Syracuse District Energy System

Final Report | Report Number 25-03 | January 2025

NEW YORK STATE

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New York State Energy Research and Development Authority

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Advance clean energy innovation and investments to combat climate change, improving the health, resiliency, and prosperity of New Yorkers and delivering benefits equitably to all.

Syracuse District Energy System

Final Report

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Notice

Abstract

This study aims to provide an alternative solution to traditional electrification approaches by proposing a district energy system to that would supply low-carbon heating to over 10 million square feet of office, multifamily and institutional space in downtown Syracuse. The proposed system takes advantage of the existing local resource of the Metro Wastewater Treatment Plant located on the southern shore of Onondaga Lake.

Keywords

district energy, wastewater heat recovery, water source heat pumps, life cycle cost analysis

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Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

°F	degrees Fahrenheit
A	amperes
ACE	U.S. Army Corps of Engineers
AHJ	authority having jurisdiction
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
ARPA	American Rescue Plan Act
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
CDFI	Community Development Finance Institution
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COVID-19	coronavirus disease 2019
CUP	central utility plant
DEC	New York State Department of Environmental Conservation
delta-t	delta T, the difference between two temperatures
DES	district energy system
DOE	U.S. Department of Energy
DTE	debt-to-equity
EIS	Environmental Impact Statement
EPC	Energy Performance Contract
ESA	Endangered Species Act
ESCOs	Energy Service Companies
ESF	Environmental Science and Forestry
EWT	entering water temperature
ft^2	Square Foot
GLHX	ground loop heat exchanger
GPM	gallons per minute
HDPE	high-density polyethylene
hp	horsepower
HVAC	heating, ventilation, and air conditioning
IRR	
JCA	joint cooperation agreement
JV	joint venture
kV	kilovolt
kVA	kilovolt-amperes
kW	kilowatt
kWh	kilowatt hour
LCCA	life-cycle cost analysis

LF	linear foot
LWT	leaving water temperature
M	million
MBH	thousand British thermal units per hour
Metro	
MGD	million gallons per day
MMBtu	million British thermal units
MW	megawatt
NIST	National Institute of Standards and Technology
NPV	net present value
NWA	non-wires alternative
NWQ	non-wires alternative
NYISO	New York Independent System Operator
NYSERDA	New York State Energy Research & Development Authority
O&M	operation & maintenance
OCWA	Central New York's Water Authority
PACE	Property Assessed Clean Energy
PON	Program Opportunity Notice
QEBC	Qualified Energy Efficiency Bond
RFP	request for proposal
RFQ	request for quotation
ROI	return on investment
SEQRA	State Environmental Quality Review Act
SPV	special purpose vehicle
SUNY	State University of New York
TOU	Time of Use
V	volt
VIST	
VRF	variable refrigerant flow
WSHP	water source heat pump
WWTP	wastewater treatment plant

Forward

In the study described within, the area identified as Phase C “Inner Harbor” is the basis of the utility thermal network project prosed by National Grid as part of the New York State Department of Public Service rate case 22-M-0429. The pilot project would develop the connection to the wastewater outfall and distribute energy to support buildings in the Inner Harbor area of Syracuse. Further development info, including the pilot proposals, detailed cost estimating and analysis can be found posted to the rate case on the Public Service Commission website at: https://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=22-M-0429

All costs cited within were calculated using 2022 U.S. dollars, and actual costs will escalate accordingly depending on if and when the project is constructed.

Summary

As a result of the Climate Leadership and Community Protection Act of 2019, there has been a renewed focus on how to decarbonize building heating at scale. By 2050, 85% of homes and commercial building space statewide should be electrified with energy efficient heat pumps and thermal energy networks. On an individual basis, converting existing buildings to electrified heating will be a challenge, and will also have aggregate effects on the electrical grid. This study aims to provide an alternative solution to traditional electrification approaches by proposing a district energy system (DES) that would supply low-carbon heating to over 10 million square feet of office, multifamily, and institutional space in downtown Syracuse.

The proposed system takes advantage of an existing local resource, the Metro Wastewater Treatment Plant (WWTP) located on the southern shore of Onondaga Lake. The plant processes, on average, 64 million gallons of water per day that maintains a year-round temperature of 50°F to 75°F and discharges that water through an outfall into Onondaga Lake. Those temperatures would generally be considered cold or tepid water but are high enough to be a supply source and can efficiently operate water source heat pumps. The DES would create an interface with this outfall and exchange heat between the outfall and a separate distribution loop that would extend from the Metro to the downtown, university hill and inner harbor areas.

The study included 34 potential customers in the downtown area as well as the existing Onondaga County district heating and cooling plant located on South State Street. A future development of 12 mixed-use buildings was included as a provision for future growth in the Inner Harbor area. The design day heating load of the connected buildings served was estimated at 85,000 thousand British thermal units per hour (MBH) with the design day cooling load estimated at 145,000 MBH.

The study considered the alternative solution to individually electrifying buildings. In many cases, retrofitting with a heat pump alternative is technical challenging and cost-prohibitive due to the size of the building, available footprint, and the type of existing heating, ventilation, and air conditioning (HVAC) systems. It was estimated that electrifying heating in all the buildings covered in the study (not including the existing district energy plant) would increase the peak system load of the electrical grid by 14 megawatts (MW). Based on prior knowledge of the "spot network" electrical grid in downtown Syracuse, additional electrical demand could not be met without substantial upgrades to the electrical infrastructure including the substation level.

The initial primary customers of the system would be those with existing water source heat pumps that are easily compatible and can connect with the district system. The next level of customers would be buildings with water cooled chilled water systems, in which the system could replace the function of the cooling tower and provide the option for future HVAC retrofits and electrified heating options.

Since the system would serve several buildings that have existing water source heat pumps, the central utility plant would need to use heat pump chillers to increase and regulate the wintertime operating temperature to optimize loop temperature for the existing buildings. A central plant would be constructed to house the pumps, heat exchangers, and heat pumps. Two options for the location are included in the Task 3 discussion, one on the site of the wastewater treatment plant and one adjacent to the site, each having different challenges in the coordination with existing utilities. The final location of the plant would be determined in detailed design with the input and consideration of a diverse group of stakeholders.

The largest capital expense of the project is creating a distribution system from the Metro to the downtown core through the existing developed areas between Hiawatha Boulevard and West Genesee Street. The main distribution would consist of two 30 inch–36 inch high-density polyethylene (HDPE) pipes that would be direct buried in a trench with a minimum depth of 5 feet. Insulating the distribution pipe is unnecessary due to the low temperature of the water that is being distributed. Two pathways were explored, one following the existing CSX transportation right of way and another that takes a direct route to West Fayette Street via Van Rensselaer Street. The direct route was found to be the more cost effective by 15% due to the shorter length, avoidance of coordination with CSX, and avoidance of costly subsurface railway crossings.

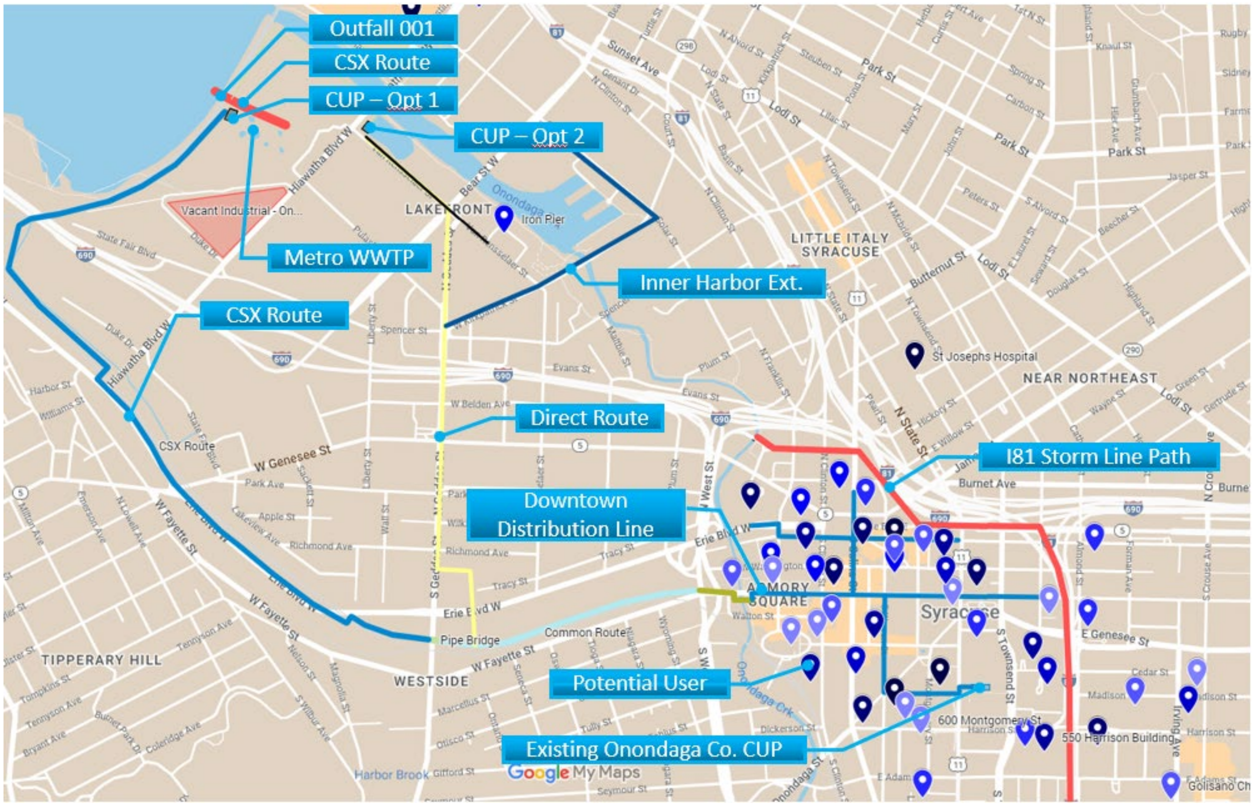
The project is estimated to have a total development and construction cost of $81.5 million (M), with a net present value (NPV) of $53.5M. Cost estimates, and financial assumptions can be found in Task 5. Total net present value of the direct benefits of the system, including avoided capital and operation costs of individual building owners as well as avoided natural gas and electric utility costs is estimated to be $55.8M. The district system is assumed to be financed over a 40-year period. Financing for a large-scale municipal project is expected to have more favorable terms in comparison to making individual building electrification HVAC upgrades.

Indirect benefits of the system include the social cost of the carbon emissions avoided during the 25-year study period as defined by the NYS Department of Environmental Conservation (DEC). A NPV of $8.8M in avoided carbon emissions was calculated; however, under current law and market conditions there is not an available avenue to monetize this valve for the benefit of the project. Additionally, we projected an indirect benefit of $10M in avoided electrical infrastructure upgrades when compared to an alternate means of building heating electrification.

Not included in the study is the additional off-taker opportunities that would become available if additional distribution piping can be installed concurrently with the I-81 project. A future Almond Street branch would allow access to State University of New York (SUNY) Upstate, Syracuse University, SUNY Environmental Science and Forestry (ESF) as well as housing in the 15th Ward area.

The project would face several challenges of coordination with all existing subsurface utilities, constructability of the outfall access, securing commitments from future system customers, project financing for the scale of the project, permit and regulatory hurdles, and escalating construction costs. Solutions to each of the challenges listed will be the focus of the design detailed study.

Figure S-1. Aerial View of Site



1 Establish Baseline Conditions

1.1 Describe Basis and Characteristics of Baseline Condition

The Metro Syracuse Wastewater Treatment Plant (Metro WWTP) is owned and operated by the Onondaga County Department of Water Environment Protection (WEP) and provides high-quality water treatment for 270,000 people and many industrial and commercial customers in the City of Syracuse and some areas outside the city within Onondaga County. Over the time period of 2011–2020, Metro treated an average of 64 million gallons per day (MGD) of sewage and storm runoff. Full secondary and tertiary treatment can be provided for up to 126 MGD. The wastewater treatment process includes a waste-activated sludge process served by six 25-horsepower (hp) pumps, eight aeration tanks served by 32 100-hp blowers, and a low-lift pumping station that includes five 600-hp pumps. Treated water is disinfected and discharged to Onondaga Lake. Metro has a total hydraulic capacity of 240 MGD during wet-weather events such as rainstorms. In the proposed system scheme, the plant discharge will serve as the primary heat sink/source in the district system. The main outfall of the wastewater treatment plant provides a year-round source of tepid water (50 degrees Fahrenheit (°F) to 75°F). A district energy plant would tap into that output that is otherwise discharged into the lake to transfer heat to a new closed-loop district system and deliver water to downtown buildings. Systems that operate at these low temperatures and whose purpose is to serve heat pump units at the building level are referred to as ambient loop systems.

Downtown Syracuse has a cohesive urban core that contains over 13 million square feet of commercial, residential, and government space within a compact area of approximately one square mile. Many of the existing buildings contain water source equipment due to their height and space usage. We have been able to characterize the systems in aggregate based on a number of publicly available information sources. After several Legionella cases were reported related to cooling tower usage in 2015, New York State put a new set of regulations for cooling towers into effect, which required the registration of all cooling towers in the state. This Department of Health documentation lists all the cooling towers located in the State, their size, model, and age. Property tax records provide a totaling of floor area and space usage. The most predominant space use in larger buildings is office space, followed by multifamily residential. Syracuse has shared in the trend toward adaptive reuse common in other industrial northeast and midwest cities, with Class B office and former industrial space retrofitted to multifamily apartments and mixed-use buildings. Additionally, there are numerous developable parcels in the Inner Harbor area that are targeted for new development that would be considered for inclusion in any district system. National Grid is the electric and gas utility serving the area in which users pay into the system benefit charge (SBC). This study will focus on identifying the buildings with existing systems that would be compatible with an ambient loop system, such as water source heat pumps, water cooled chillers, and low-temperature hot water systems. A list of buildings, their locations, groupings and assumed space types are listed below.

Table 1. Potential Customer Buildings

Building Name	Address	Area (ft^2)	Space Type
Phase A			
Barclay Damon	125 E Jefferson St	330,000	Large Office
State Tower	109 S Warren St	1,200,000	Large Office
Courtyard Marriott	300 W Fayette St	40,000	Hotel
US Social Security Admin	110 Fayette St	287,000	Large Office
M&T Bank	101 S Salina St	365,000	Large Office
State Office Building	333 E Washington St	360,000	Large Office
SU-Warehouse	350 W Fayette St	72,000	Medium Office
300 S State St	300 S State St	252,910	Large Office
Key Bank Building	201 S Warren St	132,000	Large Office
100 East Washington St	100 E Washington St	50,000	Midrise Apartment
Ramboll	333 W Washington St	137,000	Large Office
City Hall	233 E Washington St	84,555	Medium Office
1 Lincoln Center	110 W Fayette St	367,500	Large Office
SUNY Oswego MetroCenter	2 S Clinton St	185,530	Large Office
217 Montgomery St	217 Montgomery St	50,000	Medium Office
City Hall Commons	201 E Washington St	52,957	Medium Office
Salinas Place	205 S Salina St	50,000	Midrise Apartment
SU-Peck Hall	601 E Genesee St	25,920	Medium Office
Phase B			
Atrium	2 Clinton Sq	170,000	Large Office
AXA Towers	100 Madison St	653,177	Large Office
Hotel Syracuse	100 E Onondaga St	720,000	Hotel
Tech Garden	235 Harrison St	35,550	Medium Office
Bank of America	1 S Clinton St	45,000	Midrise Apartment
Clinton Exchange	101 N Clinton St	180,000	Large Office
National Grid	300 W Erie Blvd	511,200	Large Office
Post Standard	101 N Salina St	179,000	Large Office
Galleries of Syracuse	441 S Salina St	219,000	Large Office
100 Clinton Sq	100 Clinton Sq	120,000	Large Office
City of Syr Criminal Court House	505 S State St	95,977	Medium Office
550 Harrison Building	550 Harrison St	252,000	Retail

Table 1. continued

Building name	Address	Area (ft^2)	Space Type
Phase B			
Jefferson Clinton Hotel	416 S Clinton St	42,204	Hotel
Sky Armory	351 S Clinton St	40,700	Medium Office
Clinton Plaza	550 S Clinton St	254,690	Midrise Apartment
MOST	500 S Franklin St	40,000	Medium Office
600 Montgomery St	600 Montgomery St	36,684	Medium Office
Medical Office Bldg	475 Irving Ave	25,056	Retail
Phase C			
Parcel 1	Inner Harbor	180,000	Medium Office
Parcel 2	Inner Harbor	120,000	Retail
Parcel 3	Inner Harbor	45,000	Midrise Apartment
Parcel 4	Inner Harbor	110,000	Retail
Parcel 5	Inner Harbor	30,000	Midrise Apartment
Parcel 6	Inner Harbor	225,000	Midrise Apartment
Parcel 7	Inner Harbor	320,000	Retail
Parcel 8	Inner Harbor	120,000	Midrise Apartment
Parcel 9	Inner Harbor	60,000	Midrise Apartment
Parcel 10	Inner Harbor	160,000	Midrise Apartment
Parcel 11	Inner Harbor	270,000	Retail
Parcel 12	Inner Harbor	85,000	Classroom

1.2 Review of Most Recent 12 Months of Utility Bills Available by Building Owners

Utility bills were made available by the building owners for seven potential community buildings, spanning between December 2018 and January 2020. This period provides better representation of baseline building energy consumption since the coronavirus disease 2019 (COVID-19) pandemic caused temporary occupancy disruption. The utility bills serve as a sample of the primary building types that will be studied, including large office, medium office, and midrise apartments. The utility bills are a small sample of the community buildings and used to compare the accuracy of the modelled load profiles discussed later in this section of the report. Six of the seven buildings with utility bills provided are on the current list of assessed buildings. The utility bills for the seventh building were not used because the normalizing factors of building type and square foot area were indeterminate. Comparing the annual utility data to the annual cooling and heating consumptions from the load profiles for each building were calibrated with a correction factor to better match the utility data. Section 2.1 provides additional detail on the provided utility data and a discussion of the reasonableness of the load profile estimation of usage.

1.3 Use Utility Profiles to Estimate the Baseline Environmental Footprint

A baseline carbon dioxide equivalent (CO_2e) footprint attributable to the New York Independent System Operator (NYISO) electricity and on-site natural gas consumption in 2020 is calculated using the Department of Energy's (DOE's) greenhouse gas equivalencies calculator.[1] Total cooling and heating consumptions are cumulative for all buildings and were determined from the estimated thermal load profiles developed. Natural gas emissions are the result of both consumption for heating and distribution leakage. The distribution leakage typically accounts for a 3.5% factor of total consumption.[2] Future emissions profiles will be developed assuming a straight-line reduction in emissions from grid supplied electricity from current levels to the stated 2040 goal of zero direct emissions from electricity production.

Table 2. Baseline Environmental Footprint

Cooling			Heating			Total
Energy (kWh)	Factor (ton/kWh)	CO_2 (tons)	Energy (MMBtu)	Factor (ton/MMBtu)	CO_2 (tons)	CO_2 (tons)
44,740,000	0.0008	35,790	131,500	0.058	7,627	43,420

1.4 Develop Baseline Equipment Costs

Based on the building category and extrapolating characteristics known from the NYS cooling tower database, an estimated HVAC equipment list was determined for the potential connected buildings. A building roof survey using satellite images was performed to assist in estimating the type of equipment serving each building. A list of cooling towers for Onondaga county from the Department of Health was referenced for each building location to determine cooling tower equipment, which has estimated recondition cost of $3.2 M. Baseline equipment costs included new equipment costs for cooling towers, boilers, and terminal units in addition to operation and maintenance costs. Operation and maintenance costs include legionella testing and service calls estimated based on discussion with building operators, and water usage and chemical costs for the cooling towers, which are estimated at $651,000 per year. It was assumed that boilers provide the heating load for each building since boilers are a common heat source for buildings with natural gas utilities. Boiler replacement costs are based on engineering experience and recent bid pricing and estimated at $4.9 M. See the baseline life-cycle cost analysis for initial total cost and cost over the life of the equipment.

1.5 Estimate Construction Costs for Code-Conforming HVAC Replacements

Replacement costs of the existing HVAC equipment are the same as the developed baseline equipment costs. To account for the fact that replacement will likely occur in the future, an escalation rate of 2% per year was applied as part of the baseline life-cycle cost analysis.

1.6 Establish Utility Costs Using Tariffs and Existing Data

National Grid electricity and natural gas utility in the greater Syracuse area. The sample of utility rates are averaged by building type (large office, medium office, midrise, etc.) and are used to assess energy savings based on building type for the other connected buildings whose utility information is unknown.

See section 2.1 for annual consumption, cost, and rates for the provided buildings. The annual electric cooling and thermal energy costs for the entire set of community buildings were estimated using these average utility rates and the corresponding annual cooling and heating energy estimated from the thermal profiles.

Table 3. Baseline Annual Utility Costs

	Utility Cost ($)
Existing Heating Energy	$749,000
Existing Cooling Energy	$3,803,000

1.7 Generate Life-Cycle Costs for 25-Year Baseline Operations

The LCCA provide the cost of ownership of the baseline equipment over the life of the system. In this case, a life cycle of 25 years was utilized. The costs that are incorporated into the life-cycle analysis are shown below and details are provided in Appendix D.

1.7.1 Electricity and Natural Gas Costs of System Operation

Previous sections above discuss the annual electricity and natural gas costs for all buildings. Projected fuel price indices over the LCCA were based on the handbook published by the National Institute of

Standards and Technology (NIST) and assumes a general price inflation rate of 2%. Also, a system efficiency degradation of 0.25% per year representing energy increases each year was also used in the analysis.

1.7.2 Operation, Maintenance, and Repair Costs

Boilers and towers are more expensive to operate than water source heat pumps connected to a district energy system (DES). Boilers are typically serviced annually by an outside vendor, and operating costs include chemicals and makeup water. Chemicals and makeup water costs for boilers were considered negligible as part of this study. Tower maintenance includes legionella testing and annual tower servicing, and operating costs include chemicals and makeup water. This study estimates operations and maintenance (O&M) costs based on testing and service costs per vendor estimates, and water consumption rates and chemical costs based on previous projects. Water consumption rates are assumed as 2020 Central New York's Water Authority (OCWA) Rate Schedule 8. An escalation rate of 3% per year is used in the analysis.

1.7.3 Replacement Costs

Based on the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) life expectancy, it is assumed that boilers have a useful lifespan of 25 years. It is also assumed that the cooling towers will be reconditioned rather than replaced. Reconditioning towers can extend the life between 10 and 15 years. It is reasonable to assume that the boilers and towers have varying age and would need replacement before year 25. To account for this, it is assumed that boiler replacements and tower reconditioning occur at a 10% rate each year.

1.7.4 Net Present Value Analysis Results

The NPV analysis provides a current value of the projected future total costs of ownership of the baseline systems in all buildings potentially connected to the proposed district system. This provides a single value in today’s dollars so that it can be more readily compared to other scenarios (i.e., the proposed system) for business decisions. The NPV analysis shows existing systems have a baseline scenario of $125,100,000 using a discount rate of 7%. The baseline cashflows are inclusive of tower and boiler replacement costs, O&M costs, and electric and natural gas utility costs. A present value analysis for the water source heat pumps versus the existing equipment will be provided during Task 4, perform economic and financial analysis. The final project cost summary utilizes each variable’s first cost. The NPV of the baseline scenario is calculated in Appendix D.

1.8 Develop Thermal Model for Sizing Baseline and Proposed Equipment

Heating and cooling loads were modeled using DOE reference models of various building types. The DOE developed standard or reference energy models by aggregating thousands of the most common commercial buildings into building-type categories, age/construction, and climate zones to serve as an average representative data set for energy efficiency research to assess new technologies. DOE's modeling approach and assumptions are as follows:[3]

- Utilized most populous cities in each climate zone.
- Separated by post-1980 construction, and pre-1980 construction.
  - Differences between time periods are reflected in insulation values, lighting levels, and HVAC equipment types and efficiencies per ASHRAE 90.1.
- Model inputs divided into four categories:
  - Program (location, total area, occupancy, ventilation, operating schedule, etc.).
  - Form (floors, floor height, window fraction and location, shading, etc.).
  - Fabric (walls, roof, floors, infiltration, windows, internal mass, etc.).
  - Equipment (lighting, HVAC type, water heating, refrigeration, efficiency, controls).

Of the building types represented in the DOE models, five building types were considered for this study with most of the buildings falling into three main categories: large office, medium office, and midrise. Apartments for the existing end-user buildings and future development projects that were considered as potential connected loads. Reference models used for the baseline were selected as "post-1980" based on typical building construction in the Syracuse area. A list of the reference models used for the basis of the Syracuse buildings are as follows.

Table 4. Reference Building Types

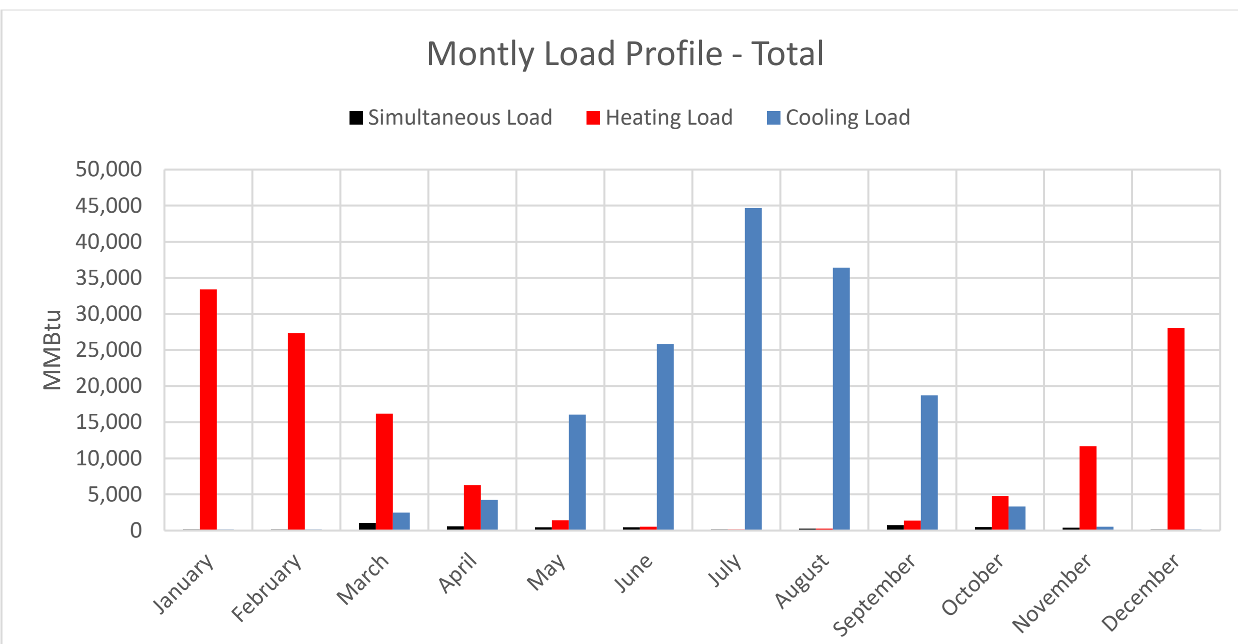
Building Type	Floor Area (ft^2)	Number of Floors
Medium Office	53,628	3
Large Office	498,588	12
Retail	24,962	1
Midrise Apartment	33,740	4
Large Hotel	122,120	6

The reference models were transformed into energy models specific to this study for all potential buildings in the community district system using the following approach:

1. DOE model was selected as reference buildings that most closely matched building construction/materials as the buildings in Syracuse and 5A climate zone based on ASHRAE 90.1.
2. The DOE model was loaded into Energy Plus software and model accuracy was verified by inputting standard climate zone weather conditions and comparing energy usage to the reference model.
3. 8,760 hourly simulations were performed using Syracuse, NY, weather, which include heating, cooling, and domestic hot water loads.
4. A space ratio was applied to scale energy usages based on the buildings actual floor area compared to the DOE reference model. Some buildings contained multiple building types and the space ratio was applied proportionally (e.g., retail on ground floor and office space on upper floors).

The graphs below show aggregated monthly load profiles. The highest monthly load occurs in the month of January for heating, and July for cooling. The district system approach is greatly benefited by simultaneous load as shown. Heat removed from buildings with cooling loads can offset a portion of the heating load during the shoulder months. There are no buildings in this district configuration that have a substantial amount of heat rejection, thus the load flattening is minimal. The small amount of load flattening is due to the increased efficiency of the system. Attracting buildings that have more substantial heat rejection, such as a data center, could provide system benefit during the heating seasons.

Figure 1. Monthly Load Profiles



Design of the proposed system is based on hourly load profiles during design days. Hourly profile graphs for all buildings combined across the entire year can be found in the load-profile calculations. Hourly variation of the design days and the week containing the design day are more useful in demonstrating peak operation. Energy consumption, peak loads, and average loads during design days and weeks for heating and cooling are summarized in the following table.

The reliance in the baseline methodology of using DOE reference buildings does tend to overstate the magnitude of the of the peak load due to building warmup for commercial buildings, since the models are defined using similar occupancy and usage schedules. In practice, building warm up periods will have variation in start times, duration, and intensity due to differences in business hours. Therefore, peak loads aggregated by the models below are therefore conservatively estimated.

Table 5. Design Loads

Model	Design Week	Design Day
Total Heating (MMBtu)	8,645	1,685
Total Cooling (MMBtu)	12,216	2,004
Peak Heating Load (MBH)	153,127	153,127
Peak Cooling Load (MBH)	145,107	145,107
Avg Heating Load (MBH)	51,819	70,198
Avg Cooling Load (MBH)	73,152	83,499

The following graphs represent the hourly load variation for all buildings during design weeks. While a number of different building types are included in the profile, the peaks tend to be driven by the needs of the large office buildings due to their relative size and load density.

Figure 2. Design Week Heating Load Profiles

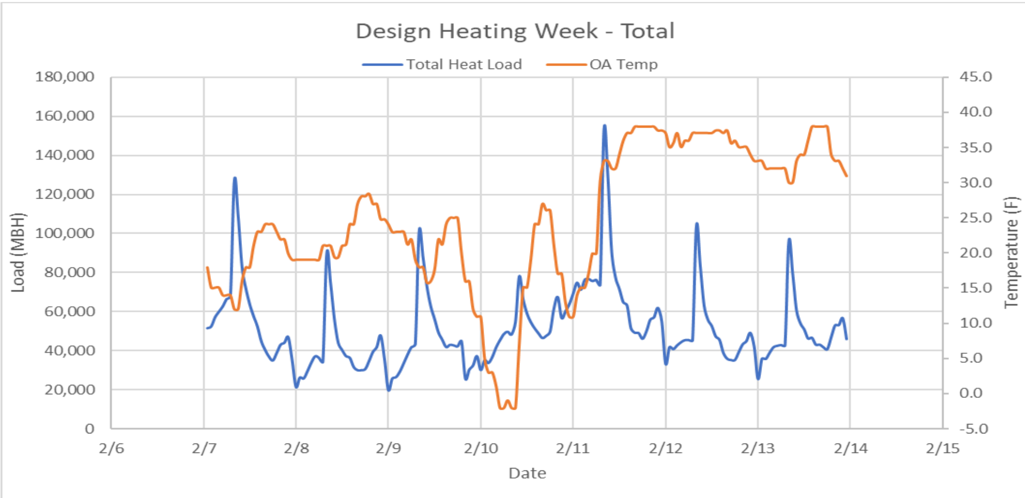
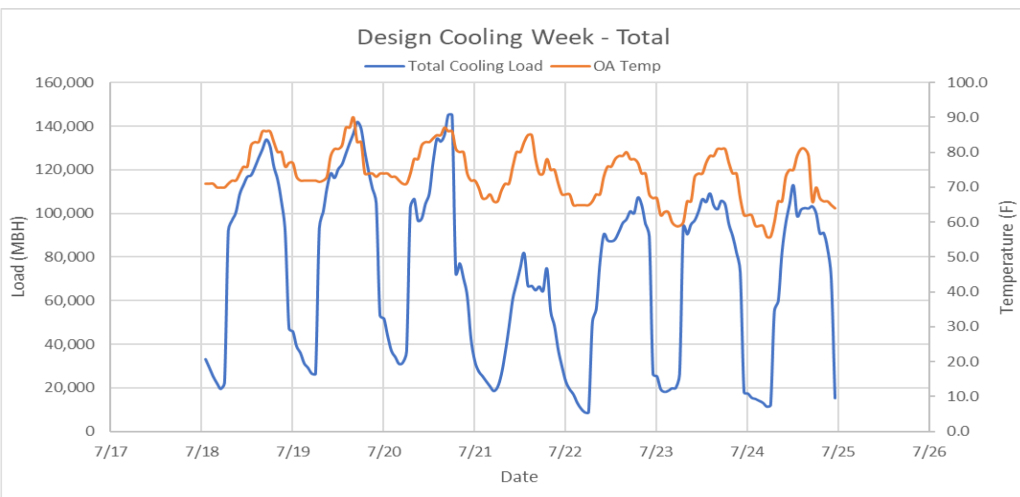


Figure 3. Design Week Cooling Load Profiles



The following graphs represent the hourly load variation for all buildings during design days. Peak heating load occurs in the morning at 8:00 a.m. around a typical morning warmup cycle for commercial buildings. An increase in cooling load can be seen during typical occupancy hours for commercial buildings as well, with the peak load occurring during the late afternoon.

Figure 4. Design Day Heating Load Profiles

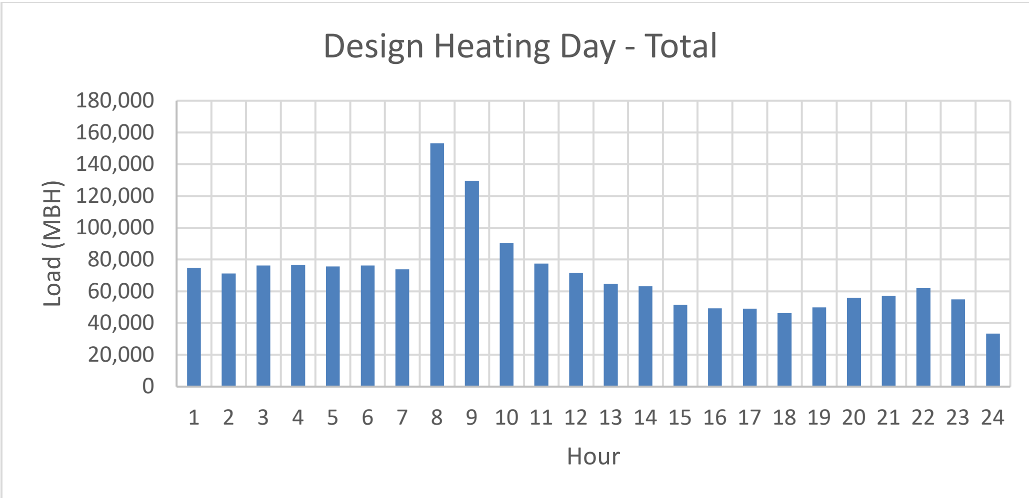
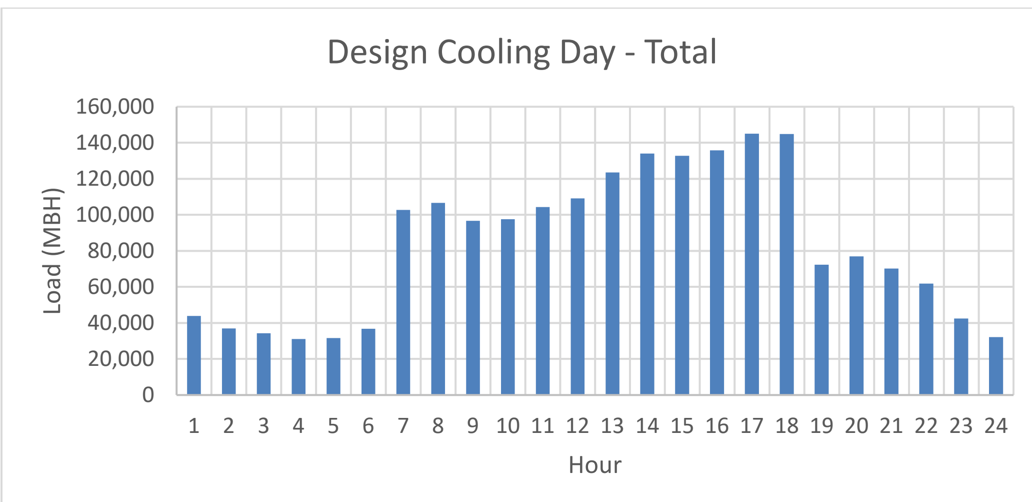


Figure 5. Design Day Cooling Load Profiles



1.9 Analyze Utility Data

Utility bills were provided by seven of the proposed community's building owners. The collected bills spanned from December 2018 through January 2020. Both electricity and gas are supplied by Direct Energy and delivered by National Grid.

The utility bills are a small sample of buildings and can be used to compare the model-predicted energy usage versus actual energy usage. There may be unique factors influencing energy usage for individual buildings that can deviate from the model. However, if the load profiles show a trend of overstating or understating actual usage across our sample, the representative models can be adjusted with a factor to reflect actual loads more accurately. For this study, it is preferred to err as an understated energy model, which would be more conservative in the resulting cost/benefit analysis.

1.9.1 Electricity

A total of 12 months of data was generally available, while some buildings had a month or two missing from the provided data. Annual consumption totals and blended electric rates for each building are shown in Table 6 below.

Table 6. Total Annual Electric Usage

Building	Utility Bills			Load Profiles	
	Annual Consumption	Annual Cost	Blended Rate	Cooling Energy	Relative Percent of Utility
	(kWh)	($)	($/kWh)	(kWh)	(%)
Apartment Buildings					
Apartment 1	774,000	$71,667	$0.093	162,228	-79.0%
Apartment 2	433,500	$37,462	$0.086	109,324	-74.8%
Apartment 3	740,400	$64,749	$0.087	142,149	-80.8%
Office Buildings					
Medium Office 1	3,937,901	$315,610	$0.080	638,151	-83.8%
Large Office 1	4,776,603	$364,728	$0.076	1,379,531	-71.1%
Medium Office 2	2,707,187	$239,499	$0.088	949,380	-64.9%
Other					
Mixed Use	1,312,716	$111,403	$0.085	N/A	N/A

The resulting comparison of the annual cooling consumption from the load profiles to the annual utility bills is also shown in Table 6. Cooling energy typically ranges between 20% and 30% of the total electrical consumption. Therefore, the percentages demonstrate that the load profiles are reasonable with the given sample of utility bills. Variances can be a result of equipment age and efficiency differences, control quality, and weather variations of the utility bill year.

1.9.2 Natural Gas

A total of 12 months of data was generally available, while some buildings had a month or two missing from the provided data. Annual consumption totals and blended gas rates for each building are shown in Table 7 below.

Table 7. Total Annual Natural Gas Usage

Building	Utility Bills			Load Profiles	
	Annual Consumption	Annual Cost	Rate	Heating Energy	Relative Percent of Utility
	(MMBtu)	($)	($/MMBtu)	(MMBtu)	(%)
Apartment Buildings					
Apartment 1	676	$3,753	$5.55	903	33.7%
Apartment 2	876	$5,393	$6.16	1,189	35.8%
Apartment 3	3,094	$15,986	$5.17	1,337	-56.8%
Office Buildings					
Medium Office 1	3,674	$19,210	$5.23	753	-79.5%
Large Office 2	13,711	$85,679	$6.25	1,627	-88.1%
Medium Office 2	1,725	$10,518	$6.10	1,120	-35.1%
Other					
Mixed Use	4,587	$23,617	$5.15	N/A	N/A

The resulting comparison of the annual heating consumption from the load profiles to the annual utility bills is also shown in Table 7. The above comparison assumes natural gas consumption is used for space heating in comparison to the actual total usage considering other gas users. The buildings with load profiles exceeding the utility consumption were residential and the buildings with load profiles below the utility consumption were commercial. One Clinton Square is an outlier for the apartment category likely due to the building's limited offering—only half of the building is dedicated to apartments. Based on gas usage trends, CHA made adjustments to the energy models by decreasing the natural gas load profile for apartment buildings using a 0.7 factor and increasing usage for office buildings using a 1.5 factor to more closely reflect the gas utility bills.

2 Develop Energy Profile

2.1 Model Hourly Energy Use from Department of Energy Reference Buildings

The preliminary thermal model developed in section 2.0 is an hourly energy model based on DOE reference buildings and includes variables such as climate zone, space type definition and assignment, and scaling based on building square footage. The configurations were modified as needed to reflect the system types found in the target buildings. Load profiles were represented as the total monthly energy consumption, hourly loads over the span of a design week, and hourly loads over the span of a design day.

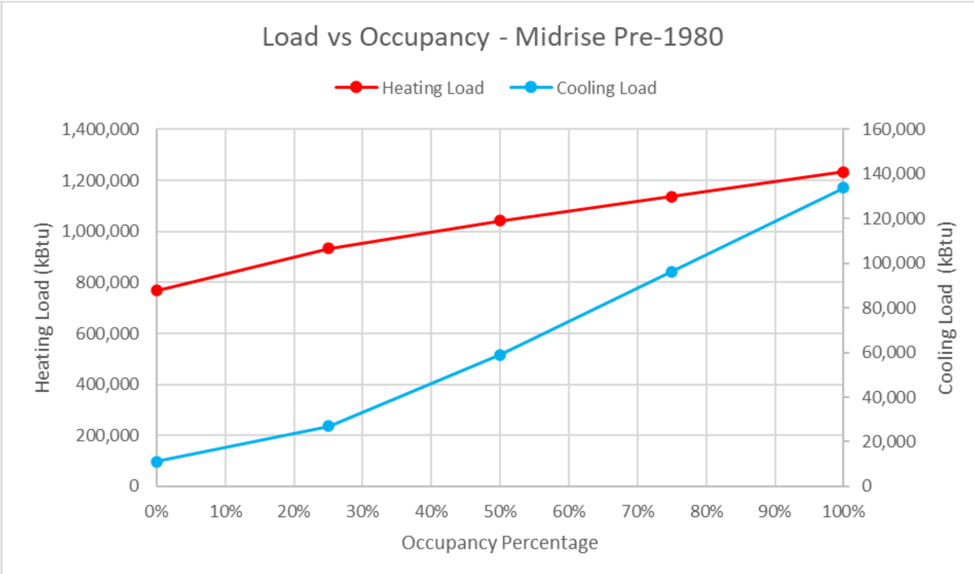
2.2 Reconcile Utility Bills and Scale Loads by Square Footage

Utility bills were provided by seven of the proposed community's building owners and spanned from December 2018 through January 2020. The utility bills were utilized to reconcile the heating and cooling consumption estimates modeled by the DOE reference buildings and summarized in section 2.1 Table 5 (electric bills/cooling loads) and Table 6 (gas bills/heating loads). Cooling models were determined to have regression based on the cooling percentage of total billed consumption for the sample buildings. The gas bill reconciliation was inconclusive.

2.3 Analyze Office Building Sensitivity to Occupancy Rates

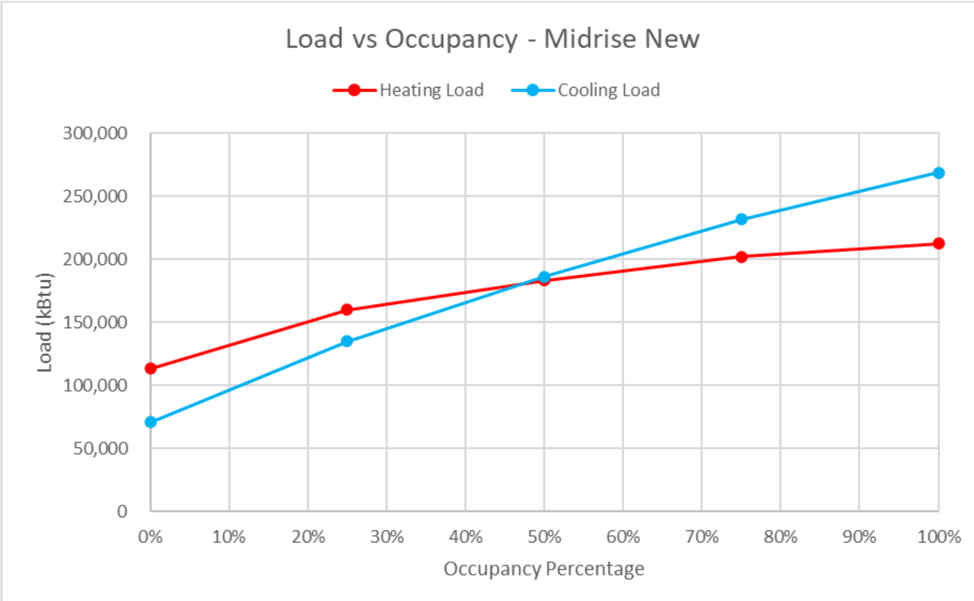
A sensitivity analysis was performed based on altering occupancy rates in three building types: pre-1980 midrise, new construction midrise, and new construction high rise. Occupancy rates from 0% to 100% were modeled as a variation in the number of total floors occupied. The impact of occupancy percentage on heating and cooling loads for each building type assessed is shown in the following graphs. Unoccupied floors were modeled with a constant setback temperature, minimal ventilation, lighting and plug loads turned off, and no internal heat gain from people or equipment.

Figure 6. Load versus Occupancy Percentage, Pre-1980



The midrise office buildling with the pre-1980 costruction has a 38% decrease in heating load for a fully unoccupied scenario due to a large amount of heating still required due to envelope losses. Occupancy has a greater effect on cooling load, though the magnitude is much less that the heating load. This can be attributed to both the lower occupied cooling setpoint but lower internal heat gains for lighting, plug loads, and people. The higher internal loads would also offset some of the winter heating loads, which would otherwise be much higher at peak occupancy.

Figure 7. Load versus Occupancy Percentage, New Construction



In comparison, the new construction midrise building has improved envelope insulation which reduced heating and cooling load and compared to an identically sized pre-1980 building. The better envelope also increases the amount of heating load that is offset by the increased internal gains resulting in a much flatter load curve. Increased internal gains from occupancy require less overall heating.

2.4 Define Phasing and Aggregate Future Thermal Profiles

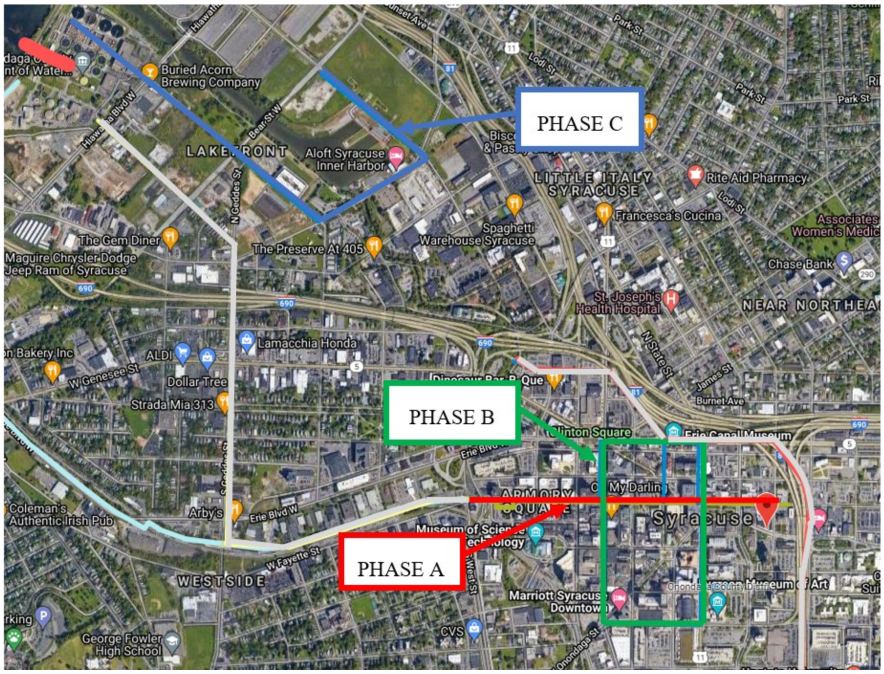
Buildings were grouped into different phases based on type of building and location to optimize load density and capital costs. The buildings were grouped (phased) by considering:

- Proximity from the treatment plant.
- Proposed distribution main piping route.
- Additional branch loops off the main.

A three-phase approach is proposed for project implementation as follows:

- Phase A: Buildings on Fayette Street along the proposed main distribution pipe.
- Phase B: Buildings north and south of Fayette Street along additional distribution branch loops.
- Phase C: Proposed Inner Harbor buildings adjacent to the Wastewater Treatment Plant.

Figure 8. Aerial View of Site Phasing Map



The load profile approach described in section 2.0 was modified to assign a phase to each building, and the baseline load profile is developed at a granular level for each phase. Hourly loads for individual buildings were summed together to obtain an hourly baseline load for all buildings combined in each phase and used to determine monthly peaks and totals.

The graphs below show monthly load profiles for each phase. The highest monthly load occurs in the month of January for heating, and in the month of July for cooling. A majority of the heating and cooling loads are part of Phase B.

Figure 9. Monthly Phased Heating Load Profiles, Stacked

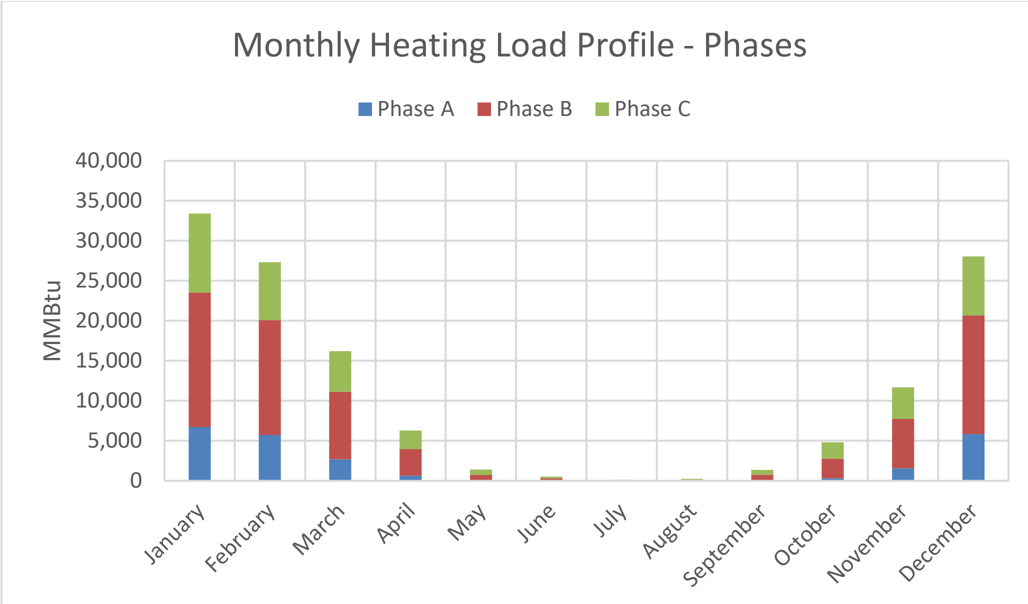


Figure 10. Monthly Phased Cooling Load Profiles, Stacked

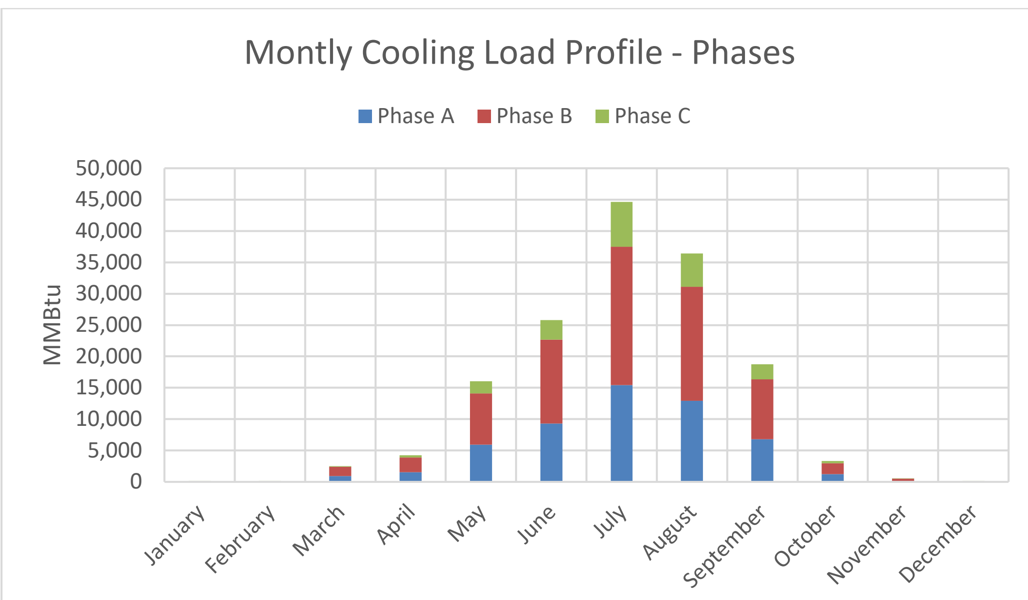


Figure 11. Monthly Phased Heating Load Profiles, Individual

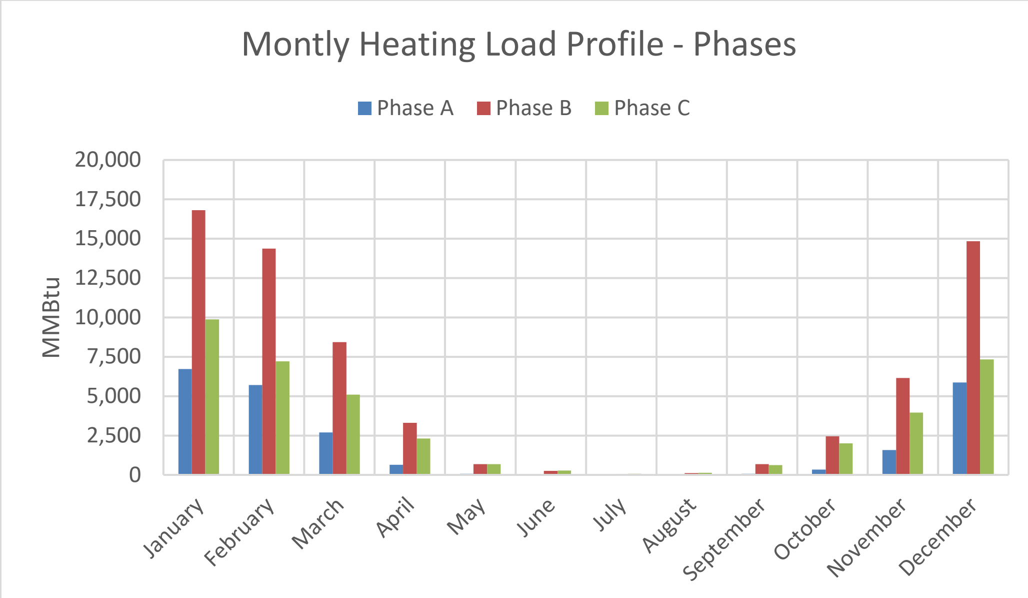
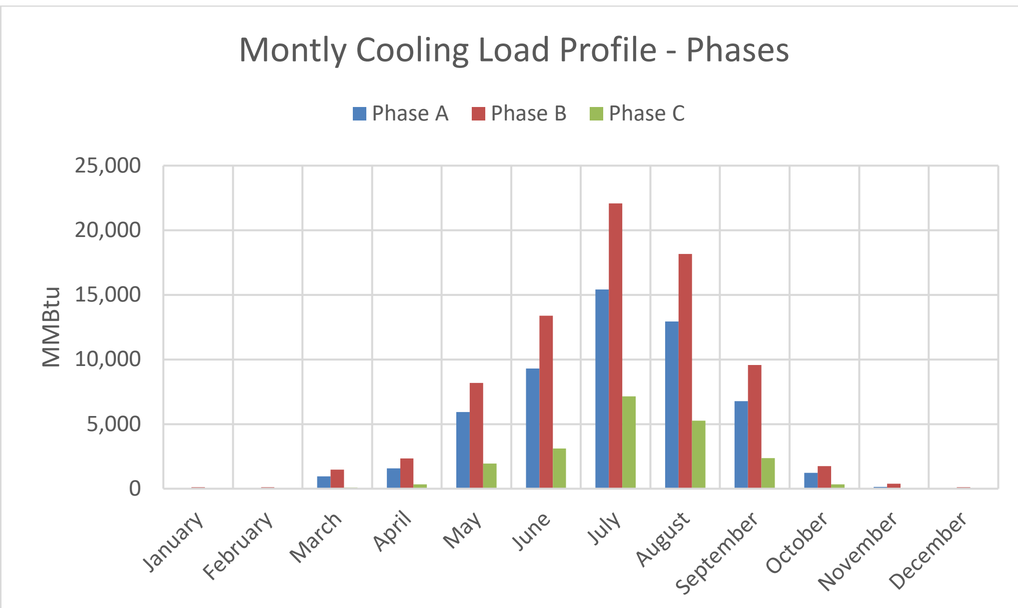


Figure 12. Monthly Phased Cooling Load Profiles, Individual



“Design loads” of the proposed phases are based on hourly load profiles during design days. Hourly variation of the design days and the week containing the design day are useful in demonstrating peak operation. Energy consumption, peak loads, and average loads during design days and weeks for heating and cooling are summarized in the following table.

Table 8. Phase Design Load

Model	Design Week				Design Day			
	Total	Phase A	Phase B	Phase C	Total	Phase A	Phase B	Phase C
Total Heating (MMBtu)	8,654	1,961	4,572	2,120	1,685	451	912	322
Total Cooling (MMBtu)	12,216	4,119	5,935	2,163	2,004	649	959	397
Peak Heating Load (MBH)	153,127	44,649	78,004	35,979	153,127	44,649	78,004	35,979
Peak Cooling Load (MBH)	145,107	45,067	64,028	40,216	145,107	45,067	64,028	40,216
Avg Heating Load (MBH)	51,819	11,745	27,380	12,694	70,198	18,777	37,992	13,429
Avg Cooling Load (MBH)	73,152	24,662	35,540	12,950	83,499	27,034	39,938	16,527

The following graphs represent the hourly load variation for each phase during design weeks.

Figure 13. Design Week Phased Heating Load Profiles

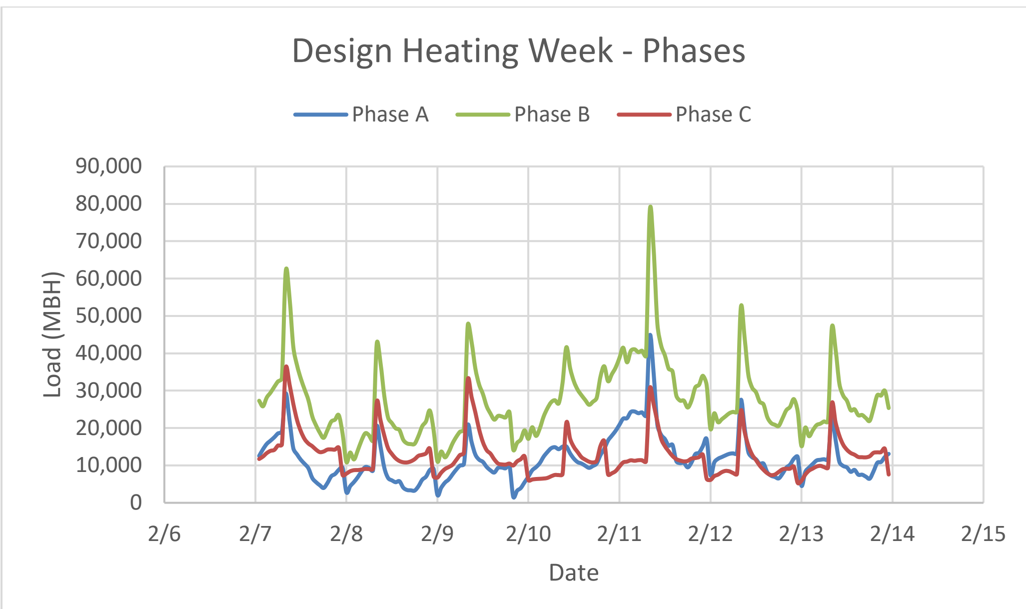
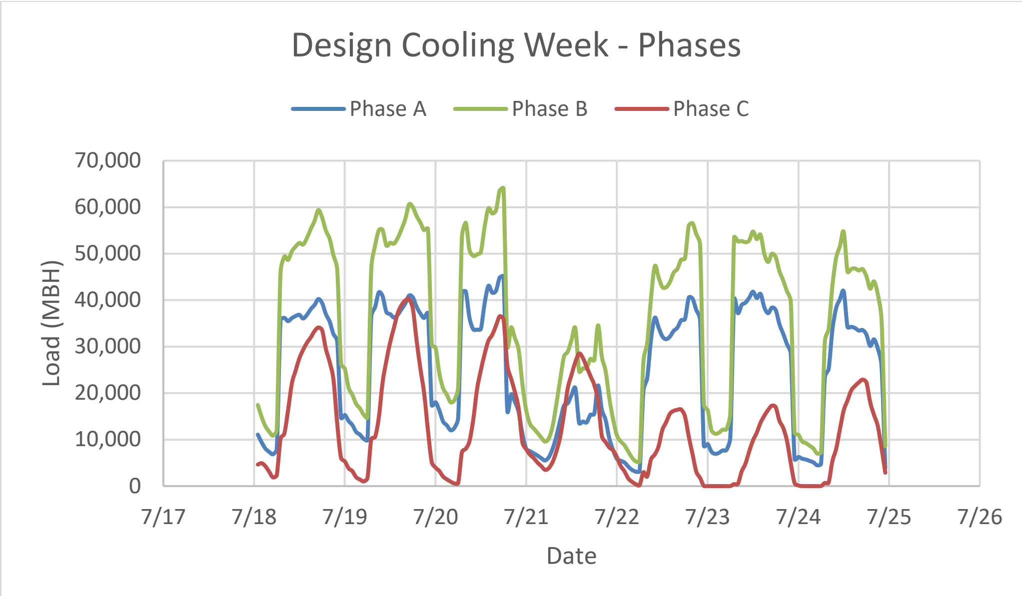


Figure 14. Design Week Phased Cooling Load Profiles



The following graphs represent the hourly load variation for each phase during design days. Aggregate values represent the same totals as in Figure 4. Peak heating load occurs at 8:00 a.m. around the typical increased occupancy hour for commercial buildings. An increase in cooling load can similarly be seen for each phase during typical occupancy hours for commercial buildings as well, with the peak load occurring during the late afternoon.

Figure 15. Design Day Phased Heating Load Profiles

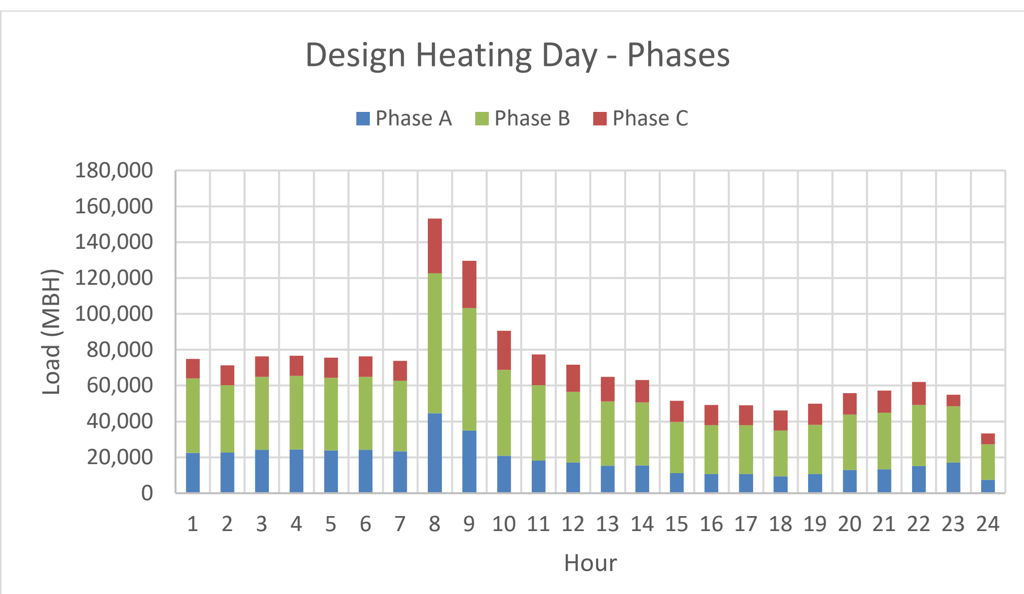
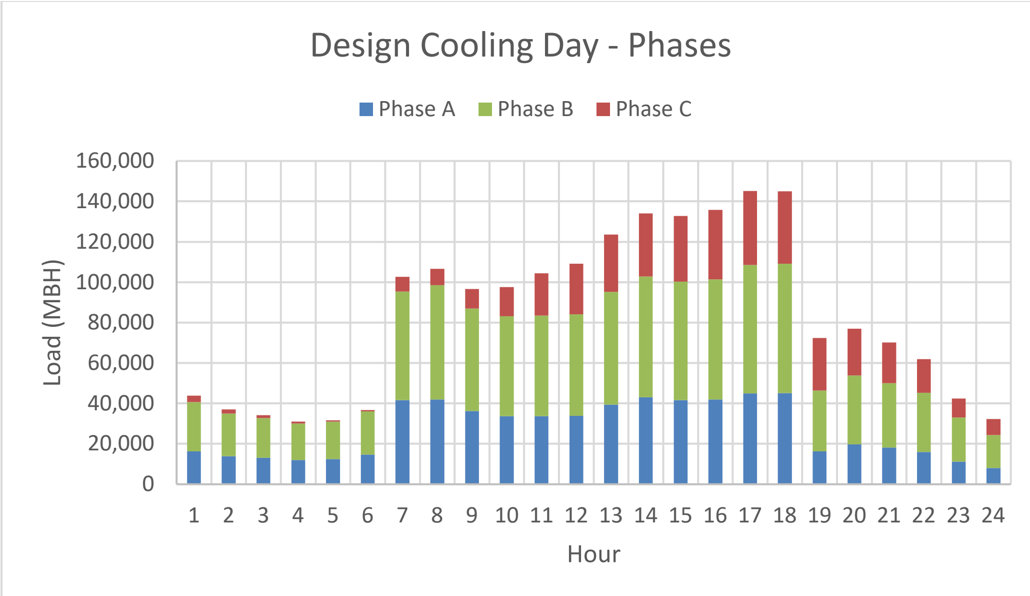


Figure 16. Design Day Phased Cooling Load Profiles



2.5 Forecast Electric Load Increases for Proposed Equipment

One of the advantages of the proposed system concept is that the existing building level equipment is utilized, and the aggregated impact of the buildings to the electrical grid is negligible. The impact would be contained to the central plant where the anticipated added load is estimated to be around 4 MW. The electric load is inclusive of the heat pump chillers for managing the loop temperature in the winter, a set of main district loop pumps, and a set of pumps to interface with the outfall. The load would increase dramatically by any inclusion of electric boiler backup. One of the central plant heat pumps has an output of almost 8 MW of heat, of which, if served by an electric boiler, would double the power requirements of the system.

In addition, a 700 kilowatt (kW) generator should be included for running the loop pumps to keep circulation during emergency situations. The existing electrical service at Metro is likely insufficient for the added load of the new Central Plant equipment. Therefore, the project will consider a new 13.2 kilovolt (kV) service from a nearby feeder.

3 Optimize Energy Source and Develop Design

3.1 Evaluate Effluent Flows for Heat Recovery and System Integration

Effluent temperature and flow tracking by the wastewater treatment plant is the basis for the analysis to determine the quality of available heat recovery. Daily averages were provided spanning from January 2010 through December 2020. Including the full 10 years of data demonstrates the data consistency and the source reliability. Monthly averages and bin percentages for temperature and flow are shown in Figures 17 through 20. Error bars in Figure 17 and Figure 19 represent two standard deviations.

Figure 17. Daily Average Effluent Temperature (2010–2020)

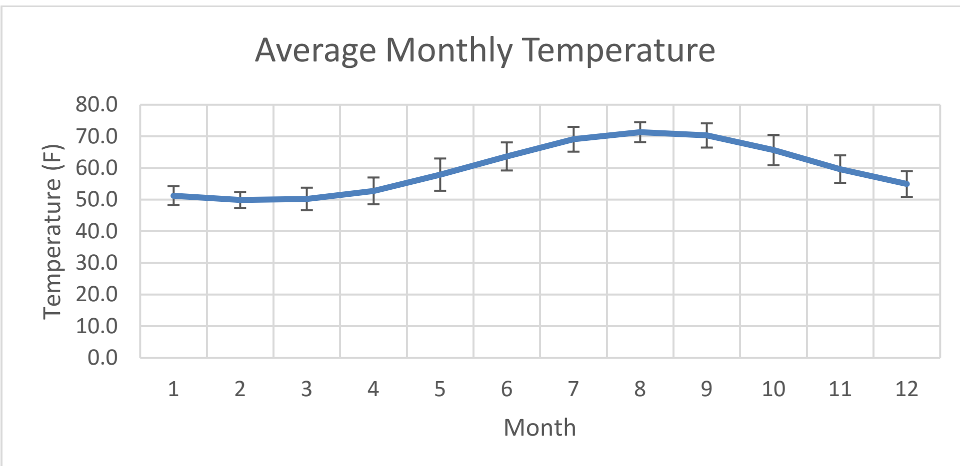
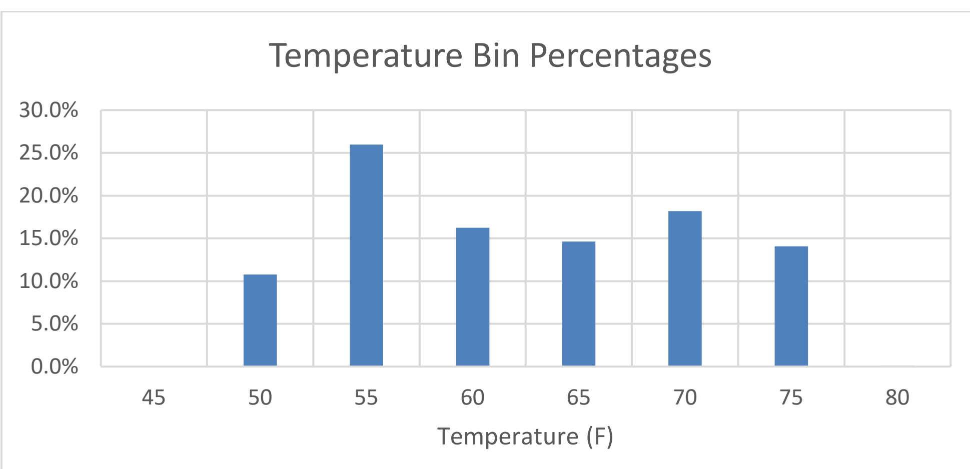


Figure 18. Percentage of Each Temperature Bin



As expected, the effluent temperature follows a temperature variation with outdoor air temperature. Two standard deviations in a data series account for 95% of the total data, showing high-data consistency year over year. The resulting availability of heat recovery depends on the heat exchanger approach temperature, and this analysis assumes a temperature difference of 10°F. The actual effluent temperature difference through the heat-transfer station is dependent upon final design. Since the city has a combined sewer, precipitation events and runoff will impact the effluent flow in addition to wastewater production. The larger flow ranges outside two standard deviations are caused by sustained weather events. System design must consider instances where low levels of precipitation, potentially combined with low levels of domestic sewer use, could limit the heat transfer due to decreased flow. For design capacity, it is assumed that we would typically extract a maximum of 30,000 gallons per minute (GPM) from the outfall but contingency would be developed for flows as low as 25,000 gpm. That discrepancy is only a concern with cooling loads of the full buildout scenario, as many buildings would have to be connected before the capacity would be approached.

Figure 19. Monthly Effluent Flow

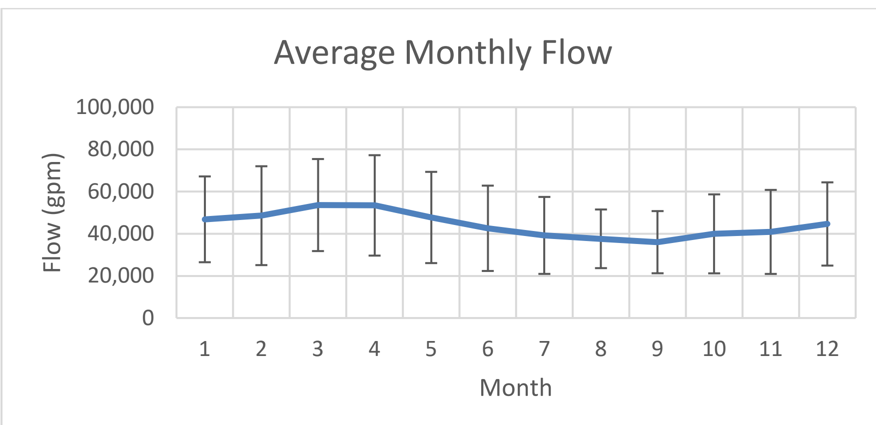
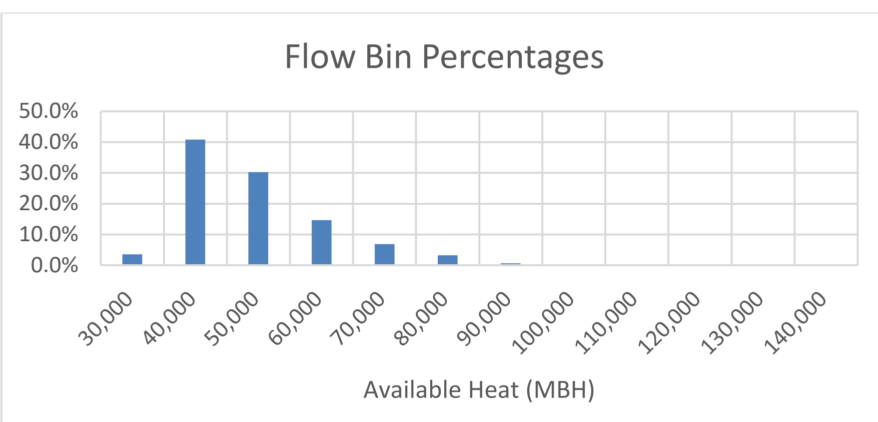


Figure 20. Binned Flow Percentages

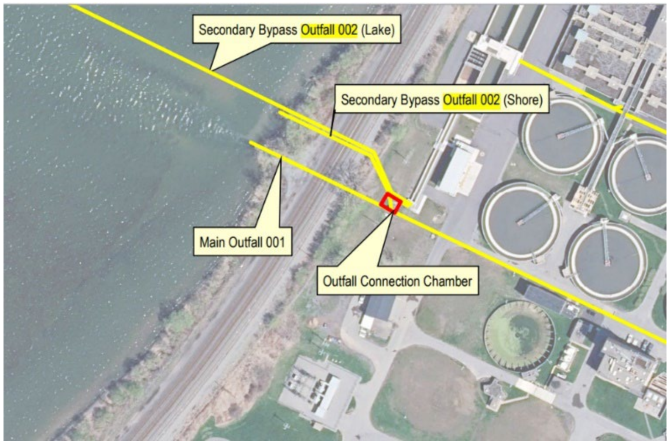


3.1.1 Metro Outfall Interface

The Metro waste water treatment plant (WWTP) has a design capacity of 84.2 MGD and can provide full secondary and tertiary treatment for up to 126.3 mgd. Fully treated flow is discharged through Outfall 001, which is located at the Onondaga Lake shoreline. Metro has a total hydraulic capacity of 240 mgd during wet weather events. Flows greater than 126 mgd bypass secondary treatment are disinfected and discharged to Onondaga Lake via Outfall 002, which has two discharge locations: one at about 20-foot depth (approximately 1,800 feet off the shoreline) and one at the shoreline. The Outfall Connection Chamber was constructed as part of the 1978 WWTP expansion and provides a connection point between Outfalls 001 and 002. The connection chamber was used to divert flow in the system when the final leg of the outfall was constructed underneath the CSX railway. A concrete stop log separates the two outfalls, and the bypass is not regularly utilized. The Metro WWTP Main Outfall pipe conveys flow from the UV Disinfection Channel to Onondaga Lake. The reinforced concrete pipe was mostly constructed as part of the 1978 WWTP expansion. Outfall 001 leaves the UV Disinfection Channel as an 84-inch diameter pipe until it joins the Metro Plant Bypass (segment activated in 2004), at which point its size increases to a 96-inch rectangular conduit.[4]

To access the flow in the pipe, a connection must be established between the central plant and the outfall pipe, which is not water solid. The operation of the plant cannot be interrupted during construction, and no additional back pressure on the outfall pipe can occur. The exact method would be determined in detailed design with consultation from WEP but the connection would likely take the form of a diverting wet well-constructed either downstream of the connection chamber, allowing the bypass to be used during construction, or using the bypass as an access point. Since the flow would be returned to the pipe after it is passed through the central utility plant (CUP) heat exchangers the overall flow through the pipe would remain unchanged. Although the permit temperature limits are not to be approached by the system design, a review from DEC would be required as the work is related to a regulated discharge.

Figure 21. Aerial View of the Metro Outfall Interface Connection



3.2 Define Central Plant Concept and Determine Equipment Sizing

3.2.1 Overview

The design criteria of the central plant are to extract and reject heat from the distribution loop to the wastewater plant outfall. The potential of the resource is outlined above. To determine the details of the central plant design, three questions must be answered:

1. Should the temperature be regulated, or can the seasonal variation of the source temperature be passed along to the system?
2. What should the system's temperatures be?
3. What will manage the loop temperature?

Should the temperature be regulated, or can the seasonal variation of the source temperature be passed along to the system?

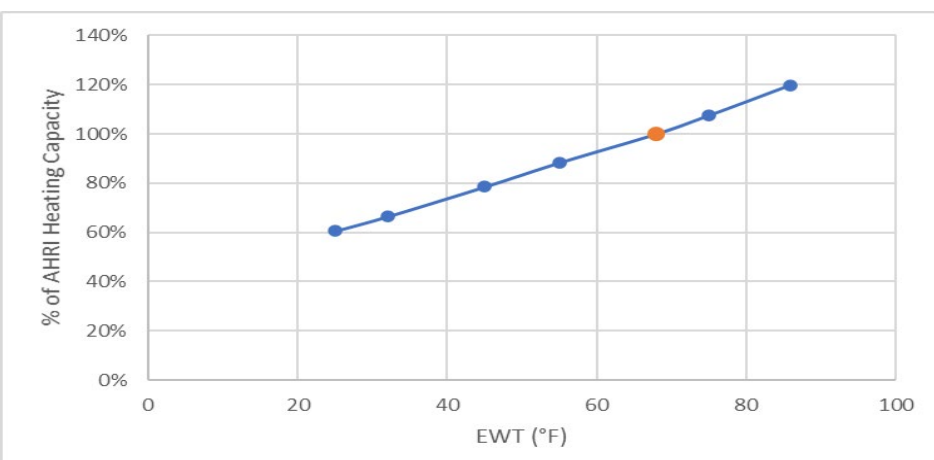
Many of the existing buildings targeting for early system adoption are chosen because they have existing water source heat pump systems, which unitize a boiler and a cooling tower for heating addition and rejection to a common building heat pump loop. Air-Conditioning, Heating, and Refrigeration Institute (AHRI) conditions for a water source heat pump (WSHP) loop is a 68° winter entering water temperature (EWT) and an 85°F summer EWT. An existing building would have been design for the heating capacity of the unit at that condition. If a lower temperature such as 45°F–50°F is provided by the system in the peak winter condition, the equipment would not be able to provide the design heating capacity and a backup heating source would be required at the building level, which greatly discounts the value proposition of the system. Therefore, an important aspect of the district loop is active temperature control by the central plant with capacity for peak heat loads to maintain system heating capacity.

Table 9. Design Parameters

AHRI conditions for Water Source Heat pump	Ideal Temperature
Winter Loop LWT (°F)	75
Winter Loop EWT (°F)	60
Winter Building EWT (°F)	68
Winter Building LWT (°F)	58
Summer Loop LWT (°F)	76
Summer Loop EWT (°F)	88
Summer Building EWT (°F)	80
Summer Building LWT (°F)	90
Summer Winter EWT (°F)	45
Outfall Winter LWT (°F)	35
Outfall Summer EWT (°F)	75
Outfall Summer LWT (°F)	85

As shown in Figure 22 below, heat pump manufacturer data shows that heating capacity will decrease with entering water temperature. The conclusion is from the standpoint of integration into existing systems, it is preferrable to have the loop temperature be actively managed by a central plant that can guarantee heating in peak winter conditions. This same analysis is not needed for the cooling side of the system, as the outfall temperatures available are an improvement over what a building cooling tower would typically provide.

Figure 22. Heat Pump Performance



What should the system temperatures be?

At the building level it is determined that the system should be able to provide 68° at the building side of the heat exchanger to match AHRI conditions and maximize the value of the system. To provide that heating a minimum temperature of 70°F would be required for the system. However, the larger the system delta-T is, the lower the flow requirement and associated pump energy will be and the smaller the resulting pipe size. A delta-T of 15°F is selected to provide a lower flow, but this parameter is one way that the system capacity could be increased in the future, by increasing the delivered temperature to 80°F. The higher the leaving temperature, the more heating will be lost in transmission so there is a practical limit to how high that temperature could be.

Table 8 details the design parameters of entering and leaving water temperatures for the outfall, district, and building loops in addition to estimated building heat pump and central plant chiller efficiencies. A balance must be maintained between the available resource and the building level temperatures. In the winter, 45°F is the minimum daily temperature recorded in the past 10 years, which would still allow for a full 10°F of heating without approaching freezing. That temperature is too low to run traditional WSHPs at full heating capacity, as discussed above.

In the summer, the temperature delivered would be managed to be as low as possible based on the outfall temperatures. Two heat exchangers would be present between the source and the building, each step necessitating a 2°F–3°F increase in the supply temperature. Based on the outfall temperature data, a peak cooling temperature of 75°F is assumed, although that can be improved upon 99% of the time. After heat transfer at the central plant and then again at the building that would guarantee 80°F peak cooling EWT for building equipment, which is lower than the AHRI condition.

These parameters were used with the building peak heating and cooling loads per the load profiles to determine the required heat rejection and total flow requirements. Given the peak outfall flow potential and the design loop temperatures, there is sufficient flow and heat rejection capability of the central plant to provide the load requirements to the buildings. The central plant will require four chiller units to manage the loop temperature.

What will manage the loop temperature?

To accomplish this loop management, a heat pump is required to mechanically move heat from the outfall to increase its system value by delivering it at a high temperature. Fortunately, this can be done easily using traditional chiller technology at a very high efficiency.

Based on the system size a centrifugal chiller was selected: a 2,000-ton Trane CDH chiller. The "chilled water" side of the machine chills the incoming outfall flow and the "condenser water" side is attached to the main distribution loop. This process is done very efficiently, with a coefficient of performance (COP) of 8.5 at the specified conditions. The chiller controls are capable of control based on the leaving condenser water temperature, allowing for the management of the loop at 75°F. Each chiller would be capable of providing almost 8 MW of heating to the system, with a total of four chillers needed to provide the full buildout capacity. Redundancy would be most effectively provided by an additional chiller, since providing capacity from an electric boiler would triple the required electrical service and a natural gas boiler option would require five 5,000 MBH boilers and large natural gas service that would otherwise not be utilized in the system.

Cooling the system would consist of a series of plate and frame heat exchangers to manage the loop temperature to be as low as possible, with a floor of 65°F. Two sets of pumps would be required, one to draw water from the outfall line through the heat exchangers/chillers, and one set of main distribution pumps. The outfall pumps would be of a relatively low head pressure but high flow, with an estimated total design flow of 30,000 gpm at 50 feet of head. Four 125 hp pumps sized at 7,500 gpm would provide the flow with an N+1 redundancy. Split case pumps are utilized due to their ability to handle large flow rates.

The distribution pumps are similarly sized at 30,000 gpm; however, due to the considerable distance the pressure requirements are much higher. An initial calculation of the distribution system provided an estimate of 110 feet of head required from the pumps. Six 200 hp pumps would provide 6,000 gpm of flow with N+1 redundancy.

Electrical power for the plant is supplied by a 4160V service to a 1000 kVA substation on the plant. Review of the National Grid records for the feeder lists 57% of the 400A capacity as utilized in the summer. Currently the peak load from the plant is estimated at 4200 kVA, which would require 600A at 4160V. Two 13.2 kV lines are located approximately 1,500 feet away that have a total of 500A available. At 13.2 kV a 200A service would be required, though National Grid would need to be consulted about adding that much load in that area, including whether lines can be "overloaded" since the usage and peak load from the plant would be in the winter and not in the summer where carrying capacity is derated due to ambient temperature.

3.3 Evaluate Required Redundancy for System Resiliency

The treatment plant is designed to treat an average of 84.2 MGD and—with full secondary and tertiary treatment—can process up to 126.3 MGD. During wet weather events, the plant has a total hydraulic capacity of 240 MGD. This capacity is provided by five 600 hp centrifugal pumps each with a capacity of 60 MGD. These ratings provide an N+1 redundancy. Typical N+1 redundancy allows a facility to run at full load with the primary equipment and has an additional component to account for failure or maintenance of one of the primary pieces of equipment so that the full load can continue to be maintained.

Emergency power would be provided by a 700-kW generator, which would be sufficient to run two loop and two outfall pumps. In emergency mode, the chillers would be offline, and heat would be added to the system directly from the outfall through the heat exchangers. The loop could either be allowed to run at the lower temperature or arrangements could be made with certain off takers to provide reserve heating capacity from their equipment. The approach would depend on the time of year and the type of buildings connected. Most non-mission critical buildings could operate through a temporary derate of their equipment, currently no inpatient healthcare buildings are located near the distribution system but provisions for back up heat at the building level could be made if that type of building was to be included in the system.

3.4 Preferred System Design

Figure 23. District Central Plant, Heating

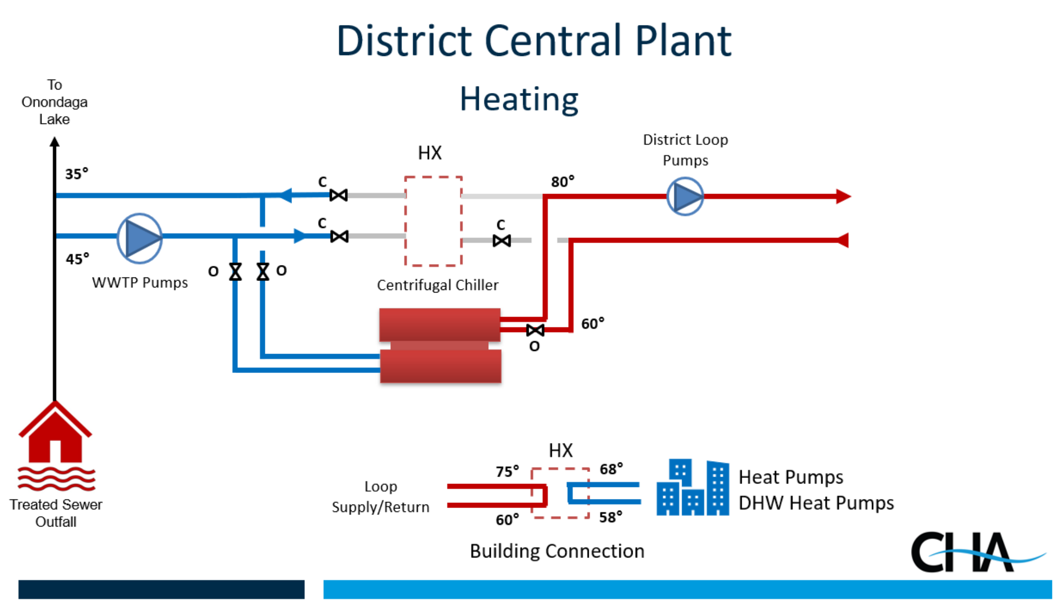
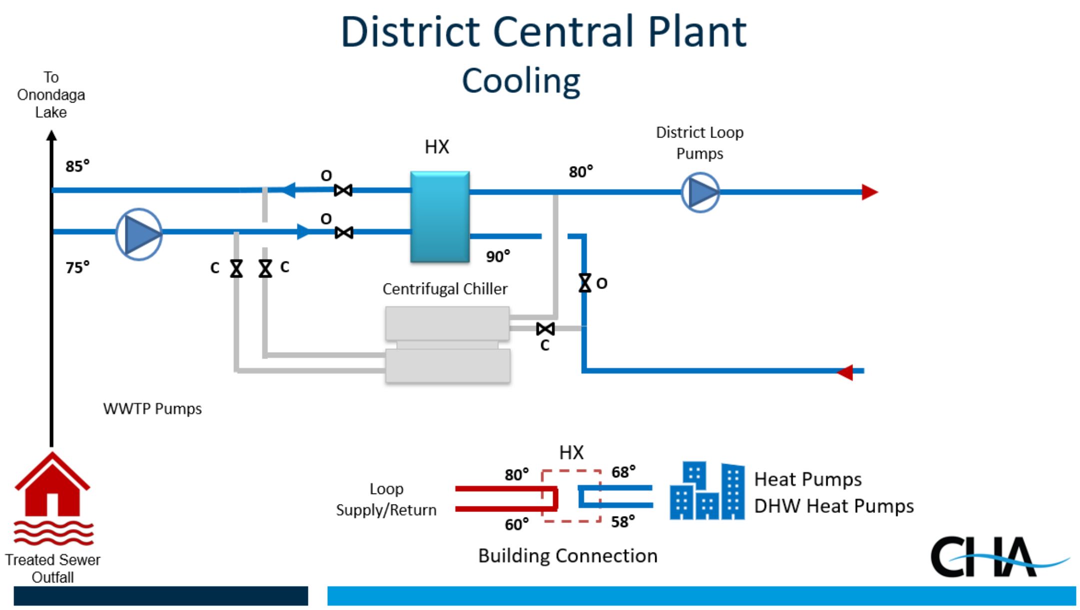


Figure 24. District Central Plant, Cooling



3.5 Preferred Distribution System Design

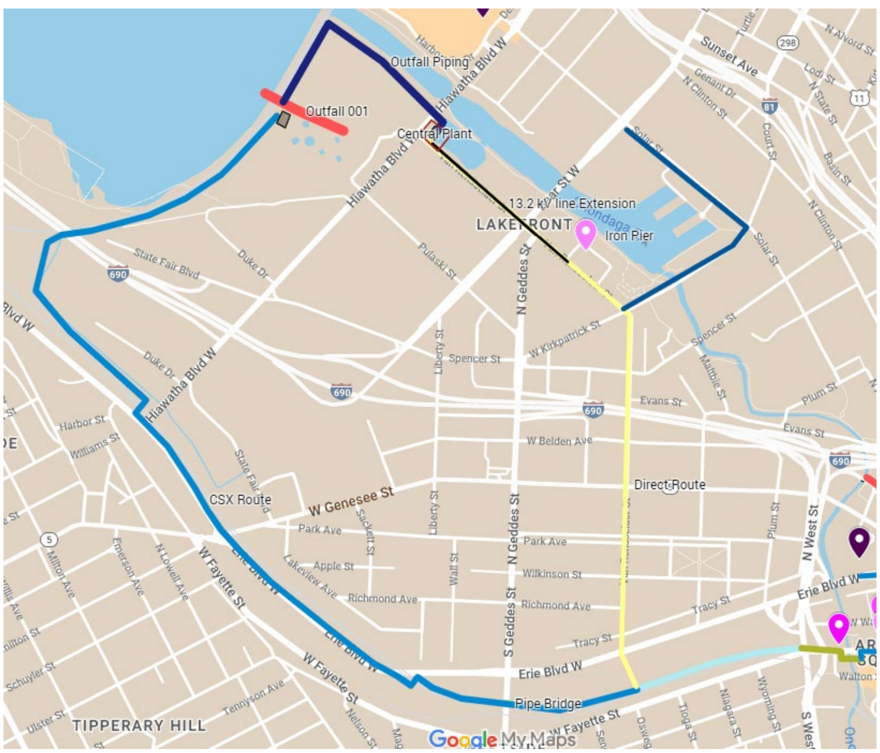
The distribution piping for the system would be provided by DR11 HDPE piping, with the main at 30–36 inches in diameter. The piping would be direct buried in a crushed stone base with no insulation required due to the working temperature of the fluid. A loss of 2.7% useful heating energy would be expected from uninsulated pipe in the winter but would be partially offset by a 1.5% increase in beneficial heat rejection during summer conditions. The primary challenge of the system routing is the distance from the water treatment plant to the load centers. The distance is 1.75 miles in a straight line and a route through existing infrastructure would be required. Two options for routing were considered, a route that would use the existing right away of the New York Susquehanna and Western Railway, which is operated by CSX, and one that takes the most direct route from Hiawatha Boulevard to West Fayette Street. Both routes would utilize two pipes, buried in parallel below the frost line and backfilled with stone and clean fill. Surface conditions are restored to their preconstruction state. Cost estimates include assumptions for areas where horizontal boring is possible.

Table 10. Piping Route Pros and Cons

CSX Route	Direct Route
Pro More pipe in green space, not under a roadway. Existing right of way. Much of land is owned by Onondaga County.	Pro Shorter Route Path is near Inner Harbor Development Some of the routing is in underdeveloped land.
Con Longer Route Would require crossing rail line. Three existing road crossings to navigate. Must follow CSX pipeline guidelines.	Con More pipe installed under roadways. More hardscape restoration. More conflicts with existing infrastructure.

The preferred route from Metro to downtown is the direct route. After reviewing the detailed cost estimate, the cost of coordination with CSX and the required rail crossing was a considerable premium over the direct route. The cost savings of avoiding roadways was also more than offset by the additional length required by the route following the rail line. The direct route provided a 15% savings when compared to the CSX route.

Figure 25. Aerial View of Routing Options



The balance of the distribution system would be similar east of South West Street. A main distribution line would follow West Fayette and East Fayette Street to Almond Street. Buildings listed as part of Phase A are within two blocks of the main distribution line. The path of most optimal distribution beyond the main will require further study. An assumption of required system length was included for cost estimating purposes.

3.6 Two-Pipe versus. One-Pipe Distribution

Many ambient loop systems take advantage of one pipe distribution to lower the installation costs. The marginal equipment performance difference between a couple of degrees of loop temperature is minimal. The customer side looks a bit different since an additional pump is required to pull flow off the main header and then inject back into the main after flowing through a heat exchanger. Often to make the single pipe work a longer length is required because the route needs to create a full loop, where a 2-pipe system already has a supply and return and can have small branches directly to customers. Looking at a sample 16-inch line in an urban area, the cost for 2-pipe distribution was estimated at $1,200 per linear foot (LF), where a similar 1-pipe system was estimated at $900/LF. If a similar length can be achieved there is a 25% savings that can be achieved, possibly more if the single pipe enables horizontal boring. In this scenario the additional length needed to create a loop more than offsets the savings in cost per linear foot, but this option can be further studied during detailed design. The cost estimate of the project carries an assumption of a 2-pipe distribution.

In a scenario such as this where there is a single large energy source to be distributed, the two-pipe approach is preferred due to the centralized nature of the system, allowing the cost of the interface to that energy source be concentrated in a single location. This is similar to existing central station DES designs. If distributed sources were available, a one pipe approach can be more effective at sharing energy between sources/sinks because it acts as a common reservoir for heat, instead as a once through loop. The third-party utility relationship is simplified as well as each customer is provided with the same temperature product on a dedicated supply line.

3.7 Analyze Annual Capacity of Thermal Resources

The prime resource leveraged as the thermal sink/source is the Metro WWTP outfall. The beginning of this section discusses the available outfall flow during the year and the consistency of its temperature. These are the key variables in determining the available capacity to supply the thermal load requirements of the building loads. Central plant design parameters are based on the design heating and cooling loads of the buildings, from the previously determined load profiles. Accounting for heat pump efficiencies and the effectiveness of the central plant heat exchangers and resulting loop temperatures, the capacity required by the outfall is within the available capacity shown in the outfall flow data.

3.8 Assess Sizing Implications for Thermal Energy Resource

Sizing the clean thermal energy resource was done as a first call to meet the overall or a fraction of the overall thermal load up to an economically optimal point. In this instance, the remaining would be supplemented with a conventional thermal system as a second-call to be able to meet the highest demands.

The central plant is sized to meet as much of the overall thermal load required by the buildings given the available outfall flow that can consistently be diverted and accounting for average temperatures of that flow. As part of the preferred system design in Figure 23 and Figure 24, supplemental thermal load will be provided by a centrifugal chiller operating either conventionally (cooling) or as a heat recovery chiller (heating). For heating, the chiller will also provide the additional heat required to actively manage the loop temperature to ensure optimal building heat pump efficiency.

3.9 Determine Optimal Ground Loop Heat Exchanger Layout

The proposed system does not include a ground loop heat exchanger (GLHX). Given a typical load per acre value of 7,500 MBH per acre, the required area for a ground loop heat exchanger is approximately 19 acres for the peak heating and cooling loads. The area surrounding Metro and Destiny USA contain many brownfield parcels which are large enough to be viable but pose a challenge for investigating geothermal well potential. The geology of the downtown Syracuse area in general is also a challenge, in many spots buildings sit above a brine aquifer with deep bedrock and loose fill. A geothermal based system would also have lower winter operating temperatures, requiring much more extensive building side HVAC retrofits, where the proposed system is meant to work within the contains of existing operations to minimize the barriers to adoption. In an urban environment, the population density and land use constraints make utilizing wastewater outfall a beneficial approach.

For example, taking a typical medium office building with an existing WSHP system with a tower/boiler configuration: to convert that building to geothermal would require replacement of all of the existing heat pumps to properly sized extended range water source heat pumps as well as about 89 boreholes of a depth of 495 feet (44,100 feet). The space required for the borefield would be about 0.89 acres, which would not generally be available. Installation cost would be in the range of $1.52M, if the space were available.

3.10 Identify Subgrade Infrastructure Impacting Borefield Design

The proposed system does not include a GLHX.

3.11 Analyze System for Hourly and Energy Consumption Profiles

The Central Plant concept and preferred system design included loop operating temperatures and equipment sizing options based on the district characterization. The District Central Plant Calculator in Appendix G reiterates the hourly total load profile and expands the profile to the required hourly heat absorption or rejection for the district and outfall loops, utilizing estimations of building heat pump and central plant chiller efficiencies. Heat rejection to the loop from the buildings accounts for the baseline equipment and if the building utilizes heat pumps or chillers. The proposed system design has less equipment heat rejection and the calculator therefore appropriately discounts the load on the loop (see Appendix G). Corresponding central plant chiller demand and total energy was determined from the heat requirements.

Using these hourly heating and cooling values, the outfall and loop operating temperatures from the preferred system design determined the corresponding district loop and outfall flows. Quantity and rated size of pumps from the system design allowed for the determination of pump speed and resulting pump demand. The following figures depict monthly and annual energy consumption profiles of the various proposed system components.

Figure 26. Monthly Proposed System Energy

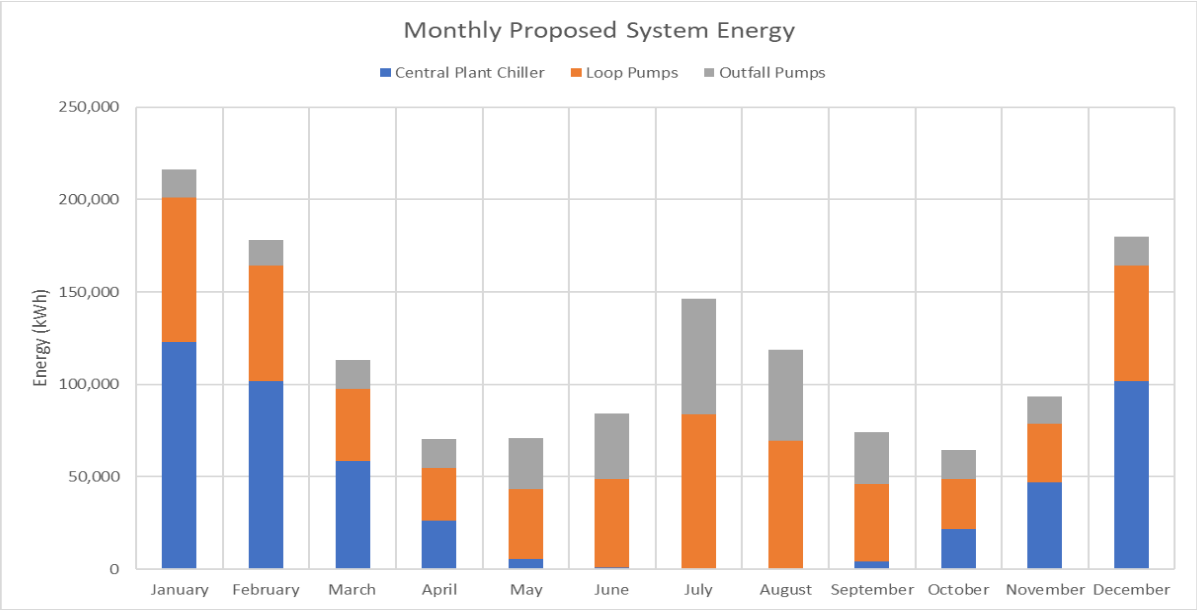
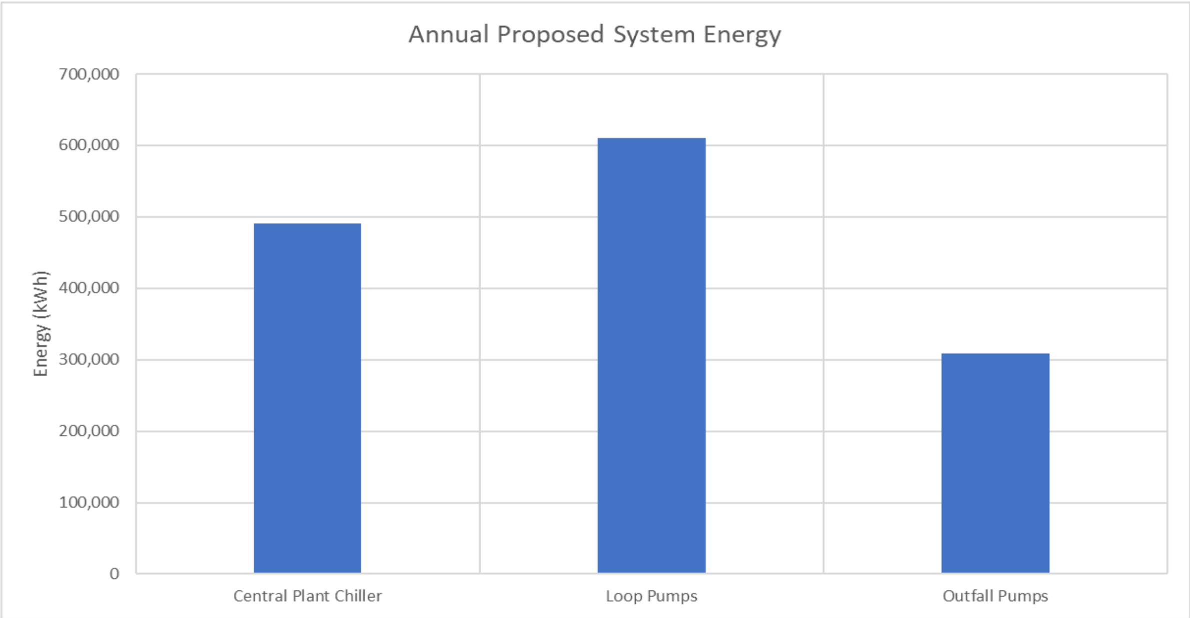


Figure 27. Annual Proposed System Energy



3.12 Integrate Baseline and Mechanical System Alternatives

Baseline operational costs, baseline heating and cooling equipment were either known or estimated based on the building category and extrapolating characteristics known from the cooling tower database for Onondaga county from the Department of Health. A building roof survey using satellite images was performed to assist in estimating the type of equipment serving each building and thus the system type. It was assumed that boilers primarily provide the heating load for each building since boilers are a common heat source for buildings with natural gas utilities.

The system alternative to the baseline and preferred systems is a fully electrified heating system. Building scenarios for electric boilers are as follows:

- Buildings taller than six-stories—typically not feasible for variable refrigerant flow units (load versus roof space).
- Existing heat pumps.

Electrifying with heat pumps is based on the following scenarios:

- Roof survey shows rooftop equipment.
- Small apartments.
- Heat pump COP of 2.5.

For existing systems utilizing natural gas boilers and heat pumps, the corresponding demand of the existing equipment is subtracted from demand of the alternative electric boiler to estimate the demand increase of the alternative electrification scenario.

Building systems were split into the downtown buildings and the potential Inner Harbor buildings since both operate on different substations. The resulting increase in demand that would be placed on the grid infrastructure for downtown is approximately 14 MW and for the Inner Harbor is approximately 5.1 MW. This level of demand likely cannot be supported by the existing electrical grid infrastructure. The alternative equipment model can be found in Appendix C.

3.13 Determine Energy Impact of Each System Alternative

A primary energy impact of the system alternatives to the existing system is that natural gas consumption will be eliminated in the interest of electrification. Use of electric boilers to electrify the system and the corresponding demand increase would have significant impact on grid infrastructure.

Energy impact of the preferred system for the central plant equipment includes outfall and loop pumps, and central plant heat pump demand. One of the advantages of the proposed system concept is the use of existing building-level equipment, and the aggregated impact of the buildings to the electrical grid is negligible. The impact would be contained to the central plant where the anticipated added load is estimated to be around 4 MW. Based on the central plant calculator, there is a reduction in heat rejection from the cooling equipment for the preferred system design, reducing total cooling requirements (see Appendix G). Depending on existing building equipment, the cooling energy savings ranges between 28% and 35%.

4 Perform Economic and Financial Analysis

4.1 Estimate Annual Utility and Operating Costs for Heat Pump System

The central plant is expected to have usage of 1,400,000 kWh per year based on the electric profile of the chillers, pumps, and other ancillary equipment. Electrical costs of approximately $188,000 were estimated based on the existing SC-3A Large time-of-use (TOU) customer rate structure, with a blended rate of $0.13/kWh, which is relatively high for a primary transmission (13.2 kV) customer. The cost is dominated (68%) by the demand costs as defined in the rate structure. This may be a point of negotiation with National Grid as to what rate the central plant is given. Additionally, operations and maintenance of the equipment is estimated at $120,000 annually for a part-time operator and maintenance activities.

4.2 Define Projected Construction Costs for Preferred System

High level projected constructed costs are in Appendix J and include a 20,000 feet² central plant construction with electrical, water, and sanitary services, tying into the existing outfall, direct-buried piping distribution, chiller, heat exchangers, expansion tank, and other equipment, and controls. The underground distribution piping is the most direct route that would reach 34 potential customers in the downtown area in the full project buildout scenario.

Table 11. Full Project Buildout, Opinion of Probable Cost

Item	Opinion of Cost
Central Plant	$20,400,000
Distribution Piping	$43,950,000
District Connections to Customer Buildings	$750,000
Construction Subtotal	**$65,100,000**
Construction Contingency	$12,890,000
Engineering Design and Planning	$7,700,000
Total Project Cost	**$85,690,000**

4.3 Identify End-of-Life Equipment and Develop Avoided Cost Model

4.3.1 Schematic-Level Construction Cost Estimates

Inner Harbor (Phase C) is shown as the initial phase because of its location nearby WEP and strong potential for savings costs through design compatibility, due to the exclusively new construction development. The initial cost would be close to the same if the Inner Harbor buildings are unable to connect to the DES, since the piping would need to pass through that general area.

Table 12. Initial Inner Harbor Project Buildout (Phase C), Opinion of Probable Cost

Item	Opinion of Cost
Central Plant	$20,400,000
Distribution Piping	$3,990,000
District Connections to Customer Buildings	$180,000
Construction Subtotal	**$24,570,000**
Construction Contingency	$4,900,000
Engineering Design and Planning	$2,960,000
Total Project Cost	**$32,400,000**

The next construction phase is continuing the main piping route through Fayette Street (Phase A), which has sizable off takers (18 total buildings identified along the route).

Table 13. Fayette Street Buildout (Phase A), Opinion of Probable Cost

Item	Opinion of Cost
Distribution Piping	$29,270,000
District Connections to Customer Buildings	$170,000
Construction Subtotal	**$29,440,000**
Construction Contingency	$5,850,000
Engineering Design and Planning	$3,510,000
Total Project Cost	**$38,800,000**

The final stage of construction involves lateral branches off Fayette Street (Phase B), which is estimated to include 26 total buildings.

Table 14. Branches off Fayette Street Buildout (Phase B), Opinion of Probable Cost

Item	Opinion of Cost
Distribution Piping	$11,090,000
District Connections to Customer Buildings	$390,000
Construction Subtotal	**$11,480,000**
Construction Contingency	$2,220,000
Engineering Design and Planning	$1,330,000
Total Project Cost	**$15,030,000**

The distribution piping in the above estimates is based on the most direct route from WEP to downtown. An alternate route following the CSX rail was explored but found to cost $7.8 million additional.

4.3.2 Estimate Equipment Life, Maintenance, and Replacement Costs

The new equipment in the central plant is expected to have a service life of 25 years or longer, so replacement costs were not included in the NPV analysis. Central plant maintenance costs are included within the O&M costs in Tables 15 to 18.

4.3.3 Develop Financial Metrics: Payback, Return on Investment, Inflation, Energy Escalation

Financial feasibility from a developer's perspective is important for developing a strong business case and financial backing. However, implementation will have significant clean energy impacts to the greater community, which is a benefit that cannot be directly monetized by the developer under current State policy. Thus, the financials have been separated into the developer's perspective and community perspective to capture the financial benefits for all project stakeholders.

The 25-year NPV analysis uses the following assumptions:

- Natural gas inflation of 5%
- Electricity inflation of 3%
- General inflation of 3%
- Discount rate of 7%
- Finance rate of 3% for 40 years for central plant and distribution pipe investment.

Table 15. Net Present Value, All Phases, Developer's Perspective

Costs	NPV (25-Year)
Design and Planning	$7,700,000
Central Plant Investment	$13,300,000
Distribution Piping Investment	$28,700,000
Central Plant O&M	$3,900,000
District Connections to Customer Buildings	$700,000
Total Costs	**$54,300,000**
Direct Benefits	
Avoided Customer O&M	$10,300,000
Avoided Customer Equipment Recondition	$12,800,000
Customer Energy Savings	$34,900,000
Total Direct Benefits	**$58,000,000**
Net Direct Benefits	**$3,700,000**
Internal Rate of Return (IRR)	**7.28%**
BCR	**1.08**

Table 16. Net Present Value, Phase C, Developer's Perspective

Costs	NPV (25-Year)
Design and Planning	$2,900,000
Central Plant Investment	$13,300,000
Distribution Piping Investment	$2,600,000
Central Plant O&M	$3,900,000
District Connections to Customer Buildings	$200,000
Total Costs	**$22,900,000**
Direct Benefits	
Avoided Customer O&M	$500,000
Avoided Customer Equipment Recondition	$2,000,000
Customer Energy Savings	$7,300,000
Total Direct Benefits	**$9,800,000**
Net Direct Benefits	**-$13,100,000**
Internal Rate of Return (IRR)	**N/A**
BCR	**0.43**

Table 17. Net Present Value, Phase A, Developer's Perspective

Costs	NPV (25-Year)
Design and Planning	$3,500,000
Central Plant Investment	$0
Distribution Piping Investment	$19,100,000
Central Plant O&M	$2,400,000
District Connections to Customer Buildings	$300,000
Total Costs	**$25,300,000**
Direct Benefits	
Avoided Customer O&M	$6,900,000
Avoided Customer Equipment Recondition	$5,100,000
Customer Energy Savings	$9,700,000
Total Direct Benefits	**$21,700,000**
Net Direct Benefits	**-$3,600,000**
Internal Rate of Return (IRR)	**1.99%**
BCR	**0.86**

Table 18. Net Present Value, Phase B, Developer's Perspective

Costs	NPV (25-Year)
Design and Planning	$1,300,000
Central Plant Investment	$0
Distribution Piping Investment	$7,200,000
Central Plant O&M	$1,500,000
District Connections to Customer Buildings	$300,000
Total Costs	**$10,300,000**
Direct Benefits	
Avoided Customer O&M	$3,000,000
Avoided Customer Equipment Recondition	$5,800,000
Customer Energy Savings	$17,900,000
Total Direct Benefits	**$26,700,000**
Net Direct Benefits	**$16,700,000**
Internal Rate of Return (IRR)	**32.48%**
BCR	**2.64**

The following tables provide a sensitivity analysis for several important financial assumptions and the resulting NPV.

Table 19. Sensitivity Analysis of Natural Gas Inflation versus Discount Rate, Full Build

(25-year NPV, in thousands)

Natural Gas Inflation Rate	Discount Rate: 3%	4%	5%	6%	7%	8%	9%	10%
1%	-$6,800	-$7,700	-$8,300	-$8,900	-$9,600	-$10,200	-$10,400	-$10,800
2%	-$2,100	-$3,600	-$4,800	-$5,800	-$6,900	-$7,800	-$8,300	-$8,900
3%	$3,500	$1,200	-$600	-$2,200	-$3,700	-$5,000	-$5,800	-$6,800
4%	$10,100	$6,800	$4,200	$2,000	-$100	-$1,800	-$3,000	-$4,300
5%	$17,800	$13,400	$9,900	$6,900	$4,200	$1,900	$200	-$1,500
6%	$27,000	$21,200	$16,600	$12,600	$9,100	$6,200	$3,900	$1,800
7%	$37,800	$30,400	$24,400	$19,400	$14,900	$11,200	$8,300	$5,600
8%	$50,700	$41,300	$33,700	$27,300	$21,700	$17,100	$13,400	$10,000

Table 20. Sensitivity Analysis of Natural Gas Inflation versus Discount Rate, Phase C

(25-year NPV, in thousands)

Natural Gas Inflation Rate	Discount Rate: 3%	4%	5%	6%	7%	8%	9%	10%
1%	-$21,800	-$19,900	-$18,400	-$17,100	-$15,900	-$15,100	-$14,100	-$13,400
2%	-$20,800	-$19,100	-$17,700	-$16,400	-$15,300	-$14,600	-$13,700	-$13,000
3%	-$19,700	-$18,100	-$16,800	-$15,700	-$14,700	-$14,000	-$13,200	-$12,600
4%	-$18,300	-$16,900	-$15,800	-$14,800	-$13,900	-$13,400	-$12,600	-$12,100
5%	-$16,700	-$15,500	-$14,600	-$13,800	-$13,000	-$12,600	-$11,900	-$11,500
6%	-$14,800	-$13,900	-$13,200	-$12,600	-$12,000	-$11,700	-$11,100	-$10,800
7%	-$12,500	-$12,000	-$11,600	-$11,200	-$10,800	-$10,600	-$10,200	-$10,000
8%	-$9,800	-$9,700	-$9,700	-$9,500	-$9,400	-$9,400	-$9,200	-$9,100

Table 21. Sensitivity Analysis of Natural Gas Inflation versus Discount Rate, Phase A

(25-year NPV, in thousands)

Natural Gas Inflation Rate	Discount Rate 3%	4%	5%	6%	7%	8%	9%	10%
1%	-$7,400	-$7,400	-$7,300	-$7,200	-$7,200	-$7,100	-$7,000	-$7,100
2%	-$6,100	-$6,300	-$6,300	-$6,400	-$6,500	-$6,500	-$6,400	-$6,600
3%	-$4,500	-$4,900	-$5,200	-$5,400	-$5,600	-$5,700	-$5,700	-$6,000
4%	-$2,700	-$3,400	-$3,800	-$4,200	-$4,600	-$4,800	-$5,000	-$5,300
5%	-$500	-$1,500	-$2,300	-$2,800	-$3,400	-$3,800	-$4,100	-$4,500
6%	$2,000	$600	-$400	-$1,200	-$2,000	-$2,600	-$3,000	-$3,600
7%	$5,100	$3,200	$1,800	$600	-$400	-$1,200	-$1,800	-$2,500
8%	$8,600	$6,200	$4,400	$2,900	$1,500	$400	-$400	-$1,300

Table 22. Sensitivity Analysis of Natural Gas Inflation versus Discount Rate, Phase B

(25-year NPV, in thousands)

Natural Gas Inflation Rate	Discount Rate 3%	4%	5%	6%	7%	8%	9%	10%
1%	$16,000	$13,900	$12,200	$10,600	$9,500	$8,300	$7,300	$6,400
2%	$18,400	$16,000	$14,000	$12,200	$10,900	$9,500	$8,400	$7,400
3%	$21,300	$18,500	$16,200	$14,100	$12,500	$10,900	$9,700	$8,500
4%	$24,600	$21,400	$18,700	$16,200	$14,400	$12,600	$11,100	$9,700
5%	$28,600	$24,800	$21,600	$18,800	$16,600	$14,500	$12,800	$11,200
6%	$33,300	$28,800	$25,000	$21,700	$19,100	$16,700	$14,700	$12,900
7%	$38,900	$33,500	$29,100	$25,200	$22,100	$19,200	$16,900	$14,800
8%	$45,500	$39,100	$33,800	$29,200	$25,600	$22,300	$19,500	$17,100

Table 23. Sensitivity Analysis of Finance Rate versus Discount Rate, Full Build

(25-year NPV, in thousands)

Finance Rate	3%	4%	5%	6%	7%	8%	9%	10%
	Discount Rate							
2.0%	$27,200	$21,900	$17,700	$13,900	$10,600	$7,900	$5,800	$3,600
2.5%	$22,600	$17,800	$13,900	$10,400	$7,500	$5,000	$3,000	$1,100
3.0%	$17,800	$13,400	$9,900	$6,900	$4,200	$1,900	$200	-$1,500
3.5%	$12,800	$8,900	$5,800	$3,100	$800	-$1,200	-$2,700	-$4,300
4.0%	$7,600	$4,200	$1,600	-$800	-$2,800	-$4,500	-$5,800	-$7,200
4.5%	$2,200	-$700	-$2,800	-$4,800	-$6,500	-$7,900	-$9,000	-$10,100
5.0%	-$3,400	-$5,700	-$7,500	-$9,000	-$10,300	-$11,500	-$12,200	-$13,200

Table 24. Sensitivity Analysis of Finance Rate versus Discount Rate, Phase C

(25-year NPV, in thousands)

Finance Rate	3%	4%	5%	6%	7%	8%	9%	10%
	Discount Rate							
2.0%	-$13,100	-$12,300	-$11,600	-$11,200	-$10,600	-$10,300	-$9,800	-$9,600
2.5%	-$14,900	-$13,900	-$13,100	-$12,500	-$11,800	-$11,400	-$10,900	-$10,500
3.0%	-$16,700	-$15,500	-$14,600	-$13,800	-$13,000	-$12,600	-$11,900	-$11,500
3.5%	-$18,600	-$17,200	-$16,200	-$15,300	-$14,300	-$13,800	-$13,000	-$12,500
4.0%	-$20,500	-$19,000	-$17,700	-$16,700	-$15,600	-$15,000	-$14,200	-$13,600
4.5%	-$22,600	-$20,900	-$19,400	-$18,300	-$17,100	-$16,300	-$15,400	-$14,700
5.0%	-$24,700	-$22,800	-$21,200	-$19,800	-$18,500	-$17,700	-$16,600	-$15,900

Table 25. Sensitivity Analysis of Finance Rate versus Discount Rate, Phase A

(25-year NPV, in thousands)

Finance Rate	3%	4%	5%	6%	7%	8%	9%	10%
	Discount Rate							
2.0%	$3,800	$2,400	$1,200	$400	-$400	-$1,100	-$1,600	-$2,200
2.5%	$1,700	$500	-$500	-$1,200	-$1,900	-$2,400	-$2,800	-$3,300
3.0%	-$500	-$1,500	-$2,300	-$2,800	-$3,400	-$3,800	-$4,100	-$4,500
3.5%	-$2,800	-$3,500	-$4,100	-$4,500	-$5,000	-$5,300	-$5,500	-$5,800
4.0%	-$5,100	-$5,700	-$6,100	-$6,300	-$6,600	-$6,800	-$6,900	-$7,000
4.5%	-$7,600	-$7,900	-$8,100	-$8,100	-$8,300	-$8,300	-$8,300	-$8,400
5.0%	-$10,100	-$10,200	-$10,200	-$10,000	-$10,000	-$9,900	-$9,800	-$9,800

Table 26. Sensitivity Analysis of Finance Rate versus Discount Rate, Phase B

(25-year NPV, in thousands)

		Discount Rate							
		3%	4%	5%	6%	7%	8%	9%	10%
Finance Rate	2.0%	$30,200	$26,300	$22,900	$20,000	$17,700	$15,600	$13,800	$12,100
	2.5%	$29,400	$25,500	$22,200	$19,400	$17,100	$15,100	$13,300	$11,700
	3.0%	$28,600	$24,800	$21,600	$18,800	$16,600	$14,500	$12,800	$11,200
	3.5%	$27,700	$24,000	$20,900	$18,200	$16,000	$14,000	$12,300	$10,800
	4.0%	$26,800	$23,200	$20,100	$17,500	$15,400	$13,400	$11,800	$10,300
	4.5%	$25,900	$22,400	$19,400	$16,800	$14,700	$12,800	$11,200	$9,800
	5.0%	$24,900	$21,500	$18,600	$16,100	$14,100	$12,200	$10,700	$9,200

4.4 Perform Carbon Reduction Calculations for Low-Carbon Solution

The DEC has issued a social cost of carbon guide for policy decisions. In 2020 the value was calculated to be $125 per metric ton of CO_2.[5]

Table 27. Net Present Value–Full Build, Community/Policy Perspective

Indirect Benefits	
Carbon Reduction Social Benefit	$8,800,000
Avoided Electrical Substation Upgrades	$12,600,000
Total Indirect Benefits	**$21,400,000**
Net Direct + Indirect Benefits	**$25,600,000**
Internal Rate of Return (IRR)	**13.74%**
BCR	**1.48**

Table 28. Net Present Value–Phase C, Community/Policy Perspective

Indirect Benefits	
Carbon Reduction Social Benefit	$2,300,000
Avoided Electrical Substation Upgrades	$3,100,000
Total Indirect Benefits	**$5,400,000**
Net Direct + Indirect Benefits	**$-7,600,000**
Internal Rate of Return (IRR)	**N/A**
BCR	**0.67**

Table 29. Net Present Value–Phase A, Community/Policy Perspective

Indirect Benefits	
Carbon Reduction Social Benefit	$2,000,000
Avoided Electrical Substation Upgrades	$4,600,000
Total Indirect Benefits	**$6,600,000**
Net Direct + Indirect Benefits	**$3,200,000**
Internal Rate of Return (IRR)	**6.74%**
BCR	**1.13**

Table 30. Net Present Value–Phase B, Community/Policy Perspective

Indirect Benefits	
Carbon Reduction Social Benefit	$4,500,000
Avoided Electrical Substation Upgrades	$4,900,000
Total Indirect Benefits	**$9,400,000**
Net Direct + Indirect Benefits	**$26,000,000**
Internal Rate of Return (IRR)	**44.93%**
BCR	**3.57**

Electrifying individual buildings downtown would not be possible with National Grid's existing infrastructure and would require a feasibility analysis to better define barriers. In anticipation of State policy changing in 10 years, a placeholder amount is shown in the table above as a potential order-of-magnitude for a substation in year 10, which does not consider actual feasibility or other costs such as distribution or electrical service upgrades. National Grid has a Non-Wires Alternative (NWA) to evaluate cost-effective projects in comparison to making electrical grid investments.[6] To address a stated need or policy change, National Grid can issue request for proposals (RFPs), which are open to all NWA solution approaches. Currently there is not an RFP issued for the downtown region of Syracuse, but if offered, a successful proposal for the DES project could provide direct financial incentives. This scenario would only be possible with a new, robust policy driving electrification of existing buildings.

4.5 Specify Preferred Business Model and Annual Costs to Site Owner

The selection of a business model for large infrastructure projects including DES should mitigate several types of risk including objectives risk (governance structure), design risk (selection of technologies and equipment), construction risk (procurement, scheduling), operational risk (commissioning, maintenance), demand/market risk (customer acquisition, rate structure), and financial risk (return on investment, or ROI). A preferred business model will not only mitigate these various forms of risk, but also establish mechanisms of control and impact the financing structure for the project.

A range of business models are available ranging from completely public-owned (i.e., public utility or municipal department-run) to completely privately-owned with a range of hybrid forms in between including concession, joint venture, and special purpose vehicles. A review of the literature suggests that the most common business models for district energy systems include public sector ownership and operation; public sector ownership with operation by a private energy company or utility; cooperative ownership; and private sector ownership; and operation through either an existing energy utility or a new energy services firm. The choice of business model will affect the cost of capital as well as overall financing structure. It is also important to note that DESs are not only large and complex engineering projects but also dynamic businesses that are subject to change, innovation, and operating/market risk. Once established, the Syracuse DES business may evolve relative to the initial business case as new opportunities and circumstances arise.

The determination of a preferred business model will require further discussion among Metro, Onondaga County, the City of Syracuse, and other key stakeholders regarding their respective appetite for risk as well as the findings of this study, specifically the expected ROI. Under certain scenarios such as a joint venture (JV) agreement, the various forms of risk noted above would be shared through joint participation in the JV vehicle and regulated by a shareholders' agreement, with returns allocated in part based on each party's share of total equity investment. This can be an attractive proposition for both parties, with the public partner providing land and access to lower-cost capital (i.e., municipal bonds) and the private partner providing skills, expertise, and access to external capital. Under a privately-owned structure, the private sector takes all risk with the possible exception of early development stages supported by the public sector, typically in the form of grants or loans. Under a concession business model, the public sector initiates and develops the project and continues to own system assets but contracts with a private operator for a specified term with renewal options subject to agreement by both parties.

The team has concluded upon a review of literature and existing case studies that private firms such as Energy Service Companies (ESCOs) play an increasingly important role in financing district energy systems in North America. This trend is particularly relevant for large, multiuser DES systems introduced into an existing built environment and which have capital costs exceeding $50 million such as the Syracuse DES. ESCOs are particularly attractive as investment partners not only because of their expertise to design, develop and operate systems, but also for their ability to provide balance sheet and internal financing. The analysis completed in this Scoping Study has shown that the Syracuse DES may have a ROI sufficiently high to attract private sector investment.

Balance sheet financing, whether in the form of equity, debt, or a hybrid debt-to-equity (DTE) model, has advantages over traditional project-based financing that uses debt backed by the system's fee revenue. First, ESCOs can utilize tax credits more readily than a special purpose vehicle entity created for the purposes of building and operating the DES. Second, internal financing may be raised and deployed more quickly compared to the time it typically takes to raise debt backed by system revenues. Third, balance sheet financing may be more flexible and patient than project-based debt financing, which may require quicker returns and more certainty regarding project revenues which will be an important consideration for potential investors as both the number of and timing of users for the new system is uncertain at this time. The use of internal funds, in combination with grant funds from NYSERDA and other sources, would allow for more stable and level-energy rates over time, as the number of customers and system load grows. Such patient forms of capital can fund revenue gaps from a low load in the initial years which are then repaid by participating customers through rates guaranteed by long-term contracts with the system owner(s). It is important to note that grants or public sector capital with a deferred return can reduce energy costs in the early years and achieve more level-energy costs over the life of the project, thus helping to attract customers over time.

As a key project stakeholder, Metro could engage potential ESCOs or other private investors for design and implementation to build, own, and operate the project on a turnkey basis through an Energy Performance Contract (EPC) as allowed under Article 9 the New York State Energy Law. Under this scenario, the developer/ESCO would be selected by a competitive Request for Qualifications (RFQ) and/or Request for Proposals (RFP) process, with the winning firm selected based on its qualifications and the financial terms, project design and other, more intangible, aspects of the firm's proposal, resulting in competitive cost and design creativity. The team proposes that a portion of NYSERDA Program Opportunity Notice (PON) 4614: Community Heat Pump Systems Program Category B: Site-Specific Design Study award could be used to address the specifications and requirements of a RFQ/RFP process.

An EPC can provide expertise that leads to the most efficient and cost-effective model for project execution while also reducing longer public sector procurement processes that would be required under other public-sector led business models including joint ventures. In this scenario, the EPC will be responsible for raising funds for upgrades and ultimately responsible for design and construction of the project. In certain cases, such as the University of Oklahoma's multiple district energy systems, Corix operates these systems under a 50-year contract. Ownership of system assets would need to be determined, but it is important to note that private ownership incentivizes high-quality initial construction by placing long-term responsibility for operation and maintenance on the developer. The team looked at Energy-as-a-Service models but determined this would likely be more feasible once there is greater certainty regarding customers and system revenue and when the future phases for district energy are built.

A drawback of the ESCO model is that it may incur higher financing costs than those for public sector sources. To mitigate this risk, Metro, Onondaga County, or the City of Syracuse could provide financing for the project in exchange for a share of the project's financial returns as well as to meet their own environmental and economic development goals. In some cases, public-private partnerships have been created utilizing a capital structure and DTE ratio similar to that of a private utility with 60% debt and 40% equity. However, it is possible that one or more of the key public stakeholders could provide a lower amount of debt capital, utilizing American Rescue Plan Act (ARPA) or other federal funds, federal Qualified Energy Efficiency Bond (QECB) proceeds, low-interest municipal bonds or tax increment financing and still realize an attractive rate of return in exchange for the use of public dollars. A public-private partnership model could be structured to generate sufficient revenue to repay the debt at prevailing or even at lower-than-market interest rates while still providing an acceptable return.

While the Syracuse DES has a strong advantage over other multi-user systems in existing built environments in that potential users will likely need to invest relatively little to connect to the system, these public funds could be used to defray any such costs in order to facilitate customer acquisition. It is important to note that the City of Syracuse has authorized the Open C-PACE (Property Assessed Clean Energy) program and is a member of the Energy Improvement Corporation, which could be used by property owners to finance necessary improvements as well. Therefore, public debt may alternatively be used to establish a reserve account to cover the "under recovery" of revenue from reduced rates in the early years to be repaid in future years, along with a return on investment for this revenue gap. For example, the City of Vancouver created a Rate Stabilization Reserve for the Southeast False Creek Project. This pool of funds provided a "revolving line of credit" used to fund system development in early years and ensure stable rates and covered cumulative financial losses in the system's early years which were repaid from revenues in later years. Public sector loans thus allow for the recovery on initial capital investments as district energy rates increase over time, especially if the customer base or future energy prices grow at rates higher than initially forecast and thus generate increased revenue from district energy services.

The literature suggests that flexible public debt tools should be used, as opposed to providing direct grants and local tax subsidies. Public debt has several advantages over grants and tax incentives as it provides the potential to recapture and recycle funds and thus can be used to finance expansion of the system or development of new DES projects. It also creates the potential to access and leverage a larger range of funding sources.

Even if the Syracuse DES were to be developed under a wholly privately owned business model, such as a special purpose vehicle, Metro, Onondaga County, or the City of Syracuse could enter into a joint cooperation agreement (JCA) with the ESCO/developer to mitigate risks in planning or expansion, or to encourage connection of customers through planning policies including in return for the granting of easements in the public right-of-way for system infrastructure or at the Metro plant. In this kind of Strategic Partnership Model, the public sector partner may benefit from reduced tariffs, profit sharing, connection of customers with higher credit risk or who are in energy poverty, and other environmental or economic development objectives. While the ESCO/developer would likely determine the governance structure under such a model, the public sector partner may have minor representation on the board of a special purpose vehicle (SPV) if the company has entered into a JCA.

Additional planning and research will be needed to determine the details of the business model and financing structure to address the capital needs of the Syracuse DES. However, it is clear that any strategy will require a pool of flexible and patient capital to finance long-term system capital investment. Consideration may be given to creating a specialized intermediary to raise, manage and supply financing for the Syracuse DES or establishing a partnership with an existing Community Development Finance Institution (CDFI).

5 Conduct Permitting and Regulatory Review Identifying Hurdles and Challenges

5.1 Identify Authorities Having Jurisdiction (AHJS) and the Associated Permitting/Approvals Required

A project of this magnitude and complexity will require permits and approvals from federal, State, and local government agencies and departments. This section discusses permit requirements and government agencies responsible for issuing them.

5.2 Federal

Section 9 of the federal Endangered Species Act (ESA) makes it unlawful for any person to harm any endangered or threatened species. In 16 U.S.C. § 1538 "harm" is broadly defined to include modifications of a species' habitat that would injure a member of the species by significantly impairing its feeding, breeding, or other essential activities (see 50 C.F.R. § 17.3). However, the Fish and Wildlife Service, a division of the U.S. Department of Interior, may issue a permit for otherwise lawful activities that might impact an endangered or threatened species or its habitat. If any of the project's construction activities will impact a federally listed endangered species anywhere along the proposed route, the project operator will be required to apply for this permit or to re-route the project away from the protected area.

5.3 State

The project will require a series of State permits and approvals, the exact number and type of which will depend upon the project's final design and its chosen route. Some of those approvals involve shared agency jurisdictions that allow for joint applications; for example, stream disturbance permitting for construction within navigable waters involves both the U.S. Army Corps of Engineers (ACE) and the DEC, and a joint application for such approvals must be filed with the agencies to allow their joint consideration and deliberation.

The State Environmental Quality Review Act (SEQRA) requires all New York State and local government entities approving, funding, or undertaking a discretionary action to conduct an assessment of the environmental impacts of that action. All potential impacts are evaluated to identify which may be significant, then a further evaluation determines whether such impacts are unavoidable or can be mitigated to the point of non-significance. Projects of considerable size or extensive scope will generally require preparation of an Environmental Impact Statement (EIS), which is intended to assist agencies' decision making by detailing potential impacts and mitigation methods. In situations involving multiple permitting jurisdictions and agencies, SEQRA provides for the selection and establishment of a single "Lead Agency" that coordinates comments from all agencies and drives the review process toward issuance of a set of findings that must be considered during the remaining permit processes. No permits or approvals may be issued for a project until the SEQRA review process has been completed.

New York State, through authorization from the U.S. Environmental Protection Agency (EPA), manages the State Pollutant Discharge Elimination System (SPDES) program for all point source discharges to surface and groundwater within the State. Three phases of the project have SPDES implications—construction, operations, and discharge of the water following thermal harvesting. The discharge of the water following thermal harvesting will likely garner the greatest level of scrutiny from DEC, depending on the final temperature of the water and the ultimate destination. New York State has specific regulations governing "thermal discharges" which may change the temperature of water bodies, including lakes.

5.4 Local

Zone Change: Depending on the location of the central plant, the project may require a zone change by the local legislature to accommodate a commercial/industrial facility.

Building Permit: The construction of any structure within a municipality will trigger a building permit. Such permits are ministerial (non-discretionary), but typically require an inspection upon completion by the local code office. Municipalities may offer expedited review of building permits as a non-financial incentive for existing building owners to connect to the district system.

Site Plan Approval: The central plant will typically require site plan approval by the local planning board to ensure compliance with the local zoning requirements and the aesthetic concerns of the neighborhood.

Highway/Excavation Work: Any excavation or pipeline installation along or within these highway rights of way will require a permit from the appropriate highway department.

5.5 Provide an Estimated Timeframe for Permitting Approval

The timeframe for permitting approval will be dependent on actual permits required and the time it takes for the authority having jurisdiction (AHJ) to review, which often does not have set timeframes. Permitting requirements will become more apparent during the detailed design stage of the project, and AHJs should be engaged as early in the process as possible to avoid potential critical path delays.

5.6 Identify Any Potential Risks for Additional Permitting Restrictions or Delays

This type of project may not be adequately contemplated or accounted for within current rules or processes, and/or rulemaking may be in process that could impact permitting. These may pose risks or delays impacting permitting.

Onondaga Lake has recently become a popular destination for bald eagles and bird watching, since the treated sewer outfall provides for open water and food source. Changing of the outfall temperatures could impact lake ice conditions that have been ideal for bald eagles.

The financial analysis for the DES project was conducted using assumptions such as cost of energy, value of emission reduction, incentives, finance rates, inflation rates, and scoping-level cost estimates. These variables were developed with the intent of predicting future conditions. However, in early 2022, the economic climate has seen a spike in real inflation, interest rates, energy costs, and material lead times. Supply chains disruptions for construction materials which have extended construction timelines. The financial analysis may need to be reevaluated if instability persists long term.

Customer enrollment and participation will be critical for the project viability. The phasing of the project should include an initial group of off takers that can be connected with the least amount of construction cost (minimum viable). Generally, off takers near the central plant, large thermal loads capable of load-flattening, and new construction projects will offer the highest cost/benefit advantages. Depending on the funding source, a proof of concept may need to be established with a defined initial phase milestone before proceeding subsequent phases and customer enrollment.

The New York State Department of Transportation has announced plans to remove the I-81 viaduct and replace with a community grid alternative, which involves installing a large storm main along the path of construction. Most of the cost for installing DES distribution piping involve trenching and earthwork; and furthermore, coinciding the routing of DES piping along the I-81 path between East Fayette Street and East Adams Street could significantly save on construction costs for the DES project. Moreover, this route would increase proximity to additional off takers outside the scope of this study, such as the 15th Ward project, Syracuse University, Crouse Hospital, and SUNY Upstate Medical University. The viability of the DES project is not dependent on coordination with the I-81 project but synchronizing the construction timeline for both projects would be beneficial to lower the cost of clean energy for the surrounding community.

5.7 Additional Unique Regulatory Obstacles

Potential additional unique regulatory obstacles to the project as they relate to the distribution of non-utility-generated electricity and thermal energy were to be identified, including those related to, but not limited to the following:

- Utility franchise rights
- Issues attributable to the preferred business model
- Project phasing
- Regulatory proceedings which are still to be determined

Regulatory obstacles will be dependent in the final business model and implementation partner responsible for construction.

6 Conclusions and Next Steps

According to Chapter 12 of the New York State Climate Action Council Draft Scoping Plan, by 2050, 85% of homes and commercial building space statewide should be electrified with energy efficient heat pumps and thermal energy networks. This study proposes the utilization of a DES to supply low-carbon heating to over 10 million ft^2 of office, multifamily, and institutional space in downtown Syracuse. Alternative and more traditional electrification approaches will be a challenge due to aggregate effects on the electrical grid (electrifying each individual building), or space constraints (utilization of geothermal loops).

Taking advantage of the existing local resource of the Metro WWTP located on the southern shore of Onondaga Lake, there is sufficient capacity to meet the required loads of the 34 buildings included in this study and for future expansion. Economic and financial analysis shows a positive NPV, which supports the implementation of the project from both the developer and community perspectives.

Next steps include determining the final business model and implementation partners. The determination of a preferred business model will require further discussion among Metro, Onondaga County, the City of Syracuse, and other key stakeholders regarding their respective appetite for risk as well as the findings of this study.

Appendix A. Load Profiles

Syracuse District Energy
CHA Project #67523

Overall Load Profile

No profile for space type - using available
No space type given - using a place holder

	Heat Pump	Heat Pump	Heat Pump	Heat Pump	Heat Pump
Heating Annual kWh	12,171	6,270	44,260	16,909	10,585
Cooling Annual kWh	384,231	197,937	1,397,205	51,401	334,165
	Barclay Damon	**Atrium**	**State Tower**	**Courtyard Marriott**	**US Social Security Admin**
Phase	**A**	**B**	**A**	**A**	**A**
Sq Footage	330,000	170,000	1,200,000	40,000	287,000
Space Type 1	Large Office	Large Office	Large Office	Hotel	Large Office
Percentage	100%	100%	100%	100%	100%
Space Ratio 1	0.66	0.34	2.41	0.33	0.58
Space Type 2	Retail	Retail	Retail	Retail	Retail
Percentage	0%	0%	0%	0%	0%
Space Ratio 2	14.67	7.56	53.33	1.78	12.76
Space Type 3					
Percentage					
Space Ratio 3					

Date	Temp-C	Temp-F	Montl	Day	Hour	Barclay Damon	Atrium	State Tower	Courtyard Marriott	US Social Security Admin
1/1/2002 1:00	2.2	36.0	1	1	1	17.7	9.1	64.4	207.5	15.4
1/1/2002 2:00	2.2	36.0	1	1	2	20.3	10.5	74.0	223.2	17.7
1/1/2002 3:00	2.2	36.0	1	1	3	22.9	11.8	83.1	236.3	19.9
1/1/2002 4:00	3	37.4	1	1	4	25.1	12.9	91.2	243.4	21.8
1/1/2002 5:00	2.8	37.0	1	1	5	34.7	17.9	126.1	248.5	30.2
1/1/2002 6:00	3	37.4	1	1	6	30.0	15.5	109.2	252.0	26.1
1/1/2002 7:00	3.3	37.9	1	1	7	686.1	353.4	2,494.7	231.1	596.7
1/1/2002 8:00	3.3	37.9	1	1	8	393.9	202.9	1,432.3	423.6	342.6
1/1/2002 9:00	3.9	39.0	1	1	9	143.0	73.7	520.0	369.8	124.4
1/1/2002 10:00	4	39.2	1	1	10	109.4	56.3	397.8	351.8	95.1

Load Profiles | Heating Profiles | Cooling Profiles | Phased Loads | Design Days

Click image to view Appendix A.

Appendix B. Utility Data and Comparison to Load Profiles

Syracuse District Energy

Utility Summary

	Electric Utility			
	Building	Consumption (kWh)	Total Cost ($)	Blended Rate ($/kWh)
205 S Salina	Salina	774,000	$71,667	$0.093
224 Harrison	224 Harrison	1,312,716	$111,403	$0.085
100 E Washington	White Memorial	433,500	$37,462	$0.086
100 N Salina	One Clinton Square	740,400	$64,749	$0.087
100 S Salina	Atrium	3,937,901	$315,610	$0.080
110 W Fayette	One Lincoln Center	4,776,603	$364,728	$0.076
300 South State	One Park Place	2,707,187	$239,499	$0.088
				$0.085

	Gas Utility			
	Building	Consumption (MMBtu)	Total Cost ($)	Rate ($/MMBtu)
205 S Salina	Salina	676	$3,753	$5.55
224 Harrison	224 Harrison	4,587	$23,617	$5.15
100 E Washington	White Memorial	876	$5,393	$6.16
100 N Salina	One Clinton Square	3,094	$15,986	$5.17
100 S Salina	Atrium	3,674	$19,210	$5.23
110 W Fayette	One Lincoln Center	13,711	$85,679	$6.25
300 South State	One Park Place	1,725	$10,518	$6.10
				$5.66

On List of Buildings

Summary | Comparison to Load Profile | Salina Elec | Salina Gas | 224 Harrison Elec | 224 Harı

Click image to view Appendix B.

Appendix C. Baseline Equipment Electrification and Operation and Maintenance Costs

Syracuse District Energy

Building Information & Operation and Maintenance Costs

	Address	Square Feet	Space Type	Peak Cooli (tons)	Annual t hrs
Phase A					
Barclay Damon	125 E Jefferson St	330,000	Large Office	310	352,222
State Tower	109 S Warren St	1,200,000	Large Office	1,126	1,280,806
Courtyard Marriott	300 W Fayette St	40,000	Hotel	71	52,731
US Social Security Admin	110 Fayette St	287,000	Large Office	269	306,326
M&T Bank	101 S Salina St	365,000	Large Office	343	389,578
State Office Building	333 E Washington St	360,000	Large Office	338	384,242
SU-Warehouse	350 W Fayette St	72,000	Medium Office	148	134,233
300 S State St	300 S State St	252,910	Large Office	237	269,940
Key Bank Building	201 S Warren St	132,000	Large Office	124	140,889
100 East Washington St	100 E Washington St	50,000	Midrise Apartment	83	31,084
Ramboll	333 W Washington St	137,000	Large Office	129	146,225
City Hall	233 E Washington St	84,555	Medium Office	174	157,640
1 Lincoln Center	110 W Fayette St	367,500	Large Office	345	392,247
SUNY Oswego MetroCenter	2 S Clinton St	185,530	Large Office	174	198,023
217 Montgomery St	217 Montgomery St	50,000	Medium Office	103	93,217
City Hall Commons	201 E Washington St	52,957	Medium Office	109	98,730
Salinas Place	205 S Salina St	50,000	Midrise Apartment	75	46,127
SU-Peck Hall	601 E Genesee St	25,920	Medium Office	53	48,324
Phase B					
Atrium	2 Clinton Sq	170,000	Large Office	160	181,447
AXA Towers	100 Madison St	653,177	Large Office	613	697,161
Hotel Syracuse	100 E Onondaga St	720,000	Hotel	1,270	949,155
Tech Garden	235 Harrison St	35,550	Medium Office	73	66,278
Bank of America	1 S Clinton St	45,000	Midrise Apartment	107	40,418
Clinton Exchange	101 N Clinton St	180,000	Large Office	169	192,121
National Grid	300 W Erie Blvd	511,200	Large Office	480	545,623
Post Standard	101 N Salina St	179,000	Large Office	168	191,054
Galleries of Syracuse	441 S Salina St	219,000	Large Office	206	233,747

Bldg Info, Cost Est | Baseline Electrification | Equipment Costs | Energy Reduction

Click image to view Appendix C.

Appendix D. Life Cycle Cost Analyses

	A	B	C	D	E	F	G	H
4	**Baseline LCA Calculation**							
5								
6	**Total buildings square footage**	**Blended Electric Rate**	**Gas Utility Rate**					
7		($/kWh)	($/therm)					System Efficiency Degredation/yea
8	9,032,610	$0.085	$0.57					General Inflation Rate (%)
9								Utility Inflation Rate (%)
10								Electric CO_2 Equivalency (kg/kWh)
11	**25 Year Energy Savings**	**25 Year tCO2e Reduction**						Gas CO_2 Equivalency (ton/MMBtu)
12	$5,933,719	98,506						
13								
14								
15	**25 Year Energy Consumption Comparison (Direct Benefit)**							
16	Nat Gas Energy Savings (Therms)	1,120,506						
17	Baseline Scenario Electric Energy Savings (kWh)	11,184,094						
18	Natural Gas Utility Rate ($/Therm)	$0.57						
19	Electric Utility Rate ($/kWh)	$0.085						
20		**Estimated First Cost**	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
21			**0**	**1**	**2**	**3**	**4**	**5**
22	Gas Cost ($)	$638,689			$348,956	$776,330	$815,147	$855,904
23	Electric Cost ($)	$950,648			$519,399	$1,155,519	$1,213,294	$1,273,959
24	**Total Customer Energy Savings ($)**	**$1,589,337**			**$868,356**	**$1,931,849**	**$2,028,441**	**$2,129,863**
25								
26	**Operations and Maintenance (Direct Benefit)**							
27		**Estimated First Cost**	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
28			**0**	**1**	**2**	**3**	**4**	**5**
29	**Avoided Customer O&M - Baseline Scenario**	**$30,000**			**$16,391**	**$33,765**	**$34,778**	**$35,822**
30								
31	**Carbon Reduction Social Benefit (Indirect Benefit)**							
32	CO_2 Emissions - Electricity(tons)	3,355						
33	CO_2 Emissions - NG(tons)	6,140						
34	Associated Methane Leakage (tons)	80			-0.94%	-9.61%		
36		**Estimated First Cost**	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
37			**0**	**1**	**2**	**3**	**4**	**5**
38	Total Ton Reduction			9,575	9,098	8,619	8,138	7,654
39	**Carbon Reduction Social Benefit**	$1,382,616		$1,382,616	$1,341,480	$1,307,665	$1,263,649	$1,217,845
40					-5.2%	-5.6%	-5.9%	-6.3%
41	**Equipment Replacement Cost at the End of Equipment Life (Direct Benefit)**							
42		**Total Cost of Reconditit**	**10% per Year**					
43	Tower Costs - Baseline Scenario	$0	$0					
44	Boiler Costs - Baseline Scenario	$229,881	$22,988					
45	**Total Cost - Baseline Scenario**	$229,881	$22,988					
47		**Estimated First Cost**	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
48			**0**	**1**	**2**	**3**	**4**	**5**
49	Tower Recondition Costs - Baseline Scenario	$0			$0	$0	$0	$0
50	Boiler Replacement Costs - Baseline Scenario	$22,988			$12,560	$25,873	$26,650	$27,449
51	**Total Avoided Customer Equipment**	**$22,988**			**$12,560**	**$25,873**	**$26,650**	**$27,449**
52								
53								
54	**Baseline Cashflow**	$3,024,941	$0	########	$2,238,786	$3,299,152	$3,353,518	$3,410,979
55								
56	Discount Rate	7.0%						
57	**Net Present Value Life Cycle Cost**	**$42,604,043**						
58								

Benefits Only LCA | Baseline LCA | DES LCA | Fuel Indices | Cost of Carbon | Sizing

Click image to view Appendix D.

Appendix E. Treatment Plant Trend Data Analysis

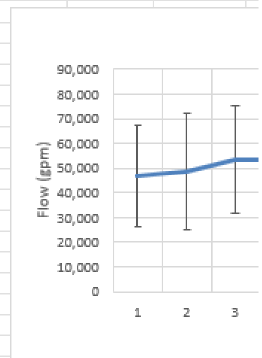
Syracuse District Energy

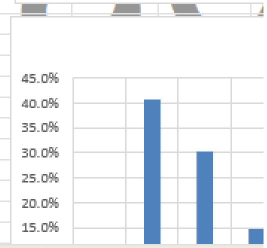
Waste Treatmet Plant Effluent Trend Data

Temperature Delta	10	°F << estimated
Load Constant	500	

Available Heat	
Avg	221,060
Max	652,124
Min	135,241
Flow (gpm)	
Avg	44,212
Max	130,425
Min	27,048

Date	Month	Day	Day of Year	Averag (°C)	Effluent Tem (°F)	Average Flow (MGD)	Flow (gpm)	Available He (MBH)
01/01/10	1	1	1	11.7	53.1	52.5	36,458	182,292
01/02/10	1	2	2	10.7	51.3	49.9	34,653	173,264
01/03/10	1	3	3	10.2	50.4	49.1	34,097	170,486
01/04/10	1	4	4	10.6	51.1	49.6	34,444	172,222
01/05/10	1	5	5	10.7	51.3	50.6	35,139	175,694
01/06/10	1	6	6	10.4	50.7	51.7	35,903	179,514
01/07/10	1	7	7	10.4	50.7	51.6	35,833	179,167
01/08/10	1	8	8	10.9	51.6	50.9	35,347	176,736
01/09/10	1	9	9	10.3	50.5	48.9	33,958	169,792
01/10/10	1	10	10	10.3	50.5	47.4	32,917	164,583
01/11/10	1	11	11	10.3	50.5	48.5	33,681	168,403
01/12/10	1	12	12	10.7	51.3	48.3	33,542	167,708
01/13/10	1	13	13	10.4	50.7	48.1	33,403	167,014
01/14/10	1	14	14	11.0	51.8	49.1	34,097	170,486
01/15/10	1	15	15	11.0	51.8	54.8	38,056	190,278
01/16/10	1	16	16	10.6	51.1	55.8	38,750	193,750
01/17/10	1	17	17	11.0	51.8	56.6	39,306	196,528
01/18/10	1	18	18	10.0	50.0	61.5	42,708	213,542
01/19/10	1	19	19	10.6	51.1	58.6	40,694	203,472
01/20/10	1	20	20	10.8	51.4	58.2	40,417	202,083
01/21/10	1	21	21	10.9	51.6	56.5	39,236	196,181
01/22/10	1	22	22	10.7	51.3	54.8	38,056	190,278
01/23/10	1	23	23	10.4	50.7	52.7	36,597	182,986
01/24/10	1	24	24	10.4	50.7	57.5	39,931	199,653
01/25/10	1	25	25	10.4	50.7	93.2	64,722	323,611
01/26/10	1	26	26	9.6	49.3	90.5	62,847	314,236
01/27/10	1	27	27	9.4	48.9	72.8	50,556	252,778
01/28/10	1	28	28	10.2	50.4	63.1	43,819	219,097





Temp & Flow Data | Effluent Temp Graph | Effluent Flow Graph | Total Flow-Temp Graph | Avai

Click image to view Appendix E.

Appendix F. Central Plant Sizing

Location	Buildling	Square Feet	Space Type	Peak Cooling	Annual ton-hrs	Annual Cooling
				(ton)		(kWh)
Downtown	Phase A	0	0	0	0	0
Downtown	Barclay Damon	330,000	Large Office	310	352,222	1,238,763
Downtown	State Tower	1,200,000	Large Office	1,126	1,280,806	4,504,593
Downtown	Courtyard Marriott	40,000	Hotel	71	52,731	185,454
Downtown	US Social Security Admin	287,000	Large Office	269	306,326	1,077,348
Downtown	M&T Bank	365,000	Large Office	343	389,578	1,370,147
Downtown	State Office Building	360,000	Large Office	338	384,242	1,351,378
Downtown	SU-Warehouse	72,000	Medium Office	148	134,233	472,097
Downtown	300 S State St	252,910	Large Office	237	269,940	949,380
Downtown	Key Bank Building	132,000	Large Office	124	140,889	495,505
Downtown	100 East Washington St	50,000	Midrise Apartment	83	31,084	109,324
Downtown	Ramboll	137,000	Large Office	129	146,225	514,274
Downtown	City Hall	84,555	Medium Office	174	157,640	554,419
Downtown	1 Lincoln Center	367,500	Large Office	345	392,247	1,379,531
Downtown	SUNY Oswego MetroCenter	185,530	Large Office	174	198,023	696,448
Downtown	217 Montgomery St	50,000	Medium Office	103	93,217	327,845
Downtown	City Hall Commons	52,957	Medium Office	109	98,730	347,234
Downtown	Salinas Place	50,000	Midrise Apartment	75	46,127	162,228
Downtown	SU-Peck Hall	25,920	Medium Office	53	48,324	169,955
Downtown	Phase B	0	0	0	0	0
Downtown	Atrium	170,000	Large Office	160	181,447	638,151
Downtown	AXA Towers	653,177	Large Office	613	697,161	2,451,914
Downtown	Hotel Syracuse	720,000	Hotel	1,270	949,155	3,338,177
Downtown	Tech Garden	35,550	Medium Office	73	66,278	233,098
Downtown	Bank of America	45,000	Midrise Apartment	107	40,418	142,149
Downtown	Clinton Exchange	180,000	Large Office	169	192,121	675,689
Downtown	National Grid	511,200	Large Office	480	545,623	1,918,956
Downtown	Post Standard	179,000	Large Office	168	191,054	671,935
Downtown	Galleries of Syracuse	219,000	Large Office	206	233,747	822,088
Downtown	100 Clinton Sq	120,000	Large Office	113	128,081	450,459
Downtown	City of Syr Criminal Court House	95,977	Medium Office	198	178,934	629,312
Downtown	550 Harrison Building	252,000	Retail	0	0	0
Downtown	Jefferson Clinton Hotel	42,204	Hotel	74	55,636	195,673
Downtown	Sky Armory	40,700	Medium Office	84	75,879	266,866
Downtown	Clinton Plaza	254,690	Midrise Apartment	307	111,392	391,766
Downtown	MOST	40,000	Medium Office	82	74,574	262,276
Downtown	600 Montgomery St	36,684	Medium Office	76	68,392	240,534
Inner Harbor	Medical Office Bldg	25,056	Retail	0	0	0
Inner Harbor	Phase C	0	0	0	0	0
Inner Harbor	Parcel 1	180,000	Medium Office	454	305,260	1,073,600
Inner Harbor	Parcel 2	120,000	Retail	268	146,428	514,986
Inner Harbor	Parcel 3	45,000	Midrise Apartment	89	33,506	117,839
Inner Harbor	Parcel 4	110,000	Retail	246	134,225	472,070

Central Plant Sizing

Click image to view Appendix F.

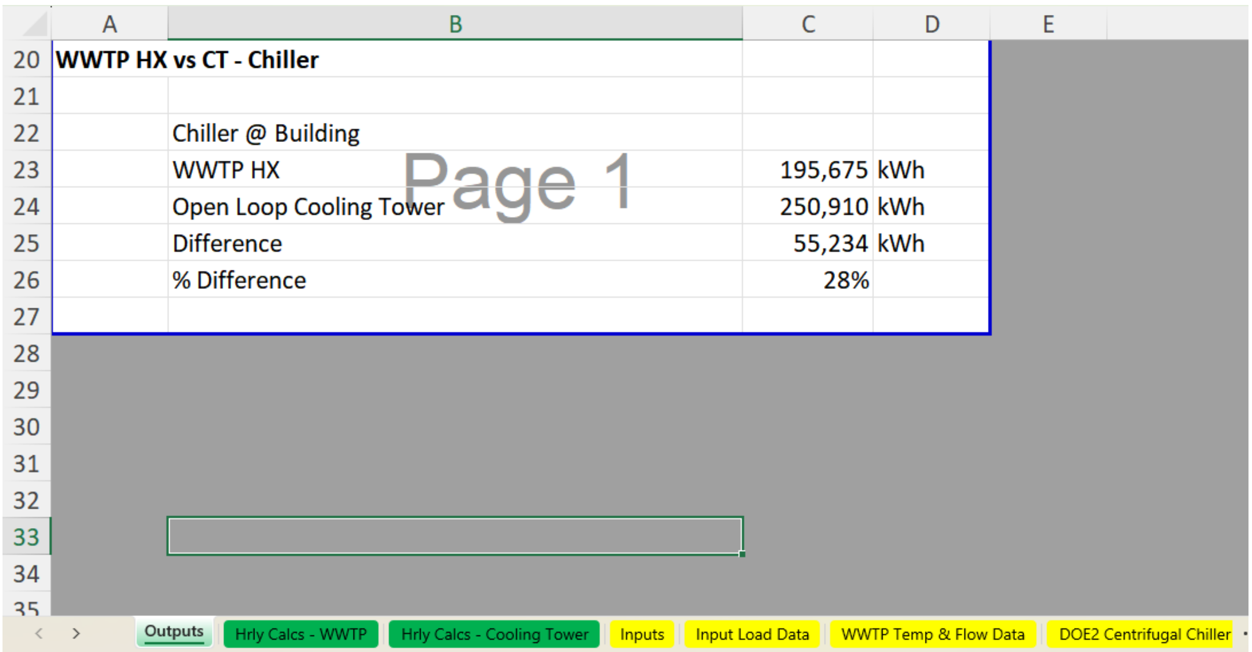
Appendix G. District Central Plant Calculator

	A	B	C	D	E	F	G	H	I	J
1	**District Central Plant Calculator**									
2								**MBH**	**MBH**	**MBH**
3	**Pick (Max)**					Max		18,348	19,399	19,399
4	**Average**					Avg		1,941	1,068	1,068
5	**Annual Energy**					Sum		17,006,023	9,358,252	9,358,252
6										
7	**DATE/TIME**							**LOADS**		
8	**Date**	**Month**	**Day**	**Hour**	**Day of Year**	**Hour of Year**	**Dry Bulb Temperature (°F)**	**Heating Load (MBH)**	**Heat Pump Cooling Load (MBH)**	**Total Cooling Load (MBH)**
9	1/1/2007 1:00	1	1	1	1	1	36.0	1,257	0	0
10	1/1/2007 2:00	1	1	2	1	2	36.0	1,668	0	0
11	1/1/2007 3:00	1	1	3	1	3	36.0	1,767	0	0
12	1/1/2007 4:00	1	1	4	1	4	37.4	1,881	0	0
13	1/1/2007 5:00	1	1	5	1	5	37.0	2,020	0	0
14	1/1/2007 6:00	1	1	6	1	6	37.4	2,106	0	0
15	1/1/2007 7:00	1	1	7	1	7	37.9	10,111	0	0
16	1/1/2007 8:00	1	1	8	1	8	37.9	8,091	0	0
17	1/1/2007 9:00	1	1	9	1	9	39.0	7,307	0	0
18	1/1/2007 10:00	1	1	10	1	10	39.2	6,317	0	0
19	1/1/2007 11:00	1	1	11	1	11	41.0	5,765	0	0
20	1/1/2007 12:00	1	1	12	1	12	44.6	5,222	0	0
21	1/1/2007 13:00	1	1	13	1	13	45.0	4,592	0	0
22	1/1/2007 14:00	1	1	14	1	14	45.0	4,104	0	0
23	1/1/2007 15:00	1	1	15	1	15	46.9	3,757	0	0
24	1/1/2007 16:00	1	1	16	1	16	46.0	3,342	0	0
25	1/1/2007 17:00	1	1	17	1	17	46.0	3,119	0	0
26	1/1/2007 18:00	1	1	18	1	18	44.6	2,989	0	0
27	1/1/2007 19:00	1	1	19	1	19	41.0	2,894	0	0
28	1/1/2007 20:00	1	1	20	1	20	41.0	2,701	0	0
29	1/1/2007 21:00	1	1	21	1	21	41.0	2,483	0	0
30	1/1/2007 22:00	1	1	22	1	22	43.0	802	0	0
31	1/1/2007 23:00	1	1	23	1	23	43.0	745	0	0
32	1/2/2007 0:00	1	2	0	2	24	43.0	724	0	0
33	1/2/2007 1:00	1	2	1	2	25	42.8	738	0	0
34	1/2/2007 2:00	1	2	2	2	26	43.0	900	0	0
35	1/2/2007 3:00	1	2	3	2	27	43.0	1,104	0	0
36	1/2/2007 4:00	1	2	4	2	28	42.1	1,237	0	0
37	1/2/2007 5:00	1	2	5	2	29	42.1	1,337	0	0

Hourly Calculations | Graphs | Inputs | Input Load Data

Click image to view Appendix G.

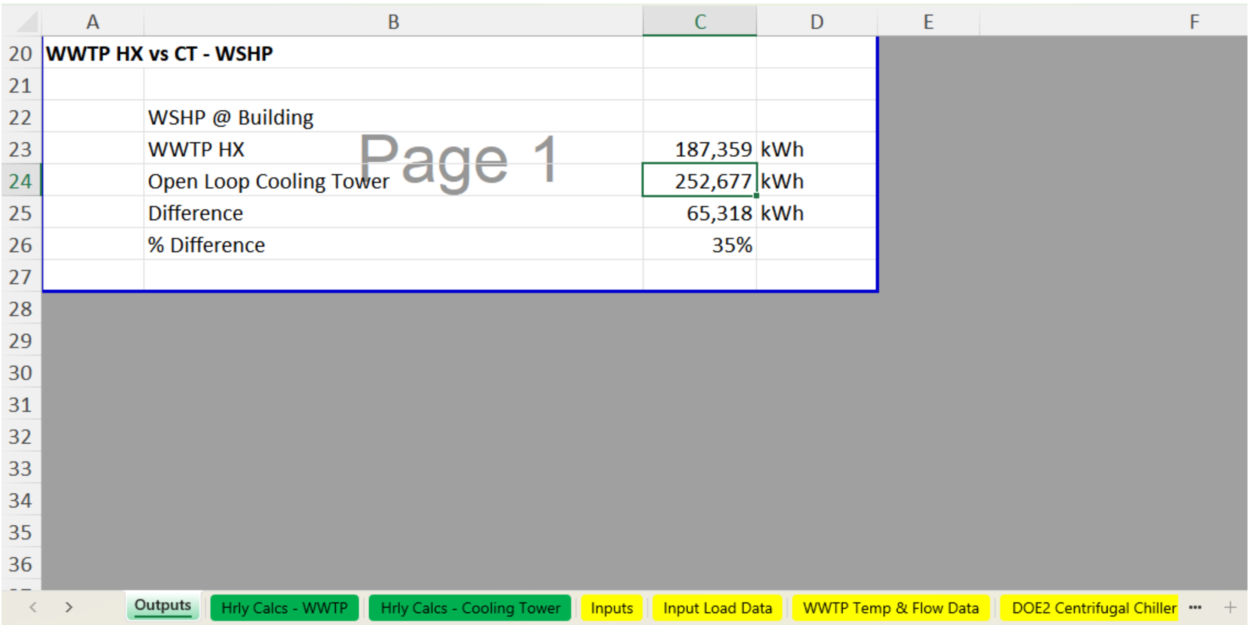
Appendix H. Waste Water Treatment Plant Heat Exchange vs Cooling Tower and Chiller



WWTP HX vs CT - Chiller		
Chiller @ Building		
WWTP HX	195,675	kWh
Open Loop Cooling Tower	250,910	kWh
Difference	55,234	kWh
% Difference	28%	

Click image to view Appendix H.

Appendix I. Waste Water Treatment Plant Heat Exchange vs cooling tower with water source heat pumps



WWTP HX vs CT - WSHP			
	WSHP @ Building		
	WWTP HX	187,359	kWh
	Open Loop Cooling Tower	252,677	kWh
	Difference	65,318	kWh
	% Difference	35%	

Click image to view Appendix I.

Appendix J Cost Summaries

CLIENT: NYSERDA
PROJECT: Syracuse Community Thermal
LOCATION: Syracuse, NY

ENGINEER: CHA
ARCHITECT: None
Trade: Mechanical/Electrical/Structural

Summary Table - Total Summary

		NPV (25 Year)	*Notes*
Costs			
	Design and Planning	$7,700,000	*~10% Construction*
	Central Plant Investment	$13,300,000	*Per CHA Estimate*
	Distribution Piping Investment	$28,700,000	*Per CHA Estimate $53M financing over 40yr*
	Central Plant O&M	$3,900,000	*($30k 0.5FTE operator, $188k electric, $14k O&M, $30k other G&A)*
	District Connections to Customer Bldgs	$700,000	*($15k/building, 50 total)*
	NYSERDA Category B&C Award	-$4,200,000	*PON 4641 Category B&C*
	Total (NPV)	**$50,100,000**	
Direct Benefits			
	Avoided Customer O&M	$10,300,000	*Per App C (Baseline Equipment - Towers and Boilers)*
	Avoided Customer Equipment Reconditic	$12,800,000	*Per App D (10% tower and boiler/yr)*
	Customer Energy Savings	$34,900,000	*Per App D eliminating customer gas heat, 25% cooling efficiency increase*
	Total Direct Benefits	**$58,000,000**	
	Net Direct Benefits	**$7,900,000**	
	IRR	**8.81%**	
	BCR	**1.16**	
Indirect Benefits			
	Carbon Reduction Social Benefit	$8,800,000	*$125/ton value NYS-DEC Guidance per evaluation*
	Avoided Electrical Substation Upgrades	$12,600,000	
	Total Indirect Benefits	**$21,400,000**	
	Net Direct + Indirect Benefits	**$29,300,000**	
	IRR	**15.87%**	
	BCR	**1.58**	

Summary | Summary-No Cat C | Summary Phase C (Initial) | Summary Phase C -No Cat C | Sun

Click image to view Appendix J.

Appendix K Attachment A-2 Category A Report Summary

Category A: Site-specific scoping study		**Report Stage** **(Final Report for Category A Instructions part 2)**			
DISTRICT CHARACTERISTICS					
Applicant:	**CNYRDPB**				
CA1 Location & Site Area					
District Street Address	**650 Hiawatha Blvd W**	**City/Town,**	**Syracuse, NY**		
District site area (acres)		**Latitude, Longitude**	**43.0621192585, -76.1759606307**		
CA2 Building Cluster Scale & Type	**Indicate all that apply**	**CA3 Building Construction/Retr**	**Indicate all that appl**	**CA4 District System**	**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,		**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**	**14% New, 86% Retrofit**	**c. If both, provide % Mix of New and Retrofit by conditioned area served**	
OTHER - Specify		**d. Replacement of Building Heating/Cooling System**		**Indicate present & proposed distribution system type (e.g., steam, High-temp**	

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 M Renova Ret Buildin (ye
Barclay Damon	125 E Jefferson St	Large Office	330,000	330,000	330,000	Retrofit of Heating and Cooling Systems	
Atrium	2 Clinton Sq	Large Office	170,000	170,000	170,000	Retrofit of Heating and Cooling Systems	
State Tower	109 S Warren St	Large Office	1,200,000	1,200,000	1,200,000	Retrofit of Heating and Cooling Systems	
Courtyard Marriott	300 W Fayette St	Hotel	40,000	40,000	40,000	Retrofit of Heating and Cooling Systems	
US Social Security Admin	110 Fayette St	Large Office	287,000	287,000	287,000	Retrofit of Heating and Cooling Systems	
M&T Bank	101 S Salina St	Large Office	365,000	365,000	365,000	Retrofit of Heating and Cooling Systems	
State Office Building	333 E Washington St	Large Office	360,000	360,000	360,000	Retrofit of Heating and Cooling Systems	
SU-Warehouse	350 W Fayette St	Medium Office	72,000	72,000	72,000	Retrofit of Heating and Cooling Systems	
One Park Place	300 S State St	Large Office	252,910	252,910	252,910	Retrofit of Heating and Cooling Systems	
Key Bank Building	201 S Warren St	Large Office	132,000	132,000	132,000	Retrofit of Heating and Cooling Systems	
White Memorial	100 E Washington St	Midrise Apartment	50,000	50,000	50,000	Retrofit of Heating and Cooling Systems	
Ramboll	333 W Washington St	Large Office	137,000	137,000	137,000	Retrofit of Heating and Cooling Systems	
City Hall	233 E Washington St	Medium Office	84,555	84,555	84,555	Retrofit of Heating and Cooling Systems	
1 Lincoln Center	110 W Fayette St	Large Office	367,500	367,500	367,500	Retrofit of Heating and Cooling Systems	
SUNY Oswego MetroCenter	2 S Clinton St	Large Office	185,530	185,530	185,530	Retrofit of Heating and Cooling Systems	
217 Montgomery St	217 Montgomery St	Medium Office	50,000	50,000	50,000	Retrofit of Heating and Cooling Systems	
City Hall Commons	201 E Washington St	Medium Office	52,957	52,957	52,957	Retrofit of Heating and Cooling Systems	

Cat A Instructions | Cat A_District | Cat A_Systems & Technology | Cat A_Business Model | Drop down lists

Click image to view Appendix K.

Endnotes

1 U.S. Environmental Protection Agency (EPA). "Greenhouse Gas Equivalencies Calculator." Accessed November 5, 2021. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator. This link leads to the Greenhouse Gas Equivalencies Calculator, which helps users estimate emissions based on energy consumption.

2. Howarth, Robert W., and Mark Z. Jacobson. 2021. "How Green Is Blue Hydrogen." *Energy Science and Engineer*, vol. 9., issue 10.

3 National Renewable Energy Laboratory. "U.S. Department of Energy Commercial Reference Building Models of the National Building Stock." Accessed October 21, 2021. https://www.nrel.gov/docs/fy11osti/46861.pdf. In-depth model details are available in the report**.**

4 Onondaga County Department of Water Environment Protection. 2020. *Metropolitan Syracuse Wastewater Treatment Plant (WWTP) 1978 Plant Expansion Infrastructure Asset Management Evaluation Project Inspection and Evaluation Report.* Accessed Nov 5, 2021.

5 New York State Energy Research and Development Authority (NYSERDA) and Resources for the Future, 2021. "Estimating the Value of Carbon: Two Approaches." 6 (January). The $125 per metric ton figure assumes a discount rate of 2% and is based on an average of modeled results.

6 National Grid. 2021. "Non-Wires Alternatives Information Page." Accessed December 10,2021. https://www.nationalgridus.com/Business-Partners/Non-Wires-Alternatives/ For more information about NWAs at National Grid, including project planning, solution submittal, and links to their System Data Portals and Ariba vendor platform.

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