	11,950
213 River Street	594	125	Boiler/PTAC HW	7,812	3,567	DES-WSHP	255	40,469	1,816
219 River Street	524	175	Boiler/PTAC HW	6,891	5,018	DES-WSHP	54	35,694	2,556
221-223 River Street	487	33	Boiler/PTAC HW	6,408	941	DES-WSHP	748	33,195	479
251 River Street	1253	288	Boiler/PTAC HW	16,491	8,242	DES-WSHP	2235	85,426	4,197
	9,316	4,872		122,578	139,510		7,384	634,963	71,046

		Utility Cost ($)
Existing - Therms	122,578	$98,062
Existing - KWH	139,510	$13,951
Existing Total $$		$112,013

Proposed - KWH (HTG)	634,963	$63,496
Proposed - KWH (CLG)	71,046	$7,105
Proposed Total KWH	706,009	$70,601

Therms to KWH	3,591,535
Delta KWH	(566,499)
KWH Savings	3,025,036
$$ Savings	$41,412

Phase 1B Savings Analysis

Baseline	Boiler Efficiency	76%
Baseline	PTAC EER	10.2
Proposed	Heating COP - WSHP	4.3
Proposed	Cooling EER - WSHP	20.1

			BASELINE			PROPOSED WSHP			
	Thermal Load	Cooling Load	Existing Systems	Existing HTG	Existing CLG	Proposed System	Thermal Load	Proposed HTG	Proposed CLG
Building	MMBtu/yr	MMBtu/yr		Baseline Therms	KWH		MMBtu/yr	KWH	KWH
Taylor – 1	4,380	525	Boiler/PTAC HW	57,633	15,027	DES-WSHP	4380.113808	298,544	7,653
Taylor - 2	4,380	525	Boiler/PTAC HW	57,633	15,027	DES-WSHP	4380.113808	298,544	7,653
Taylor - 3	4,380	525	Boiler/PTAC HW	57,633	15,027	DES-WSHP	4380.113808	298,544	7,653
Taylor - 4	4,380	525	Boiler/PTAC HW	57,633	15,027	DES-WSHP	4380.113808	298,544	7,653
Cowee Hall	443	311	Boiler/PTAC HW	5,823	8,905	DES-WSHP	442.5120571	30,161	4,535
Slingerland Alumnae House	228	27	Boiler/PTAC HW	3,002	783	DES-WSHP	228.1163271	15,548	399
Roy Courtyard	147	103	Boiler/PTAC HW	1,937	2,963	DES-WSHP	147.2382802	10,036	1,509
Hart Hall	409	288	Boiler/PTAC HW	5,383	8,232	DES-WSHP	409.0859115	27,883	4,192
Ricketts Hall	649	456	Boiler/PTAC HW	8,539	13,060	DES-WSHP	648.9911099	44,235	6,651
Manning Hall	1,218	146	Boiler/PTAC HW	16,021	4,177	DES-WSHP	1217.584036	82,989	2,127
Esteves School of Education	239	168	Boiler/PTAC HW	3,147	4,813	DES-WSHP	239.164926	16,301	2,451
Plum Memorial	186	131	Boiler/PTAC HW	2,446	3,741	DES-WSHP	185.9032766	12,671	1,905
	21,039	3,729		276,830	106,782			1,433,998	54,379

		Utility Cost ($)
Existing - Therms	276,830	$221,464
Existing - KWH	106,782	$10,678
Existing Total $$		$232,142

Proposed - KWH (HTG)	1,433,998	$143,400
Proposed - KWH (CLG)	54,379	$5,438
Proposed Total KWH	1,488,378	$148,838

Therms to KWH	8,111,108
Delta KWH	(1,381,595)
KWH Savings	6,729,512
$$ Savings	$83,304

Phase 2 Savings Analysis

Baseline	Boiler Efficiency	76%
Baseline	PTAC EER	10.2
Proposed	Heating COP - WSHP	4.3
Proposed	Cooling EER - WSHP	20.1

			BASELINE			PROPOSED WSHP			
	Thermal Load	Cooling Load	Existing Systems	Existing HTG	Existing CLG	Proposed System	Thermal Load	Proposed HTG	Proposed CLG
Building	MMBtu/yr	MMBtu/yr		Baseline Therms	KWH		MMBtu/yr	KWH	KWH
100 2nd Street	96	219	Boiler/PTAC HW	1,258	6,272	DES-WSHP	95.57994549	6,515	3,194
141 Congress Street	1,264	828	Boiler/PTAC HW	16,637	23,694	DES-WSHP	1264.431965	86,182	12,066
1646 5th Avenue	229	150	Boiler/PTAC HW	3,014	4,293	DES-WSHP	229.0913151	15,615	2,186
119 Congress Street	250	164	Boiler/PTAC HW	3,292	4,688	DES-WSHP	250.156309	17,050	2,387
51 State Street	193	441	Boiler/PTAC HW	2,535	12,641	DES-WSHP	192.6240446	13,129	6,438
1700 6th Avenue	149	341	Boiler/PTAC HW	1,959	9,769	DES-WSHP	148.8556136	10,146	4,975
57-59 State Street	120	275	Boiler/PTAC HW	1,580	7,880	DES-WSHP	120.0703543	8,184	4,013
61 State Street	99	226	Boiler/PTAC HW	1,300	6,485	DES-WSHP	98.8206054	6,736	3,303
State Street	2,265	1482	Boiler/PTAC HW	29,802	42,443	DES-WSHP	2264.981155	154,379	21,614
1776 6th Avenue	468	1073	Boiler/PTAC HW	6,159	30,721	DES-WSHP	468.1191815	31,906	15,645
1800 6th Avenue	5,957	714	Boiler/PTAC HW	78,384	20,438	DES-WSHP	5957.173784	406,034	10,408
1801 6th Avenue	360	825	Boiler/PTAC HW	4,737	23,628	DES-WSHP	360.0451255	24,540	12,033
2000 6th Avenue	5,375	644	Boiler/PTAC HW	70,720	18,440	DES-WSHP	5374.750051	366,337	9,391
720 Federal Street	6,696	802	Boiler/PTAC HW	88,106	22,973	DES-WSHP	6696.055182	456,396	11,699
503 Grand Street	2,023	242	Boiler/PTAC HW	26,624	6,942	DES-WSHP	2023.437375	137,915	3,535
2001 5th Avenue	323	740	Boiler/PTAC HW	4,249	21,193	DES-WSHP	322.9434739	22,011	10,793
92-96 Fourth Street	116	265	Boiler/PTAC HW	1,521	7,587	DES-WSHP	115.6095664	7,880	3,864
30 3rd Street	105	241	Boiler/PTAC HW	1,381	6,889	DES-WSHP	104.9700504	7,155	3,508
43 3rd Street	225	27	Boiler/PTAC HW	2,966	773	DES-WSHP	225.4444577	15,366	394
32 2nd Street	191	438	Boiler/PTAC HW	2,515	12,546	DES-WSHP	191.169652	13,030	6,389
	26,504	10139		348,741	290,294			1,806,506	147,833

		Utility Cost ($)
Existing - Therms	348,741	$278,993
Existing - KWH	290,294	$29,029
Existing Total $$		$308,022

Proposed - KWH (HTG)	1,806,506	$180,651
Proposed - KWH (CLG)	147,833	$14,783
Proposed Total KWH	1,954,339	$195,434

Therms to KWH	10,218,116
Delta KWH	(1,664,045)
KWH Savings	8,554,071
$$ Savings	$112,588

Phase 3 Savings Analysis

Baseline	Boiler Efficiency	76%
Baseline	PTAC EER	10.2
Proposed	Heating COP - WSHP	4.3
Proposed	Cooling EER - WSHP	20.1

			BASELINE			PROPOSED WSHP			
	Thermal Load	Cooling Load	Existing Systems	Existing HTG	Existing CLG	Proposed System	Thermal Load	Proposed HTG	Proposed CLG
Building	MMBtu/yr	MMBtu/yr		Baseline Therms	KWH		MMBtu/yr	KWH	KWH
Building – 1	5,172	2,671	Boiler/PTAC HW	68,053	76,463	DES-WSHP	5172.024606	352,519	38,939
Building – 2	7,236	4,200	Boiler/PTAC HW	95,206	120,254	DES-WSHP	7235.628741	493,172	61,240
Building – 3	5,767	2,978	Boiler/PTAC HW	75,880	85,258	DES-WSHP	5766.91102	393,066	43,418
Building – 4	5,444	2,811	Boiler/PTAC HW	71,626	80,478	DES-WSHP	5443.582671	371,029	40,984
Building – 5	5,344	3,102	Boiler/PTAC HW	70,318	88,818	DES-WSHP	5344.145941	364,251	45,231
Building – 6	8,781	5,097	Boiler/PTAC HW	115,543	145,942	DES-WSHP	8781.245198	598,520	74,321
Building – 7	1,095	551	Boiler/PTAC HW	14,402	15,771	DES-WSHP	1094.551258	74,603	8,032
Building – 8	729	367	Boiler/PTAC HW	9,596	10,508	DES-WSHP	729.2925208	49,708	5,351
Building – 9	554	279	Boiler/PTAC HW	7,291	7,984	DES-WSHP	554.1242302	37,768	4,066
Building – 10	684	344	Boiler/PTAC HW	9,003	9,858	DES-WSHP	684.1919756	46,634	5,020
Building – 11	137	69	Boiler/PTAC HW	1,805	1,977	DES-WSHP	137.1947451	9,351	1,007
Building – 12	1,027	517	Boiler/PTAC HW	13,510	14,794	DES-WSHP	1026.733401	69,981	7,534
Building – 13	691	348	Boiler/PTAC HW	9,089	9,953	DES-WSHP	690.7621785	47,082	5,069
Building – 14	7,534	4,316	Boiler/PTAC HW	99,132	123,580	DES-WSHP	7534.050874	513,513	62,934
Building – 15	3,291	1,534	Boiler/PTAC HW	43,300	43,922	DES-WSHP	3290.793429	224,297	22,367
Building – 16	738	841	Boiler/PTAC HW	9,712	24,073	DES-WSHP	738.1166362	50,309	12,259
Building – 17	601	757	Boiler/PTAC HW	7,910	21,675	DES-WSHP	601.1544712	40,974	11,038
	54,825	30,780		721,375	881,310			3,736,777	448,811

		Utility Cost ($)
Existing - Therms	721,375	$577,100
Existing - KWH	881,310	$88,131
Existing Total $$		$665,231

Proposed - KWH (HTG)	3,736,777	$373,678
Proposed - KWH (CLG)	448,811	$44,881
Proposed Total KWH	4,185,588	$418,559

Therms to KWH	21,136,289
Delta KWH	(3,304,278)
KWH Savings	17,832,011
$$ Savings	$246,672

Energy Escalation Rates

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
Electricity	1	1.05	1.09	1.14	1.19	1.24	1.3	1.35	1.4	1.43	1.48	1.52	1.59	1.65	1.71	1.75	1.8	1.85	1.9	1.97	2.04	2.12	2.18	2.25	2.33
Natural Gas	1	1.03	1.04	1.03	1.06	1.1	1.13	1.17	1.22	1.26	1.3	1.34	1.38	1.43	1.48	1.52	1.56	1.61	1.66	1.71	1.76	1.81	1.87	1.92	1.98

Table S-1. Projected fuel price indices with assumed general price inflation rates of 2%, 3%, 4%, and 5%, by end-use sector and fuel type.

Census Region 1

Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont

Projected April 1 Fuel Price Indices (April 2021 = 1.00)

Residential

Year	Electricity Inflation Rate				Distillate Oil Inflation Rate				LPG Inflation Rate				Natural Gas Inflation Rate			
	2%	3%	4%	5%	2%	3%	4%	5%	2%	3%	4%	5%	2%	3%	4%	5%
2022	1.04	1.05	1.06	1.07	1.07	1.08	1.09	1.10	1.04	1.05	1.06	1.07	1.02	1.03	1.04	1.05
2023	1.07	1.09	1.11	1.13	1.20	1.22	1.24	1.27	1.08	1.10	1.12	1.14	1.02	1.04	1.06	1.08
2024	1.10	1.14	1.17	1.20	1.30	1.34	1.38	1.42	1.13	1.16	1.19	1.23	1.00	1.03	1.06	1.09
2025	1.14	1.19	1.24	1.29	1.38	1.44	1.50	1.55	1.18	1.23	1.27	1.32	1.02	1.06	1.10	1.14
2026	1.18	1.24	1.30	1.37	1.47	1.54	1.62	1.69	1.24	1.30	1.36	1.43	1.04	1.10	1.15	1.21
2027	1.22	1.30	1.38	1.46	1.52	1.61	1.71	1.81	1.29	1.37	1.45	1.53	1.07	1.13	1.20	1.27
2028	1.26	1.35	1.44	1.54	1.58	1.69	1.81	1.93	1.35	1.44	1.54	1.65	1.09	1.17	1.25	1.34
2029	1.29	1.40	1.51	1.63	1.63	1.76	1.90	2.05	1.40	1.52	1.64	1.77	1.13	1.22	1.32	1.42
2030	1.31	1.43	1.56	1.70	1.69	1.84	2.01	2.19	1.46	1.59	1.74	1.89	1.15	1.26	1.37	1.50
2031	1.34	1.48	1.63	1.79	1.74	1.92	2.11	2.32	1.51	1.67	1.84	2.02	1.18	1.30	1.43	1.57
2032	1.36	1.52	1.69	1.88	1.79	1.99	2.22	2.46	1.57	1.75	1.94	2.16	1.20	1.34	1.49	1.65
2033	1.41	1.59	1.79	2.00	1.84	2.07	2.32	2.60	1.63	1.83	2.05	2.30	1.23	1.38	1.55	1.74
2034	1.46	1.65	1.87	2.12	1.88	2.14	2.42	2.75	1.68	1.91	2.16	2.45	1.26	1.43	1.63	1.84
2035	1.49	1.71	1.96	2.24	1.93	2.21	2.53	2.90	1.73	1.99	2.27	2.60	1.29	1.48	1.69	1.93
2036	1.51	1.75	2.03	2.34	1.98	2.29	2.64	3.05	1.79	2.07	2.39	2.76	1.31	1.52	1.76	2.03
2037	1.54	1.80	2.10	2.45	2.03	2.37	2.77	3.23	1.84	2.15	2.51	2.93	1.34	1.56	1.82	2.13
2038	1.57	1.85	2.18	2.57	2.09	2.47	2.91	3.42	1.90	2.24	2.64	3.11	1.36	1.61	1.90	2.23
2039	1.60	1.90	2.27	2.69	2.14	2.55	3.03	3.60	1.96	2.33	2.77	3.30	1.39	1.66	1.97	2.34
2040	1.63	1.97	2.36	2.84	2.20	2.65	3.19	3.82	2.02	2.43	2.92	3.50	1.42	1.71	2.05	2.46
2041	1.68	2.04	2.47	2.99	2.27	2.76	3.35	4.05	2.08	2.53	3.07	3.72	1.45	1.76	2.14	2.59
2042	1.73	2.12	2.60	3.18	2.33	2.86	3.50	4.28	2.15	2.63	3.23	3.94	1.48	1.81	2.22	2.71
2043	1.76	2.18	2.70	3.33	2.40	2.97	3.67	4.53	2.21	2.74	3.39	4.18	1.51	1.87	2.31	2.85
2044	1.80	2.25	2.82	3.51	2.45	3.07	3.83	4.77	2.27	2.85	3.56	4.43	1.54	1.92	2.40	2.99
2045	1.84	2.33	2.93	3.69	2.50	3.16	3.98	5.01	2.33	2.94	3.71	4.67	1.57	1.98	2.50	3.14

LCA Calculation for Troy DES Geothermal Phase 1A

Total buildings square footage	Blended Electric Utility Rate (per kWh)	Gas Utility Rate (per Therm)
400,509	$0.10	$0.80

System Efficiency Degredation/year	0.250%
O&M Growth Rate (%)	3.0%

25 Year Energy Cost Savings & Revenue	25 Year Project Savings (Construction Cost - Energy Savings)
$ 1,422,922	

25 Year Energy Consumption Comparison (system efficiency deteriorates by 0.25% every year)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25		Total
Baseline scenario Nat Gas energy consumption (Therms)	122,578	122,884	123,192	123,500	123,808	124,118	124,428	124,739	125,051	125,364	125,677	125,991	126,306	126,622	126,939	127,256	127,574	127,893	128,213	128,533	128,855	129,177	129,500	129,823	130,148	130,473	126,327
Heat Pump scenario Nat Gas energy consumption (Therms)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Baseline scenario electric energy consumption (kWh)	139,510	139,859	140,208	140,559	140,910	141,263	141,616	141,970	142,325	142,681	143,037	143,395	143,753	144,113	144,473	144,834	145,196	145,559	145,923	146,288	146,654	147,020	147,388	147,756	148,126	148,496	143,777
Heat Pump scenario electric energy consumption (kWh)	634,963	636,550	638,142	639,737	641,336	642,940	644,547	646,159	647,774	649,393	651,017	652,644	654,276	655,912	657,551	659,195	660,843	662,495	664,152	665,812	667,477	669,145	670,818	672,495	674,176	675,862	654,382
Natural Gas Utility Rate ($/Therm)	$0.80	$0.82	$0.83	$0.82	$0.85	$0.88	$0.90	$0.94	$0.98	$1.01	$1.04	$1.07	$1.10	$1.14	$1.18	$1.22	$1.25	$1.29	$1.33	$1.37	$1.41	$1.45	$1.50	$1.54	$1.58		1.1
Electric Utility Rate ($/kWh)	$0.10	$0.11	$0.11	$0.11	$0.12	$0.12	$0.13	$0.14	$0.14	$0.14	$0.15	$0.15	$0.16	$0.17	$0.17	$0.18	$0.18	$0.19	$0.19	$0.20	$0.20	$0.21	$0.22	$0.23	$0.23		0.16

Natural Gas Rate Escalation Factor	1.00	1.03	1.04	1.03	1.06	1.10	1.13	1.17	1.22	1.26	1.30	1.34	1.38	1.43	1.48	1.52	1.56	1.61	1.66	1.71	1.76	1.81	1.87	1.92	1.98
Electricity Rate Escalation Factor	1.00	1.05	1.09	1.14	1.19	1.24	1.30	1.35	1.40	1.43	1.48	1.52	1.59	1.65	1.71	1.75	1.80	1.85	1.90	1.97	2.04	2.12	2.18	2.25	2.33

Operations and Maintenance

Boiler : 25 yr life | PTAC: 15 yr life | WSHP: 19 yr life

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Total Cost
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
O&M - Baseline Scenario	$31,500	$32,445	$33,418	$34,421	$35,454	$36,517	$37,613	$38,741	$39,903	$41,100	$42,333	$43,603	$44,911	$46,259	$47,647	$49,076	$50,548	$52,065	$53,627	$55,235	$56,893	$58,599	$60,357	$62,168	$64,033	$1,148,467
O&M - Heat Pump (DES) Scenario	$4,500	$4,635	$4,774	$4,917	$5,065	$5,217	$5,373	$5,534	$5,700	$5,871	$6,048	$6,229	$6,416	$6,608	$6,807	$7,011	$7,221	$7,438	$7,661	$7,891	$8,128	$8,371	$8,622	$8,881	$9,148	$164,067
Replacement Costs - Baseline Scenario										$490,052	$493,192	$496,427	$499,760	$503,192	$506,727	$510,368	$514,118	$517,981	$521,960	$70,350	$72,461	$74,635	$76,874	$79,180	$163,111	$5,590,385
Replacement Costs - Heat Pump (DES) Scenario														$177,504	$182,829	$188,314	$193,963	$199,782	$205,776	$211,949	$218,307	$224,857	$231,602	$119,275	$122,853	$2,277,012

= 10% of the boilers and terminal units are being replaced that year
= 5% of the terminal units being replaced that year

Terminal Equipment Replacement Cost at the End of Equipment Life

	Total Cost of Replacemen	at 10% per Year	at 5% per Year
Baseline Scenario	$779,025	$77,903	$38,951
Heat Pump (DES) Scenario	$1,173,510	$117,351	$58,676

Boiler Replacement Cost at the End of Equipment Life

	Total Cost of Replacemen	at 10% per Year	at 5% per Year
Baseline Scenario	$ 3,853,571	$385,357	$192,679

Energy Cost Savings

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Totals	
Natural Gas Cost Savings	$ 98,062	$ 101,257	$ 102,495	$ 101,764	$ 104,990	$ 109,224	$ 112,483	$ 116,756	$ 122,050	$ 126,367	$ 130,704	$ 135,063	$ 139,442	$ 144,856	$ 150,295	$ 154,743	$ 159,213	$ 164,726	$ 170,267	$ 175,834	$ 181,427	$ 187,048	$ 193,732	$ 199,409	$ 206,155	$ 3,588,360	
Electric Cost Savings	$ (49,545)	$ (52,153)	$ (54,275)	$ (56,906)	$ (59,551)	$ (62,208)	$ (65,381)	$ (68,065)	$ (70,763)	$ (72,460)	$ (75,181)	$ (77,406)	$ (81,173)	$ (84,447)	$ (87,736)	$ (90,013)	$ (92,816)	$ (95,633)	$ (98,463)	$ (102,346)	$ (106,248)	$ (110,690)	$ (114,108)	$ (118,066)	$ (122,570)	$ (2,068,205)	
Total Energy Savings	$ 16,171	$ 16,366	$ 16,072	$ 44,857	$ 45,439	$ 47,016	$ 47,102	$ 48,690	$ 51,287	$ 53,907	$ 55,523	$ 57,657	$ 58,269	$ 60,409	$ 62,559	$ 64,730	$ 66,396	$ 69,093	$ 71,803	$ 73,487	$ 75,179	$ 76,358	$ 79,624	$ 81,343	$ 83,585	$ 1,422,922	
% Savings Claimed due to Construction Completion	33%	33%	33%																								

Central Plant Equipment Installation

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Total Cost
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Baseline Scenario - Boiler/DX	$1,348,748	$1,416,186	$1,486,995																							
Heat Pump (DES) Scenario	$5,350,303	$5,617,818	$5,898,709																							
Replacement Rate	33.3%																									

Note: Existing Equipment will be replaced from Year 1 through Year 3 at the rate of 33.33%
Note: Boiler/DX will be replaced with DES

Total NYSERDA Aid	$ 4,000,000																									
$$ QUALIFIED FOR NYSERDA AID	$ 1,333,200	$ 1,333,200	$ 1,333,200																							

NPV ANALYSIS

Initial Capital Investment - WSHP (DES)	$ 15,286,595
Initial Capital Investment - Boiler/Ch/Twr	$ 3,853,571
Net Investment without NYSERDA Aid	$ (11,433,025)
Net Investment with NYSERDA Aid	$ (7,433,025)
Discount Rate	5.0%

Project Cash Flow with NYSERDA Category C Funding	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25
	$ (2,625,184)	$ (2,824,256)	$ (3,033,798)	$ 74,361	$ 75,828	$ 78,316	$ 79,341	$ 81,897	$ 85,490	$ 579,187	$ 585,001	$ 591,459	$ 596,524	$ 425,747	$ 427,296	$ 428,849	$ 429,878	$ 431,919	$ 433,953	$ (20,767)	$ (21,902)	$ (23,637)	$ (23,370)	$ 94,534	$ 178,727
Net Present Worth of Investment with NYSERDA funding	$ (4,786,809)																								

Project Cash Flow without NYSERDA Category C Funding	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25
	$ (3,958,384)	$ (4,157,456)	$ (4,366,998)	$ 74,361	$ 75,828	$ 78,316	$ 79,341	$ 81,897	$ 85,490	$ 579,187	$ 585,001	$ 591,459	$ 596,524	$ 425,747	$ 427,296	$ 428,849	$ 429,878	$ 431,919	$ 433,953	$ (20,767)	$ (21,902)	$ (23,637)	$ (23,370)	$ 94,534	$ 178,727
Net Present Worth of Investment without NYSERDA funding	$ (8,417,443)																								

City of Troy

Phase 1A
WSHP District Energy

Multipliers	
Material:	0.98
Labor:	1.09
Equipment:	1.00

Description	QTY	UNIT	UNIT COSTS			SUBTOTAL COSTS			TOTAL COST	REMARKS
			MAT.	LABOR	EQUIP.	MAT.	LABOR	EQUIP.		
Geothermal Well Install										
Hardscape Restroration	300	LF			$ 150	$ -	$ -	$ 45,000	$ 45,000	
Parking Lot Excavation	25000	SF			$ 40	$ -	$ -	$ 1,000,000	$ 1,000,000	
Parking Lot Restoration	25000	SF			$ 1.5	$ -	$ -	$ 37,500	$ 37,500	
Geothermal Boreholes (150 Boreholes x 500 ft)	75000	LF			$ 50	$ -	$ -	$ 3,750,000	$ 3,750,000	
Heat Exchanger	2	EA	$ 75,000	$ 50,000		$ 147,450	$ 109,000	$ -	$ 256,450	
						$ -	$ -	$ -	$ -	
Mechanical Systems										
Central Plant Building	1000	SF			$ 750	$ -	$ -	$ 750,000	$ 750,000	
Pump Station	250	SF			$ 750	$ -	$ -	$ 187,500	$ 187,500	
HDPE Piping	14050	LF	$ 25	$ 5.5		$ 345,279	$ 84,230	$ -	$ 429,509	
Loop Pumps	6	EA	$ 8,500	$ 1,125		$ 50,133	$ 7,358	$ -	$ 57,491	
Pump VFD	6	EA	$ 7,500	$ 1,350		$ 44,235	$ 8,829	$ -	$ 53,064	
Borefield Pumps	6	EA	$ 12,600	$ 1,130		$ 74,315	$ 7,390	$ -	$ 81,705	
Borefield Pump VFD	6	EA	$ 15,500	$ 3,500		$ 91,419	$ 22,890	$ -	$ 114,309	
6" Black Iron Pipe	2500	LF	$ 45	$ 42		$ 110,588	$ 114,450	$ -	$ 225,038	
Steel Fittings	15	LS			$ 15,000	$ -	$ -	$ 225,000	$ 225,000	
4" HDPE	5000	LF	$ 4			$ 18,824	$ -	$ -	$ 18,824	
3' HDPE	5000	LF	$ 3	$ 8		$ 12,386	$ 40,875	$ -	$ 53,261	
2 1/2" HDPE	5000	LF	$ 2	$ 8		$ 11,305	$ 40,875	$ -	$ 52,180	
2" HDPE	3000	LF	$ 2	$ 8		$ 5,574	$ 24,525	$ -	$ 30,099	
1 1/2" HDPE	1500	LF	$ 1	$ 8		$ 1,681	$ 12,263	$ -	$ 13,943	
HDPE Fittings	15	LS			$ 10,657	$ -	$ -	$ 159,852	$ 159,852	
Air Separator - 6"	6	EA	$ 3,950	$ 533		$ 23,297	$ 3,486	$ -	$ 26,783	
Expansion Tanks -300 gal	6	EA	$ 3,000	$ 200		$ 17,694	$ 1,308	$ -	$ 19,002	
Snow Melt System	1	EA	$ 225,000	########	$ 50,000	$ 221,175	$ 190,750	$ 50,000	$ 461,925	
						$ -	$ -	$ -	$ -	
River Heat Exchanger						$ -	$ -	$ -	$ -	
Rigging	1	EA			$ 75,000	$ -	$ -	$ 75,000	$ 75,000	
HEX Equipment (100 Ton)	70	TONS		$ 750		$ -	$ 57,225	$ -	$ 57,225	
HEX Labor	120	HRS		$ 250		$ -	$ 32,700	$ -	$ 32,700	
Piping	150	LF	$ 45	$ 40		$ 6,635	$ 6,540	$ -	$ 13,175	
Pumps (2 x 15 HP) + Motor + VFD	2	EA	$ 6,500	$ 2,500		$ 12,779	$ 5,450	$ -	$ 18,229	300 GPM/100'
Electricals	1	EA	$ 8,500	$ 4,500		$ 8,356	$ 4,905	$ -	$ 13,261	
						$ -	$ -	$ -	$ -	
WSHP Heat Pump Terminal Equipment Cost										
231-249 River Street - Monument Sq. (already has HP)	120,000	SF			$ 2.0	$ -	$ -	$ 240,000	$ 240,000	
261-269 River Street -	63,000	SF			$ 20.0					
2 3rd Street	40867	SF			$ 20.0	$ -	$ -	$ 817,340	$ 817,340	
Third St (already has HP)	16720	SF			$ 2.0	$ -	$ -	$ 33,440	$ 33,440	
Fourth ! (already has HP)	36632	SF			$ 2.0	$ -	$ -	$ 73,264	$ 73,264	
213 River Street -	14000	SF			$ 20.0	$ -	$ -	$ 280,000	$ 280,000	
219 River Street -	16080	SF			$ 20.0	$ -	$ -	$ 321,600	$ 321,600	
221-223 River Street -	3450	SF			$ 20.0	$ -	$ -	$ 69,000	$ 69,000	
251 River Street -	29760	SF			$ 20.0	$ -	$ -	$ 595,200	$ 595,200	
Misc and Electrical										
SWPPP/Erosion Control	1	LS			$ 35,000	$ -	$ -	$ 35,000	$ 35,000	
Site Prep/Access	1	LS			$ 30,000	$ -	$ -	$ 30,000	$ 30,000	
Construction Management	1	LS			$ 300,000	$ -	$ -	$ 300,000	$ 300,000	
						$ -	$ -	$ -	$ -	

Geothermal Side Totals (Includes contractor O&P)

$ 8,413,434		Subtotal
$ 1,682,687	20%	Contingency
$ -	0%	Contractor O&P
$ 1,009,612	10%	Engineering
$ 11,105,732		**Total**

Terminal and River HX side totals

$ 2,639,434		Subtotal
$ 527,887	20%	Contingency
$ 633,464	20%	Contractor O&P
$ 380,078	10%	Engineering
$ 4,180,863		**Total**

City of Troy

Multipliers	
Material:	0.98
Labor:	1.09
Equipment:	1.00

Phase 1A

Boiler_Chiller_Tower System

Description	QTY	UNIT	UNIT COSTS			SUBTOTAL COSTS			TOTAL COST	REMARKS
			MAT.	LABOR	EQUIP.	MAT.	LABOR	EQUIP.		
Boilers										
213 River Street -2 x 500 MBH	2	EA	$ 20,000	$ 9,500		$ 39,320	$ 20,710	$ -	$ 60,030	
219 River Street -2 x 500 MBH	2	EA	$ 20,000	$ 9,500		$ 39,320	$ 20,710	$ -	$ 60,030	
221-223 River Street - 75 MBH -Furnace	1	EA	$ 8,000	$ 2,500		$ 7,864	$ 2,725	$ -	$ 10,589	
1 MO SQ -231-249 River Street -2 x 1000 MBH	2	EA	$ 30,400	$ 13,500		$ 59,766	$ 29,430	$ -	$ 89,196	
251 River Street -2 x 1000 MBH	2	EA	$ 30,400	$ 13,500		$ 59,766	$ 29,430	$ -	$ 89,196	
261-269 River Street -2 x 1500 MBH	2	EA	$ 38,000	$ 13,500		$ 74,708	$ 29,430	$ -	$ 104,138	
2 3rd Street - 2 x 1000 MBH	2	EA	$ 30,400	$ 13,500		$ 59,766	$ 29,430	$ -	$ 89,196	
Fourth Street -2 x 1500 MBH	2	EA	$ 38,000	$ 13,500		$ 74,708	$ 29,430	$ -	$ 104,138	
Third St - 200 MBH - Furnace	1	EA	$ 10,000	$ 4,500		$ 9,830	$ 4,905	$ -	$ 14,735	
		EA						$ -	$ -	
Main Pumps										
213 River Street -2x5 HP Pump	2	EA	$ 12,500	$ 650		$ 24,575	$ 1,417	$ -	$ 25,992	
219 River Street -2x5 HP Pump	2	EA	$ 12,500	$ 650		$ 24,575	$ 1,417	$ -	$ 25,992	
221-223 River Street - Fan	2	EA	$ 7,500	$ 650		$ 14,745	$ 1,417	$ -	$ 16,162	
1 MO SQ - 231-249 River Street -2x7.5 HP Pump	2	EA	$ 13,800	$ 750		$ 27,131	$ 1,635	$ -	$ 28,766	
251 River Street -2x7.5 HP Pump	2	EA	$ 13,800	$ 750		$ 27,131	$ 1,635	$ -	$ 28,766	
261-269 River Street -2x10 HP Pump	2	EA	$ 14,950	$ 950		$ 29,392	$ 2,071	$ -	$ 31,463	
2 3rd Street - 2 x 5 HP Pump	2	EA	$ 12,500	$ 650		$ 24,575	$ 1,417	$ -	$ 25,992	
Fourth Street -2x10 HP Pump	2	EA	$ 14,950	$ 950		$ 29,392	$ 2,071	$ -	$ 31,463	
Third Street - Fan/Motor/VFD	1	EA	$ 7,500	$ 550		$ 7,373	$ 600	$ -	$ 7,972	
Cooling PTAC with Hot Water Heat -0620										
Cooling PTACs w/ HW coil included in terminal costs									$ 779,025	
Circ Pumps										
213 River Street -Circulation Pumps - 1 HP	2	EA	$ 2,050	$ 300		$ 4,030	$ 654	$ -	$ 4,684	
219 River Street -Circulation Pumps - 1 HP	2	EA	$ 2,050	$ 300		$ 4,030	$ 654	$ -	$ 4,684	
221-223 River Street -Circulation Pumps - 2 HP	2	EA	$ 3,500	$ 325		$ 6,881	$ 709	$ -	$ 7,590	
1 MO SQ -231-249 River Street -Circulation Pumps- 2HP	2	EA	$ 3,500	$ 325		$ 6,881	$ 709	$ -	$ 7,590	
251 River Street -Circulation Pumps - 2HP	2	EA	$ 3,500	$ 325		$ 6,881	$ 709	$ -	$ 7,590	
261-269 River Street -Circulation Pumps - 3HP	2	EA	$ 3,700	$ 500		$ 7,274	$ 1,090	$ -	$ 8,364	
2 3rd Street - 1 HP Pump	2	EA	$ 2,050	$ 300		$ 4,030	$ 654	$ -	$ 4,684	
Fourth Street -1 HP Pump	2	EA	$ 2,050	$ 300		$ 4,030	$ 654	$ -	$ 4,684	
Third Street - 1 HP pump	2	EA	$ 2,050	$ 300		$ 4,030	$ 654	$ -	$ 4,684	
Electricals and Misc.										
Misc Electricals - xformer/ Panel/ Switchgear	9	EA	$ 17,500	$ 7,500		$ 154,823	$ 73,575	$ -	$ 228,398	
Chemical Tratment	7	EA			$ 6,500	$ -	$ -	$ 45,500	$ 45,500	
Concrete Pad - Primary Boilers	7	EA	$ 4,500	$ 1,500		$ 30,965	$ 11,445	$ -	$ 42,410	
Boiler Rigging - Boilers	7	EA			$ 7,500	$ -	$ -	$ 52,500	$ 52,500	
Boiler - Flue Venting (double wall stainless steel AL-294c)	7	EA	$ 20,000	$ 5,500		$ 137,620	$ 41,965	$ -	$ 179,585	
Boiler / Furnace Controls and Wiring	7	EA	$ 7,500	$ 4,500		$ 51,608	$ 34,335	$ -	$ 85,943	
Power Wiring to new equipment	9	EA	$ 5,000	$ 4,500		$ 44,235	$ 44,145	$ -	$ 88,380	
Startup & Testing	300	HRS	$ -	$ 100		$ -	$ 32,700	$ -	$ 32,700	

$ 2,432,810	Subtotal
$ 486,562	20% Contingency
$ 583,874	20% Contractor O&P
$ 350,325	10% Engineering
$ 3,853,571	**Total**

LCA Calculation for Troy DES Geothermal

Total buildings square footage	Blended Electric Utility Rate (per kWh)	Gas Utility Rate (per Therm)
542,213	$0.10	$0.80

System Efficiency Degredation/year	0.250%
O&M Growth Rate (%)	3.0%

25 Year Energy Cost Savings & Revenue	25 Year Project Savings (Construction Cost - Energy Savings)
$ 2,387,780	

25 Year Energy Consumption Comparison (system efficiency deteriorates by 0.25% every year)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Total kWh	
Baseline scenario Nat Gas energy consumption (Therms)	276,830	277,522	278,216	278,911	279,609	280,308	281,008	281,711	282,415	283,121	283,829	284,539	285,250	285,963	286,678	287,395	288,113	288,834	289,556	290,280	291,005	291,733	292,462	293,193	293,926	294,661	285,296
Heat Pump scenario Nat Gas energy consumption (Therms)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Baseline scenario electric energy consumption (kWh)	106,782	107,049	107,317	107,585	107,854	108,123	108,394	108,665	108,936	109,209	109,482	109,755	110,030	110,305	110,581	110,857	111,134	111,412	111,691	111,970	112,250	112,530	112,812	113,094	113,377	113,660	110,048
Heat Pump scenario electric energy consumption (kWh)	1,433,998	1,437,583	1,441,177	1,444,780	1,448,392	1,452,013	1,455,643	1,459,282	1,462,930	1,466,587	1,470,254	1,473,930	1,477,614	1,481,308	1,485,012	1,488,724	1,492,446	1,496,177	1,499,918	1,503,667	1,507,427	1,511,195	1,514,973	1,518,761	1,522,557	1,526,364	1,477,854
Natural Gas Utility Rate ($/Therm)	$0.80	$0.82	$0.83	$0.82	$0.85	$0.88	$0.90	$0.94	$0.98	$1.01	$1.04	$1.07	$1.10	$1.14	$1.18	$1.22	$1.25	$1.29	$1.33	$1.37	$1.41	$1.45	$1.50	$1.54	$1.58		1.1
Electric Utility Rate ($/kWh)	$0.10	$0.11	$0.11	$0.11	$0.12	$0.12	$0.13	$0.14	$0.14	$0.14	$0.15	$0.15	$0.16	$0.17	$0.17	$0.18	$0.18	$0.19	$0.19	$0.20	$0.20	$0.21	$0.22	$0.23	$0.23		0.16

Natural Gas Rate Escalation Factor	1.00	1.03	1.04	1.03	1.06	1.10	1.13	1.17	1.22	1.26	1.30	1.34	1.38	1.43	1.48	1.52	1.56	1.61	1.66	1.71	1.76	1.81	1.87	1.92	1.98
Electricity Rate Escalation Factor	1.00	1.05	1.09	1.14	1.19	1.24	1.30	1.35	1.40	1.43	1.48	1.52	1.59	1.65	1.71	1.75	1.80	1.85	1.90	1.97	2.04	2.12	2.18	2.25	2.33

Operations and Maintenance

Boiler : 25 yr life PTAC: 15 yr life WSHP: 19 yr life

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Total Cost
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
O&M - Baseline Scenario	$40,500	$41,715	$42,966	$44,255	$45,583	$46,951	$48,359	$49,810	$51,304	$52,843	$54,429	$56,061	$57,743	$59,476	$61,260	$63,098	$64,991	$66,940	$68,949	$71,017	$73,148	$75,342	$77,602	$79,930	$82,328	$1,476,600
O&M - Heat Pump (DES) Scenario	$4,500	$4,635	$4,774	$4,917	$5,065	$5,217	$5,373	$5,534	$5,700	$5,871	$6,048	$6,229	$6,416	$6,608	$6,807	$7,011	$7,221	$7,438	$7,661	$7,891	$8,128	$8,371	$8,622	$8,881	$9,148	$164,067
Replacement Costs - Baseline Scenario										$692,195	$697,509	$702,982	$708,620	$714,427	$720,408	$726,568	$732,913	$739,449	$746,181	$119,027	$122,598	$126,276	$130,064	$133,966	$275,970	$8,089,152
Replacement Costs - Heat Pump (DES) Scenario														$229,060	$235,932	$243,009	$250,300	$257,809	$265,543	$273,509	$281,715	$290,166	$298,871	$153,919	$158,536	$2,938,368

= 10% of the boilers and terminal units are being replaced that year
= 5% of the terminal units being replaced that year

Terminal Equipment Replacement Cost at the End of Equipment Life

	Total Cost of Replacemen	at 10% per Year	at 5% per Year
Baseline Scenario	$1,318,050	$131,805	$65,902
Heat Pump (DES) Scenario	$1,514,355	$151,435	$75,718

Boiler Replacement Cost at the End of Equipment Life

	Total Cost of Replacemen	at 10% per Year	at 5% per Year
Baseline Scenario	$ 5,150,597	$515,060	$257,530

Energy Cost Savings

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Totals
Natural Gas Cost Savings	$ 221,464	$ 228,678	$ 231,476	$ 229,823	$ 237,109	$ 246,671	$ 254,032	$ 263,682	$ 275,637	$ 285,386	$ 295,182	$ 305,025	$ 314,916	$ 327,142	$ 339,427	$ 349,472	$ 359,565	$ 372,018	$ 384,530	$ 397,102	$ 409,735	$ 422,429	$ 437,523	$ 450,345	$ 465,579	$ 8,103,948
Electric Cost Savings	$ (132,722)	$ (139,706)	$ (145,391)	$ (152,440)	$ (159,524)	$ (166,642)	$ (175,142)	$ (182,333)	$ (189,559)	$ (194,105)	$ (201,394)	$ (207,354)	$ (217,446)	$ (226,216)	$ (235,028)	$ (241,127)	$ (248,636)	$ (256,182)	$ (263,763)	$ (274,164)	$ (284,616)	$ (296,517)	$ (305,671)	$ (316,275)	$ (328,339)	$ (5,540,293)
Total Energy Savings	$ 29,578	$ 29,654	$ 26,692	$ 77,383	$ 77,584	$ 80,029	$ 78,889	$ 81,349	$ 86,078	$ 91,281	$ 93,788	$ 97,671	$ 97,470	$ 100,926	$ 104,399	$ 108,345	$ 110,929	$ 115,836	$ 120,767	$ 122,938	$ 125,119	$ 125,912	$ 131,852	$ 134,070	$ 137,240	$ 2,387,780
% Savings Claimed due to Construction Completion	33%	33%	33%																							

Central Plant Equipment Installation

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Total Cost
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Baseline Scenario - Boiler/DX	$1,802,707	$1,892,843	$1,987,485																							
Heat Pump (DES) Scenario	$8,814,660	$9,255,393	$9,718,163																							
Replacement Rate	33.3%																									

Note: Existing Equipment will be replaced from Year 1 through Year 3 at the rate of 33.33%
Note: Boiler/DX will be replaced with DES

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25
Total NYSERDA Aid	$ 4,000,000																								
$$ QUALIFIED FOR NYSERDA AID	1,333,200	1,333,200	1,333,200																						

NPV ANALYSIS

Initial Capital Investment - WSHP (DES)	$ 25,184,768
Initial Capital Investment - Boiler/Ch/Twr	$ 5,150,597
Net Investment without NYSERDA Aid	$ (20,034,171)
Net Investment with NYSERDA Aid	$ (16,034,171)
Discount Rate	5.0%

Project Cash Flow with NYSERDA Category C Funding	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25
	$ (5,613,175)	$ (5,962,616)	$ (6,330,593)	$ 116,721	$ 118,102	$ 121,762	$ 121,875	$ 125,624	$ 131,682	$ 830,448	$ 839,678	$ 850,486	$ 857,417	$ 639,160	$ 643,328	$ 647,991	$ 651,312	$ 656,979	$ 662,692	$ 31,582	$ 31,023	$ 28,993	$ 32,025	$ 185,166	$ 327,855
Net Present Worth of Investment with NYSERDA funding	$ (11,811,618)																								

Project Cash Flow without NYSERDA Category C Funding	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25
	$ (6,946,375)	$ (7,295,816)	$ (7,663,793)	$ 116,721	$ 118,102	$ 121,762	$ 121,875	$ 125,624	$ 131,682	$ 830,448	$ 839,678	$ 850,486	$ 857,417	$ 639,160	$ 643,328	$ 647,991	$ 651,312	$ 656,979	$ 662,692	$ 31,582	$ 31,023	$ 28,993	$ 32,025	$ 185,166	$ 327,855
Net Present Worth of Investment without NYSERDA funding	$ (15,442,253)																								

City of Troy

Multipliers	
Material:	0.98
Labor:	1.09
Equipment:	1.00

Phase 1B
WSHP District Energy

Description	QTY	UNIT	UNIT COSTS			SUBTOTAL COSTS			TOTAL COST	REMARKS
			MAT.	LABOR	EQUIP.	MAT.	LABOR	EQUIP.		
Geothermal Well Install										
Hardscape Restroration	300	LF			$ 150	$ -	$ -	$ 45,000	$ 45,000	
Parking Lot Excavation	25000	SF			$ 40	$ -	$ -	$ 1,000,000	$ 1,000,000	
Parking Lot Restoration	25000	SF			$ 1.5	$ -	$ -	$ 37,500	$ 37,500	
Geothermal Boreholes (280 Boreholes x 500 ft)	140000	LF			$ 50	$ -	$ -	$ 7,000,000	$ 7,000,000	
Heat Exchanger	6	EA	$ 75,000	$ 50,000		$ 442,350	$ 327,000	$ -	$ 769,350	
						$ -	$ -	$ -	$ -	
Mechanical Systems										
Central Plant Buildings	1500	SF			$ 750	$ -	$ -	$ 1,125,000	$ 1,125,000	
Pump Station	500	SF			$ 750	$ -	$ -	$ 375,000	$ 375,000	
HDPE Piping	25000	LF	$ 25	$ 5.5		$ 614,375	$ 149,875	$ -	$ 764,250	
Loop Pumps	6	EA	$ 8,500	$ 1,125		$ 50,133	$ 7,358	$ -	$ 57,491	
Pump VFD	6	EA	$ 7,500	$ 1,350		$ 44,235	$ 8,829	$ -	$ 53,064	
Borefield Pumps	6	EA	$ 12,600	$ 1,130		$ 74,315	$ 7,390	$ -	$ 81,705	
Borefield Pump VFD	6	EA	$ 15,500	$ 3,500		$ 91,419	$ 22,890	$ -	$ 114,309	
6" Black Iron Pipe	2250	LF	$ 45	$ 42		$ 99,529	$ 103,005	$ -	$ 202,534	
Steel Fittings	12	LS			$ 15,000	$ -	$ -	$ 180,000	$ 180,000	
4" HDPE	1250	LF	$ 4			$ 4,706	$ -	$ -	$ 4,706	
3' HDPE	1250	LF	$ 3	$ 8		$ 3,096	$ 10,219	$ -	$ 13,315	
2 1/2" HDPE	1250	LF	$ 2	$ 8		$ 2,826	$ 10,219	$ -	$ 13,045	
2" HDPE	1250	LF	$ 2	$ 8		$ 2,322	$ 10,219	$ -	$ 12,541	
1 1/2" HDPE	1250	LF	$ 1	$ 8		$ 1,401	$ 10,219	$ -	$ 11,620	
HDPE Fittings	7	LS			$ 10,657	$ -	$ -	$ 74,598	$ 74,598	
Air Separator - 6"	6	EA	$ 3,950	$ 533		$ 23,297	$ 3,486	$ -	$ 26,783	
Expansion Tanks -300 gal	6	EA	$ 3,000	$ 200		$ 17,694	$ 1,308	$ -	$ 19,002	
						$ -	$ -	$ -	$ -	
River Heat Exchanger						$ -	$ -	$ -	$ -	
Rigging	1	EA			$ 75,000	$ -	$ -	$ 75,000	$ 75,000	
HEX Equipment (100 Ton)	70	TONS		$ 750		$ -	$ 57,225	$ -	$ 57,225	
HEX Labor	120	HRS		$ 250		$ -	$ 32,700	$ -	$ 32,700	
Piping	500	LF	$ 45	$ 40		$ 22,118	$ 21,800	$ -	$ 43,918	
Pumps + Motor + VFD	2	EA	$ 25,000	$ 17,500		$ 49,150	$ 38,150	$ -	$ 87,300	
Electricals	1	EA	$ 8,500	$ 4,500		$ 8,356	$ 4,905	$ -	$ 13,261	
						$ -	$ -	$ -	$ -	
WSHP Heat Pump Terminal Equipment Cost										
Taylor 1 - New construction will already have HPs	100,000	SF			$ 2.0	$ -	$ -	$ 200,000	$ 200,000	
Taylor 2 - New construction will already have HPs	100,000	SF			$ 2.0					
Taylor 3 - New construction will already have HPs	100,000	SF			$ 2.0					
Taylor 4 - New construction will already have HPs	100,000	SF			$ 2.0	$ -	$ -	$ 200,000	$ 200,000	
Hart Hall	21,552	SF			$ 20	$ -	$ -	$ 431,040	$ 431,040	
Ricketts Hall	34,191	SF			$ 20	$ -	$ -	$ 683,820	$ 683,820	
Roy Courtyard	7,757	SF			$ 20	$ -	$ -	$ 155,140	$ 155,140	
Cowee Hall + Swimming Pool	23,313	SF			$ 20	$ -	$ -	$ 466,260	$ 466,260	
Slingerland Alumnae House	5,208	SF			$ 20	$ -	$ -	$ 104,160	$ 104,160	
Manning Hall	27,798	SF			$ 20	$ -	$ -	$ 555,960	$ 555,960	
Esteves School of Education	12,600	SF			$ 20	$ -	$ -	$ 252,000	$ 252,000	
Plum Memorial	9,794	SF			$ 20	$ -	$ -	$ 195,880	$ 195,880	
						$ -	$ -	$ -	$ -	
Misc and Electrical										
SWPPP/Erosion Control	1	LS			$ 35,000	$ -	$ -	$ 35,000	$ 35,000	
Site Prep/Access	1	LS			$ 30,000	$ -	$ -	$ 30,000	$ 30,000	
Construction Management	1	LS			$ 300,000	$ -	$ -	$ 300,000	$ 300,000	
						$ -	$ -	$ -	$ -	

$ 15,899,475	Subtotal
$ 3,179,895	20% Contingency
$ 3,815,874	20% Contractor O&P
$ 2,289,524	10% Engineering
$ 25,184,768	**Total**

City of Troy

Multipliers	
Material:	0.98
Labor:	1.09
Equipment:	1.00

Phase 1B

Boiler_Chiller_Tower System

Description	QTY	UNIT	UNIT COSTS			SUBTOTAL COSTS			TOTAL COST	REMARKS
			MAT.	LABOR	EQUIP.	MAT.	LABOR	EQUIP.		
Boilers										
Taylor 1 -2 x 1500 MBH	2	EA	$ 38,000	$ 13,500		$ 74,708	$ 29,430	$ -	$ 104,138	
Taylor 2 -2 x 1500 MBH	2	EA	$ 38,000	$ 13,500		$ 74,708	$ 29,430	$ -	$ 104,138	
Taylor 3 -2 x 1500 MBH	2	EA	$ 38,000	$ 13,500		$ 74,708	$ 29,430	$ -	$ 104,138	
Taylor 4 -2 x 1500 MBH	2	EA	$ 38,000	$ 13,500		$ 74,708	$ 29,430	$ -	$ 104,138	
Cowee Hall + Swimming Pool -2 x 500 MBH	2	EA	$ 20,000	$ 9,500		$ 39,320	$ 20,710	$ -	$ 60,030	
Slingerland Alumnae House - 100 MBH Furnace	1	EA	$ 4,500	$ 1,500		$ 4,424	$ 1,635	$ -	$ 6,059	
Roy Courtyard - 150 MBH Furnace	1	EA	$ 7,500	$ 2,250		$ 7,373	$ 2,453	$ -	$ 9,825	
Hart Hall - 2 x 500 MBH	2	EA	$ 20,000	$ 9,500		$ 39,320	$ 20,710	$ -	$ 60,030	
Ricketts Hall - 2 x 500 MBH	2	EA	$ 20,000	$ 9,500		$ 39,320	$ 20,710	$ -	$ 60,030	
Manning Hall - 2 x 500 MBH	2	EA	$ 20,000	$ 9,500		$ 39,320	$ 20,710	$ -	$ 60,030	
Esteves School of Education - 2 x 300 MBH	2	EA	$ 12,000	$ 5,150		$ 23,592	$ 11,227	$ -	$ 34,819	
Plum Memorial - 200 MBH Furnace	1	EA	$ 10,000	$ 4,500		$ 9,830	$ 4,905	$ -	$ 14,735	
						$ -	$ -	$ -	$ -	
Main Pumps										
Taylor 1 -2x10 HP Pump	2	EA	$ 14,950	$ 950		$ 29,392	$ 2,071	$ -	$ 31,463	
Taylor 2 -2x10 HP Pump	2	EA	$ 14,950	$ 950		$ 29,392	$ 2,071	$ -	$ 31,463	
Taylor 3 -2x10 HP Pump	2	EA	$ 14,950	$ 950		$ 29,392	$ 2,071	$ -	$ 31,463	
Taylor 4 -2x10 HP Pump	2	EA	$ 14,950	$ 950		$ 29,392	$ 2,071	$ -	$ 31,463	
Cowee Hall + Swimming Pool - 2x5 HP	2	EA	$ 12,500	$ 650		$ 24,575	$ 1,417	$ -	$ 25,992	
Hart Hall - 2x5 HP	2	EA	$ 12,500	$ 650		$ 24,575	$ 1,417	$ -	$ 25,992	
Ricketts Hall - 2x5 HP	2	EA	$ 12,500	$ 650		$ 24,575	$ 1,417	$ -	$ 25,992	
Manning Hall - 2x5 HP	2	EA	$ 12,500	$ 650		$ 24,575	$ 1,417	$ -	$ 25,992	
Esteves School of Education - 2x3 HP	2	EA	$ 7,500	$ 500		$ 14,745	$ 1,090	$ -	$ 15,835	
Slingerland Alumnae House - Fan/Motor/VFD	1	EA	$ 4,500	$ 450		$ 4,424	$ 491	$ -	$ 4,914	
Roy Courtyard - Fan/Motor/VFD	1	EA	$ 5,500	$ 550		$ 5,407	$ 600	$ -	$ 6,006	
Plum Memoria - Fan/Motor/VFD	1	EA	$ 6,500	$ 550		$ 6,390	$ 600	$ -	$ 6,989	
						$ -	$ -	$ -	$ -	
						$ -	$ -	$ -	$ -	
						$ -	$ -	$ -	$ -	
Cooling PTAC with Hot Water Heat -0620										
Cooling PTACs w/ HW coil	11,217	MBH			$ 118				$ 1,318,050	
Circ Pumps										
Taylor 1 -Circulation Pumps 3-HP	2	EA	$ 3,000	$ 500		$ 5,898	$ 1,090	$ -	$ 6,988	
Taylor 2 -Circulation Pumps 3-HP	2	EA	$ 3,000	$ 500		$ 5,898	$ 1,090	$ -	$ 6,988	
Taylor 3 -Circulation Pumps 3-HP	2	EA	$ 3,000	$ 500		$ 5,898	$ 1,090	$ -	$ 6,988	
Taylor 4 -Circulation Pumps 3-HP	2	EA	$ 3,000	$ 500		$ 5,898	$ 1,090	$ -	$ 6,988	
Cowee Hall + Swimming Pool - 1 HP	2	EA	$ 2,050	$ 250		$ 4,030	$ 545	$ -	$ 4,575	
Hart Hall - 1 HP	2	EA	$ 2,050	$ 250		$ 4,030	$ 545	$ -	$ 4,575	
Ricketts Hall - 1 HP	2	EA	$ 2,050	$ 250		$ 4,030	$ 545	$ -	$ 4,575	
Manning Hall - 1 HP	2	EA	$ 2,050	$ 250		$ 4,030	$ 545	$ -	$ 4,575	
Esteves School of Education - 3/4 HP	2	EA	$ 1,500	$ 200		$ 2,949	$ 436	$ -	$ 3,385	
For four new buildings/ Use existing for all others.										
Misc Electricals - xformer/ Panel/ Switchgear	12	EA	$ 20,000	$ 9,500		$ 235,920	$ 124,260	$ -	$ 360,180	
Chemical Tratment	9	EA			$ 6,500	$ -	$ -	$ 58,500	$ 58,500	
Concrete Pad - Primary Boilers	9	EA	$ 4,500	$ 1,500		$ 39,812	$ 14,715	$ -	$ 54,527	
Boiler Rigging - All Boilers	9	EA			$ 7,500	$ -	$ -	$ 67,500	$ 67,500	
Boiler - Flue Venting (double wall stainless steel AL-294c)	9	EA	$ 20,000	$ 5,500		$ 176,940	$ 53,955	$ -	$ 230,895	
Boiler / Furnace Controls and Wiring	12	EA	$ 7,500	$ 4,500		$ 88,470	$ 58,860	$ -	$ 147,330	
Power Wiring to new equipment	12	EA	$ 5,000	$ 4,500		$ 58,980	$ 58,860	$ -	$ 117,840	
Startup & Testing	400	HRS	$ -	$ 100		$ -	$ 43,600	$ -	$ 43,600	

$ 3,433,732	Subtotal	
$ 686,746	20%	Contingency
$ 686,746	20%	Contractor O&P
$ 343,373	10%	Engineering
$ 5,150,597	**Total**	

LCA Calculation for Troy DES Geothermal Phase 2

Total buildings square footage	Blended Electric Utility Rate (per kWh)	Gas Utility Rate (per Therm)
901,095	$0.10	$0.80

System Efficiency Degredation/year	0.250%
O&M Growth Rate (%)	3.0%

25 Year Energy Cost Savings & Revenue	25 Year Project Savings (Construction Cost - Energy Savings)
$ 2,743,652	

25 Year Energy Consumption Comparison (system efficiency deteriorates by 0.25% every year)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Baseline scenario Nat Gas energy consumption (Therms)	458,654	459,801	460,950	462,103	463,258	464,416	465,577	466,741	467,908	469,078	470,250	471,426
Heat Pump scenario Nat Gas energy consumption (Therms)	-	-	-	-	-	-	-	-	-	-	-	-
Baseline scenario electric energy consumption (kWh)	115,064	115,352	115,640	115,929	116,219	116,510	116,801	117,093	117,386	117,679	117,973	118,268
Heat Pump scenario electric energy consumption (kWh)	2,619,833	2,626,383	2,632,949	2,639,531	2,646,130	2,652,745	2,659,377	2,666,025	2,672,690	2,679,372	2,686,071	2,692,786
Natural Gas Utility Rate ($/Therm)	$0.80	$0.82	$0.83	$0.82	$0.85	$0.88	$0.90	$0.94	$0.98	$1.01	$1.04	$1.07
Electric Utility Rate ($/kWh)	$0.10	$0.11	$0.11	$0.11	$0.12	$0.12	$0.13	$0.14	$0.14	$0.14	$0.15	$0.15

	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Total kWh	
Baseline scenario Nat Gas energy consumption (Therms)	472,604	473,786	474,970	476,158	477,348	478,542	479,738	480,937	482,140	483,345	484,553	485,765	486,979	488,197	472,681
Heat Pump scenario Nat Gas energy consumption (Therms)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Baseline scenario electric energy consumption (kWh)	118,564	118,860	119,157	119,455	119,754	120,053	120,353	120,654	120,956	121,258	121,561	121,865	122,170	122,475	118,583
Heat Pump scenario electric energy consumption (kWh)	2,699,518	2,706,267	2,713,032	2,719,815	2,726,614	2,733,431	2,740,264	2,747,115	2,753,983	2,760,868	2,767,770	2,774,689	2,781,626	2,788,580	2,699,955
Natural Gas Utility Rate ($/Therm)	$1.10	$1.14	$1.18	$1.22	$1.25	$1.29	$1.33	$1.37	$1.41	$1.45	$1.50	$1.54	$1.58		1.1
Electric Utility Rate ($/kWh)	$0.16	$0.17	$0.17	$0.18	$0.18	$0.19	$0.19	$0.20	$0.20	$0.21	$0.22	$0.23	$0.23		0.16

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25
Natural Gas Rate Escalation Factor	1.00	1.03	1.04	1.03	1.06	1.10	1.13	1.17	1.22	1.26	1.30	1.34	1.38	1.43	1.48	1.52	1.56	1.61	1.66	1.71	1.76	1.81	1.87	1.92	1.98
Electricity Rate Escalation Factor	1.00	1.05	1.09	1.14	1.19	1.24	1.30	1.35	1.40	1.43	1.48	1.52	1.59	1.65	1.71	1.75	1.80	1.85	1.90	1.97	2.04	2.12	2.18	2.25	2.33

Operations and Maintenance

Boiler : 25 yr life

PTAC: 15 yr life

WSHP: 19 yr life

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Year	1	2	3	4	5	6	7	8	9	10	11	12
O&M - Baseline Scenario	$90,000	$92,700	$95,481	$98,345	$101,296	$104,335	$107,465	$110,689	$114,009	$117,430	$120,952	$124,581
O&M - Heat Pump (DES) Scenario	$13,500	$13,905	$14,322	$14,752	$15,194	$15,650	$16,120	$16,603	$17,101	$17,614	$18,143	$18,687
Replacement Costs - Baseline Scenario										$1,085,848	$1,092,956	$1,100,278
Replacement Costs - Heat Pump (DES) Scenario												

	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Total Cost	
Year	13	14	15	16	17	18	19	20	21	22	23	24	25		
O&M - Baseline Scenario	$128,318	$132,168	$136,133	$140,217	$144,424	$148,756	$153,219	$157,816	$162,550	$167,427	$172,449	$177,623	$182,951	$3,281,334	131,253
O&M - Heat Pump (DES) Scenario	$19,248	$19,825	$20,420	$21,033	$21,664	$22,313	$22,983	$23,672	$24,383	$25,114	$25,867	$26,643	$27,443	$492,200	19,688
Replacement Costs - Baseline Scenario	$1,107,819	$1,115,586	$1,123,587	$1,131,828	$1,140,315	$1,149,058	$1,158,062	$159,218	$163,994	$168,914	$173,982	$179,201	$369,154	12,419,799	
Replacement Costs - Heat Pump (DES) Scenario		$232,114	$239,078	$246,250	$253,638	$261,247	$269,084	$277,157	$285,472	$294,036	$302,857	$155,971	$160,650	2,977,554	

= 10% of the boilers and terminal units are being replaced that year

= 5% of the terminal units being replaced that year

Terminal Equipment Replacement Cost at the End of Equipment Life

	Total Cost of Replacement	at 10% per Year	at 5% per Year
Baseline Scenario	$1,763,100	$176,310	$88,155
Heat Pump (DES) Scenario	$1,534,550	$153,455	$76,728

Boiler Replacement Cost at the End of Equipment Life

	Total Cost of Replacement	at 10% per Year	at 5% per Year
Baseline Scenario	$ 8,489,018	$848,902	$424,451

Energy Cost Savings

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Natural Gas Cost Savings	$ 122,306	$ 126,292	$ 127,837	$ 380,772	$ 392,843	$ 408,686	$ 420,882	$ 436,869	$ 456,678	$ 472,830	$ 489,060	$ 505,368
Electric Cost Savings	$ (83,492)	$ (87,886)	$ (91,462)	$ (287,691)	$ (301,059)	$ (314,493)	$ (330,535)	$ (344,106)	$ (357,743)	$ (366,322)	$ (380,078)	$ (391,327)
Total Energy Savings	$ 38,815	$ 38,406	$ 36,375	$ 93,082	$ 91,783	$ 94,193	$ 90,347	$ 92,764	$ 98,935	$ 106,508	$ 108,982	$ 114,042
	33%	33%	33%									

	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Totals
Natural Gas Cost Savings	$ 521,755	$ 542,011	$ 562,365	$ 579,008	$ 595,731	$ 616,362	$ 637,092	$ 657,922	$ 678,853	$ 699,883	$ 724,892	$ 746,135	$ 771,375	$ 12,673,808
Electric Cost Savings	$ (410,372)	$ (426,922)	$ (443,553)	$ (455,063)	$ (469,235)	$ (483,475)	$ (497,783)	$ (517,413)	$ (537,137)	$ (559,597)	$ (576,873)	$ (596,885)	$ (619,653)	$ (9,930,156)
Total Energy Savings	$ 111,384	$ 115,089	$ 118,812	$ 123,945	$ 126,496	$ 132,887	$ 139,309	$ 140,509	$ 141,715	$ 140,286	$ 148,018	$ 149,249	$ 151,722	$ 2,743,652

Central Plant Equipment Installation

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Total Cost
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Baseline Scenario - Boiler/DX	$2,971,153	$3,119,711	$3,275,696																							$9,366,560
Heat Pump (DES) Scenario	$17,186,429	$18,045,751	$18,948,039																							$54,180,219
Replacement Rate	33.3%																									

Note: Existing Equipment will be replaced from Year 1 through Year 3 at the rate of 33.33%

Note: Boiler/DX will be replaced with DES

Total NYSERDA Aid	$ 4,000,000		
$$ QUALIFIED FOR NYSERDA AID	$ 1,320,000	$ 1,320,000	$ 1,320,000

NPV ANALYSIS

Initial Capital Investment - WSHP (DES)	$ 49,104,133
Initial Capital Investment - Boiler/Ch/Twr	$ 8,489,018
Net Investment without NYSERDA Aid	$ (40,615,116)
Net Investment with NYSERDA Aid	$ (36,615,116)
Discount Rate	5.0%

Project Cash Flow with NYSERDA Category C Funding	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
	$ (12,779,961)	$ (13,488,839)	$ (14,234,809)	$ 176,675	$ 177,885	$ 182,877	$ 181,692	$ 186,849	$ 195,843	$ 1,292,171	$ 1,304,747	$ 1,320,213
Net Present Worth of Investment with NYSERDA funding	$ (29,380,541)											

Project Cash Flow with NYSERDA Category C Funding	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25
	$ 1,328,273	$ 1,110,904	$ 1,119,035	$ 1,128,707	$ 1,135,933	$ 1,147,140	$ 1,158,523	$ 156,714	$ 158,405	$ 157,477	$ 165,725	$ 323,458	$ 515,734

Project Cash Flow without NYSERDA Category C Funding	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
	$ (14,099,961)	$ (14,808,839)	$ (15,554,809)	$ 176,675	$ 177,885	$ 182,877	$ 181,692	$ 186,849	$ 195,843	$ 1,292,171	$ 1,304,747	$ 1,320,213
Net Present Worth of Investment without NYSERDA funding	$ (32,975,228)											

Project Cash Flow without NYSERDA Category C Funding	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25
	$ 1,328,273	$ 1,110,904	$ 1,119,035	$ 1,128,707	$ 1,135,933	$ 1,147,140	$ 1,158,523	$ 156,714	$ 158,405	$ 157,477	$ 165,725	$ 323,458	$ 515,734

City of Troy

Multipliers	
Material:	0.98
Labor:	1.09
Equipment:	1.00

Phase 2
WSHP District Energy

Description	QTY	UNIT	UNIT COSTS			SUBTOTAL COSTS			TOTAL COST	REMARKS
			MAT.	LABOR	EQUIP.	MAT.	LABOR	EQUIP.		
Geothermal Well Install										
Hardscape Restroration	300	LF			$ 150	$ -	$ -	$ 45,000	$ 45,000	
Parking Lot Excavation	25000	SF			$ 40	$ -	$ -	$ 1,000,000	$ 1,000,000	
Parking Lot Restoration	25000	SF			$ 1.5	$ -	$ -	$ 37,500	$ 37,500	
Geothermal Boreholes (230 Boreholes x 500 ft)	115000	LF			$ 50	$ -	$ -	$ 5,750,000	$ 5,750,000	
Heat Exchanger	6	EA	$ 75,000	$ 50,000		$ 442,350	$ 327,000	$ -	$ 769,350	
						$ -	$ -	$ -	$ -	
Mechanical Systems										
Central Plant Buildings	2100	SF			$ 750	$ -	$ -	$ 1,575,000	$ 1,575,000	
Pump Station	750	SF			$ 750	$ -	$ -	$ 562,500	$ 562,500	
HDPE Piping	35000	LF	$ 25	$ 5.5		$ 860,125	$ 209,825	$ -	$ 1,069,950	
Loop Pumps	12	EA	$ 8,500	$ 1,125		$ 100,266	$ 14,715	$ -	$ 114,981	
Pump VFD	12	EA	$ 7,500	$ 1,350		$ 88,470	$ 17,658	$ -	$ 106,128	
Borefield Pumps	12	EA	$ 12,600	$ 1,130		$ 148,630	$ 14,780	$ -	$ 163,410	
Borefield Pump VFD	12	EA	$ 15,500	$ 3,500		$ 182,838	$ 45,780	$ -	$ 228,618	
6" Black Iron Pipe	3500	LF	$ 45	$ 42		$ 154,823	$ 160,230	$ -	$ 315,053	
Steel Fittings	15	LS			$ 15,000	$ -	$ -	$ 225,000	$ 225,000	
4" HDPE	2500	LF	$ 4			$ 9,412	$ -	$ -	$ 9,412	
3' HDPE	2500	LF	$ 3	$ 8		$ 6,193	$ 20,438	$ -	$ 26,630	
2 1/2" HDPE	2500	LF	$ 2	$ 8		$ 5,652	$ 20,438	$ -	$ 26,090	
2" HDPE	2500	LF	$ 2	$ 8		$ 4,645	$ 20,438	$ -	$ 25,082	
1 1/2" HDPE	2500	LF	$ 1	$ 8		$ 2,802	$ 20,438	$ -	$ 23,239	
HDPE Fittings	10	LS			$ 10,657	$ -	$ -	$ 106,568	$ 106,568	
Air Separator - 6"	12	EA	$ 3,950	$ 533		$ 46,594	$ 6,972	$ -	$ 53,566	
Expansion Tanks -300 gal	12	EA	$ 3,000	$ 200		$ 35,388	$ 2,616	$ -	$ 38,004	
						$ -	$ -	$ -	$ -	
River Heat Exchanger						$ -	$ -	$ -	$ -	
Rigging	1	EA			$ 75,000	$ -	$ -	$ 75,000	$ 75,000	
HEX Equipment (100 Ton)	100	TONS		$ 750		$ -	$ 81,750	$ -	$ 81,750	
HEX Labor	150	HRS		$ 250		$ -	$ 40,875	$ -	$ 40,875	
Piping	500	LF	$ 45	$ 40		$ 22,118	$ 21,800	$ -	$ 43,918	
Pumps + Motor + VFD	2	EA	$ 25,000	$ 17,500		$ 49,150	$ 38,150	$ -	$ 87,300	
Electricals	1	EA	$ 8,500	$ 4,500		$ 8,356	$ 4,905	$ -	$ 13,261	
						$ -	$ -	$ -	$ -	
WSHP Heat Pump Terminal Equipment Cost										
WSHP Heat Pump Terminal Equipment and Installation Cost	901,095	SF			$ 20.0	$ -	$ -	$ 18,021,900	$ 18,021,900	
						$ -	$ -	$ -	$ -	
Misc and Electrical										
SWPPP/Erosion Control	1	LS			$ 35,000	$ -	$ -	$ 35,000	$ 35,000	
Site Prep/Access	1	LS			$ 30,000	$ -	$ -	$ 30,000	$ 30,000	
Construction Management	1	LS			$ 300,000	$ -	$ -	$ 300,000	$ 300,000	
						$ -	$ -	$ -	$ -	

$ 31,000,084	Subtotal
$ 6,200,017	20% Contingency
$ 7,440,020	20% Contractor O&P
$ 4,464,012	10% Engineering
$ 49,104,133	**Total**

City of Troy

Phase 2

Boiler_Chiller_Tower System

Multipliers	
Material:	0.98
Labor:	1.09
Equipment:	1.00

Description	QTY	UNIT	UNIT COSTS			SUBTOTAL COSTS			TOTAL COST	REMARKS
			MAT.	LABOR	EQUIP.	MAT.	LABOR	EQUIP.		
Boilers										
100 2nd Street 200 MBH	2	EA	$ 20,000	$ 7,500		$ 39,320	$ 16,350	$ -	$ 55,670	
141 Congress Street 1000 MBH	2	EA	$ 38,000	$ 12,500		$ 74,708	$ 27,250	$ -	$ 101,958	
1646 5th Avenue 200 MBH	2	EA	$ 20,000	$ 7,500		$ 39,320	$ 16,350	$ -	$ 55,670	
119 Congress Street 200 MBH	2	EA	$ 20,000	$ 7,500		$ 39,320	$ 16,350	$ -	$ 55,670	
51 State Street 400 MBH	2	EA	$ 25,000	$ 7,500		$ 49,150	$ 16,350	$ -	$ 65,500	
1700 6th Avenue 300 MBH	2	EA	$ 22,500	$ 7,500		$ 44,235	$ 16,350	$ -	$ 60,585	
57-59 State Street 200 MBH	2	EA	$ 20,000	$ 7,500		$ 39,320	$ 16,350	$ -	$ 55,670	
61 State Street 200 MBH	2	EA	$ 20,000	$ 7,500		$ 39,320	$ 16,350	$ -	$ 55,670	
State Street 2000 MBH	2	EA	$ 50,000	$ 15,000		$ 98,300	$ 32,700	$ -	$ 131,000	
1776 6th Avenue 1000 MBH	2	EA	$ 38,000	$ 12,500		$ 74,708	$ 27,250	$ -	$ 101,958	
1800 6th Avenue 2000 MBH	2	EA	$ 50,000	$ 15,000		$ 98,300	$ 32,700	$ -	$ 131,000	
1801 6th Avenue 750 MBH	2	EA	$ 30,000	$ 10,000		$ 58,980	$ 21,800	$ -	$ 80,780	
2000 6th Avenue 2000 MBH	2	EA	$ 50,000	$ 15,000		$ 98,300	$ 32,700	$ -	$ 131,000	
720 Federal Street 3000 MBH	2	EA	$ 60,000	$ 15,000		$ 117,960	$ 32,700	$ -	$ 150,660	
503 Grand Street 750 MBH	2	EA	$ 30,000	$ 10,000		$ 58,980	$ 21,800	$ -	$ 80,780	
2001 5th Avenue 750 MBH	2	EA	$ 30,000	$ 10,000		$ 58,980	$ 21,800	$ -	$ 80,780	
92-96 Fourth Street 200 MBH	2	EA	$ 20,000	$ 7,500		$ 39,320	$ 16,350	$ -	$ 55,670	
30 3rd Street 200 MBH	2	EA	$ 20,000	$ 7,500		$ 39,320	$ 16,350	$ -	$ 55,670	
43 3rd Street 100 MBH	2	EA	$ 10,000	$ 5,000		$ 19,660	$ 10,900	$ -	$ 30,560	
32 2nd Street 300 MBH	2	EA	$ 22,500.0	$ 7,500		$ 44,235	$ 16,350	$ -	$ 60,585	
Main Pumps										
100 2nd Street 2x 5 HP	2	EA	$ 5,000	$ 950		$ 9,830	$ 2,071	$ -	$ 11,901	
141 Congress Street 2x 15 HP	2	EA	$ 12,500	$ 1,500		$ 24,575	$ 3,270	$ -	$ 27,845	
1646 5th Avenue 2x 5 HP	2	EA	$ 5,000	$ 950		$ 9,830	$ 2,071	$ -	$ 11,901	
119 Congress Street 2x 5 HP	2	EA	$ 5,000	$ 950		$ 9,830	$ 2,071	$ -	$ 11,901	
51 State Street 2x 7.5 HP	2	EA	$ 7,500	$ 1,250		$ 14,745	$ 2,725	$ -	$ 17,470	
1700 6th Avenue 2x 7.5 HP	2	EA	$ 7,500	$ 1,250		$ 14,745	$ 2,725	$ -	$ 17,470	
57-59 State Street 2x 5 HP	2	EA	$ 5,000	$ 950		$ 9,830	$ 2,071	$ -	$ 11,901	
61 State Street 2x 5 HP	2	EA	$ 5,000	$ 950		$ 9,830	$ 2,071	$ -	$ 11,901	
State Street 2x 15 HP	2	EA	$ 12,500	$ 1,500		$ 24,575	$ 3,270	$ -	$ 27,845	
1776 6th Avenue 2 x 10 HP	2	EA	$ 10,000	$ 1,500		$ 19,660	$ 3,270	$ -	$ 22,930	
1800 6th Avenue 2x 15 HP	2	EA	$ 12,500	$ 1,500		$ 24,575	$ 3,270	$ -	$ 27,845	
1801 6th Avenue 2 x 10 HP	2	EA	$ 10,000	$ 1,250		$ 19,660	$ 2,725	$ -	$ 22,385	
2000 6th Avenue 2x 15 HP	2	EA	$ 12,500	$ 1,500		$ 24,575	$ 3,270	$ -	$ 27,845	
720 Federal Street 2x 15 HP	2	EA	$ 12,500	$ 1,500		$ 24,575	$ 3,270	$ -	$ 27,845	
503 Grand Street 2 x 10 HP	2	EA	$ 10,000	$ 1,250		$ 19,660	$ 2,725	$ -	$ 22,385	
2001 5th Avenue 2 x 10 HP	2	EA	$ 10,000	$ 1,250		$ 19,660	$ 2,725	$ -	$ 22,385	
92-96 Fourth Street 2x 5 HP	2	EA	$ 5,000	$ 950		$ 9,830	$ 2,071	$ -	$ 11,901	
30 3rd Street 2x 5 HP	2	EA	$ 5,000	$ 950		$ 9,830	$ 2,071	$ -	$ 11,901	
43 3rd Street 2x 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533	
32 2nd Street 2x 5 HP	2	EA	$ 5,000	$ 950		$ 9,830	$ 2,071	$ -	$ 11,901	
Cooling PTAC with Hot Water Heat -0620										
Cooling PTACs w/ HW coil included in terminal costs	901,095	SQFT							$ 1,534,550	
Circ Pumps										
100 2nd Street 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477	
141 Congress Street 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533	
1646 5th Avenue 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477	
119 Congress Street 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477	
51 State Street 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005	
1700 6th Avenue 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477	
57-59 State Street 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477	
61 State Street 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533	
State Street 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005	
1776 6th Avenue 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533	
1800 6th Avenue 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005	
1801 6th Avenue 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533	
2000 6th Avenue 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533	
720 Federal Street 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005	
503 Grand Street 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005	
2001 5th Avenue 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005	
92-96 Fourth Street 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477	
30 3rd Street 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477	
43 3rd Street 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477	
32 2nd Street 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477	
For four new buildings/ Use existing for all others.										
Misc Electricals - xformer/ Panel/ Switchgear	20	EA	$ 16,000	$ 7,500		$ 314,560	$ 163,500	$ -	$ 478,060	
Chemical Tratment	20	EA			$ 3,500	$ -	$ -	$ 70,000	$ 70,000	
Concrete Pad - Primary Boilers	20	EA	$ 4,500	$ 1,500		$ 88,470	$ 32,700	$ -	$ 121,170	
Boiler Rigging - All Boilers	20	EA			$ 7,500	$ -	$ -	$ 150,000	$ 150,000	
Boiler - Flue Venting (double wall stainless steel AL-294c)	20	EA	$ 20,000	$ 4,500		$ 393,200	$ 98,100	$ -	$ 491,300	
Gas Piping	20	EA	$ 7,500	$ 5,000		$ 147,450	$ 109,000	$ -	$ 256,450	
Boiler Controls and Wiring	20	EA	$ 5,000	$ 3,500		$ 98,300	$ 76,300	$ -	$ 174,600	
Power Wiring to new equipment	20	EA	$ 5,000	$ 4,500		$ 98,300	$ 98,100	$ -	$ 196,400	
Startup & Testing	1000	HRS	$ -	$ 100		$ -	$ 109,000	$ -	$ 109,000	

$ 5,659,345	Subtotal
$ 1,131,869	20% Contingency
$ 1,131,869	20% Contractor O&P
$ 565,935	10% Engineering
$ 8,489,018	**Total**

LCA Calculation for Troy DES Geothermal Phase 3

Total buildings square footage	Blended Electric Utility Rate (per kWh)	Gas Utility Rate (per Therm)
2,566,657	$0.10	$0.80

System Efficiency Degredation/year	0.250%
O&M Growth Rate (%)	3.0%

25 Year Energy Cost Savings & Revenue	25 Year Project Savings (Construction Cost - Energy Savings)
$ 5,381,367	

25 Year Energy Consumption Comparison (system efficiency deteriorates by 0.25% every year)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Baseline scenario Nat Gas energy consumption (Therms)	702,833	704,590	706,352	708,117	709,888	711,662	713,442	715,225	717,013	718,806	720,603	722,404
Heat Pump scenario Nat Gas energy consumption (Therms)	-	-	-	-	-	-	-	-	-	-	-	-
Baseline scenario electric energy consumption (kWh)	826,283	828,349	830,420	832,496	834,577	836,663	838,755	840,852	842,954	845,061	847,174	849,292
Heat Pump scenario electric energy consumption (kWh)	4,367,649	4,378,568	4,389,515	4,400,488	4,411,490	4,422,518	4,433,575	4,444,659	4,455,770	4,466,910	4,478,077	4,489,272
Natural Gas Utility Rate ($/Therm)	$0.80	$0.82	$0.83	$0.82	$0.85	$0.88	$0.90	$0.94	$0.98	$1.01	$1.04	$1.07
Electric Utility Rate ($/kWh)	$0.10	$0.11	$0.11	$0.11	$0.12	$0.12	$0.13	$0.14	$0.14	$0.14	$0.15	$0.15

	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Total kWh	
Baseline scenario Nat Gas energy consumption (Therms)	724,210	726,021	727,836	729,656	731,480	733,308	735,142	736,979	738,822	740,669	742,521	744,377	746,238	748,103	724,328
Heat Pump scenario Nat Gas energy consumption (Therms)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Baseline scenario electric energy consumption (kWh)	851,415	853,544	855,678	857,817	859,961	862,111	864,267	866,427	868,593	870,765	872,942	875,124	877,312	879,505	851,553
Heat Pump scenario electric energy consumption (kWh)	4,500,495	4,511,746	4,523,026	4,534,333	4,545,669	4,557,033	4,568,426	4,579,847	4,591,297	4,602,775	4,614,282	4,625,818	4,637,382	4,648,976	4,501,225
Natural Gas Utility Rate ($/Therm)	$1.10	$1.14	$1.18	$1.22	$1.25	$1.29	$1.33	$1.37	$1.41	$1.45	$1.50	$1.54	$1.58		1.1
Electric Utility Rate ($/kWh)	$0.16	$0.17	$0.17	$0.18	$0.18	$0.19	$0.19	$0.20	$0.20	$0.21	$0.22	$0.23	$0.23		0.16

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25
Natural Gas Rate Escalation Factor	1.00	1.03	1.04	1.03	1.06	1.10	1.13	1.17	1.22	1.26	1.30	1.34	1.38	1.43	1.48	1.52	1.56	1.61	1.66	1.71	1.76	1.81	1.87	1.92	1.98
Electricity Rate Escalation Factor	1.00	1.05	1.09	1.14	1.19	1.24	1.30	1.35	1.40	1.43	1.48	1.52	1.59	1.65	1.71	1.75	1.80	1.85	1.90	1.97	2.04	2.12	2.18	2.25	2.33

Operations and Maintenance

PTAC: 15 yr life

WSHP: 19 yr life

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Year	1	2	3	4	5	6	7	8	9	10	11	12
O&M - Baseline Scenario	$76,500	$78,795	$81,159	$83,594	$86,101	$88,684	$91,345	$94,085	$96,908	$99,815	$102,810	$105,894
O&M - Heat Pump (DES) Scenario	$33,000	$33,990	$35,010	$36,060	$37,142	$38,256	$39,404	$40,586	$41,803	$43,058	$44,349	$45,680
Replacement Costs - Baseline Scenario										$475,091	$489,344	$504,024
Replacement Costs - Heat Pump (DES) Scenario												

	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Total Cost	
Year	13	14	15	16	17	18	19	20	21	22	23	24	25		
O&M - Baseline Scenario	$109,071	$112,343	$115,713	$119,185	$122,760	$126,443	$130,236	$134,143	$138,168	$142,313	$146,582	$150,979	$155,509	$2,789,134	111,565
O&M - Heat Pump (DES) Scenario	$47,050	$48,462	$49,915	$51,413	$52,955	$54,544	$56,180	$57,866	$59,602	$61,390	$63,231	$65,128	$67,082	$1,203,156	48,126
Replacement Costs - Baseline Scenario	$519,145	$534,719	$550,761	$567,284	$584,302	$601,831	$619,886	$319,241	$328,819	$338,683	$348,844	$359,309	$740,177	7,881,461	
Replacement Costs - Heat Pump (DES) Scenario		$465,404	$479,366	$493,747	$508,559	$523,816	$539,531	$555,717	$572,388	$589,560	$607,246	$312,732	$322,114	5,970,180	

= 10% of the units being replaced that year

= 5% of the units being replaced that year

Terminal Equipment Replacement Cost at the End of Equipment Life

	Total Cost of Replacement	at 10% per Year	at 5% per Year
Baseline Scenario	$3,535,125	$353,512	$176,756
Heat Pump (DES) Scenario	$3,076,866	$307,687	$153,843

Energy Cost Savings

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13
Natural Gas Cost Savings	$ 187,422	$ 193,527	$ 195,895	$ 583,489	$ 601,585	$ 626,263	$ 644,951	$ 669,451	$ 699,805	$ 724,556	$ 749,427	$ 774,417	$ 799,528
Electric Cost Savings	$ (118,046)	$ (124,258)	$ (129,314)	$ (406,751)	$ (425,653)	$ (444,646)	$ (467,327)	$ (486,514)	$ (505,794)	$ (517,924)	$ (537,374)	$ (553,277)	$ (580,204)
Total Energy Savings	$ 69,377	$ 69,270	$ 66,581	$ 176,738	$ 176,332	$ 181,617	$ 177,625	$ 182,937	$ 194,011	$ 206,632	$ 212,053	$ 221,140	$ 219,324
	33%	33%	33%										

	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Totals
Natural Gas Cost Savings	$ 830,568	$ 861,758	$ 887,261	$ 912,887	$ 944,501	$ 976,268	$ 1,008,188	$ 1,040,261	$ 1,072,489	$ 1,110,811	$ 1,143,363	$ 1,182,041	$ 19,421,112
Electric Cost Savings	$ (603,603)	$ (627,117)	$ (643,390)	$ (663,427)	$ (683,561)	$ (703,790)	$ (731,544)	$ (759,431)	$ (791,186)	$ (815,612)	$ (843,906)	$ (876,098)	$ (14,039,745)
Total Energy Savings	$ 226,964	$ 234,641	$ 243,871	$ 249,459	$ 260,941	$ 272,478	$ 276,644	$ 280,830	$ 281,303	$ 295,199	$ 299,457	$ 305,944	$ 5,381,367

Central Plant Equipment Installation

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Total Cost	
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25		
Baseline Scenario - Boiler/DX	$3,645,954	$3,828,252	$4,019,665																							$11,493,871	
Heat Pump (DES) Scenario	$12,127,254	$12,733,617	$13,370,298																							$38,231,169	
Replacement Rate	33.3%																										

Note: Existing Equipment will be replaced from Year 1 through Year 3 at the rate of 33.33%

Total NYSERDA Aid	$ 4,000,000		
$$ QUALIFIED FOR NYSERDA AID	$ 1,320,000	$ 1,320,000	$ 1,320,000

NPV ANALYSIS

Initial Capital Investment - WSHP (DES)	$ 34,649,333
Initial Capital Investment - Boiler/Ch/Twr	$ 10,417,023
Net Investment without NYSERDA Aid	$ (24,232,310)
Net Investment with NYSERDA Aid	$ (20,232,310)
Discount Rate	5.0%

Project Cash Flow with NYSERDA Category C Funding	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25
	$ (7,048,423)	$ (7,471,290)	$ (7,917,903)	$ 224,271	$ 225,292	$ 232,045	$ 229,566	$ 236,436	$ 249,115	$ 738,481	$ 759,858	$ 785,379	$ 800,490	$ 360,161	$ 371,834	$ 385,179	$ 395,007	$ 410,855	$ 426,889	$ 116,447	$ 115,826	$ 111,349	$ 120,146	$ 431,885	$ 812,434
Net Present Worth of Investment with NYSERDA funding	$ (15,966,136)																								

Project Cash Flow without NYSERDA Category C Funding	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25
	$ (8,368,423)	$ (8,791,290)	$ (9,237,903)	$ 224,271	$ 225,292	$ 232,045	$ 229,566	$ 236,436	$ 249,115	$ 738,481	$ 759,858	$ 785,379	$ 800,490	$ 360,161	$ 371,834	$ 385,179	$ 395,007	$ 410,855	$ 426,889	$ 116,447	$ 115,826	$ 111,349	$ 120,146	$ 431,885	$ 812,434
Net Present Worth of Investment without NYSERDA funding	$ (19,560,824)																								

City of Troy

Phase 3

WSHP District Energy

Multipliers	
Material:	0.98
Labor:	1.09
Equipment:	1.00

Description	QTY	UNIT	UNIT COSTS			SUBTOTAL COSTS			TOTAL COST	REMARKS	NYSERDA AID
			MAT.	LABOR	EQUIP.	MAT.	LABOR	EQUIP.			
Central Plant Buildings											(Y/N?)
Central Plant Buildings	2100	SF			$ 175	$ -	$ -	$ 367,500	$ 367,500		Y
Pump Station	750	SF			$ 125	$ -	$ -	$ 93,750	$ 93,750		Y
Excavation and backfill	6000	LF				$ -	$ -	$ -	$ -		Y
Compact backfill	6300	LF			$ 15	$ -	$ -	$ 94,500	$ 94,500		Y
HDPE Piping	15000	LF	$ 20	$ 7.0		$ 294,900	$ 114,450	$ -	$ 409,350		Y
Hardscape Restroration	2000	LF			$ 650	$ -	$ -	$ 1,300,000	$ 1,300,000		Y
Parking lot excavation	35000	SF			$ 50	$ -	$ -	$ 1,750,000	$ 1,750,000		Y
Parking Lot Restoration	35000	SF			$ 2	$ -	$ -	$ 52,500	$ 52,500		Y
						$ -	$ -	$ -	$ -		Y
Geothermal System for Phase 2						$ -	$ -	$ -	$ -		Y
Loop Pumps - 40 HP	2	EA	$ 15,000	$ 1,125		$ 29,490	$ 2,453	$ -	$ 31,943		Y
Pump VFD - 40 HP	2	EA	$ 7,500	$ 1,350		$ 14,745	$ 2,943	$ -	$ 17,688		Y
Borefield Pumps - 20 HP	2	EA	$ 10,600	$ 1,130		$ 20,840	$ 2,463	$ -	$ 23,303		Y
Pump VFD - 20 HP	2	EA	$ 4,350	$ 1,350		$ 8,552	$ 2,943	$ -	$ 11,495		Y
Borefield Pumps - 10 HP	2	EA	$ 7,500	$ 7,500		$ 14,745	$ 16,350	$ -	$ 31,095		Y
Pump VFD - 10 HP	2	EA	$ 3,100	$ 3,100		$ 6,095	$ 6,758	$ -	$ 12,853		Y
6" Black Iron Pipe	750	LF	$ 45	$ 42		$ 33,176	$ 34,335	$ -	$ 67,511		Y
Steel Fittings	2	LS			$ 7,144	$ -	$ -	$ 14,288	$ 14,288		Y
4" HDPE	500	LF	$ 4			$ 1,882	$ -	$ -	$ 1,882		Y
Site Trenching and backfill	6300	LF			$ 15	$ -	$ -	$ 94,500	$ 94,500		Y
3' HDPE	3500	LF	$ 3	$ 8		$ 8,670	$ 28,613	$ -	$ 37,283		Y
2 1/2" HDPE	1500	LF	$ 2	$ 8		$ 3,391	$ 12,263	$ -	$ 15,654		Y
2" HDPE	7500	LF	$ 2	$ 8		$ 13,934	$ 61,313	$ -	$ 75,247		Y
1 1/2" HDPE	1500	LF	$ 1	$ 8		$ 1,681	$ 12,263	$ -	$ 13,943		Y
HDPE Fittings	1	LS			$ 10,657	$ -	$ -	$ 10,657	$ 10,657		Y
Air Separator - 6"	3	EA	$ 3,950	$ 533		$ 11,649	$ 1,743	$ -	$ 13,391		Y
Expansion Tanks -300 gal	3	EA	$ 3,000	$ 200		$ 8,847	$ 654	$ -	$ 9,501		Y
Geothermal Boreholes (440 Boreholes x 500 ft)	220000	LF			$ 50	$ -	$ -	$ 11,000,000	$ 11,000,000		Y
Heat Exchanger	17	EA	$ 15,000	$ 6,000		$ 250,665	$ 111,180	$ -	$ 361,845		Y
						$ -	$ -	$ -	$ -		Y
Sewer Waste Heat Recovery											Y
7.3 MMBtu/hr sewer heat recovery system	3	EA	$ 500,000	$ 75,000		$ 1,474,500	$ 245,250	$ -	$ 1,719,750		Y
Circ Pumps											Y
Building – 1 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477		Y
Building – 2 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533		Y
Building – 3 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477		Y
Building – 4 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477		Y
Building – 5 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005		Y
Building – 6 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477		Y
Building – 7 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477		Y
Building – 8 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533		Y
Building – 9 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005		Y
Building – 10 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533		Y
Building – 11 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005		Y
Building – 12 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533		Y
Building – 13 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533		Y
Building – 14 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005		Y
Building – 15 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005		Y
Building – 16 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005		Y
Building – 17 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477		Y
											Y
Electrical											Y
75 kVA Transfomer	2	EA	$ 16,000	$ 1,800		$ 31,456	$ 3,924	$ -	$ 35,380		Y
100 A Panel - 460 V/3 Ph	2	EA	$ 2,150	$ 1,050		$ 4,227	$ 2,289	$ -	$ 6,516		Y
100 A Panel - 240V/1Ph	2	EA	$ 1,250	$ 1,000		$ 2,458	$ 2,180	$ -	$ 4,638		Y
Equipment Connection - Pumps	4	EA			$ 1,000	$ -	$ -	$ 4,000	$ 4,000		N
Misc Elec	2	LS			$ 10,000	$ -	$ -	$ 20,000	$ 20,000		
											Y
HVAC Controls											Y
Pumps	2	EA			$ 7,500	$ -	$ -	$ 15,000	$ 15,000		Y
Heat Exchanger	1	EA			$ 7,500	$ -	$ -	$ 7,500	$ 7,500		Y
Front End	1	EA			$ 20,000	$ -	$ -	$ 20,000	$ 20,000		Y
Startup & Testing	300	HRS	$ -	$ 100		$ -	$ 32,700	$ -	$ 32,700		Y
											Y
											$ 24,995,205.82

50%

Central Equipment Costs	Central Equipment Costs	$ 17,877,718
WSHP Heat Pump Terminal Equipment Cost	Terminal Equipment Costs	$ 4,621,848

$ 4,000,000

$ 22,499,567	Subtotal
$ 4,499,913	20% Contingency
$ 4,499,913	20% Contractor O&P
$ 3,149,939	10% Engineering
$ 34,649,333	**Total**

City of Troy

Phase 3

Boiler_Chiller_Tower System

Multipliers	
Material:	0.98
Labor:	1.09
Equipment:	1.00

Description	QTY	UNIT	UNIT COSTS			SUBTOTAL COSTS			TOTAL COST	REMARKS
			MAT.	LABOR	EQUIP.	MAT.	LABOR	EQUIP.		
Boilers										
Building – 1 200 MBH	2	EA	$ 20,000	$ 7,500		$ 39,320	$ 16,350	$ -	$ 55,670	
Building – 2 1000 MBH	2	EA	$ 38,000	$ 12,500		$ 74,708	$ 27,250	$ -	$ 101,958	
Building – 3 200 MBH	2	EA	$ 20,000	$ 7,500		$ 39,320	$ 16,350	$ -	$ 55,670	
Building – 4 200 MBH	2	EA	$ 20,000	$ 7,500		$ 39,320	$ 16,350	$ -	$ 55,670	
Building – 5 400 MBH	2	EA	$ 25,000	$ 7,500		$ 49,150	$ 16,350	$ -	$ 65,500	
Building – 6 300 MBH	2	EA	$ 22,500	$ 7,500		$ 44,235	$ 16,350	$ -	$ 60,585	
Building – 7 200 MBH	2	EA	$ 20,000	$ 7,500		$ 39,320	$ 16,350	$ -	$ 55,670	
Building – 8 200 MBH	2	EA	$ 20,000	$ 7,500		$ 39,320	$ 16,350	$ -	$ 55,670	
Building – 9 2000 MBH	2	EA	$ 50,000	$ 15,000		$ 98,300	$ 32,700	$ -	$ 131,000	
Building – 10 1000 MBH	2	EA	$ 38,000	$ 12,500		$ 74,708	$ 27,250	$ -	$ 101,958	
Building – 11 2000 MBH	2	EA	$ 50,000	$ 15,000		$ 98,300	$ 32,700	$ -	$ 131,000	
Building – 12 750 MBH	2	EA	$ 30,000	$ 10,000		$ 58,980	$ 21,800	$ -	$ 80,780	
Building – 13 2000 MBH	2	EA	$ 50,000	$ 15,000		$ 98,300	$ 32,700	$ -	$ 131,000	
Building – 14 3000 MBH	2	EA	$ 60,000	$ 15,000		$ 117,960	$ 32,700	$ -	$ 150,660	
Building – 15 750 MBH	2	EA	$ 30,000	$ 10,000		$ 58,980	$ 21,800	$ -	$ 80,780	
Building – 16 750 MBH	2	EA	$ 30,000	$ 10,000		$ 58,980	$ 21,800	$ -	$ 80,780	
Building – 17 200 MBH	2	EA	$ 20,000	$ 7,500		$ 39,320	$ 16,350	$ -	$ 55,670	
Main Pumps										
Building – 1 2x 5 HP	2	EA	$ 5,000	$ 950		$ 9,830	$ 2,071	$ -	$ 11,901	
Building – 2 2x 15 HP	2	EA	$ 12,500	$ 1,500		$ 24,575	$ 3,270	$ -	$ 27,845	
Building – 3 2x 5 HP	2	EA	$ 5,000	$ 950		$ 9,830	$ 2,071	$ -	$ 11,901	
Building – 4 2x 5 HP	2	EA	$ 5,000	$ 950		$ 9,830	$ 2,071	$ -	$ 11,901	
Building – 5 2x 7.5 HP	2	EA	$ 7,500	$ 1,250		$ 14,745	$ 2,725	$ -	$ 17,470	
Building – 6 2x 7.5 HP	2	EA	$ 7,500	$ 1,250		$ 14,745	$ 2,725	$ -	$ 17,470	
Building – 7 2x 5 HP	2	EA	$ 5,000	$ 950		$ 9,830	$ 2,071	$ -	$ 11,901	
Building – 8 2x 5 HP	2	EA	$ 5,000	$ 950		$ 9,830	$ 2,071	$ -	$ 11,901	
Building – 9 2x 15 HP	2	EA	$ 12,500	$ 1,500		$ 24,575	$ 3,270	$ -	$ 27,845	
Building – 10 2 x 10 HP	2	EA	$ 10,000	$ 1,500		$ 19,660	$ 3,270	$ -	$ 22,930	
Building – 11 2x 15 HP	2	EA	$ 12,500	$ 1,500		$ 24,575	$ 3,270	$ -	$ 27,845	
Building – 12 2 x 10 HP	2	EA	$ 10,000	$ 1,250		$ 19,660	$ 2,725	$ -	$ 22,385	
Building – 13 2x 15 HP	2	EA	$ 12,500	$ 1,500		$ 24,575	$ 3,270	$ -	$ 27,845	
Building – 14 2x 15 HP	2	EA	$ 12,500	$ 1,500		$ 24,575	$ 3,270	$ -	$ 27,845	
Building – 15 2 x 10 HP	2	EA	$ 10,000	$ 1,250		$ 19,660	$ 2,725	$ -	$ 22,385	
Building – 16 2 x 10 HP	2	EA	$ 10,000	$ 1,250		$ 19,660	$ 2,725	$ -	$ 22,385	
Building – 17 2x 5 HP	2	EA	$ 5,000	$ 950		$ 9,830	$ 2,071	$ -	$ 11,901	
Cooling PTAC with Hot Water Heat -0620										
Cooling PTACs w/ HW coil included in terminal costs									$ 3,076,868	
Circ Pumps										
Building – 1 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477	
Building – 2 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533	
Building – 3 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477	
Building – 4 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477	
Building – 5 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005	
Building – 6 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477	
Building – 7 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477	
Building – 8 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533	
Building – 9 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005	
Building – 10 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533	
Building – 11 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005	
Building – 12 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533	
Building – 13 3 HP	2	EA	$ 3,000	$ 750		$ 5,898	$ 1,635	$ -	$ 7,533	
Building – 14 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005	
Building – 15 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005	
Building – 16 2 HP	2	EA	$ 2,500	$ 500		$ 4,915	$ 1,090	$ -	$ 6,005	
Building – 17 1 HP	2	EA	$ 2,000	$ 250		$ 3,932	$ 545	$ -	$ 4,477	
For four new buildings/ Use existing for all others.										
Misc Electricals - xformer/ Panel/ Switchgear	20	EA	$ 16,000	$ 7,500		$ 314,560	$ 163,500	$ -	$ 478,060	
Chemical Tratment	20	EA			$ 3,500	$ -	$ -	$ 70,000	$ 70,000	
Concrete Pad - Primary Boilers	20	EA	$ 4,500	$ 1,500		$ 88,470	$ 32,700	$ -	$ 121,170	
Boiler Rigging - All Boilers	20	EA			$ 7,500	$ -	$ -	$ 150,000	$ 150,000	
Boiler - Flue Venting (double wall stainless steel AL-294c)	20	EA	$ 20,000	$ 4,500		$ 393,200	$ 98,100	$ -	$ 491,300	
Gas Piping	20	EA	$ 7,500	$ 5,000		$ 147,450	$ 109,000	$ -	$ 256,450	
Boiler Controls and Wiring	20	EA	$ 5,000	$ 3,500		$ 98,300	$ 76,300	$ -	$ 174,600	
Power Wiring to new equipment	20	EA	$ 5,000	$ 4,500		$ 98,300	$ 98,100	$ -	$ 196,400	
Startup & Testing	400	HRS	$ -	$ 100		$ -	$ 43,600	$ -	$ 43,600	

Central Equipment Costs	Central Equipment Costs	$ 6,944,682
PTAC with HW Heat	Terminal Equipment Costs	$ 3,076,868

$ 6,944,682	Subtotal	
$ 1,388,936	20%	Contingency
$ 1,388,936	20%	Contractor O&P
$ 694,468	10%	Engineering
$ 10,417,023	**Total**	

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.

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