The New York Power Authority

Decarbonization Action Plan

for the

Governor Nelson A. Rockefeller Empire State Plaza

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Executive Summary

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Executive Summary

A Decarbonization Action Plan was developed for Empire State Plaza (ESP). The goals of the project focus on a path toward full decarbonization with a desire for near-term emission reductions. This plan provides a roadmap for near-term actions and a decision-making framework for the long-term vision to achieve NYS energy efficiency and greenhouse gas (GHG) reduction mandates and set a path for carbon neutrality by 2050. Many of the key findings, metrics, and methodologies contained within this Decarbonization Action Plan are based on the former ESP Energy Infrastructure Master Plan report[1].

Drivers

A high-level summary of the mandates, energy and carbon reduction targets, and directives that the New York Power Authority (NYPA) and Empire State Plaza are addressing includes the following:

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

[1] ESP Energy Infrastructure Master Plan report issued by Ramboll to NYPA, final issue dated May 20, 2024.

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Approach

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

The planning process began with a comprehensive assessment of the Plaza's current energy systems and identification of opportunities for decarbonization. Key steps included:

1. **Initial Assessment**: An in-depth review of the existing heating and cooling infrastructure, energy consumption profiles, and potential areas for improvement. This involved building walk-through surveys and consultations with facility staff.
2. **Scenario Development**: Multiple decarbonization scenarios were developed, each proposing a unique combination of technologies and strategies to achieve significant reductions in greenhouse gas emissions. Scenarios included various mixes of renewable energy sources, energy efficiency measures, and infrastructure upgrades.
3. **Modeling and Analysis**: Detailed modeling and analysis were conducted to evaluate the effectiveness, costs, and feasibility of each scenario. This included assessing energy and electrical infrastructure impacts, greenhouse gas reduction, and financial implications over the life of the project.
4. **Stakeholder Engagement**: Regular discussions with stakeholders, including the Plaza's management and external experts, provided valuable insights and feedback. This ensured alignment with ESP's priorities, regulatory requirements, and practical considerations.
5. **Selection of Preferred Scenario**: Based on the results of the scenario assessment, Scenario 1C2 was selected as the preferred option for full decarbonization of heating and cooling systems. Scenario 1C2 was chosen due to its feasibility, effective use of existing infrastructure, and ability to achieve full decarbonization by its use of electrified heat pumps and electric peaking boilers.
6. **Phasing and Implementation Plan**: A phased approach was developed to systematically implement the preferred scenario over time, addressing immediate needs and long-term goals. This plan includes specific actions, estimated costs, and projected carbon impacts for each phase.

Decarbonization Action Plan

Scenario 1C2: Full Decarbonization of Heating and Cooling

Scenario 1C2 emerged as the preferred solution for developing the decarbonization action plan, offering full decarbonization of heating and cooling for the Plaza.

Centralized Distribution

For buildings currently receiving district steam and chilled water, the plan involves replacing the steam system with a centralized low-temperature hot water (LTHW) distribution system and continuing the use of the existing chilled water system, together resulting in a centralized 4-pipe distribution system.

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Centralized heat recovery chillers and ground-source heat pumps would produce heating and cooling that would supply the distribution systems[2]. Electric boilers, sized to provide the peak heating load, will supply 10% of the annual heating load. Electric chillers would supply any remaining cooling load throughout the year that is not covered by the heat recovery chillers and ground-source heat pumps. Full electrification will be achieved under this scenario. The inclusion of full electrification will require significant upgrades to the Plaza's electric infrastructure and will result in peak electrical demands that are roughly triple that of current peaks.

This project investigated four main pathways to generate the heat that is needed on site: heat recovery chillers, geothermal heat pumps, wastewater heat pumps, and industrial heat recovery. Heat recovery chillers are recommended to the extent they can be utilized and in conjunction with one or more of the three remaining technologies. All three technologies proved viable, and although Scenario 1C2 uses geothermal heat pumps as its primary baseload technology, it is recommended that all three technologies continue to be considered[3]. Since this is the third phase of implementation, it may be several years before a final approach needs to be chosen. Figure 1 shows the three sources for future consideration.

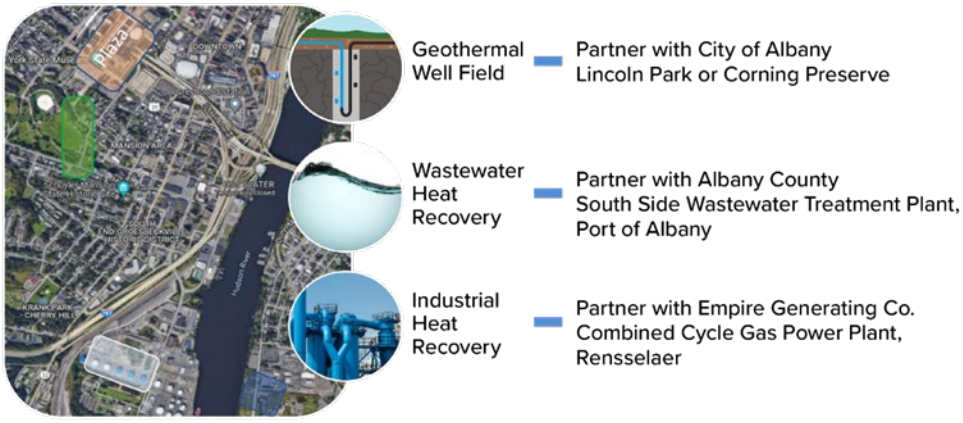

Figure 1. Potential Thermal Energy Network Sources

[2] While ground-source heat pumps are the primary baseload technology for Scenario 1C2 as presented, feasibility of the technology along with industrial heat recovery heat pumps and wastewater heat pumps will further be investigated in subsequent efforts to determine which option is best suited to provide means of baseload heat in a full electrification scenario.

[3] Recent conversations between major project stakeholders have identified industrial heat recovery as being less desirable due to the use of fossil fuels at the source. As per Figure 1, the Empire Generating Company's Rensselaer power plant is a combined cycle gas plant.

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Phasing and Implementation Plan

A four-phase approach was developed to achieve the desired carbon reductions, summarized in Figure 2.

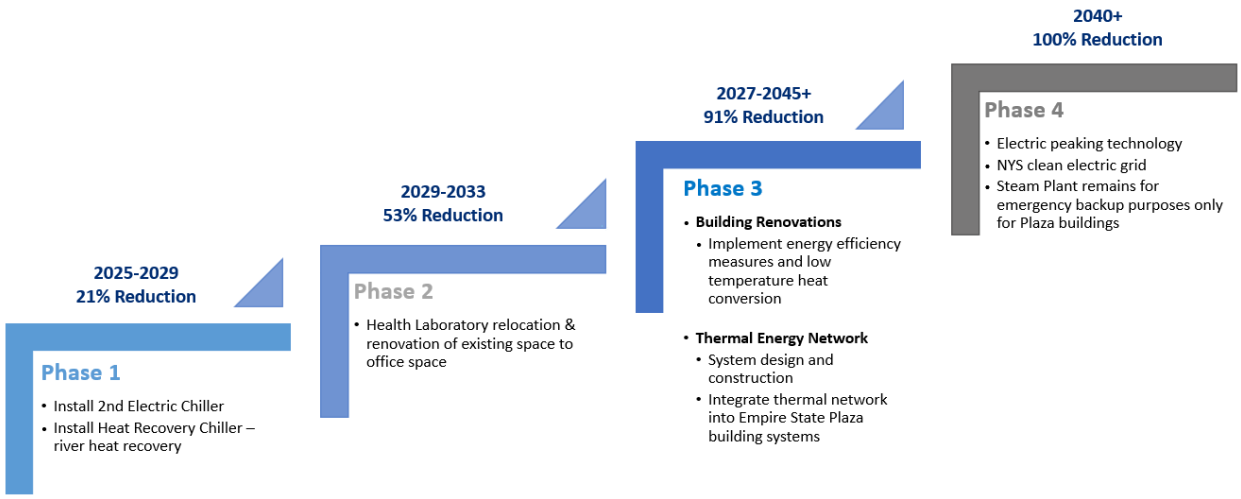

Figure 2. Decarbonization Phasing Plan

1. **Phase 1 (2025-2029):** The initial phase continues the electrification efforts of the existing comfort cooling systems at the Plaza's Central Air Conditioning Plant (CACP). A second electric chiller as well as a heat recovery chiller(s) would be installed during this phase to increase the total electrified cooling capacity following the recent replacement of steam-driven turbine Chiller 4. Doing so would both increase chiller plant efficiency and displace the amount of fossil fuels consumed that would otherwise be burned to produce steam to run the existing steam turbine chillers. The displacement of total steam turbine chiller operating hours with electrified chillers would result in a 21% reduction in GHG emissions, or roughly 19,600 metric tons of carbon dioxide equivalent (MTCO2e).

2. **Phase 2 (2029-2033):** The second phase involves the relocation of the health laboratories to an offsite location and subsequent renovation and repurposing of the existing space. While the exact use of the future space is not known, it was estimated that the building will be repurposed to an office type use. Other possible uses include storage, additional utility space, or archives. Any of these space types would result in a significantly lower energy intensity when compared to the existing health lab and thus would yield sizeable GHG emission reductions, approximately 30,200 MTCO2e (roughly 32% reduction).

3. **Phase 3 (2027-2045+):** The third phase consists of building renovations for all buildings within the Plaza. The building renovations are the most cost intensive aspect of the Empire State Plaza's decarbonization plans but are needed as the mechanical systems are over 50 years old, are inefficient, and are at end of life. Other improvements at the building level during these renovations will also result in a reduced heating and cooling demand. These building renovations

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are projected to yield roughly 25,800 MTCO2e of GHG reductions, or an additional 28% reduction.

In parallel with the building renovations, a LTHW thermal energy network will be installed to replace the use of the existing district steam network. This installation will involve new electrified heat pumps at the central plant, as well as the routing of LTHW distribution piping throughout the Plaza. Another 9,400 MTCO2e or 10% GHG reductions would be achieved following the substantial completion of this step. The completion of Phase 3 would altogether achieve 38% of GHG emission reductions.

4. **Phase 4 (2040+):** The final phase for full decarbonization would eliminate the use of any natural gas under normal operating conditions. This would be achieved by installing electric peaking boilers at CACP. The heating assets installed in previous phases would still operate in the same manner, but when peak heating events occur the electric boilers would be called on to make up the difference in heating load instead of the fossil fuel boilers. While proposed as LTHW-producing peak heating assets in this approach, further evaluation of electric boilers as steam-producing heating assets could accelerate the Plaza's decarbonization timeline by deploying these assets in an earlier phase and covering a greater portion of the heating load. In either case, the natural gas infrastructure and dual-fuel boilers at Sheridan Ave Steam Plant (SASP) would remain and serve as backup heating systems in the event of an electrical outage at the Plaza. This phase alone would achieve roughly 8,400 MTCO2e of emissions reductions, or 9%. After completion of this phase, a 100% total reduction in GHG emissions would be achieved.

Table 1 outlines the phased approach for the decarbonization action plan, detailing the cost and carbon impact associated with each phase. Each phase represents a significant step towards achieving full decarbonization of heating and cooling systems at the Plaza.

Table 1. Phased Implementation Cost and Carbon Impact

Phase	Cost (2022 USD)	Cost (2025 USD)	% of Project Cost	% of total carbon reduction
Phase 1	$100,000,000	$245,609,708[4]	19%	21%
Phase 2	$0	$0	0%	32%
Phase 3	$950,000,000	$1,041,292,230	79%	38%
Phase 4	$30,000,000	$32,882,913	2%	9%
Total	**$1.08B**	**$1.32B**	**100%**	**100%**

[4] Phase 1 costs have been updated to include recently announced funding allocated to building renovations and mechanical upgrades that would supplement the heat recovery chiller installation(s). Announced total in the FY2026 budget is $136M.

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Key Points:

1. **Phase 1** realizes significant near-term carbon reductions by displacing steam-driven chilled water production with electrified chillers and heat recovery chillers.
2. **Phase 2** reduces the overall energy use and carbon footprint of the Plaza by relocating energy-intensive lab spaces to an offsite location.
3. **Phase 3** is the most critical, accounting for a large majority of the total project cost and delivering nearly 40% of the overall carbon reductions.
4. **Phase 4** completes the decarbonization process by addressing peak heating loads, finalizing the transition to carbon neutrality.

Key Assumptions and Considerations

The plan is based on several key assumptions:

- **Electric Grid:** The plan assumes the electric grid meets the CLCPA's renewable energy and carbon reduction goals, which is crucial for achieving full decarbonization at ESP. The plan also assumes that 100% renewable energy is being procured and/or produced by ESP by 2030, in accordance with EO 22.
- **Baseload/Peaking Strategy:** A cost-efficient baseload/peaking strategy was chosen. Geothermal heat pumps and heat recovery chillers were sized to handle about 40% of the peak heating load, covering approximately 90% of the annual heating load. Increasing the number of boreholes and heat pump capacity to cover 100% load would be significantly more expensive than utilizing existing infrastructure or lower-cost peaking technologies like electric boilers.

The development of the plan highlights several critical points, particularly concerning the impacts of electric peaking strategies versus natural gas peaking:

- **Electric Peaking Impact:** Employing an electric peaking strategy significantly impacts costs and the electric grid. Full decarbonization through electric peaking requires substantial upfront investment not only in heating production technologies but also in electrical infrastructure to accommodate the boilers. These upgrades are necessary to manage the increased electric load, especially winter peak demand, which sees a ~36 MW increase in peak demand relative to the peaks experienced at the Plaza currently. Section E.2.2 describes the expected impacts on the local electrical grid should a full decarbonization approach be implemented and identifies the need for coordination with the electric utility.
- **Natural Gas Peaking Advantage:** Conversely, peaking with natural gas can substantially reduce grid impacts and overall costs for the Plaza while still achieving significant emission savings. Utilizing existing natural gas infrastructure helps cover peak heating loads, decreasing the need for immediate extensive electrical upgrades. This approach results in about a 91% reduction in business-as-usual emissions from heating and cooling production, effectively meeting CLCPA goals without the substantial financial burden and grid impact associated with full electric peaking.

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A – Energy Demand and Usage Summary

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Section A – Energy Demand and Usage Summary

An Energy Demand and Usage Summary was developed to document the existing conditions of energy using systems, assess current energy usage patterns, and identify areas that warrant greater consideration in the subsequent phase of the decarbonization planning process.

A.1 Existing Energy Consumption Load Profiles

A.1.1 Energy Analysis Overview

A building-level energy analysis of the Plaza was completed to establish current performance and energy savings potential. Buildings included in the analysis are all buildings in and around the Empire State Plaza complex that receive electricity, district steam and district chilled water (CHW) from the complex's distribution network. The Sheridan Avenue Steam Plant (SASP) is the central heating plant for ESP and generates the district steam. The Central Air Conditioning Plant (CACP) is the central cooling plant for ESP and generates the district CHW. All buildings within the complex are owned and operated by the New York State Office of General Services (OGS), with the exception of the Old Education Building adjacent to the Plaza[5].

The baseline period for the energy use analysis is three calendar years, 2018 through 2020. The fuels (energy inputs) consumed by the complex are electricity and natural gas. Electricity, district steam, and district CHW are consumed at the individual buildings. Electricity is supplied and delivered by National Grid under the "Large General (SC-3A)" tariff for customers whose electric demand has surpassed 2,000 kW in any two consecutive months of the previous year. Natural gas is used to generate district steam at SASP. Natural gas is also consumed directly at the Executive Residence to serve its space and water heating needs. Natural gas is delivered to SASP by National Grid under the "Firm Gas Sales and Transportation (SC-8)" tariff for customers with an annual consumption of at least 1,000,000 therms.

Building-level electric, steam, and CHW submeter data as well as electric and natural gas utility billing summaries were provided for the entire complex. The annual input energy of each fuel source was weather normalized. Regression models were developed from the utility data and actual weather data for normalization to typical year weather conditions. Energy use data from the third calendar year (2020) was excluded in regression calculations to avoid influences of COVID-19 on energy use. This section provides high-level results of the energy analysis.

A.1.2 Annual Energy Consumption Summary

Table 2 summarizes the weather normalized annual results from the baseline energy use analysis period 2018 through 2020. Appendix A includes more detailed information and monthly profiles for each fuel source. Data include monthly energy use and cost for each year as well as an average of the years and a weather-normalized year. Additional key performance indicators (KPIs) and monthly energy use, demand,

[5] The Old Education Building is owned and operated by the New York State Education Department (NYSED). All other buildings within and adjacent to the Plaza are owned and operated by OGS.

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and cost were charted and analyzed for each fuel source. Data are also depicted in bar charts along with end use allocation estimates.

Table 2. Energy Consumption Summary

Energy Type	Total Weather-Normalized [1] Annual Use	Units	mmBtu	Total Weather-Normalized Annual Cost
Electricity	117,669,681	kWh	401,489	$ 6,617,279
Natural Gas	14,813,634	Therms	1,481,363	$ 5,542,157
Total	-	-	1,882,852	$ 12,159,435

Notes:

1. Weather normalized totals based on annual data from 2018 - 2020

A.1.3 Energy Consumption Load Profiles

Figure 3 and Figure 4 below present the complex's total energy consumption by month for each fuel type.

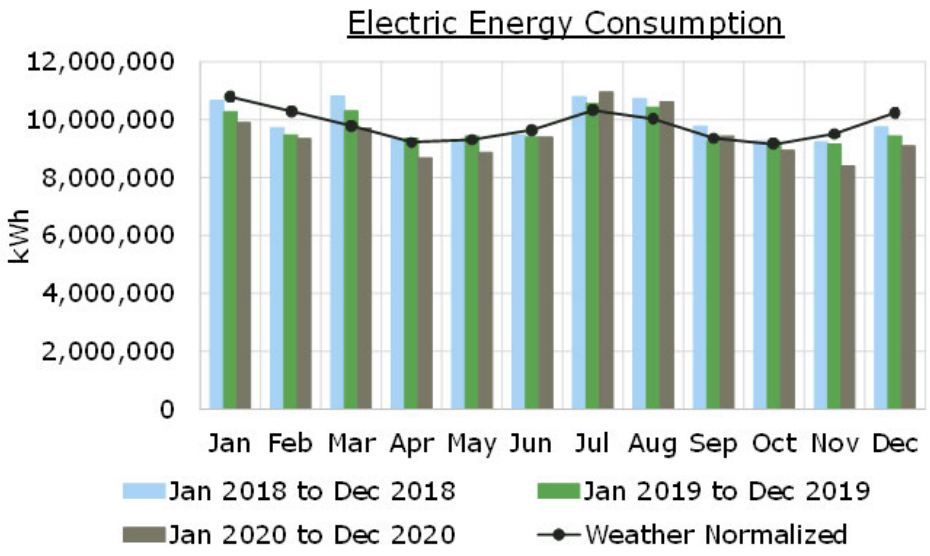

Figure 3. Monthly Energy Consumption Profile – Electricity

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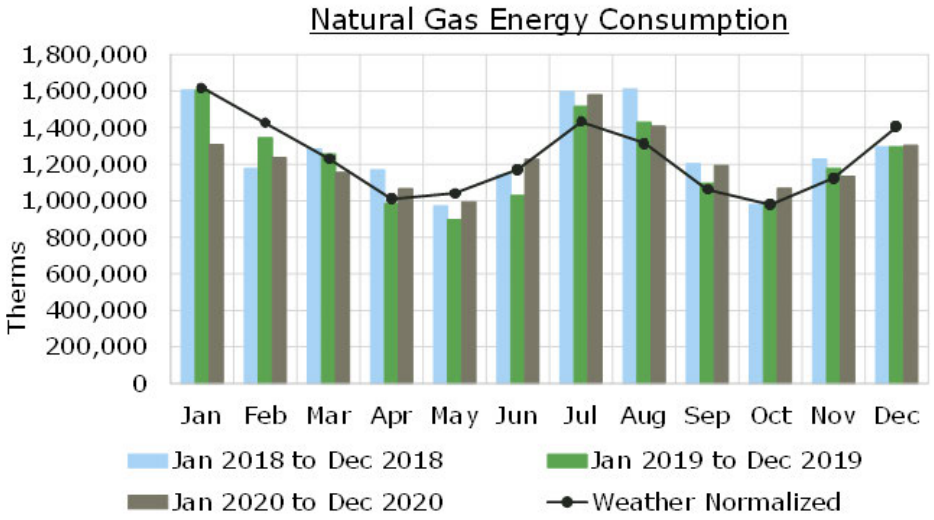

Figure 4. Monthly Energy Consumption Profile – Natural Gas

The electric demand profile is based on 15-minute interval submeter data of the 34.5 kV main service to Empire State Plaza and is presented in Figure 5. Hourly heating demand was derived from 15-minute interval submeter data of the individual buildings served by the steam plant (SASP). Similarly, hourly cooling demand was derived from 15-minute interval submeter data of the individual buildings served by the Central Air Conditioning Plant. The heating profile is shown in Figure 6 and the cooling profile is shown in Figure 7. In the profile curves, the hour specified on the top horizontal axis denotes the hour from the start of the year.

It is noted that the heating and cooling profiles represent heating and cooling demand, not electric or fuel consumption. It should also be noted that these demands collectively reflect buildings served by the central heating and cooling systems; individual cooling systems such as the Plaza ice rink's glycol system or buildings with stand-alone systems such as the Executive Residence are not included or reflected in these profiles.

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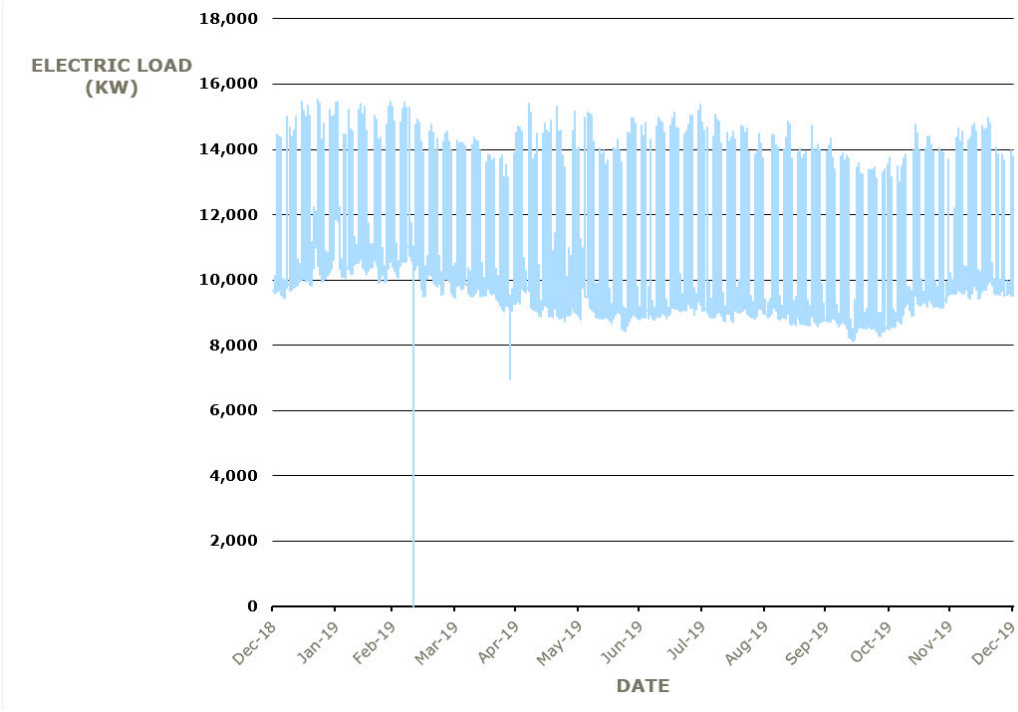

Figure 5. Current Hourly Electrical Demand

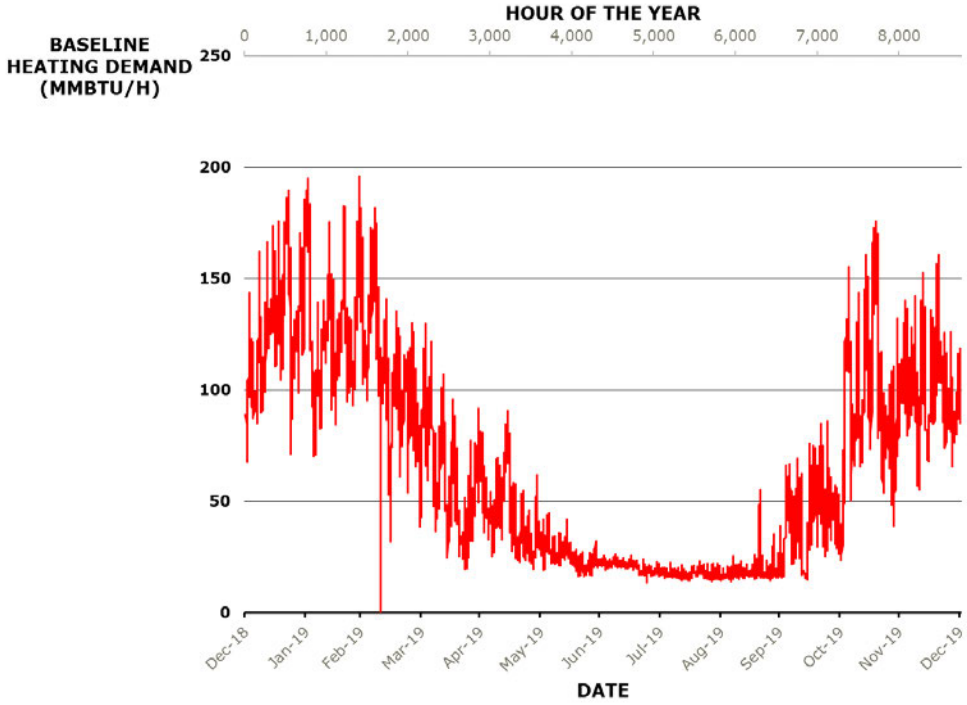

Figure 6. Baseline Heating Load Profile

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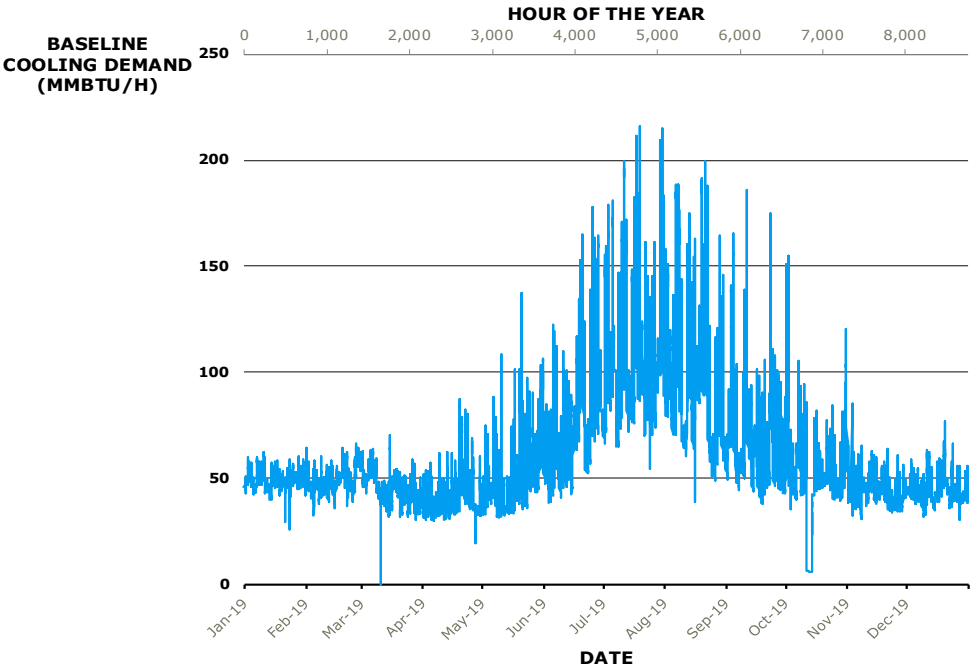

Figure 7. Baseline Cooling Load Profile

A.2 Existing GHG Emissions

A.2.1 GHG Emissions Overview

The Greenhouse Gas Protocol Corporate Standard, established by the World Resources Institute and the World Business Council for Sustainable Development, provides a framework for GHG accounting and reporting. It specifies how to measure an organization's carbon footprint, with three categorizations of emissions:

Scope 1 emissions are direct emissions from owned or controlled sources. This includes emissions generated from combustion in owned or controlled boilers, furnaces, vehicles, etc., as well as emissions from chemical production in owned or controlled process equipment.

Scope 2 emissions are indirect emissions from the generation of purchased energy, primarily electricity, but also any heating or cooling purchased by the organization. While the greenhouse gases from Scope 2 sources are not directly emitted on site, they are considered part of the organization's carbon footprint because the organization is using the energy whose production resulted in the GHG emissions.

Scope 3 emissions, which are not included in this analysis, are those generated by the Plaza's value chain.

Scope 1 and Scope 2 GHG emissions were calculated using the energy analysis results summarized in Section A.1.2, 2023 fuel consumption data provided for the Plaza's vehicle fleet, the CO_2 equivalent (CO_2e) conversion factors provided in the *NYPA Energy Savings Calculation and Cost Analysis Handbook, V3 Rev. 3 (April 2024),* as presented in Table 3, and CO_2 emission factors for vehicles from

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MOVES4, the U.S. Environmental Protection Agency (EPA) mobile source emissions factor model, as presented in Table 4.

Table 3. CO2e Emission Factors

Index	Energy Source	Units	Metric Tons CO2e per Unit
1	Electricity (NYC & Westchester)	kWh	4.02146 X 10^{-4}
2	Electricity (Long Island)	kWh	5.48535 X 10^{-4}
3	Electricity (Upstate NY)	kWh	1.24914 X 10^{-4}
4	Natural Gas	Therm	5.31100 X 10^{-3}
5	Steam	Mlb (kLb)	5.64400 X 10^{-2}
6	Distillate Fuel Oil (#s 1 and 2)	Gallon	1.02410 X 10^{-2}
7	Residual Fuel Oil (#s 4, 5, & 6)	Gallon	1.13025 X 10^{-2}
8	Diesel	Gallon	1.02410 X 10^{-2}
9	Gasoline	Gallon	8.50388 X 10^{-3}
10	Kerosene	Gallon	1.04882 X 10^{-2}
11	Propane	Gallon	5.91100 X 10^{-3}
12	District Hot Water	Therm	6.64000 X 10^{-3}
13	Chilled Water (From Elec Plant)	Ton-hr	6.32400 X 10^{-4}

Table 4. CO2 Emission Factors, Mobile Sources

Index	Mobile Source	Units	Metric Tons CO_2 per Unit[1]
1a	Gasoline, Light-Duty Vehicles	Mile	3.470 X 10^{-4}
1b	Gasoline, Light-Duty Trucks	Mile	4.430 X 10^{-4}
1c	Gasoline, Heavy-Duty Trucks	Mile	1.047 X 10^{-3}
2	Diesel, Heavy-Duty Trucks	Mile	1.438 X 10^{-3}

Notes:

1. MOVES4 data downloaded from the Bureau of Transportation Statistics, https://www.bts.gov/content/estimated-national-average-vehicle-emissions-rates-vehicle-vehicle-type-using-gasoline-and. Values presented are national averages for the 2023 calendar year. A detailed breakdown of fuel type and consumption by individual vehicle was not available. Vehicle electric consumption was not available.

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Scope 1 air quality pollutant emissions were calculated using the energy analysis results summarized in Section A.1.2, 2023 fuel consumption data provided for the Plaza's vehicle fleet, the air quality pollutant emission factors for stationary sources provided in EPA's AP-42, Compilation of Air Pollutant Emissions Factors from Stationary Sources, as presented in Table 5, and air quality pollutant emission factors for mobile sources from MOVES4, as presented in Table 6. Pollutants included in this analysis are nitrogen oxides (NOx), sulfur oxides (SOx), and particulate matter (PM). The factors presented below should be considered industry averages; actual air quality pollutant emissions can be difficult to quantify. All boilers at SASP were rebuilt between 2005-2008 and have low-NOx burners. Analysis of Scope 2 air quality pollutant emissions is beyond the scope of this project.

Table 5. Air Quality Pollutant Emission Factors, Thermal Energy

Index	Energy Source	Units	lb NO_x per Unit	lb SO_x per Unit	lb PM^1 per Unit
1a	Natural Gas – Large Wall-Fired Boilers (>100 MMBtu/hr input), Uncontrolled (Post-NSPS)	10^6 scf	190	0.6	7.6
1b	Natural Gas – Large Wall-Fired Boilers (>100 MMBtu/hr input), Controlled – Low NOx Burners	10^6 scf	140	0.6	7.6

Notes:

1. Total PM, inclusive of both condensable and filterable PM, estimated at less than 1.0 micrometer in diameter

The boilers utilized at SASP are equipped with controlled – low NOx Burners. Therefore, the calculations conducted in Section A.2.2 and shown in Table 7 utilize the emission factors listed in Index 1b given in Table 5 above.

Table 6. Air Quality Pollutant Emissions Factors, Mobile Sources[1]

Index	Mobile Source	Units	lb NO_x per Unit	lb SO_x per Unit[2]	lb PM per Unit[3]
1a	Gasoline, Light-Duty Vehicles	Mile	4.387×10^{-4}	-	8.818×10^{-6}
1b	Gasoline, Light-Duty Trucks	Mile	6.129×10^{-4}	-	1.323×10^{-5}
1c	Gasoline, Heavy-Duty Trucks	Mile	1.206×10^{-3}	-	4.630×10^{-5}
2	Diesel, Heavy-Duty Trucks	Mile	6.865×10^{-3}	-	1.433×10^{-4}

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Notes:

1. MOVES4 data downloaded from the Bureau of Transportation Statistics, https://www.bts.gov/content/estimated-national-average-vehicle-emissions-rates-vehicle-vehicle-type-using-gasoline-and. Values presented are national averages for the 2023 calendar year. A detailed breakdown of fuel type and consumption by individual vehicle was not available. Vehicle electric consumption was not available.
2. Emission factors for sulfur oxides were not available.
3. MOVES4 considers PM2.5 emissions.

A.2.2 Weather-Normalized Annual Emissions Summary

Table 7 and Table 8 present the complex's total annual Scope 1 and Scope 2 emissions, respectively, in metric tons of CO2 equivalent (MTCO2e) and pounds of air quality pollutants. Table 9 presents the total emissions associated with Empire State Plaza from Scope 1 and Scope 2 sources. The GHG pollutants seen in Table 7 are calculated from weather normalized annual energy use totals shown in Table 2. Weather normalized totals are based on actual energy use data from 2018-2020 as stated in Table 2.

Table 7. Scope 1 Emissions Summary

Weather-Normalized Annual Scope 1 Emissions[1] and Annual Air Quality Pollutants				
	GHG Pollutants	**Air Quality Pollutants**		
	$MTCO_2e$	**lb NO_x**	**lb SOx**	**lb PM**
Emissions from stationary combustion (e.g., nat gas, propane, diesel, coal)	78,675	207,391	889	11,258
Emissions from transportation	97	376	-	12
Scope 1 Total	78,772	207,767	889	11,270

Notes:

1. Weather normalized totals based on annual data from 2018, 2019, 2020

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Table 8. Scope 2 Emissions Summary

Weather-Normalized Annual Scope 2 Emissions[1]	
	GHG Pollutants
	$MTCO_2e$
Purchased electricity	14,699
Scope 2 Total	14,699

Notes:

1. Weather normalized totals based on annual data from 2018, 2019, 2020

Table 9. Scope 1 + Scope 2 Emissions Summary

	$MTCO_2e$	**lb NO_x**	**lb SO_x**	**lb PM**
Scope 1 Subtotal	78,772	207,767	889	11,270
Scope 2 Subtotal	14,699	N/A	N/A	N/A
Scope 1 + Scope 2 Total	**93,471**	207,767	889	11,270

A.2.3 Environmental Justice Impacts

Environmental justice addresses the fair treatment and meaningful involvement of all people, regardless of race, color, national origin, or income, concerning the development, implementation, and enforcement of environmental laws, regulations, and policies. The local-scale impacts of air pollutants highlight significant environmental justice issues, particularly in marginalized communities. This narrative explores the local impact of air pollutants on the health of the local population.

Marginalized communities often bear the brunt of air pollution due to their proximity to industrial zones, highways, and other pollution sources. Greenhouse gases, while contributing to global climate change, are often accompanied by other harmful pollutants like particulate matter (PM), nitrogen oxides (NOx), and volatile organic compounds (VOCs). These pollutants exacerbate respiratory and cardiovascular conditions. For instance, in neighborhoods near large emission sources, residents often experience higher rates of asthma, bronchitis, and other respiratory ailments. Children and the elderly are particularly vulnerable, leading to a cycle of poor health outcomes and increased healthcare costs. The negative impacts of air quality pollutants are discussed further in this section.

A.2.4 Local Disadvantaged Communities (DAC)

Using the federal Council on Environmental Quality's (CEQ) Climate and Economic Justice Screening Tool and the New York State Climate Justice Working Group's (CJWG) DAC map, Ramboll identified two

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DACs found within a half mile radius of SASP[6]. Figure 8 below shows these two DACs outlined in blue. The location of the SASP is indicated by a red dot. The race/ethnicity and age demographics of the DACs are given in Table 11 below. It is noted that in both the federal and state databases referenced, DAC 36001001100 boundaries correspond to census tract boundaries. DAC 36001000200 combines two census tract boundaries. The two identified tracts are considered disadvantaged because they meet the CEQ thresholds listed in Table 10.

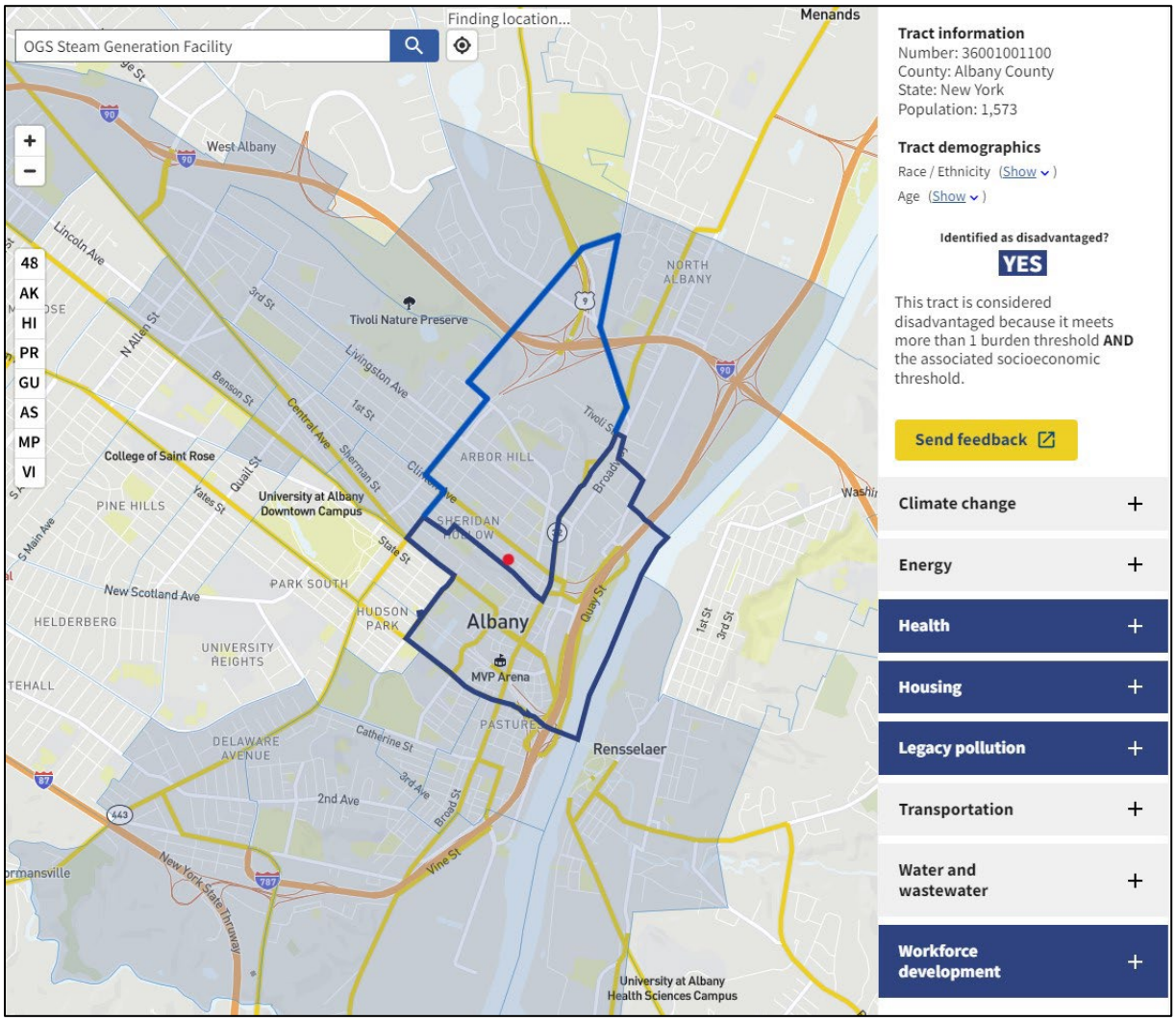

Figure 8. Search for DACs around Sheridan Ave Steam Plant (SASP), via the CEQ's Climate and Economic Justice Screening Tool

[6] SASP is the only major direct consumer of fossil fuels within the ESP complex and the largest emitter of air pollutants, hence why the plant was used as the central point in the radial projection.

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Table 10. DAC CEQ Thresholds Met

Census Tract Number	36001001100	36001000200
Threshold Category	**Threshold(s) Met**	
Climate Change	None	None
Energy	None	None
Health	Asthma (92nd percentile)	Asthma (97th percentile)
	Diabetes (96th percentile)	
	Heart disease (96th percentile)	
	Low life expectancy (92nd percentile)	
Housing	Lack of green space (90th percentile)	Historic underinvestment (Yes)
		Housing cost (94th percentile)
Legacy Pollution	Proximity to hazardous waste facilities (96th percentile)	Proximity to hazardous waste facilities (96th percentile)
	Proximity to Risk Management Plan facilities (94th percentile)	Proximity to Risk Management Plan facilities (94th percentile)
Transportation	None	None
Water and Wastewater	None	None
Workforce Development	Low median income (99th percentile)	Low median income (97th percentile)
	Poverty (96th percentile)	Poverty (92nd percentile)
	High school education (26%)	High school education (15%)

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Table 11: Tract Demographics

Census Tract Number	36001001100	36001000200
Demographics	**Percent of Population**	
White	47%	12%
Black or African American	33%	77%
American Indian or Alaska Native	0%	0%
Asian	4%	1%
Native Hawaiian or Pacific Islander	0%	0%
Other	2%	0%
Two or more races	5%	7%
Hispanic or Latino	9%	4%
Age Group		
Children under 10	4%	16%
Ages 10-64	75%	77%
Elderly over 65	20%	6%

Energy Impacts on the Local Community

Fossil fuel combustion necessarily releases air pollutants that are known to have negative impacts on public health. These include NO_x, SO_x, and PM, for which the Plaza's emissions estimates are given in Section A.2.2. The short-term, long-term, and cumulative impacts of exposure to these air pollutants are as follows:

Short-term impacts include respiratory complications, such as respiratory tract inflammation and shortness of breath, exacerbation of preexisting diseases, such as asthma and heart disease, and increased risk of lung infection.

Long-term impacts include chronic health conditions, especially respiratory and cardiovascular diseases, increased risk of lung infection, and reduced life expectancy.

Cumulative impacts include compounded health problems for individuals and for the community, economic problems, such as increased healthcare costs and declining workforce productivity, and damage to the environment, including production of acid rain.

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DACs are often disproportionally affected by air pollutants, the impacts of which are exacerbated by the other health, economic, and environmental challenges faced by the community. For individuals and communities who may already be struggling financially, as Table 10 suggests may be the case for the DACs adjacent to Empire State Plaza, the economic impacts described above can be especially burdensome.

As the complex evaluates its existing energy systems and prepares for the decarbonization transition, it is imperative to take advantage of emission control technologies, such as low-NO_x burners, consider alternative fuels, implement energy efficiency strategies, and engage the local community in order to minimize the negative impacts of the complex's on-site energy generation. Transitioning away from fossil fuels will be the most effective way to reduce the air quality pollution attributable to ESP in the immediate area. Section E.1.3 of this report quantifies pollution reductions that could be realized across multiple decarbonization scenarios and describes the outcome that such reductions could have on the surrounding communities. New York State's Climate Leadership and Community Protection Act (CLCPA) mandates that DACs receive at least 35% of the benefits of State spending on clean energy and energy efficiency.

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B – Facility Description

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Section B – Facility Description

B.1 Summary of Facilities

B.1.1 ESP Overview

The Empire State Plaza is a large complex located in downtown Albany, New York that serves as the hub of New York State's government. Covering approximately 98 acres, the site is comprised of numerous state government buildings, cultural institutions, and public spaces. The complex was designed in the early 1960s, with construction taking place from 1965 up until the complex's completion in 1978. Some buildings that are external to Empire State Plaza predate the complex, such as the Capitol and Alfred E. Smith Office Building.

A high-level summary of the complex's buildings and its utility aspects is as follows:

- 14 buildings within the Plaza – 10.4M gross square feet (GSF)
    - 13 buildings heated via steam from SASP – 6.8M GSF
    - 13 buildings cooled via chilled water from CACP – 6.8M GSF
    - 14 buildings fed power from main Plaza electric service - 10.4M GSF
- 7 buildings external to Plaza – 2.5M GSF
    - 5 buildings heated – 2.0M GSF
        - 3 buildings heated via steam from SASP – 1.9M GSF
        - 2 buildings heated via stand-alone natural gas service – 107,000 GSF
    - 4 buildings cooled – 1.9M GSF
        - 3 buildings cooled via chilled water from CACP – 1.9M GSF
        - 1 building cooled via building-level chiller – 30,000 GSF
    - 1 building fed power from main Plaza electric service – 30,000 GSF
    - 6 buildings fed power from separate utility services – 2.5M GSF

The only building within the Plaza that does not receive district heating & cooling is the East Parking Garage. The three buildings external to the Plaza that do receive district heating & cooling are the Alfred E. Smith Office Building (AESOB), the Capitol, and the Old Education Building[7]. The Executive Residence has stand-alone heating and cooling systems, but receives power from the main plaza distribution.

Table 12 and Table 13 list the specific buildings included within ESP and those external to the Plaza.

[7] The Old Education Building is owned and operated by the New York State Education Department (NYSED). All other buildings within and adjacent to the Plaza are owned and operated by OGS.

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Table 12. Buildings included within Empire State Plaza.

#	Building	Gross Square Feet
1	Legislative Office Building (LOB)	650,348
2	Justice Building (JOB)	261,177
3	Agency Building 1	198,196
4	Agency Building 2	198,196
5	Agency Building 3	198,196
6	Agency Building 4	198,196
7	Corning Tower	927,423
8	Cultural Education Center (Museum)	1,582,504
9	Health Department Laboratory	485,210
10	Meeting Center (The Egg)	159,362
11	Swan Street Office Building	842,727
12	Main Platform	3,878,694
13	Central Air Conditioning Plant (CACP)	144,261
14	East Parking Garage	715,610
	Total	**10,440,100**

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Table 13. List of buildings external to Empire State Plaza

#	Building	Gross Square Feet
15	Sheridan Avenue Steam Plant (SASP)	77,350
16	Sheridan Avenue Parking Garage	450,000
17	Riverfront Pump Station	15,471
18	Alfred E Smith Office Building (AESOB)	598,866
19	Capitol	572,025
20	Executive Residence	30,000
21	Old Educational Building[8]	750,000
	Total	**2,493,712**

B.1.2 Building Walk-Through Survey

Building walk-through surveys were performed at the Plaza focused on assessing existing conditions and evaluating current energy consumption profiles following methodologies for level 1 and level 2 audits outlined in ASHRAE's *Procedures for Commercial Building Energy Audits, Second Edition*.

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

In addition to walking through the buildings, interviews were conducted with facilities and maintenance staff to identify potential opportunities and deficiencies that might not be revealed through a physical survey. Facility staff provided their observations and perspective on the operation of the building and its

[8] Building is owned and operated by NYSED.

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energy systems, which enhanced the understanding of special problems, planned improvements, and maintenance issues and/or practices that impact energy usage. These findings are also documented in the BA reports.

Building walk-throughs and subsequent BA reports that were completed as part of the former ESP Energy Infrastructure Master Plan covered the following buildings:

- Agency Buildings 1 through 4
- Corning Tower
- Cultural Education Center (CEC)
- Health Laboratory
- Swan Street Building
- The Egg
- Justice Abrams Building (JOB)
- Legislative Office Building (LOB)
- Main Platform

BA reports summarizing these Plaza buildings are included in Appendix B of this report. Additional building walk-throughs and BA reports were completed in this effort for buildings excluded from the former report. These buildings are:

- Alfred E. Smith Office Building
- New York State Capitol
- Old Education Building

BA reports for these buildings, along with a matrix listing potential EEMs identified for each building, are presented in Appendix B of this report.

B.1.3 Energy Infrastructure

Central Heating Plant

All but one of the buildings within the Plaza and three of the seven off-site buildings are heated via district steam provided by SASP, which is located approximately half a mile from ESP and interconnected to the Plaza via underground utility tunnels. This district steam is provided to ESP buildings for space heating and domestic hot water (DHW) heating. Some buildings use the district steam directly in medium and low-pressure heating applications (e.g. steam coils), while others use the steam to generate building-level heating hot water via shell & tube heat exchangers.

SASP consists of six (x6) [redacted] high-pressure steam boilers. Each boiler is rated to produce superheated steam [redacted]. The boilers primarily fire on natural gas, but can also use No.2 fuel oil as a backup fuel which is stored in subterranean tanks. The six boilers were manufactured in 1967 and rebuilt between 2005-2008. The boilers operate year-round, generating superheated steam for the steam turbine chillers in CACP and distributing [redacted] steam out to the ESP buildings. Each of the boilers have been furnished with three (x3) 38 MMBtuh input, dual-fuel, low-NOx burners equipped with pneumatic actuators along with individual motorized valves. Each boiler is also equipped with a feedwater economizer on the flue gas outlet to increase boiler efficiency. Facility

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operators indicated that the boilers are typically run between 20% and 65% rated capacity. Boiler operation and/or staging is controlled via a local computerized boiler control system.

Central Cooling Plant

Similar to the central steam system, all but one of the buildings within the Plaza and three of the seven off-site buildings are cooled via district chilled water provided by the Central Air Conditioning Plant (CACP). All buildings within the Plaza feature 'blending stations' which utilize a decoupling valve with bypass and building-level pumps to pull CHW from the district loop. Some buildings outside the Plaza that receive district CHW feature plate & frame heat exchangers that generate isolated building-level CHW.

CACP is equipped with four (x4) steam turbine-driven centrifugal chillers and one (x1) electric centrifugal chiller. [redacted]
The steam turbine-driven chillers are original to CACP and are of 1960s vintage, while the single electric chiller was installed in 2021. [redacted]
Each chiller is tested every five years and are all currently in good condition with only minor signs of corrosion and infrequent leaks. [redacted] The CACP's chillers will run as needed and at a reduced capacity during this period to supplement the heat exchanger-served cooling loads. CACP operates to provide district CHW year-round, relying on mechanical cooling operations via the chillers and 'free' cooling operation via the plate & frame heat exchangers. [redacted]

[redacted]

ESP maintains a river water cooling system that operates under NYS Department of Environmental Conservation (DEC) SPDES Permit number NY0104060. The river water system extracts water from the Hudson River and returns it to the Hudson River at an elevated temperature. [redacted]
Although this river water is utilized by CACP's chillers and heat exchangers as a means of heat rejection,

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the water is entirely isolated and never comes into contact with the district chilled water or any other fluids that could cause contamination.

As briefly stated in Section A.1.3, ESP features a seasonal ice rink on the Plaza level that is supplied with a continuously circulating glycol system served by two reciprocating chillers. Heat rejection at the chillers' condensers is achieved via chilled water from the larger CACP chillers. The chillers are 25 years old and are equipped with R-22 refrigerant. As of January 1st, 2020, R-22 refrigerant has been banned in the United States due to its harmful effects on the ozone layer. As a result, the supply for R-22 is becoming low and will result in the R-22 stock price to rise exponentially, thus driving up regular maintenance costs on these chillers. Despite the chillers being 25 years old and using an outdated refrigerant, the system components including pumps and controls are in good condition and are well maintained.

Electrical

The Empire State Plaza electrical system is comprised of four (x4) 34.5 kV underground feeders [redacted] Each of the four feeders has a dedicated below-ground substation underneath the Plaza level. These substations provide N+3 redundancy, whereas each substation is capable of handling the peak load for the entire Plaza.

[redacted] Due to this level of redundancy, preventive maintenance is completed on a regular basis. As such, none of the equipment in the ESP is in urgent need of replacement.

[redacted]

[redacted]

B.2 Identification of Major Energy & Water Using Systems

B.2.1 Major Energy Using Systems

Table 14 lists all major energy using systems at ESP.

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Table 14. Major Energy Using Systems

Building	Existing System	Major Equipment	Fuel(s) Used	Capacity	Year Installed	Expected End-of-Life
Health Lab	AH-2	AHU	Electricity	60 HP	1974	Before 2026
Health Lab	AH-5	AHU	Electricity	60 HP	1974	Before 2026
Health Lab	AH-10	AHU	Electricity	60 HP	1974	Before 2026
Health Lab	AH-15	AHU	Electricity	75 HP	1974	Before 2026
CEC	AC-M-7	AHU	Electricity	75 HP	1976	Before 2026
CEC	AC-M-22	AHU	Electricity	60 HP	1976	Before 2026
CEC	AC-L-1	AHU	Electricity	75 HP	1976	Before 2026
CEC	AC-L-2	AHU	Electricity	75 HP	1976	Before 2026
CEC	AC-L-3	AHU	Electricity	75 HP	1976	Before 2026
CEC	AC-L-4	AHU	Electricity	75 HP	1976	Before 2026
Justice Office Building	AC-1	AHU	Electricity	60 HP	1972	Before 2026
Justice Office Building	AC-2	AHU	Electricity	60 HP	1972	Before 2026
Main Platform	AC-1-2	AHU	Electricity	125 HP	1970	Before 2026
Main Platform	AC-1-3	AHU	Electricity	75 HP	1970	Before 2026
Main Platform	AC-1-4	AHU	Electricity	60 HP	1970	Before 2026
Main Platform	S-1-10	AHU	Electricity	125 HP	1970	Before 2026
Main Platform	S-1-11	AHU	Electricity	125 HP	1970	Before 2026
Main Platform	S-1-12	AHU	Electricity	125 HP	1970	Before 2026
Main Platform	S-1-13	AHU	Electricity	150 HP	1970	Before 2026
Main Platform	S-1-14	AHU	Electricity	200 HP	1970	Before 2026
Main Platform	S-1-15	AHU	Electricity	150 HP	1970	Before 2026
Main Platform	S-1-16	AHU	Electricity	150 HP	1970	Before 2026

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Building	Existing System	Major Equipment	Fuel(s) Used	Capacity	Year Installed	Expected End-of-Life
Main Platform	S-1-17	AHU	Electricity	250 HP	1970	Before 2026
Main Platform	S-9-1	AHU	Electricity	125 HP	1970	Before 2026
Main Platform	S-9-2	AHU	Electricity	150 HP	1970	Before 2026
Main Platform	S-9-3	AHU	Electricity	150 HP	1970	Before 2026
Main Platform	S-9-4	AHU	Electricity	200 HP	1970	Before 2026
Main Platform	S-9-5	AHU	Electricity	100 HP	1970	Before 2026
Main Platform	S-9-6	AHU	Electricity	125 HP	1970	Before 2026
Main Platform	S-10-1	AHU	Electricity	150 HP	1970	Before 2026
Main Platform	S-10-2	AHU	Electricity	150 HP	1970	Before 2026
Main Platform	S-10-3	AHU	Electricity	150 HP	1970	Before 2026
Main Platform	S-10-4	AHU	Electricity	250 HP	1970	Before 2026
Main Platform	S-10-5	AHU	Electricity	150 HP	1970	Before 2026
SASP	Boiler 1	Boiler	Natural Gas	101200 MBH	Rebuilt in 2005-2008	2031-2035
SASP	Boiler 2	Boiler	Natural Gas	101200 MBH	Rebuilt in 2005-2008	2031-2035
SASP	Boiler 3	Boiler	Natural Gas	101200 MBH	Rebuilt in 2005-2008	2031-2035
SASP	Boiler 4	Boiler	Natural Gas	101200 MBH	Rebuilt in 2005-2008	2031-2035
SASP	Boiler 5	Boiler	Natural Gas	101200 MBH	Rebuilt in 2005-2008	2031-2035

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Building	Existing System	Major Equipment	Fuel(s) Used	Capacity	Year Installed	Expected End-of-Life
SASP	Boiler 6	Boiler	Natural Gas	101200 MBH	Rebuilt in 2005-2008	2031-2035
CACP	Chiller #1	Chiller	Steam	4500 tons	1960s	2040
CACP	Chiller #2	Chiller	Steam	4500 tons	1960s	2040
CACP	Chiller #3	Chiller	Steam	4500 tons	1960s	2040
CACP	Chiller #4	Chiller	Steam	4500 tons	1960s	2040
CACP	Electric Chiller	Chiller	Electricity	6000 tons	2021	Between 2040 and 2050
CACP	EDP Chiller 1	Chiller	Electricity	500 tons	2021	Between 2040 and 2050
CACP	EDP Chiller 2	Chiller	Electricity	500 tons	2021	Between 2040 and 2050
CACP	Pump #1	Distribution pumps	Electricity	500 HP	1960 (est.)	Before 2026
CACP	Pump #2	Distribution pumps	Electricity	500 HP	1960 (est.)	Before 2026
CACP	Pump #3	Distribution pumps	Electricity	500 HP	1960 (est.)	Before 2026
CACP	Pump #4	Distribution pumps	Electricity	500 HP	1960 (est.)	Before 2026
CACP	Pump #5	Distribution pumps	Electricity	500 HP	1960 (est.)	Before 2026
CACP	Pump #6	Distribution pumps	Electricity	500 HP	1960 (est.)	Before 2026

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Building	Existing System	Major Equipment	Fuel(s) Used	Capacity	Year Installed	Expected End-of-Life
AESOB	PAC-2	AHU	Electricity	75 HP	2003-2005	Before 2026
River pumping Station	Pump #1	Pump	Electricity	800 HP	1960 (est.)	Before 2026
River pumping Station	Pump #2	Pump	Electricity	800 HP	1960 (est.)	Before 2026
River pumping Station	Pump #3	Pump	Electricity	800 HP	1960 (est.)	Before 2026
River pumping Station	Pump #4	Pump	Electricity	800 HP	1960 (est.)	Before 2026
River pumping Station	Pump #5	Pump	Electricity	800 HP	1960 (est.)	Before 2026
River pumping Station	Pump #6	Pump	Electricity	800 HP	1960 (est.)	Before 2026

B.2.2 Major Water Using Systems

Major systems consuming water in HVAC processes include cooling towers, evaporative coolers, and boiler makeup water. Table 15 lists the major water using systems identified at the ESP complex. Since makeup water data was not available for each individual boiler, the annual makeup water usage was divided evenly between the six boilers. [redacted]

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[redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

B.3 Elements Unavailable for Decarbonization

Certain systems will be deemed too critical to be decarbonized through electrification or other means. The project team worked together to identify any such system at Empire State Plaza and determined that the complex's emergency backup generators are the only systems that fall into this category. Although the Plaza's existing heating network served by SASP is critical and would need to be operational during prolonged electrical outages, decarbonization of the plant via electrification could still be achieved so long as the plant maintained fully redundant fossil-fired heating assets.

B.3.1 Backup Power Generation

The complex has onsite [redacted] backup generators that provide power to SASP and individual buildings at the Plaza in the event of an emergency. [redacted] At the time of writing, these generators were offline and undergoing permitting and code compliance actions. Once operational, these emergency assets will ensure the operation of mission critical systems such as the central heating system, data center chilled water system, and building-level systems like fire protection, data centers, and laboratories.

Decarbonizing backup power generation presents unique challenges, outlined below, and will not be considered in the decarbonization plan.

1. Reliability Requirements: Backup power systems, such as diesel generators, are designed to provide immediate, reliable energy during power outages. While transitioning to alternative, low-carbon energy sources, reliability cannot be compromised, which limits the options available.
2. Intermittent Operation: Backup generators are not used continuously, but instead operate intermittently and often without much notice. This sporadic operation does not always align well with renewable energy sources, which are often dependent on specific weather conditions.
3. Energy Density and Storage: Fossil fuels like diesel have high energy density, making them efficient for storing large amounts of energy in a relatively small space. Decarbonized energy

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systems such as batteries or hydrogen fuel cells currently face challenges in terms of energy density and delivery at the scale required for effective backup power.

4. Economic Considerations: Decarbonizing backup power generation involves significant upfront investment in new technology and infrastructure. Many solutions are still in development or not yet cost-competitive with conventional systems, which can deter investment.
5. Infrastructure Compatibility: Transitioning to decarbonized backup power may require changes to existing infrastructure, which can be costly and complex, especially for facilities that are already built and operational.
6. Technological Maturity: Low-carbon alternatives to conventional backup power generation like battery storage and green hydrogen are still under development and may not be as mature or proven in terms of performance, especially for high-capacity and high-reliability needs.

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[redacted]

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C – Energy Efficiency

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Section C – Energy Efficiency

Energy audits were conducted to assess existing conditions of energy-using systems and identify opportunities for improving efficiency within the buildings. Twelve recommendations were analyzed in greater detail to quantify their potential impact on ESP's energy consumption and costs. This section outlines the methodology and results of the energy efficiency study.

The analyses of eight out of the twelve energy efficiency measures presented in this section were conducted in 2022. Thus, the original results for these measures were based on 2022 dollars. Costs presented in this section were escalated to 2025 dollars using the historical consumer price index (CPI) published by the United States Bureau of Labor Statistics[9].

C.1 Energy Efficiency

C.1.1 Building Walk-Through Survey and Gap Analysis

As mentioned in Section B.1.2, building walk-through surveys that were performed at ESP focused on assessing existing conditions and evaluating current energy consumption profiles following methodologies for Level 1 and Level 2 audits outlined in ASHRAE's *Procedures for Commercial Building Energy Audits, Second Edition*. Level 1 audits of the Plaza buildings included in Appendix B were conducted in the fall of 2021. As stated in Section B.1.2, additional Level 1 audits for three buildings outside of the Plaza were also conducted later in the summer of 2024.

C.1.2 Targeted Audits

Targeted audit (Level 2) efforts focused on building upon the results and findings from the Level 1 walk-throughs and EEM matrix. NYPA, OGS, and Ramboll identified the following measures for focus during the targeted audit survey, which was conducted in the spring of 2022:

- Replace Double Pane Windows
- Lab Exhaust Energy Recovery
- Laboratory VAV Exhaust/Supply
- Additional Zone Controls on FTR
- Laboratory DCV
- Replace Single pane Windows with High Performance Windows
- AHU Modernization
- Install Occupancy based HVAC Controls

OGS also identified that the Health Department Laboratory is planned to be relocated offsite to a new facility, with planning and design efforts already underway for the new facility. Based on discussions with OGS regarding expected timeline, the full relocation of the laboratory and subsequent renovation of the

[9] https://www.bls.gov/regions/mid-atlantic/data/consumerpriceindexhistorical_us_table.htm
2022 average CPI = 292.6
2025 estimated CPI = 320.8
9.61% inflation rate from 2022 to 2025

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existing space was assumed to be substantially complete by 2033. It was also assumed that the building will continue to be used at the Plaza after the relocation, but with an energy use profile more representative of an office building rather than a laboratory. Since the Health Department Laboratory is the largest energy consumer and most energy intensive building, lower energy use at the Plaza will be realized following the relocation. Energy savings associated with this relocation have thus been captured as a measure and are summarized in Section C.2.

Level 2 efforts for the three buildings outside of the Plaza occurred shortly after the initial Level 1 audits in summer of 2024. Measures of focus for these buildings were determined to be:

- Retro-Commissioning (RCx)
- Pump Differential Reset
- Pneumatic Control to DDC
- Steam Trap Program

C.1.3 Energy Savings Estimates

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

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

The utility costs previously presented in Table 2 are based on weather-normalized annual energy costs for electricity and fossil fuels that include blended commodity, delivery, demand charges, taxes, and other fees, represented in 2019 dollars as the weather-normalization period was 2018 through 2020. The values shown in Table 16 were used to estimate energy cost savings, simple payback, and savings to investment ratio (SIR) for each EEM analyzed. The analysis of the eight measures completed as part of the former ESP Energy Infrastructure Master Plan used utility rates that were escalated to 2022 dollars based on historical CPI[10]. The utility rates in 2025 dollars are also presented for comparison. These 2025 rates were used in the analysis of the remaining four measures completed as part of this effort.

[10] https://www.bls.gov/regions/mid-atlantic/data/consumerpriceindexhistorical_us_table.htm
2019 average CPI = 255.7
2022 average CPI = 292.6
14.45% inflation from 2019 to 2022

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Table 16. Energy Unit Costs Used in EEM Assessments

Fuel	Total in 2019 Dollars	Total in 2022 Dollars	Total in 2025 Dollars
Electricity	$0.056 $/kWh	$0.064 $/kWh	$0.070 $/kWh
Natural Gas	$0.374 $/therm	$0.428 $/therm	$0.469 $/therm

C.1.4 Energy Measure Cost Estimates

Material and labor cost data for the measures were derived from a variety of sources, including R.S. Means Company, Inc., Ramboll's in-house construction cost database, and various published papers and reports as referenced herein. In some instances, budgetary cost estimates were solicited directly from equipment suppliers. Cost estimates were normalized on a square foot basis and were applied to multiple buildings where appropriate. In addition to labor and materials, project specific contingencies were also applied. While the project approach did not include environmental testing or surveys, and costs related to environmental abatement have not been accounted for, contingencies for specific EEMs that may require this work have been appropriately adjusted. Future phases of the project should incorporate testing for environmental hazards, including lead, PCBs, and asbestos.

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

C.2 Energy Efficiency Measure Table

C.2.1 EEM Results

Appendix C contains detailed writeups for the measures developed as part of the targeted audit effort of the three additional buildings. Each measure writeup discusses the existing conditions (baseline), recommended actions, estimated energy savings, estimated project costs, and implementation considerations. Detailed assumptions, manufacturers literature, and other supporting documents are also included within the measure writeups. Appendix C also contains detailed EEM results from calculations performed as part of the former ESP Energy Infrastructure Master Plan, which target twelve of the Plaza buildings. Appendix D lists the EEM estimated project costs on a building-level basis.

A Life Cycle Cost Analysis (LCCA) was performed for each option based on the first costs developed for the project and annually recurring energy costs. The LCCA was performed over the expected useful life (EUL) of each measure. Annual escalation rates for the utility costs are based on a U.S. Department of Energy (DOE) rate schedule for commercial buildings in the State of New York (Annual Supplement to Handbook 135, Energy Price Indices and Discount Factors for LCC Analysis, NISTIR 85-3273). Annual

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maintenance cost savings are expected as a result of the EEMs. Labor savings were not included in the analysis as it is expected that they would be repurposed or redirected to other maintenance tasks. Annual costs are discounted back to year zero using a 3% discount rate. The savings to investment ratio (SIR) is calculated as the net present value of lifetime savings calculated from the LCCA divided by the first cost. A project is typically considered cost effective if the SIR is greater than or equal to 1.2. Additionally, BuildSmart 2025 considers measures cost effective if the simple payback (SPB) is 10 years or less or it has a 7% or greater internal rate of return (IRR).

Table 17 summarizes energy and economic results for these EEMs referenced in Appendix C . The EEM results generated for the previous ESP report mentioned above were calculated using 2022 dollars, while the EEMs targeting the additional three buildings were calculated using 2025 dollars. For comparison, Table 17 presents results in both 2022 and 2025 dollars where applicable. A total project summary table presented in Appendix F shows a more detailed summary of these EEM results together with the projected impacts of a decarbonization scenario, discussed later in Section E.1.

If all measures are implemented, the total implementation cost would be approximately $925.0 million with an aggregate simple payback period of 42.8 years, with cost of carbon included. Numerous capital-intensive projects for equipment and systems that are at or beyond their useful life increase the simple payback period of the entire package of measures. However, these projects can be justified from an infrastructure renewal perspective. For the equipment that is already due for replacement, one could argue to include only the EEM incremental cost for a high efficiency replacement, rather than the full replacement cost; that was not done here, but it would lower the simple payback considerably.

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Table 17. Summary of Energy Efficiency Measures (EEMs)

EEM	Measure Description[1]	Annual Energy Cost Savings (2022 $/yr)	Annual Energy Cost Savings (2025 $/yr)	Estimated Capital Cost (2022 $)	Estimated Capital Cost (2025 $)	Annual GHG Reduction (MTCO2e)	Cost of Carbon Savings (2025 $/yr)	Simple Payback (yr) including Cost of Carbon[2]
PL-EEM-2	Replace Double Pane Windows	$176,064	$192,983	$56,908,290	$62,377,011	1,612	$239,842	144.1
PL-EEM-4	Lab Exhaust Energy Recovery	$834,030	$914,178	$15,790,450	$17,307,866	9,092	$1,360,104	7.6
PL-EEM-5	Laboratory VAV Exhaust/Supply	$287,622	$315,262	$19,825,297	$21,730,450	1,346	$208,112	41.5
PL-EEM-7	Additional Zone Controls on FTR	$379,943	$416,454	$252,221	$276,458	3,581	$534,949	0.3
PL-EEM-8	Laboratory DCV	$270,665	$296,675	$1,487,166	$1,630,078	1,317	$203,472	3.3
PL-EEM Package	Package Results for EEM-1, EEM-3, EEM-6, and Repurpose of Health Lab	$7,352,579	$8,059,140	$747,509,773	$819,343,283	55,999	$8,470,307	49.6
EEM-1	Retro-commissioning	-	$36,859	-	$191,637	300	$47,930	2.3

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EEM	Measure Description[1]	Annual Energy Cost Savings (2022 $/yr)	Annual Energy Cost Savings (2025 $/yr)	Estimated Capital Cost (2022 $)	Estimated Capital Cost (2025 $)	Annual GHG Reduction (MTCO2e)	Cost of Carbon Savings (2025 $/yr)	Simple Payback (yr) including Cost of Carbon[2]
EEM-2	Pump Differential Reset	-	$9,483	-	$46,020	15	$2,365	3.9
EEM-3	Pneumatic Control to DDC	-	$132,083	-	$2,068,997	798	$127,682	8.0
EEM-4	Steam Trap Program	-	$16,128	-	$66,867	183	$29,206	1.5
Grand Total			**$10,389,246**		**$925,038,668**	**74,242**	**$11,223,970**	**42.8**

Notes:

1. PL-EEM-Package considers interactive effects among measures that were included in the energy model. Interactive measures for other individual energy savings calculations were not considered.
2. Based on a rate of $166 per metric ton of CO_2, estimated based on the New York State Department of Environmental Conservation (NYSDEC) document "Establishing a value of carbon" (Establishing a Value of Carbon) and escalated to 2025 dollars based on historical CPI.

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The packaged measure *PL-EEM Package* has the largest impact on energy savings and greenhouse gas reductions, as shown in Table 17. The portion of overall energy savings that each measure within the packaged EEM contributes is shown below in Figure 9. PL-EEM-3 AHU Modernization contributes to about 44% of the total package savings, while the repurposed health lab contributes to about 54% of the total savings. These two measures have a significant impact on reducing the heating and cooling plant loads.

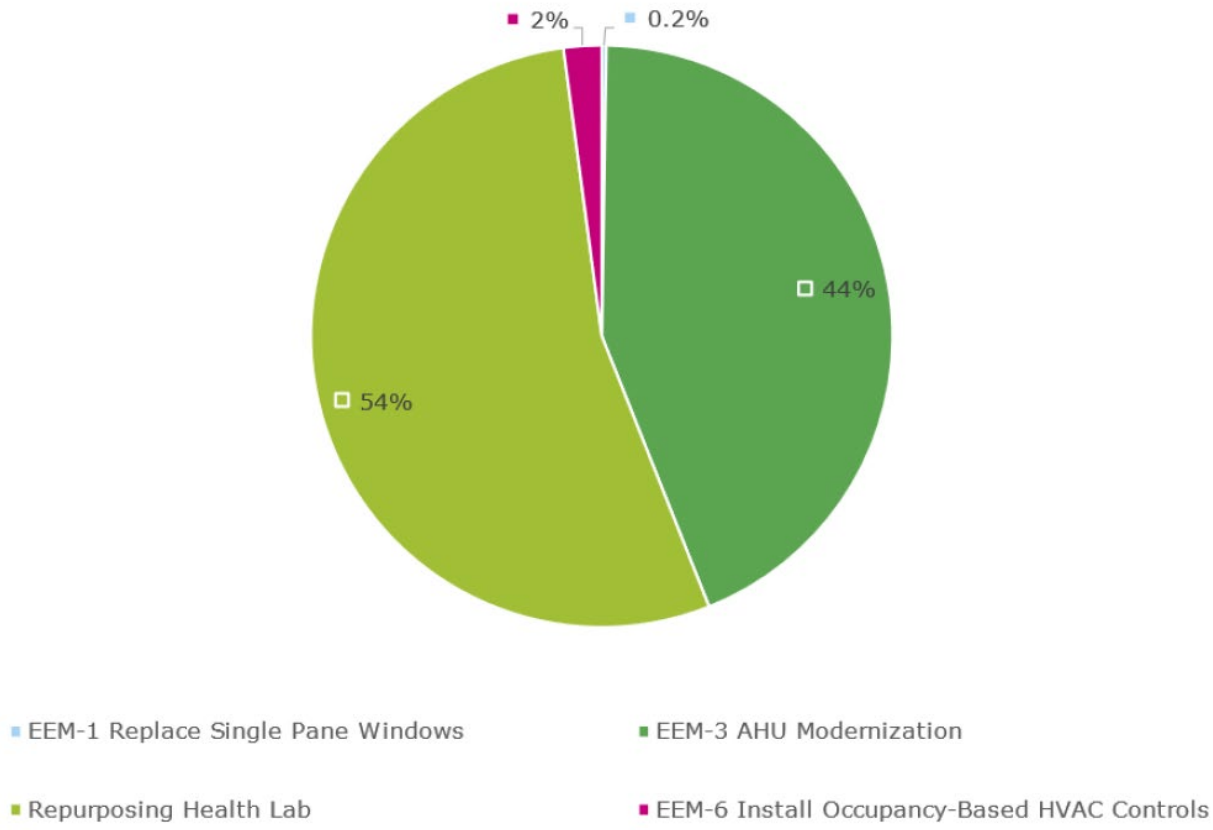

Figure 9. EEM contributions to PL-EEM Package savings

C.2.2 Measures Considered but Not Analyzed

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

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C.2.3 Operation & Maintenance

The Federal Energy Management Program's (FEMP) Operations & Maintenance (O&M) Best Practices[11] (*FEMP 2010*) document provides a tool for developing O&M strategies and benchmarking best practices against industry standards. Per the FEMP manual, O&M programs targeting energy and water efficiency can save from 5 to 20 percent of annual energy use without significant capital investment.

The BA reports identify several opportunities for energy and maintenance cost savings. A conservative estimate of 5% annual energy savings (equivalent to roughly $670,000 in annual cost savings in today's dollars) is considered achievable through the identified O&M strategies, including replacing missing piping insulation, repairing weather seals, addressing space temperature control and occupant behaviors, and reviewing program space needs.

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

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D – Thermal Energy and Thermal Energy Networks

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Section D – Thermal Energy and Thermal Energy Networks

This section presents a wide range of technical considerations for implementing decarbonization heating and cooling technologies. This includes a screening of available technologies, heat sources, and energy storage systems, as well as a preliminary assessment of necessary upgrades to building-level systems and electrical and thermal distribution networks, and an evaluation of the technical feasibility of eight potential decarbonization scenarios.

D.1 Thermal Energy Considerations and Screening

D.1.1 Future Energy Demands

The existing building loads were adjusted to reflect implementing EEMs presented in Section C.2. The EEM Package results, as presented and described in Section C.2, have a notable impact on existing building loads as that set of EEMs quantifies energy savings that would be realized from major renovation projects at the Plaza buildings. The Plaza buildings impacted by these renovations would be:

- Agency Buildings 1 through 4
- Corning Tower
- Cultural Education Center (CEC)
- Health Laboratory
- Swan Street Building
- The Egg
- Justice Abrams Building (JOB)
- Legislative Office Building (LOB)
- Main Platform

The relocation of the health lab to an offsite location, and subsequent repurposing of that space to a much-less energy intensive space type, is a major component of the EEM Package results and is reflected in the projected renovation considerations.

Table 18 summarizes the effects that the various measures, renovation projects, and relocation of the health lab have on overall energy demands, and compares the current demands to the future estimated use[12]. Since there are no new buildings anticipated for the Plaza, no additional cooling load is anticipated. The effects of implementing the EEMs described in Section C, along with performing full-scale building renovations and relocating the energy-intensive health lab, are significant and result in large decreases in overall energy demands. Cooling demand is anticipated to decrease by 62%, while heating is expected to decrease by 56%. Electricity use for purposes other than heating and cooling is estimated to decrease by 53%. The impact of electrification on heating and cooling will be assessed in Section D.

[12] This table summarizes current energy demands and projected future energy use for all of the Plaza buildings, plus the three external buildings served by the Plaza's thermal heating and cooling networks (Capitol, Old Education Building, AESOB).

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Table 18. Energy Conservation and Growth Estimates

Estimate	Cooling (MMBtu/yr)	Heating[1] (MMBtu/yr)	Electricity[2] (MWh/yr)
Current Annual Demand[3]	558,188	569,588	96,570
Additional Cooling Loads	0	N/A	N/A
Reductions from EEMs, Renovations, Health Lab Move	-348,279	-317,366	-51,356
Future Annual Demand	209,909	252,223	45,214
Percent Growth Over Current	-62%	-56%	-53%

Notes:

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

Future peak heating loads of each building to be served by the future heating network are estimated and shown in Appendix E . Note the peak demands in Appendix E represent the energy required for the end use; not the input energy, which considers equipment conversion efficiency and on-site distribution losses. Opportunities to improve thermal production are discussed later in this section.

Figure 10 shows the future hourly profile and load duration curve developed for total net heat demand (SH as well as DHW in both summer and winter) of the buildings that will be connected to the future heating network. Figure 11 shows the future cooling demand for the buildings connected to the future cooling network.

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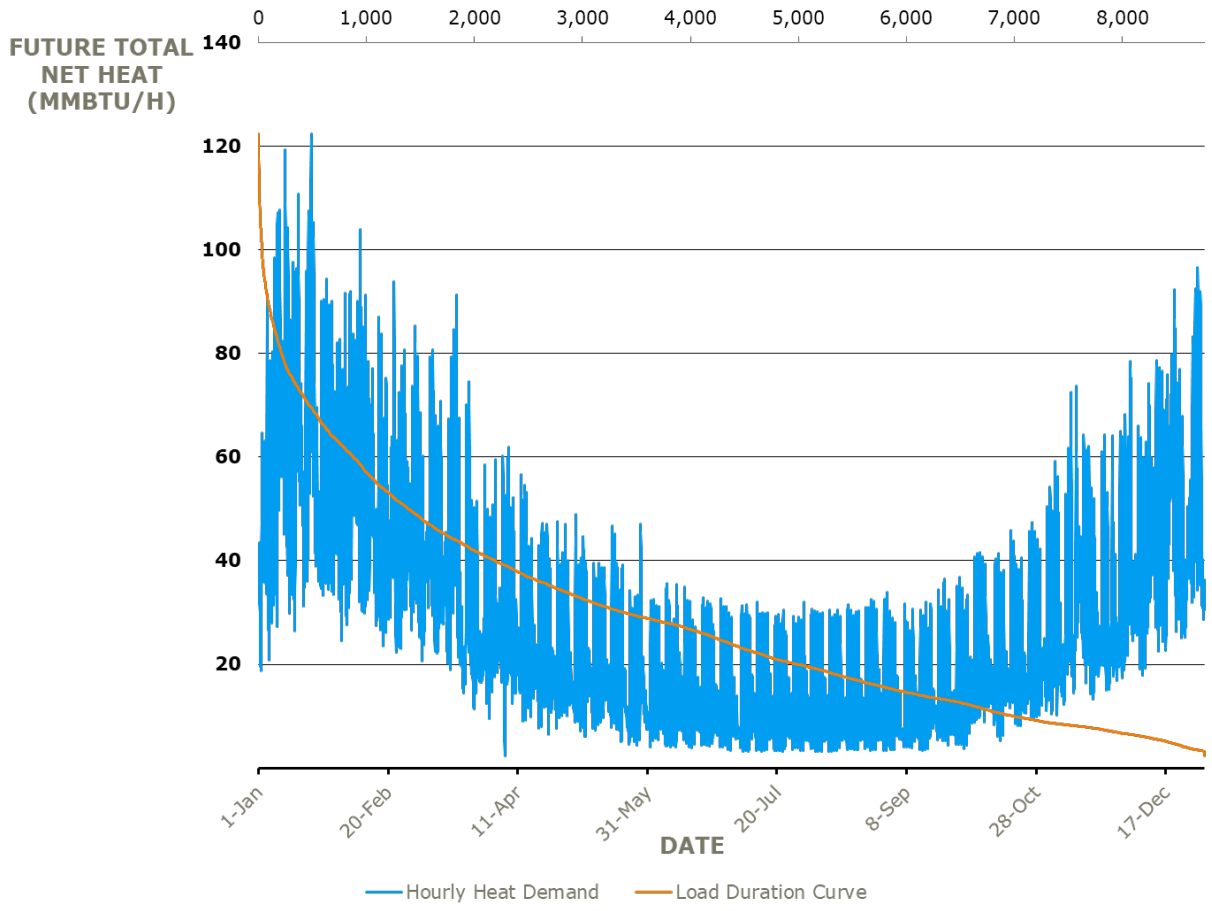

Figure 10. Future heat demand (SH + DHW)

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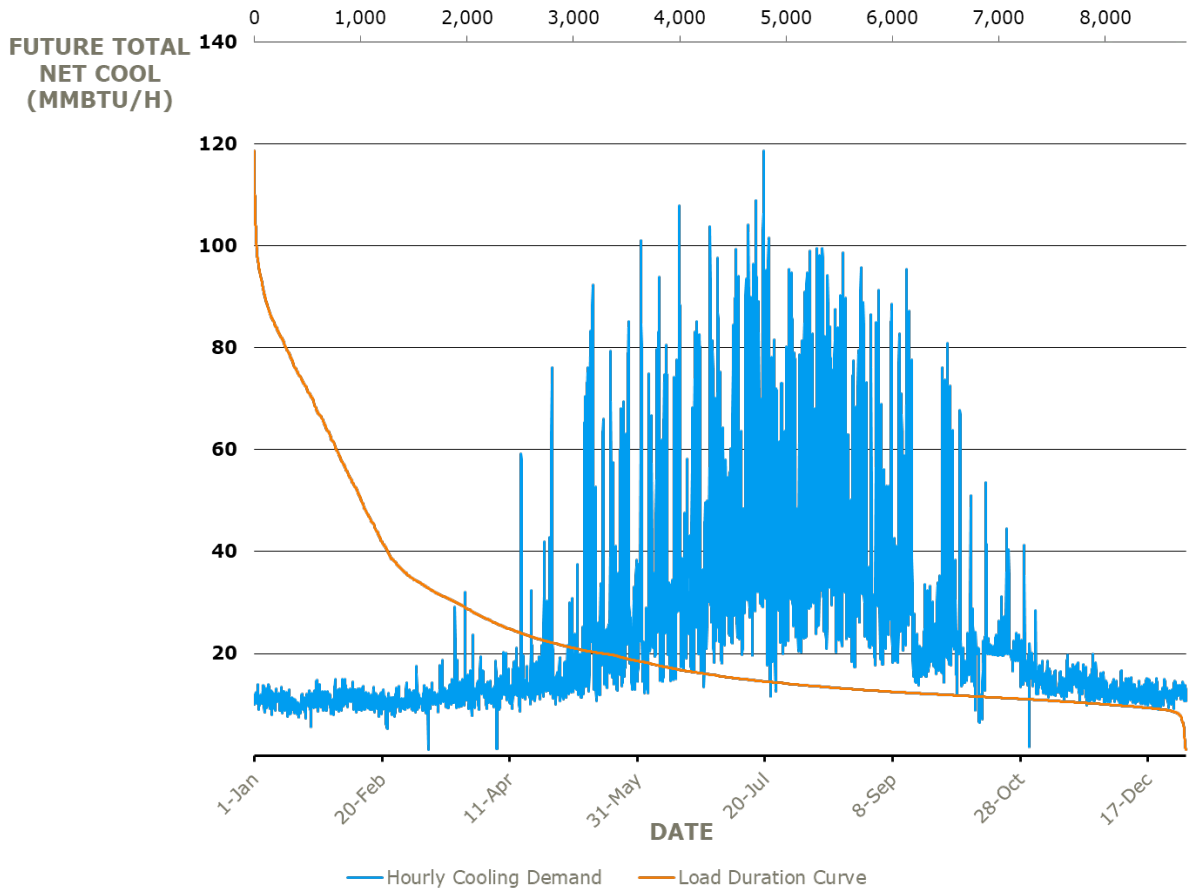

Figure 11. Future cooling demand

D.1.2 Diversity Factor

The peak heating demand in a centralized system will be lower than the sum of the peaks for all buildings since buildings do not have peaks in the exact same hour. The share between the peak heating demand in the central solution and the sum of the peaks in the individual solution is called the diversity factor and is typically estimated between 0.85 and 0.95 depending on the number of buildings. Accounting for the diversity factor provides an economic advantage for a central solution and means that the production capacity requirement in a central solution will be lower than the sum of building level demands. Figure 12 below illustrates the diversity factor for space heating as a function of the number of buildings according to different norms.[13]. However, consideration has been given for situations when a central plant trips offline during peak load by sizing the less expensive backup equipment with the capacity to meet the total of all individual building peak loads.

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

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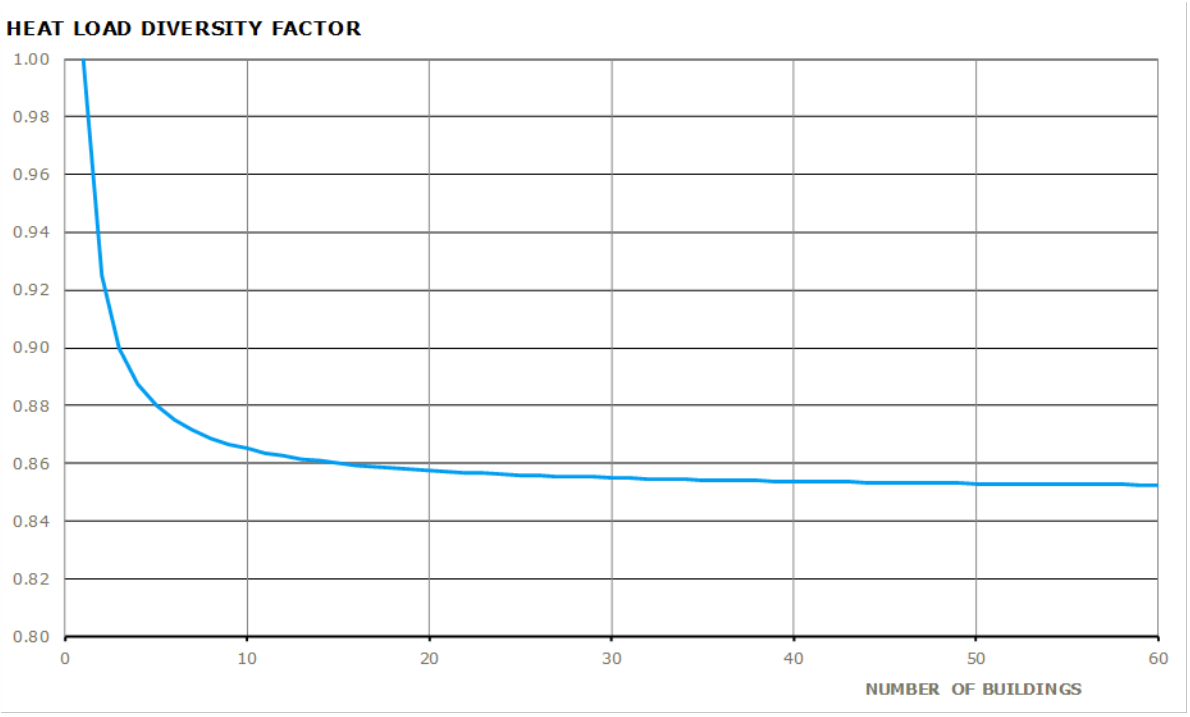

Figure 12. Diversity factor for space heating

D.1.3 Baseload, Peaking, and Backup

Baseload technologies for electrification strategies, such as heat pumps, generally entail high installation costs, particularly when designed for 100% of the peak heating demands. In contrast, peak load technologies, such as existing boilers, often incur limited or no installation costs if the equipment has significant life remaining. Utilizing boilers for peak load operation during the coldest times of winter can extend their technical lifetime due to limited annual operating hours during these peak periods.

Establishing dedicated baseload and peaking technologies is essential because peaking is only necessary during limited annual hours but requires high capacity (see Figure 13). Determining the optimal coverage of annual heat demand by baseload technology involves careful consideration and iterative optimization processes. However, aiming for the baseload to cover roughly 40% of the peak heating load, thereby covering approximately 90% of the annual heating load, is a sufficient approach for this level of study. Increasing the number of boreholes in a ground heat source system to cover nearly 100% load would be significantly more expensive than utilizing existing assets or lower-cost peaking technologies, like natural gas or electric boilers. This strategy provides resiliency through fuel diversification and capital cost management, allowing financial resources to be allocated to other projects effectively.

Backup heating production technologies are crucial in the event of grid outages. Heat production backup considerations are as follows:

- If baseload technology is electric, backup heat production should be based on another fuel, such as gas or oil boilers
- The backup technology should be highly reliable and have lower installation costs

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- The supply of the backup fuel should be non-interruptible and reliable
- The backup technology should be familiar to the operational staff, and adequate training should be provided

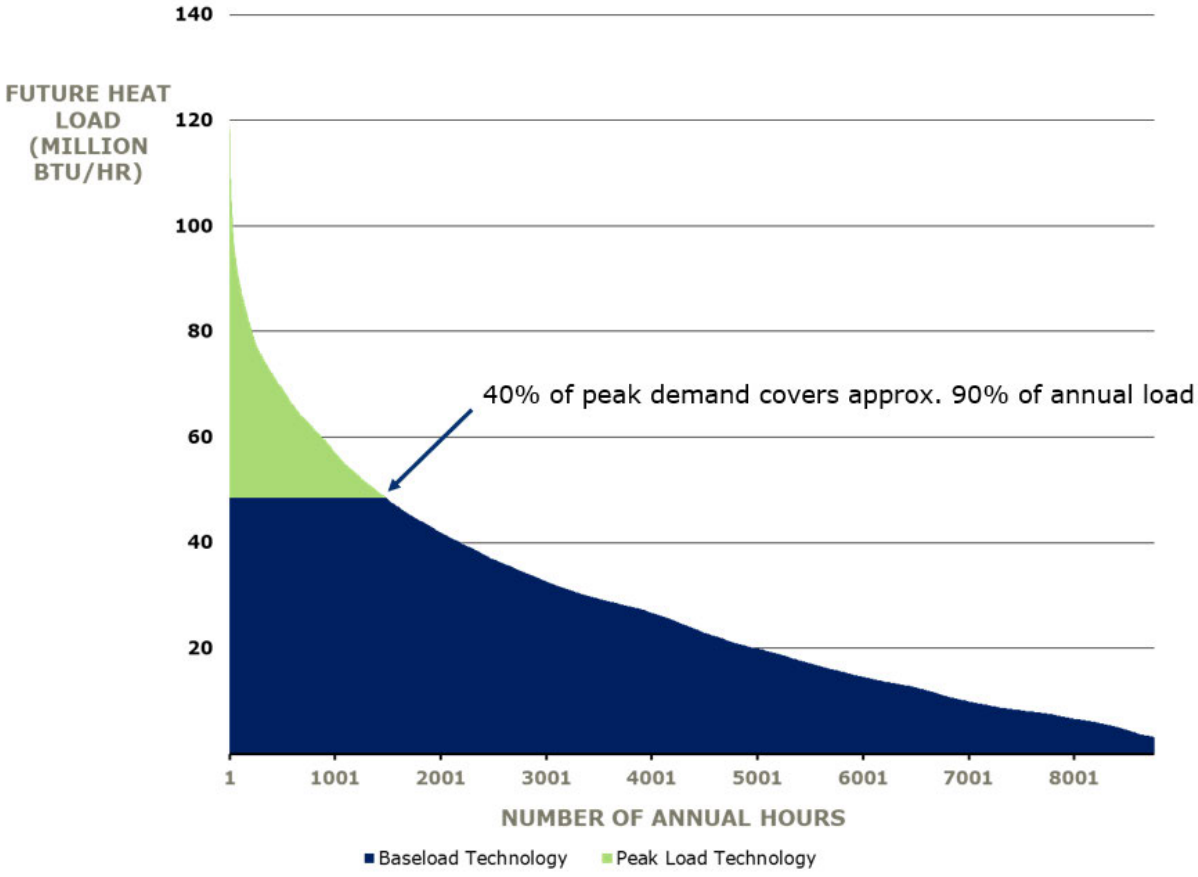

Figure 13. Heat Load Curve - Baseload and Peaking Illustration

D.1.4 Supply Temperature Considerations

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

Some heat pumps can produce hot water over 200°F, but these are less common and typically used in specialized applications. As of now, most industrial heat pumps readily available in the U.S. can produce hot water temperatures up to around 170°F. There are exceptions, and the market is also developing rapidly to include more multi-stage heat pumps and other refrigerant options that are more common in other parts of the world. High temperature heat pump offerings also tend to be available in larger sizes that are more applicable to centralized solutions rather than individual building scale, although expanded size offerings are a likely future development as well. Market offerings should be monitored within the timeframe for implementation of this study (refer to Section E.2.3).

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

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

D.1.5 Building Design Temperature Considerations

Steam is currently being supplied to most buildings at the Plaza for space heating and domestic hot water generation. Buildings at the Plaza that utilize this steam feature a steam to hot water heat exchanger(s) to generate 160°F – 190°F heating hot water. Since a heat pump efficiency increases through a reduction in supply temperature, consideration should be given to the optimal lowest temperature that could be reached, including reset of the setpoint for off-design conditions.

There should be a focus on increasing the delta T in the buildings, which will increase the overall energy system efficiency. New buildings should be designed for a low supply temperature (also higher delta T) at potentially 120°F to 140°F. For the Plaza buildings identified to undergo HVAC system replacements, it is recommended that those systems be designed for supply temperatures of 135°F or less and at design delta Ts of 30°F or more.

D.1.6 Building-Level Temperature Monitoring to Support Low Temperature Hot Water Transition

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

Although the buildings within the Plaza are recommended to undergo renovations and full HVAC system replacements (part of which would include new heating hot water systems at lower design temperatures), building-level temperature monitoring of the heating systems today could still prove to be advantageous. Temperature monitoring could also be useful for buildings adjacent-to or outside the Plaza that are currently on the district steam system but are not included in the EEM Package results proposing full HVAC upgrades. If OGS can monitor hot water supply and return temperatures of these buildings over the course of at least one heating season, the data could be used to define design parameters of the

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proposed heat pump solutions in addition to identifying coil retrofits that currently require higher supply temperatures. For example, if the data reveals that some of the buildings can meet design loads with a 140°F supply temperature (and reset lower for off-design conditions), but other buildings still require 180°F supply temperature on a design day, then it may be more cost effective and time efficient to prioritize those buildings with higher supply temperatures when initiating renovation or HVAC upgrade plans. Doing so will both get more buildings connected sooner to the new thermal system and enable the system to operate more efficiently at a lower supply temperature. Refer to Section E.2.1 for more details on where temperature monitoring would fall within the phased implementation plan.

Empire State Plaza has hot water supply and return temperatures in its building automation systems for all or most building hot water loops. It is unknown if the data is monitored or stored. In the case that the data are not monitored or stored, all building hot water supply and return points should be verified for accuracy and set up for trend data collection. It is important that the building hot water supply setpoints be set up for outdoor air temperature reset functionality as well. For a majority of the heating season, the supply temperature can be lower than the design point and heat pump capacity and efficiency will improve significantly.

The original building design hot water supply reset schedules can also be adjusted to optimize the reset, which is much more important for a heat pump application than for fossil fuel supply equipment. For example, the original reset schedule may call for adjusting the supply temperature from 180°F at 0°F outside air temperature down to 120°F at 60°F outside air temperature. This will improve heat pump performance as compared to a constant design supply temperature, but it is likely that the reset schedule can be adjusted and still meet building needs. For example, it may be found that a reset of 160°F at 0°F outside air temperature down to 110°F at 60°F outside air temperature provides sufficient coil capacity. The implications to a heat pump system design and operation are very important, so it is worth the effort of optimizing the reset schedules. A regular review (at least monthly through one heating season) of the data and reset schedule optimization by the Plaza's staff and/or outside energy consultants is recommended. Refer to Section E.2.1 for more details on where reset schedule optimization would fall within the phased implementation plan.

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

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

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D.1.7 Heating Supply Temperature Recommendations

Heat supplied from a central plant will be around 140°F at peak load and operate based on an outdoor air temperature reset schedule to reduce distribution temperatures as outdoor temperature rises, increasing overall seasonal efficiency. At a supply temperature of 140°F from the central plant and allowing for distribution losses and losses at building heat exchangers, building operating temperatures will be approximately 135°F or less. Most building-side heating systems at the Plaza are currently designed to meet the peak heating load with a range of 160°F to 190°F hot water, pending on the building.

As mentioned in Section D.1.1, all Plaza buildings that are served by district steam are recommended for renovations and full HVAC system replacements. Designing the new building HVAC systems to operate at a maximum hot water supply temperature of 135°F or less would enable compatibility with the proposed low-temperature hot water district, which will produce hot water at around 140°F at peak load. Implementing outdoor air hot water reset capabilities at each of the renovated buildings could further increase the efficiency of the hot water district. By linearly decreasing the hot water setpoints at the buildings as outdoor air temperature increases, the low-temperature hot water district could subsequently lower its respective hot water supply setpoint. Doing so would allow for central district-scale heat pumps to run at greater efficiencies, or coefficients of performance (COPs).

The typical meteorological year (TMY) weather data for Albany shows only 819 hours (9%) below 20°F outside air temperature, while the remaining number of ‘heating’ hours between 20°F and 60°F is 5,046 (58%). In the case of Empire State Plaza, implementing a hot water supply temperature reset control scheme at both the connected buildings and the central plant would enable the plant’s heat pumps to run at higher COPs for a great majority of the heating season when compared to a design COP assumed with producing 140°F hot water while outdoor air temperatures are at or below 20°F. An example supply temperature reset schedule illustrating this concept is given in Figure 14 below. The figure shows an outdoor air temperature of 30°F would require 130°F hot-water temperature. Albany TMY weather data shows approximately 1,854 hours, or 21% of the year, at or below 30°F outside air temperature (OAT).

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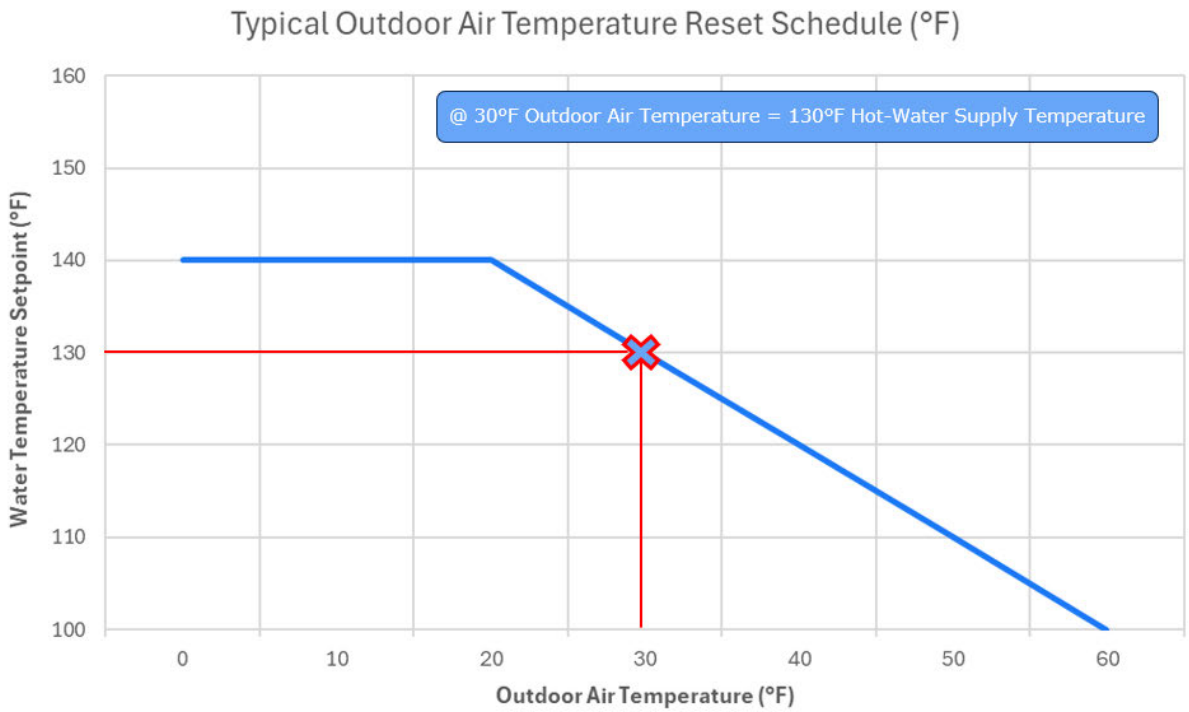

Figure 14. Example outdoor air temperature reset schedule

The overall capacity of a distribution network is dependent on the supply and the return temperature in the distribution system. Among the Plaza buildings, there are differences in the required heat to each building and each building's ability to reduce the temperature of that supplied heat (delta T). Buildings with a low heat demand and a higher delta T will have a low influence on the overall delta T in the distribution network, whereas buildings with a high heat demand and low delta T will have a high influence on the overall delta T. When building renovations are planned, focus should be on the buildings with a high influence on the overall distribution system delta T. Often it may only be necessary to concentrate on a limited number of buildings. This could be assessed through further hydraulic modeling in subsequent phases.

Furthermore, high return temperatures can limit the contribution heat pumps can make to the heating load at higher supply temperatures. If the return temperature at design conditions exceeds the maximum heat pump supply temperature, then the heat pump could not operate, and the peaking technology would need to meet the design load independently. This would have a major impact on peaking technology design capacity and, for electric peaking, required electrical infrastructure requirements. It is possible that NYISO Class Year limits.[14] or regional capacity limits may become an issue. Further evaluation, investigation and testing are recommended for buildings which have a high influence on the delta T.

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

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D.1.8 Building upgrade/modification considerations

The EEM calculation 'PL-EEM Package' described in Section C involves the renovation and full HVAC system replacement of all major buildings at the Plaza. This HVAC system replacement would include replacing existing building-level steam and hot water heating systems with low-temperature hot water systems operating at supply design temperatures of 135°F or less and at temperature deltas of 30°F or more. Implementing this measure across all identified buildings at the Plaza would ultimately enable compatibility of those buildings' respective heating systems with a central low-temperature hot water thermal energy network.

As described in Section B.1.1, there are three buildings that currently receive district steam and chilled water despite being outside of the Plaza: the Alfred E. Smith Office Building (AESOB), the Capitol, and the Old Education Building. These buildings were not considered in the 'PL-EEM Package' calculation that involved renovations and HVAC system replacements. For compatibility with a 140°F hot water district, actions that are summarized below will be required for each building:

Alfred E. Smith Office Building (AESOB)

Existing Condition
All of the zone/perimeter heating systems currently serving AESOB are hot water-based. All air handling unit and fan coil unit heating coils, however, are steam based and use low-pressure steam (LPS) directly. Domestic hot water (DHW) generation uses LPS. The hot water zone and perimeter heating systems feature automatic outdoor air hot water resets.

Recommendation
Replace AHUs and FCUs with low-temperature hot water heating equivalents over time, as the existing assets begin to surpass their respective end-of-useful-lives. Test and/or modify the existing hot water reset controls to assess if the zone heating systems can operate at a ~135°F upper-limit setpoint. Replace these systems over time as needed if it is determined that these systems cannot operate at a lower design temperature. Replace DHW equipment with low-temperature hot water-based equivalents, or independent electric-based equivalents, over time as the existing assets begin to surpass their respective end-of-useful-lives.

Capitol

Existing Condition
A large majority of the zone/perimeter heating systems and AHU/FCU coils are steam based, using LPS directly. Some AHU heating coils and a radiant floor loop utilize hot water systems that have automatic supply temperature resets. These reset controls linearly decrease hot water supply setpoints from a maximum 170°F at 10°F outdoor air temperatures down to 80°F at 60°F outdoor air temperatures. DHW generation uses LPS.

Recommendation
Replace AHUs, FCUs, and zone/perimeter heating systems with low-temperature hot water heating equivalents over time, as the existing assets/systems begin to surpass their respective end-of-useful-lives. Test and/or modify the existing hot water reset controls to assess if the zone heating systems can operate at a ~135°F upper-limit setpoint. Replace these systems over time as needed if it is determined

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that these systems cannot operate at a lower design temperature. Replace DHW equipment with low-temperature hot water-based equivalents, or independent electric-based equivalents, over time as the existing assets begin to surpass their respective end-of-useful-lives.

Old Education Building

Existing Condition

There is no direct-use of steam for heating purposes at this building; heating hot water is used at the building and generated via shell & tube heat exchangers from the district steam. All AHUs either feature hot water heating coils or are cooling-only units. All zone/perimeter heating systems are also hot water-based. Setpoints of these hot water systems are typically manually reset on a seasonal basis. DHW generation uses LPS.

Recommendation

Implement automatic outdoor air hot water resets for all heating systems in the building. Test and/or modify the existing hot water reset controls to assess if the heating systems can operate at a ~135°F upper-limit setpoint. Replace these systems over time as needed if it is determined that these systems cannot operate at a lower design temperature. Replace DHW equipment with low-temperature hot water-based equivalents, or independent electric-based equivalents, over time as the existing assets begin to surpass their respective end-of-useful-lives.

Cost Estimates

The budgetary cost estimates for building upgrades as described above are shown in Table 19. The cost estimate covering the renovations of the Plaza buildings was initially calculated in the previous ESP report in 2022 dollars and is thus escalated to 2025 dollars in Table 19. This initial $1,000M cost consisted of two components: Plaza building renovation costs as priced out by Trophy Point and renovation costs associated with the relocation of the Health Lab. The former of the two components is captured as energy efficiency measure ‘PL-EEM Package’ and was estimated at a total cost of $747.5M, which was subsequently rounded up to $800M given the scale of costs and complexities anticipated for the effort. Appendix G contains these original Trophy Point cost estimates. The latter of the two components was not priced out by Trophy Point, but rather collectively determined by OGS and other project stakeholders during the former ESP project. This cost was estimated to be $200M in 2022 dollars. Together, the two components are estimated to total $1,096.1M after escalating to 2025 dollars.

The total cost estimate covering the scope of work associated with targeted coil replacements, equipment replacements, and other associated HVAC upgrades for the three buildings external to the Plaza was determined to be $259.8M in 2025 dollars. Ramboll leveraged pricing data from the Plaza building renovation cost estimates completed by Trophy Point, and together with findings from the building walkthroughs of these three buildings was able to project a budgetary cost estimate for this effort.

The recommended renovation and full HVAC system replacement of the Plaza buildings (as quantified in the packaged EEM) brings most of the building stock down to building-level hot water design temperatures of 130-135°F, which would achieve compatibility with the future low-temperature hot water district. Targeted coil and other equipment replacements (in addition to hot water reset optimization) would bring the remaining three building outside of the Plaza down to the target 130-135°F hot water design temperatures. Additional details of these building upgrades are provided in Appendix D .

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Table 19. Building modifications budgetary cost estimate for 130°F supply temperature

Modification	Cost, 2022 USD	Cost, 2025 USD
Plaza Building HVAC Renovations	$1,000.0M	$1,096.1M
Targeted Coil/Equipment Replacements	-	$259.8M
Total	**-**	**$1,355.9M**

Overall, it would cost $1,355.9M for ESP to operate with a 130-135°F building-level hot water supply design temperature. These upgrades would enable compatibility with a 140°F low-temperature hot water district. At that design supply temperature, a wider-array of market available heat pumps would be able to sufficiently serve the network while operating at improved COPs, as previously noted in Section D.1.4. Refer to Section E.2.1 for when implementation of these building upgrades will occur over the phased project timeline.

D.1.9 Piping materials considerations

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

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

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

D.1.10 Energy transfer stations in buildings

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

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

Due to the approach temperatures of the heat exchanger, an indirect connection requires slightly higher central supply and return temperatures than a direct connection, which minimally impacts heat pump performance.

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

The ETS itself would come as a prefabricated packaged unit solution and depending on the heating demand, will look similar to the unit in Figure 15. A skid mounted unit is suitable for larger demands; for smaller demands, a wall mounted ETS will be more suited.

Figure 15. Typical ETS installation (source: Danfoss)

D.2 Technical Screening

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

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

The following subsections document the options considered for each technology category. Each aspect in the table is rated on a scale from 1 to 5 to assess the performance of the technology. The rating scale is based on subjective evaluations influenced by previous project experiences, research findings, site conditions, and specific requirements. These subjective ratings help to compare and evaluate different technologies based on their performance across various factors such as:

CO2 Neutrality: This rating reflects the extent to which the technology contributes to reducing greenhouse gas emissions. A score of 5 denotes excellent CO2 neutrality, indicating the technology significantly minimizes carbon emissions, while a score of 1 indicates the technology has higher CO2 emissions.

CAPEX: Capital Expenditure (CAPEX) measures the initial investment and costs required to acquire and set up the technology. A score of 5 represents low CAPEX, meaning the technology requires minimal upfront investment, whereas a score of 1 signifies high CAPEX, indicating substantial initial costs.

OPEX: Operational Expenditure (OPEX) refers to the ongoing costs to operate and maintain the technology. A score of 5 denotes low OPEX, indicating cost-efficiency in operational expenses, while a score of 1 signifies high OPEX, meaning the technology incurs significant ongoing costs.

System Integration: This rating signifies how seamlessly the technology can be integrated into the existing energy infrastructure. A score of 5 represents excellent compatibility and ease of integration, ensuring smooth incorporation into the current system, while a score of 1 indicates significant challenges and difficulties in integration.

Conclusions on which specific technologies to proceed with were ultimately made in each technology category during the screening process held with OGS and NYPA in the previous Energy Infrastructure Master Plan effort.

D.2.1 Fossil Fuel Technologies

Table 20 shows the relevant fossil fuel technologies and the result from the screening process:

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Table 20. Technology Screening Process, Fossil-Based Technologies

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

The fossil-based technologies are mentioned in the left column of Table 20 above. The topmost row of the table contains different characteristics or criteria of the technologies in which each technology was evaluated and subsequently scored against on a scale of 1 to 5, with 5 being the best performance. To qualitatively assist in the evaluation of the technologies, color coding is utilized where red is a "low score" and green is a "high score". For example, all technologies in Table 20 have a low score for "CO2 Neutrality" since they are fossil-based. The technology "Gas Boiler" has a high score when evaluated for CAPEX (capital expenditures, i.e. upfront installation/construction costs and material costs) since the CAPEX associated with installing a gas boiler system is relatively low in comparison to some other technologies. The column titled "System Integration" considers different characteristics for the technologies (e.g., support to the local energy system [e.g., peak / backup], integration with electricity market, space requirements, potential regulatory impact, etc.). All scores are based on a qualitative evaluation.

As seen from Table 20, only natural gas-fired and fuel oil-fired boilers will continue to the subsequent phases. This is primarily due to their ability to act as reliable and effective peaking and/or backup heating assets, as mentioned previously in Section D.1.3. While both types of boilers would still contribute to carbon emissions if implemented, use of these assets is limited, as mentioned previously in Section D.1.3.

D.2.2 Renewable Source Technologies

Table 21 shows the relevant renewable source technologies and the result from the screening process:

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Table 21. Technology Screening Process, Renewable Sources

Technology	Notes	CO2 neutrality	CAPEX	OPEX	System integration	Go Forward
Bio-oil fired turbine (simple cycle)	- Base load technology - High CAPEX - Very high OPEX	4	2	1	3	No
Bio-oil engines	- Base load technology - Very high OPEX	4	2	1	4	No
Biomass ORC CHP, wood chips	- Relatively high CAPEX - Low OPEX - Unreliable fuel availability	4	1	4	3	No
Biomass ORC, wood pellets	- Relatively high CAPEX - High OPEX - Unreliable fuel availability	4	1	2	3	No
Biomass boiler, wood chips	- Low CAPEX - Low OPEX - Unreliable fuel availability	4	4	4	5	No
Biomass boiler, wood pellets	- Low CAPEX - High OPEX - Unreliable fuel availability	4	4	2	5	No
Bio-oil boiler	- Low CAPEX - High OPEX	4	5	2	5	Yes
Photovoltaics	- Intermittent source / need backup from grid - Limited production winter / high in summer	5	2	5	3	Yes
Wind turbine	- Low CAPEX - Need backup from grid	5	2	5	3	Yes
Biogas production - anaerobic digester	-High CAPEX / OPEX	5	1	2	2	No
Large Solar Thermal	- High CAPEX - Limited production in winter / high in summer	5	1	5	3	No
Boiler, hydrogen	- High CAPEX / OPEX	4	1	1	1	No
Cogeneration, hydrogen	- High CAPEX / OPEX	3	1	1	1	No
Blue Hydrogen	- Derived from n-gas and produced from fossil fuels - CO2 is captured in a CCS process and stored	4	1	1	2	No
Green Hydrogen	- Produced from electrolysis - Electricity is based on renewable electricity	5	2	1	2	No

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Technology	Notes	CO2 neutrality	CAPEX	OPEX	System integration	Go Forward
Run of river - underwater turbine	- Limitation in electricity production - Fully developed?	5	2	1	2	No
Rooftop solar thermal		5	3	4	3	No

As noted in Table 21, the following technologies continued to the scenario planning phase:

- Bio-oil boilers
- Photovoltaics
- Wind turbine

The bio-oil boiler technology could be implemented either through conversion of existing boilers or as a new asset. Bio-oil boilers could be considered a low-carbon alternative for peaking and back-up LTHW generation. Bio-oil boilers are a relatively low CAPEX asset, however the OPEX costs would likely be high (much higher than fossil fuels) due to the high cost of bio-oil.

Large scale photovoltaics have already been considered offsite, but may also have limited viability for onsite generation (as summarized later in Section F.1). While the limited amount of open space at the Plaza limits the potential for onsite wind turbines, the technology may be considered for offsite opportunities.

An underwater turbine concept was evaluated for placement in the Hudson River, though was later deemed unviable due to current velocities being lower than required for adequate generation.

Though technology is advancing in the utilization of “green” hydrogen, which can be derived through electrolysis of water using renewable energy, this hydrogen variant is not considered energy efficient, nor cost-effective for low-temperature heating applications, where well-established and more efficient solutions already exist. “Grey” and “blue” hydrogen were also screened out, as they are both derived from natural gas, with higher CAPEX, OPEX and environmental footprint. Hydrogen was evaluated both as a combustible fuel in boilers and cogeneration applications, as well as fuel cell technology.

Large-scale solar thermal technology was evaluated though excluded from further analysis as production potential would be very limited in winter months and not easily utilized in higher production summer months. Additionally, this technology would require large amounts of space which is not available onsite.

The utilization of biomass ORC and heat only boilers (using wood pellets or chips) were screened out as well as bio-oil fired turbines and engines and biogas from anaerobic digestion. Uncertainty on local fuel availability was the primary factor behind the screening out of the biomass technologies and biogas, while relatively high CAPEX and OPEX drove the decision to screen out the bio-oil fired turbines and engines.

D.2.3 Electrification Technologies

Table 22 shows the relevant electrification technologies and the result from the screening process. Most are heat pumps (HPs) with different capacities (single building or central) and different heat sources (wastewater, air, or ground).

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Table 22. Technology Screening Process, Electrification Technologies

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

As noted in Table 22, the following technologies continued to the scenario planning phase:

- Electric boiler
- HP (air-to-water) – large scale

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- GSHP closed-loop, vert
- GSHP open-loop, deep geothermal
- HP (sewage water-to-water)
- Heat recovery chillers, electric
- Chillers, electric

The following were screened out:

- HP (air-to-water) – small scale: Preference for centralized decarbonization over building-by-building.
- Closed loop horizontal geothermal: vertical borehole arrangements are more suitable due to lack of available space required for horizontal loop systems. Additionally, vertical boreholes reach deeper depths, where the soil temperature is more constant and results in higher performance of the GSHP compared to shallow horizontal loops.

D.2.4 Ground Source Heat Pump Boreholes & Borehole Thermal Energy Storage

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

Number of Boreholes

The analysis to estimate the number of boreholes was completed prior to the 500-ft test bore being drilled and the thermal response test being completed. At the time of the analysis the following assumptions were made.

The boreholes for the ground source heat pumps are assumed to have a depth of 800 ft. The average heat extraction rate was assumed to be 45 Btu/h per foot of borehole. The resulting heat extraction per 800-foot borehole was assumed to be 36 MBH.

In the ground source heat pump scenarios, the ground source heat pumps are sized so that, together with the heat capacity of the heat recovery chillers, these two technologies can cover the baseload of the heat demand, i.e., about 48 MMBtu/h. The ground source heat pump should then be sized for a capacity on the evaporator side (borefield side) of 2850 tons (i.e., 34 MMBtu/h).

Given the heat extraction capacity mentioned above, approximately 900 boreholes were anticipated. Assuming a spacing between the boreholes of 20 ft, the total borefield area is about 360,000 square feet, or 8.4 acres (see Figure 16).

On August 15, 2023 a test borehole was drilled and a thermal response test was also performed on the 499-ft well with a Rygan heat exchanger. The results of the analysis were compared against the assumptions that were made at the time of the analysis. While the 499-ft well is less than the assumed

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depth of 800-ft, the results of the 499-ft well gave confidence that the assumptions made were valid or conservative in nature.

Potential Borefield Location

The borefield should be located as close as possible to the site to reduce the length of connection pipes between the borefield and the ground source heat pumps.

Because the lifetime of the boreholes is quite long (in the order of 40-50 years), these should be ideally located in areas where the surface is not expected to be disturbed in the future. Based on these considerations, the borehole field was assumed for this project to be located in nearby Lincoln Park, as shown in Figure 16 which would require coordination with the City of Albany.

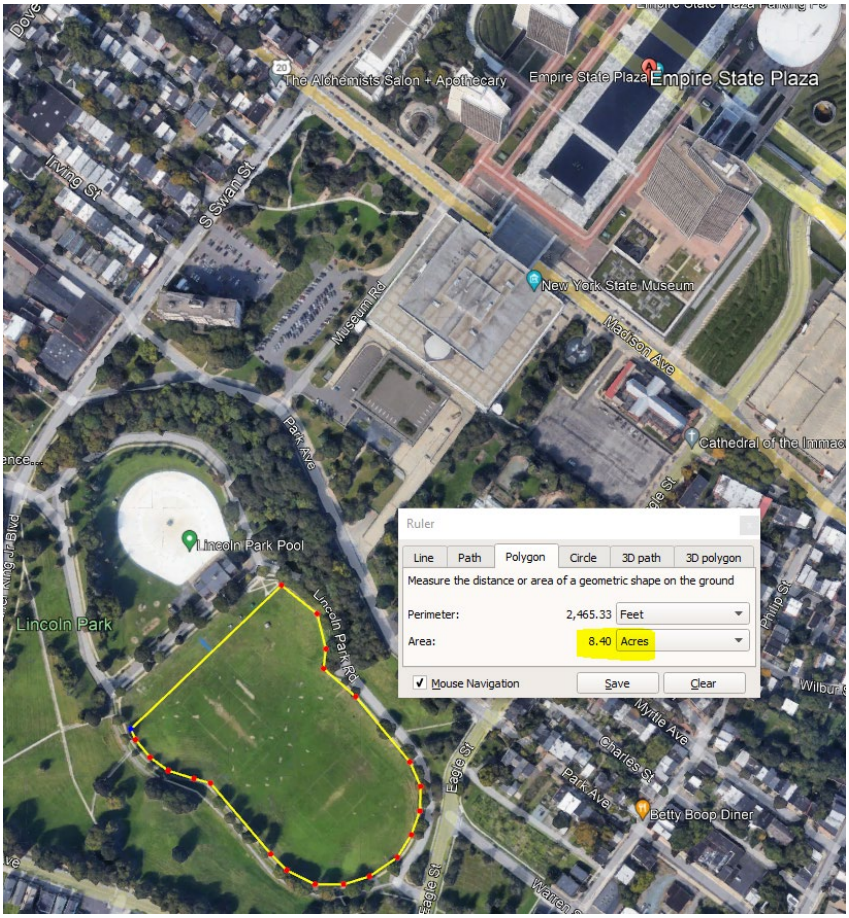

Figure 16. Potential location for the borehole field

While Lincoln Park was the assumed borehole field site for purposes of this effort, other land within and surrounding the Plaza (specifically OGS-owned land parcels and parking lots) could be considered and further evaluated in the future.

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Borehole Balancing

Using the subsoil at the potential borefield site mentioned above as a BTES means that the ground temperature for the entire area of the BTES field varies. The future energy demand profiles of the Plaza, as shown previously in Section D.1.1, suggest that the magnitudes of the annual heating load and annual cooling load would be marginally similar. These future annual loads as currently estimated are:

Heating: 252,223 MMBtu/yr

Cooling: 209,909 MMBtu/yr

While the annual loads suggest that the Plaza is slightly heating dominant, the relative similarity of the two numbers indicate that no significant impact to the balance of the borefield would occur on a year-over-year basis. Thus, any means of re-balancing the boreholes should not be needed.

D.2.5 Potential Waste Heat Recovery Facilities

Ramboll utilized the New York State Department of Environmental Conservation DECinfo Locator website to identify facilities which have a SPDES permit to discharge into the Hudson River. Seventeen locations were identified within a three-mile radius of the Empire State Plaza.

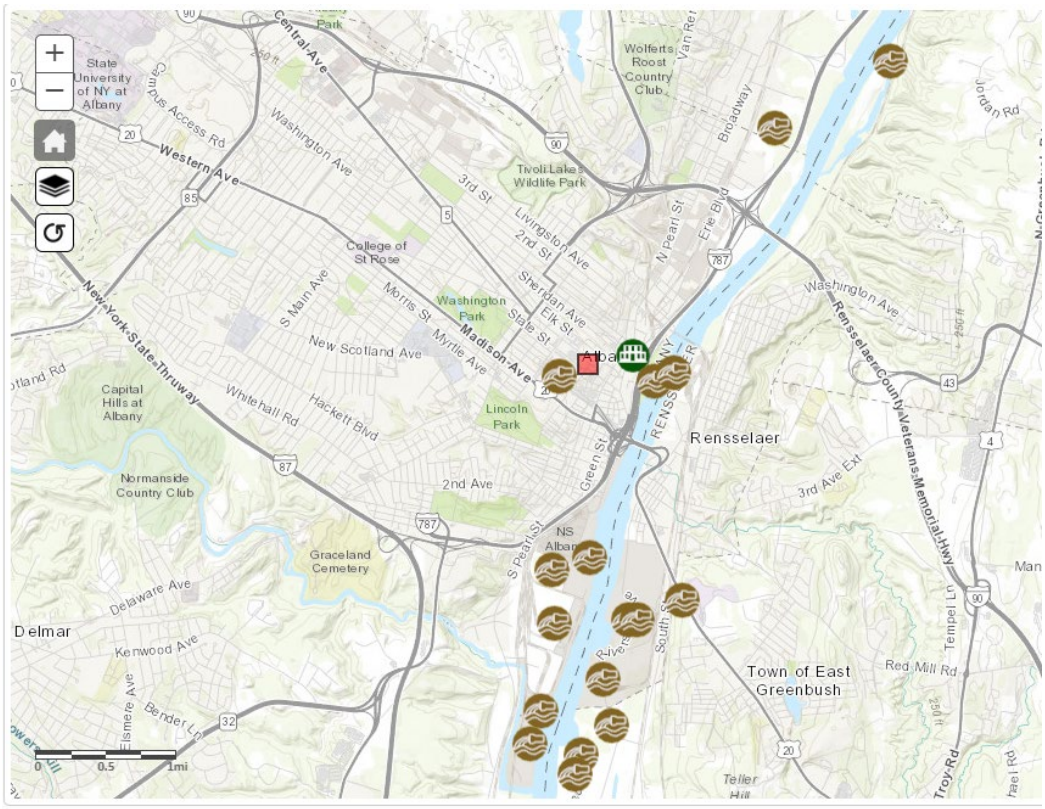

Figure 17. DECinfo locator website screenshot

Figure 17 shows the geographical location of each SPDES permit along with a unique identifier which correlates to the facility name and SPDES permit number presented in Table 23.

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Table 23. DECinfo locator sites

Location ID	Facility Name	SPDES Permit
DEC-1	RENSSELAER CO SD 1 WWTP	NY0087971
DEC-2	Albany County Water Purification District	NY0026875
DEC-3	RENSSELAER -C COMBINED SEWER OVERFLOWS	NY0026026
DEC-4	ALBANY – C COMBINED SEWER OVERFLOWS	NY0025747
DEC-5	NYS EMPIRE STATE PLAZA	NY0104060
DEC-6	GLOBAL COMPANIES LLC – ALBANY TERMINAL	NY0021026
DEC-7	Albany County Water Purification District – SOUTH PLANT	NY0026867
DEC-8	CAPITAL DISTRICT SALT STORAGE	NY0241652
DEC-9	BUCKEYE ALBANY TERMINAL LLC	NY0028592
DEC-10	PORT TERMINAL LTD	NY0260738
DEC-11	NATIONAL GYPSUM COMPANY	NY0122980
DEC-12	BUCKEYE RENSSELAER TERMINAL	NY0005690
DEC-13	SPRAGUE OPERATING RESOURCES LLC	NY0028843
DEC-14	CENEX TERMINALS	NY0006220
DEC-15A	RENSSELAER COGEN FACILIY	NY0242586
DEC-15B	EMPIRE POWER PLANT	NY0267545
DEC-16	EAST GREENBUSH WWTP	NY0026034

Evaluation of Wastewater Potential

The Albany County Water Purification District-South Plant made available data on their effluent for the period from January 1st, 2020, to March 31st, 2022. The provided data consisted of daily flow rate, average temperature and maximum temperature of the wastewater effluent leaving the plant. These are shown in Figure 18.

The data from 2021 was used to estimate the heat potential when using the wastewater effluent as the heat source for a water-to-water HP. The following assumptions were used:

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- The daily average effluent temperature (provided), and not the maximum temperature, is used as representative effluent temperature.
- The effluent is assumed to be cooled down by 18°F, but no lower than 39°F.
- Flow rate (as provided) and the temperature difference calculated as described above define the amount of heat (MMBtu/h) which can be extracted from the effluent in each day of the year.
- An intermediate heat exchanger separates the wastewater and the evaporator of the heat pump. The temperature difference between the warm and cold side of the heat exchanger is assumed to be 9°F.
- On the condenser side, the inlet and outlet temperature of the heat pump are the return and supply temperature of the LTHW loop, respectively (see the paragraph “Thermal District Design Temperatures” in Section D.4.3).
- The COP of the heat pump is a first approximation evaluated based on the evaporator and condenser temperatures defined via the Lorentz-efficiency method[15]. The Lorentz efficiency of the heat pump is assumed to be 55%.
- The heat output potential of the heat pump is therefore calculated based on the amount of heat which can be extracted from the effluent and the heat pump’s COP. This is shown in Figure 19.

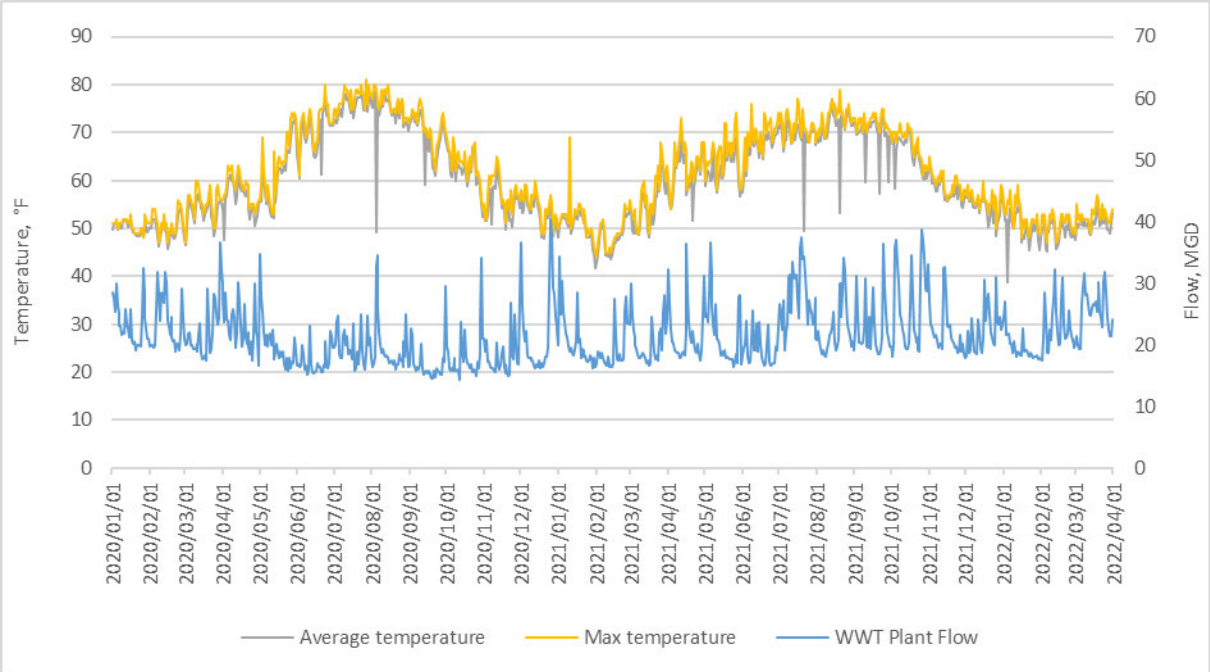

Figure 18. Effluent data (flow and temperature) as provided

[15] https://airconditionerlab.com/coefficient-of-performance/

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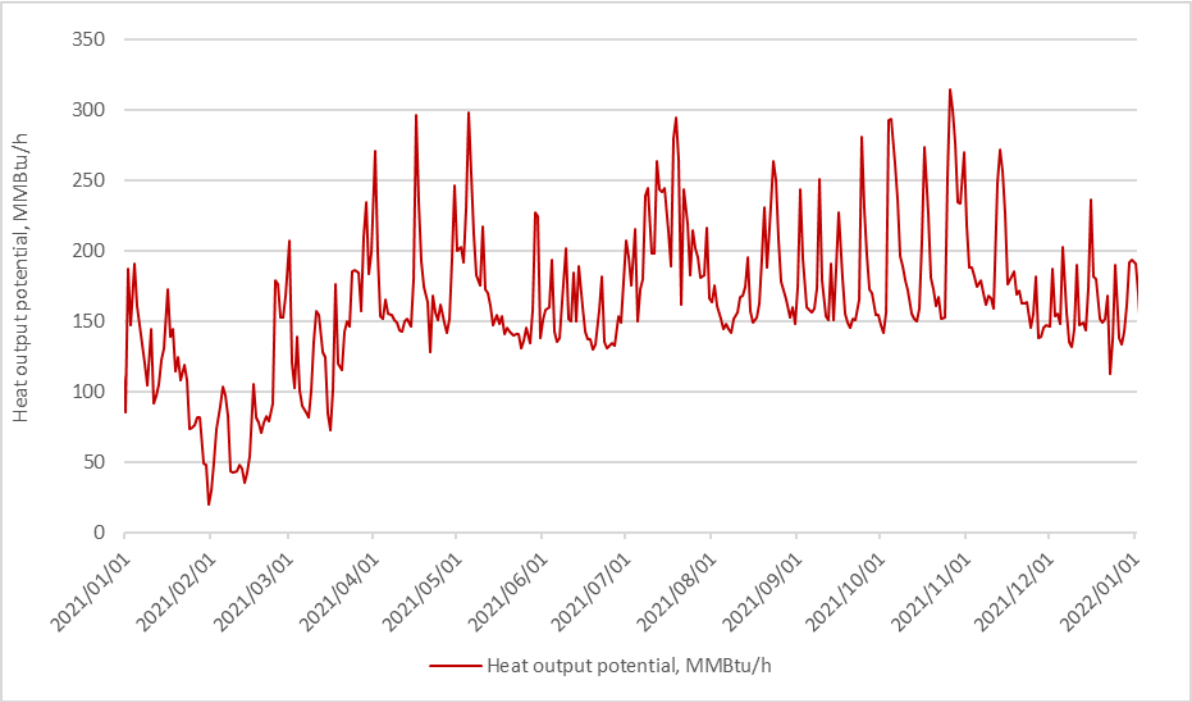

Figure 19. Heat output potential from wastewater heat pump

By comparing the heat output potential from the wastewater heat pump and the heat demand of Empire State Plaza (see Section D.1.1), it is seen that the heat output potential is most often quite higher than the heat demand. However, in order to avoid oversizing of expensive assets (wastewater heat pump and transmission pipe between the wastewater facility to ESP) and to achieve a reasonably high number of full-load hours, the heat output potential from the wastewater heat pump is assumed to be exploited only to the level required to cover the baseload of the heat demand of ESP.

If a wider district heating system would develop from ESP to the surrounding areas, then the heat potential from the wastewater heat pump could be exploited to a larger extent, with limited additional costs, given the economies of scale of both heat pump technology and transmission pipes.

Evaluation of Heat Recovery from Empire Generating Power Plant

Empire Generating made available some information regarding their current setup and the amount of waste heat it rejects to the environment.

Based on the information received, the current setup of the plant as understood by Ramboll has been depicted in Figure 20. The condenser of the power plant is cooled down by cooling water at about 81 °F (average value over 2020-2021 period), which then leaves the condenser at about 98 °F (average value over 2020-2021 period). The cooling water leaving the condenser is cooled down in cooling towers. Here heat is dissipated to the ambient air, and also a small portion of the water flow evaporates. The remaining cooling water is collected in a cooling tower basin for recirculation in the cooling system.

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Water from the wastewater treatment plant is supplied to Empire Generating plant as make-up water for the cooling water loop. This flow is about 2100 gpm.

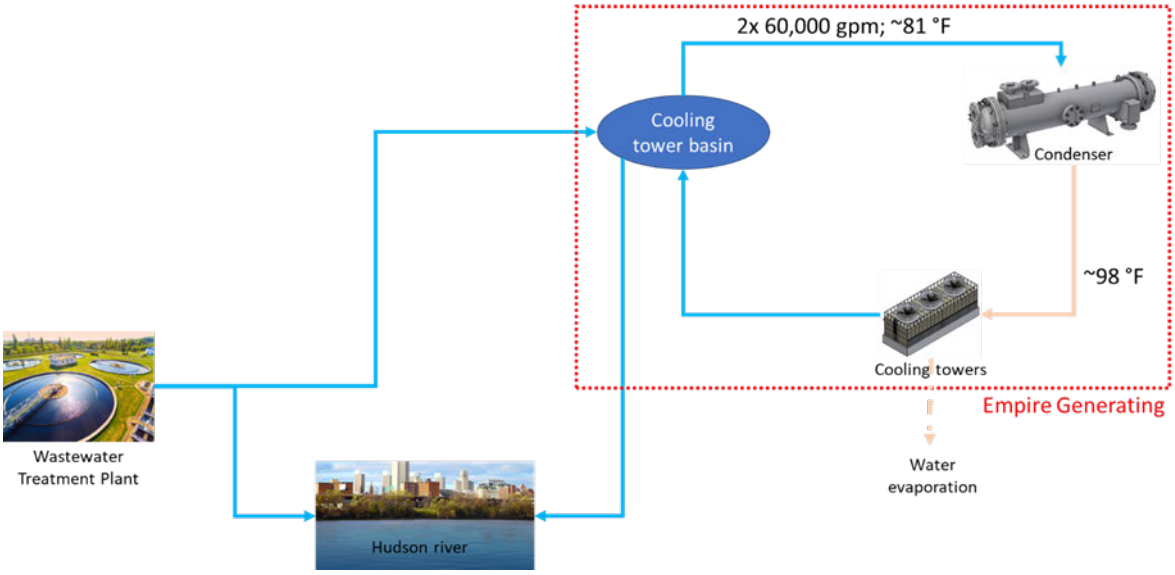

Figure 20. Current setup of Empire Generating Power Plant

Empire Generating stated that the cooling water loop is equipped with two pumps, each pumping up to 60,000 gpm. Assuming that both pumps run at full capacity and using average temperatures of the cooling water inlet/outlet, the amount of heat which is rejected by the plant is about 1,000 MMBH. This is consistent with the size of Empire Generating plant, which is a 635 MW Combined Cycle Gas Turbine, with 2x 179 MW Gas Turbines and 1x 296 MW Steam Turbine[16]. Assuming that the Steam Turbine has an efficiency of 50%, it is reasonable that a 296 MW Steam Turbine would dissipate about 1,000 MMBH of heat at the condenser. This would indicate both pumps running at full load when the plant is in full load.

In order to recover heat from the Empire Generating plant, it is proposed to divert part of the cooling water exiting the condenser and pump it across the Hudson River to a water-to-water heat pump located in proximity of the Albany County Water Purification District-South Plant. After being cooled down by the heat pump's evaporator, the cooling water is returned to the east bank of the Hudson and fed into the cooling tower basin of Empire Generating. In this way, the water-to-water heat pump works in conjunction with the cooling tower in cooling down the cooling water of the power plant; recovering its heat for useful purpose instead of dissipating it to the environment. The proposed configuration requires construction of a flow and return pipe between Empire Generating and the Water Purification Plant.

It should be noted that recent conversations between major project stakeholders have identified this method of heat recovery to be less desirable (relative to other heat pump heat sources) due to the use of fossil fuels at the Empire Generating plant.

[16] https://www.power-technology.com/marketdata/power-plant-profile-empire-generating-station-us/

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D.2.6 Tank Thermal Energy Storage

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

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

The benefits of TTES include the following:

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

TTES typically can be in the form of cylindrical steel tanks (typically located above ground level) or concrete tanks (which can be partially buried if necessary). The tanks are insulated in both cases. In most installations, the temperature supplied to the storage is the supply temperature in the district heating network. Temperature stratification (i.e., having distinct layers of water at different temperatures within the storage tank rather than a fully mixed tank with a uniform temperature) can be achieved through multiple inlets, which increase the performance of the storage. Figure 21 shows the principles of TTES:

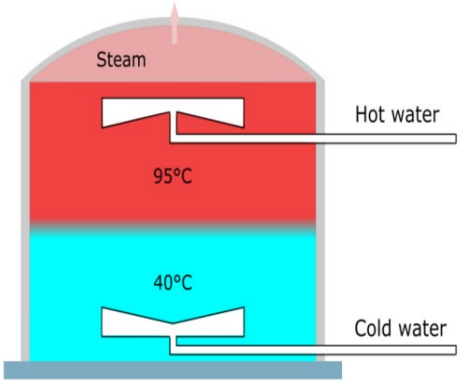

Figure 21. Principles of Tank Thermal Energy Storage

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

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

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

The basic structure of connecting the heat storage tank to the district heating system, as a pressure holding vessel, is shown in Figure 22 below. With the heat storage tank included in the system, the instantaneous demand of the heat consumers does not have to equal the heating plant output; instead, the storage component allows flexibility in operation of the system to achieve energy cost and GHG emission savings.

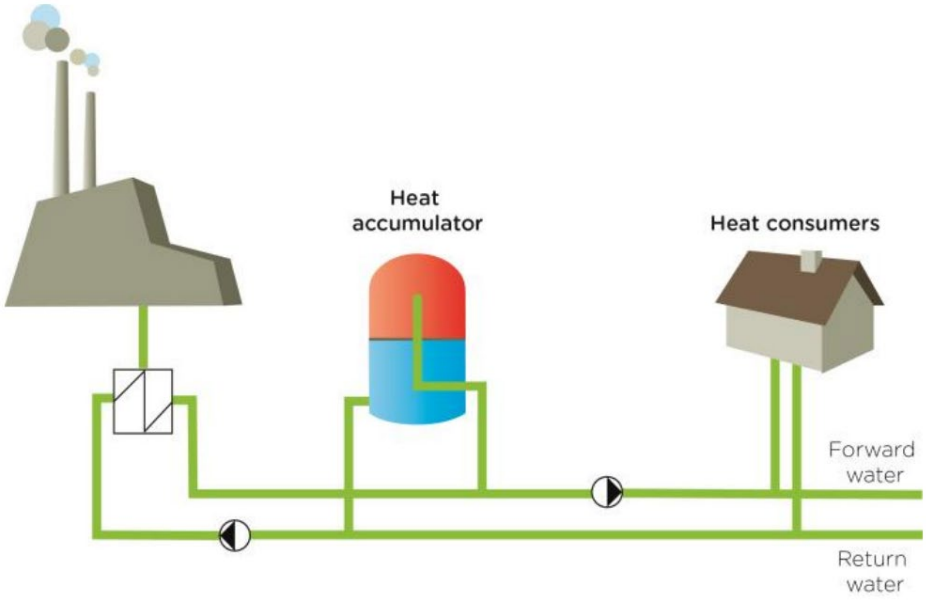

Figure 22. Connection of TTES - Heating Storage

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Figure 23 below is from DN Tanks[17] and illustrates how thermal energy (chilled water in this case) is produced during off-peak electrical periods, collected in a thermal energy storage tank, then withdrawn and distributed to the facility during on-peak periods.

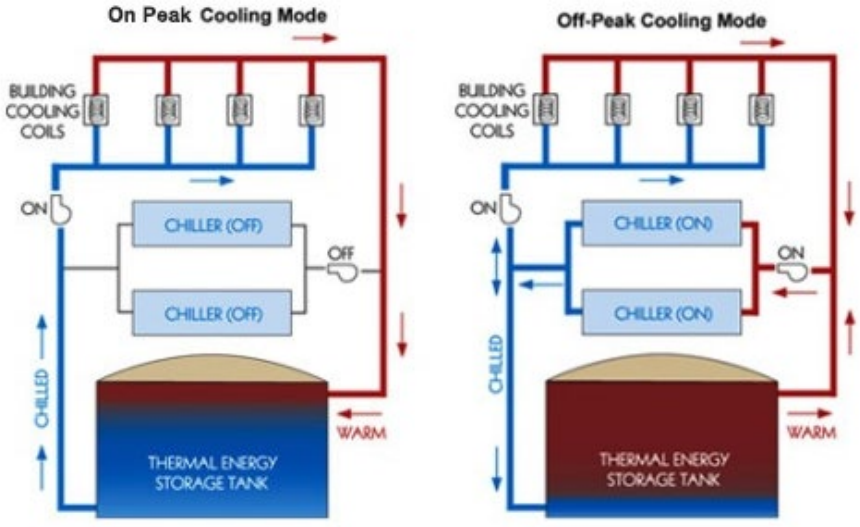

Figure 23. Connection of TTES - Cooling Storage

Preliminary Sizing of TTES

The TTES should be able to provide heating or cooling to the energy system when there is limited renewable electricity in the grid. Therefore, in principle, it should be designed based on a thorough analysis of the prices for electricity and their fluctuations. However, since the further build out of intermittent renewable energy in New York State will occur over many years to meet the goals of the CLCPA, for purpose of this analysis, Ramboll assumed that TTES would cover roughly 5 hours of heating base load operation.

From the load curve described in Section D.1.3, it is estimated that 40% of the peak heating demand covers approximately 90% of the heat demand. This load has been used as the basis for the preliminary design. The peak heating demand is approximately 122 MMBtu/h, and the maximum baseload is approximately 49 MMBtu/h.

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

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

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For this assessment, Ramboll has estimated two thermal storage tanks (one for heating, one for cooling) with each at a gross tank volume of 1,000,000 gallons. Based on a diameter-to-height ratio of 0.8, the water level height is estimated at 65 ft with a diameter of 52 ft (excluding insulation).

D.2.7 Biofuel Availability

A series of inquiries was made to over fifteen large-scale fuel suppliers in New York and neighboring states in early 2022. This investigation found that, of the different types of biofuels, including biomass, biogas, biodiesel and hydrogen, only biodiesel is readily available for bulk delivery in the Albany area.

The blending of petroleum diesel with biodiesel is a common practice in the United States, and particularly in New York, where state law will require heating oil to contain at least 5% biodiesel by July 2022, scaling up to a minimum of 20% by July 2030. Biodiesel blends, like ethanol blends, are typically referred to according to the percent of biofuel they contain; B5 is a blend of 5% biodiesel and 95% petroleum diesel, B20 is a blend of 20% biodiesel and 80% petroleum diesel and B100 is pure biodiesel.

Eleven of the companies contacted indicated they had the capacity to make wholesale deliveries of bio-oil to downtown Albany. These potential suppliers are presented below in Table 24.

Table 24. Potential bio-oil suppliers

Company	Terminal Location	Miles from ESP	Highest Level Blend Offered
Global Partners	Albany, NY	1.9	B50
Dennis K. Burke, Inc.	Albany, NY	2.6	B5[3]
Sprague	Rensselaer, NY	3.8	B100
Main-Care Energy[1]	Albany, NY	4.2	B10
John Ray & Sons	Troy, NY	9.9	B20
Mirabito Energy Products	Castleton-On-Hudson, NY	15	B100
Peterson Oil	Worcester, MA	133[2]	B100
NOCO	Cato, NY	167	B20
Shipley Energy	York, PA	301[2]	B100
World Energy	Harrisburg, PA	302	B100
Ensyn	Renfrew, Ontario	326	100%[4]

Notes:

1. 5,000-gallon delivery capacity
2. Have not previously delivered this far from their terminal

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3. Expect to offer higher-level blends in the near future
4. Ensyn produces biocrude, branded Renewable Fuel Oil (RFO)

As of May 2022, the cost of biodiesel was significantly higher than that of petroleum diesel. B100 was priced around $8.25 per gallon, while lower-level blends were more comparable to petroleum products, with supply costs around $5.00 per gallon.

D.2.8 Distribution System: 4-Pipe Versus 2-Pipe

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

Diagrams representing 4-pipe and 2-pipe systems are shown in Figure 24 and Figure 25, respectively.

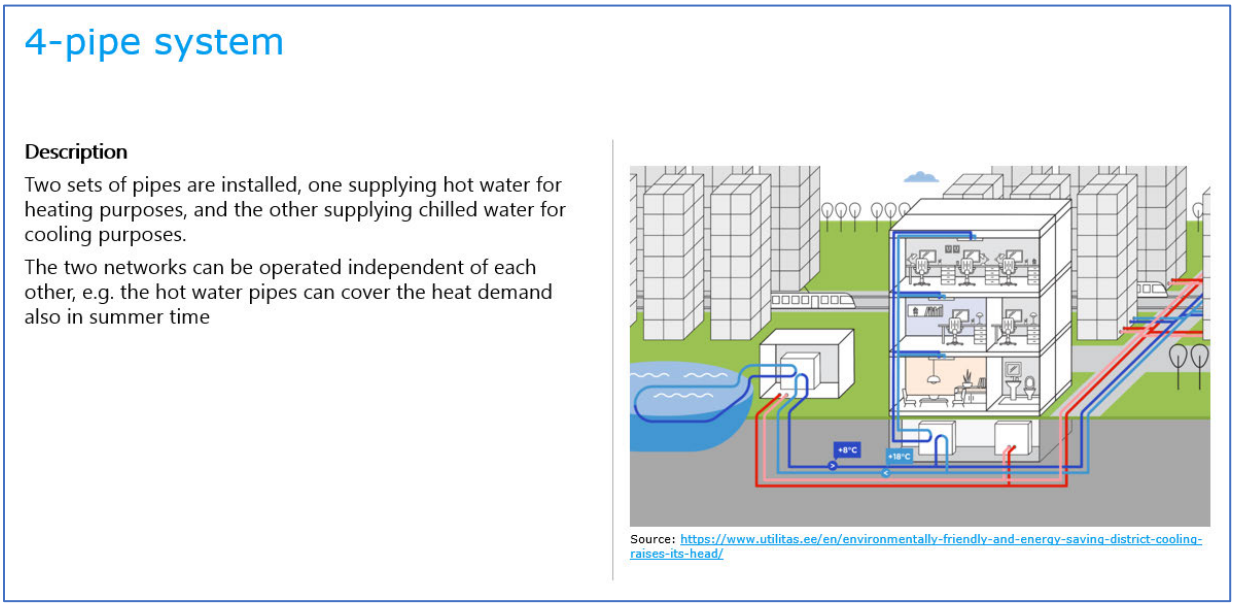

Figure 24. 4-Pipe Distribution System

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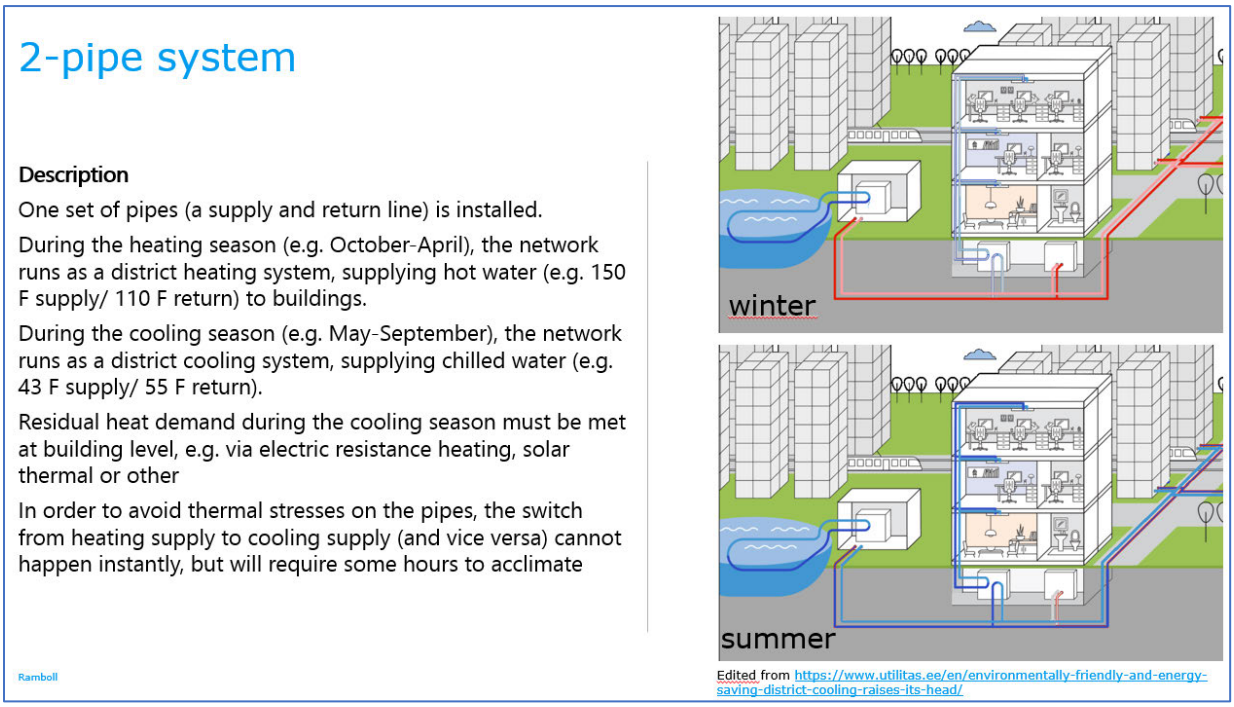

Figure 25. 2-Pipe Distribution System

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

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

The project team considered the advantages and drawbacks of both system types. Since the Plaza currently features both a chilled water and steam district that are together capable of providing simultaneous heating and cooling to connected buildings, and since simultaneous heating and cooling needs are still anticipated for the future state of the Plaza, the 4-pipe configuration was advanced into the list of scenarios selected for analysis. In each of these scenarios, the existing chilled water distribution system (comprised of chilled water supply and return piping) would remain. The existing steam and condensate return piping system would be replaced with low-temperature hot water supply and return piping. Section D.4 describes the hydraulic modeling approach and modeling results for this 4-pipe configuration that would be implemented for any of the selected decarbonization scenarios.

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D.2.9 Ambient Loop

An ambient loop circulates ambient temperature water throughout a district piping network. The low temperature is not suitable for direct heating; however, it is the source water supply for individual water source heat pumps (WSHPs) installed at each building. Building-level heat pumps, as opposed to central heat pumps, is the fundamental difference between an ambient loop and a low temperature hot water network. While ambient loop systems have their benefits in certain applications, ESP ultimately decided to maintain consistency by continuing to use a 4-pipe configuration in future scenarios.

D.2.10 Viable Technologies, Post-Screening

Following the technology screening step, several technologies and other systems/components have been identified as viable solutions and were ultimately carried forward into the scenario planning process. These technologies are:

Heating/cooling equipment

- Heat recovery chillers
- Ground-source heat pumps
- Air-source heat pumps
- Wastewater heat pumps
- Industrial heat recovery heat pumps
- Electric chillers
- Natural gas boilers
- Electric boilers
- Renewable oil boilers

Distribution system

- Centralized, 4-pipe configuration
    - Low-temperature hot water heating
    - Chilled water cooling

Energy storage

- Tank thermal energy storage
- Borehole thermal energy storage

Fuels

- Electricity
- Natural Gas
- Renewable Oil

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D.3 River Water Evaluations and Considerations

D.3.1 River Water Permits and Limits

The NYS DEC imposes three permitting constraints on the system to protect the local waterway. The SPDES Number is NY0104060 and the DEC Number is 4-0101-00010-00001-0 with an effective date of 8/1/2024 and an expiration date of 7/31/2029. Those constraints are:

- Maximum river water use of 92 million gallons per day (MGD) (monitored continuously)
- Maximum discharge temperature of 90°F; this requirement is identified in the current SPDES permit
- Maximum temperature difference between inlet and outlet temperatures of 24°F

Risks of Permit Non-compliance

As designed, the river water system does not have the ability to exceed the maximum river water use of 92 MGD and follows this requirement. ESP does not exceed the 24°F temperature differential and follows this requirement. On occasion, the discharge temperature exceeds 90°F.

On 8/4/2022 the river water system discharged water at 92°F. While the conditions experienced on 8/4/22 resulted in an outlet temperature above the current permitted level, it is important to note that they are not the most extreme that could be expected for the location during the permit life cycle. The Hudson River has reached temperatures up to 85°F during times coinciding with the peak cooling season. The 20- and 50-year anticipated extreme conditions are 99°F and 104°F, respectively[18]. The coincidence of these conditions would lead to additional non-compliance events.

Hudson River Temperature Trends

Daily Hudson River water temperatures recorded from 2003 to 2021 were analyzed to better understand typical and extreme operating conditions. The analysis, including the analysis period average, is included in Figure 26. The highest recorded daily river water temperature was approximately 85°F, while the average high is approximately 78°F. These conditions generally occur during July and August.

An additional permit constraint states that the differential temperature between the Hudson River water temperature and discharge temperature can be a maximum of 24°F. At the maximum recorded river water temperature of 85°F the differential temperature can only be 5°F to remain in compliance with the permit constraint of 90°F maximum discharge temperature. This is an 80% reduction in differential temperature from the possible 24°F. The cooling capacity of the river water system is directly proportional to the change in temperature between the intake water temperature and discharge water, thus at the recorded daily high river water temperature of 85°F, the cooling capacity is also reduced by approximately 80%, when the cooling demand is generally highest.

[18] ASHRAE Design Basis Weather Data for Albany, NY.

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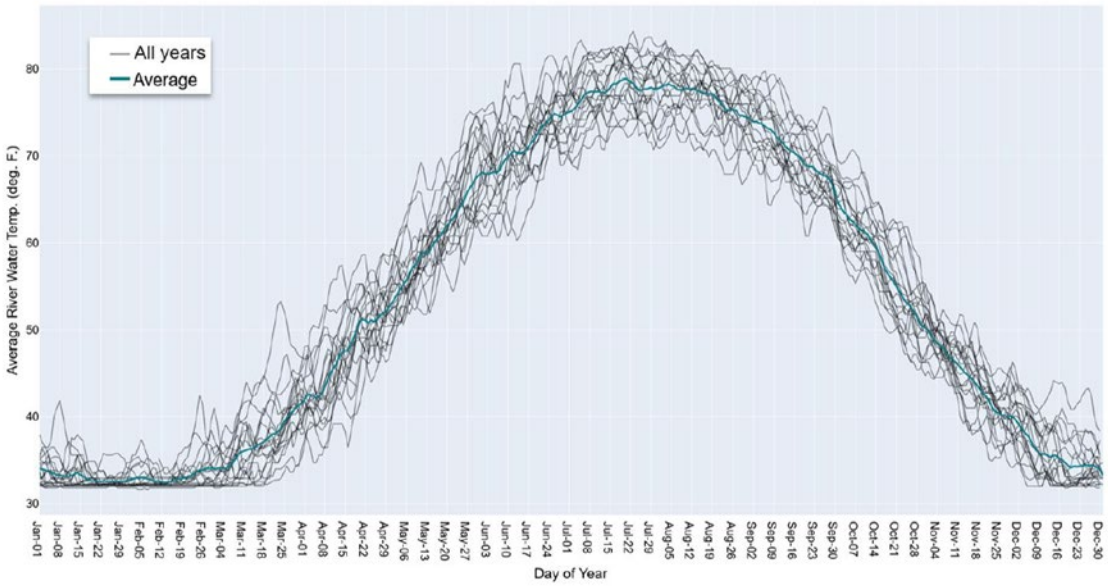

Figure 26. Daily river water temperature (USGA Gauge 01359139 From 2003 to 2021)

Peak Cooling Demand

On 8/4/22, the Albany NY area experienced unusually hot weather conditions which exceeded the ASHRAE design day conditions. The observed dry bulb temperature was 97°F where the ASHRAE Cooling dry bulb temperature for a 0.4% confidence interval is 89°F. Since the weather conditions were so extreme, the project team monitored and recorded the system performance. These conditions were chosen to represent the peak cooling condition. Subsequent analyses use this extreme weather day as a peak reference condition for modeling purposes.

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Table 25. Reference day conditions

8/4/22 Operating Conditions	
RPS River Water Flow	44,413 GPM
River Water Inlet Temperature	81.3°F
River Water Outlet Temperature	92.4°F
CACP Water Supply Temperature	81.3°F
CACP Water Return Temperature	95.8°F
River Water Flow Through Chiller Condensers	37,958 GPM[19]
Total Chiller Tonnage	14,504 Tons

D.3.2 Evaluation of Mitigation Options

Using the historical data and peak day event as references, alternatives are identified that will ensure compliance under the forthcoming permit cycle. Four approaches with varying degrees of implementation durations and complexity are described here.

Dilution with Additional River Water

The river water pump station has six vertical turbine pumps. OGS will operate all six pumps during the height of the summer when river water temperatures are warmest. OGS has a daily river water extraction limit of 92 million gallons per day (MGD). During the reference peak day condition, the maximum extraction rate with all six pumps running was 63.95 MGD. This extraction rate occurred on the reference day which led to a discharge temperate of 92.4°F. This exceeds the 2024 permit's allowable discharge temperature constraint.

The river discharge temperature is a function of the inlet temperature, the heat being rejected, and the volume of water that it is rejected into. By increasing the flow rate, the discharge temperature will be reduced. Current system configuration was tested to identify any opportunity for increasing maximum flow with the existing system. The plant operators identified various opportunities for flow increase which resulted in a maximum flow of 72.96 MGD. This analysis also considered the maximum allowable flow rate if the system could be modified to increase the flow rate. Options to maximize flow rate of the system are being considered in a three-step sequential process as outlined below.

1. Enhancement of the system's Ross Valve to reduce backpressure and increase system flow capabilities. The current Ross Valve was recently rebuilt in 2024, but continued damage to the valve caused by cavitation has driven plans to replace the valve entirely with a new Ross Valve featuring multiple orifices.

[19] As calculated by summing up the three river water flow meters on chillers 2, 3, and 4 at the time of the observation.

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2. Revise piping flow paths to increase system flow.
3. Add additional pumping capacity.

Steps 1 and 2 are currently identified as necessary work and are planned for implementation in 2026. Step 3 will be considered more thoroughly as necessary based on the flow rates achieved through the implementation of Steps 1 and 2. Improving the system to offer the ability to use the permit maximum flow of 92 MGD is the ultimate intent of this alternative. Table 26 includes the capabilities of thermal dilution to maintain temperature outlet compliance. Importantly, at the system's currently identifiable maximum flow rate of 72.96 MGD, the plant would be able to maintain outlet temperature compliance up to an 80.27°F inlet temperature, roughly 1°F below the inlet temperature experienced on the reference day. To maintain outlet temperature compliance on the reference day, river water flow would need to increase to 81.6 MGD. If the permittable flow of 92 MGD can be achieved, the system would be able to maintain outlet temperature compliance with an inlet temperature up to 82.3°F; 1°F above the reference day conditions.

Table 26. Various flow conditions, maximum system flow rate, corresponding outlet temperature and maximum inlet temperature for permit compliance

Flow	River Water Flow Rate (MGD)	Outlet Temp. at Reference Conditions, 81.3°F Inlet Temp. (°F)	Max. Inlet Temp. for Permit Compliance 90°F Outlet Temp. (°F)
Reference Day Condition	63.95	92.40	78.90
Max Flow Immediate Implementation	72.96	91.03	80.27
Outlet Temperature Compliance Flow	81.60	90.00	81.30
Permit Max Flow	92.00	89.02	82.28

Effects of Steam Condensers on River Water Discharge Temperature

Steam turbine driven chillers have two forms of heat to reject. The first is the heat of refrigeration which is common to all chillers. The second is the heat from the steam condenser which is the latent heat of vaporization as the steam condenses back into a liquid. The condensate is recirculated back to the boiler plant to be evaporated again. Because of the steam condenser heat source, steam driven chillers reject more heat than electrically driven chillers.

The ESP CACP replaced a steam driven chiller in 2020 and 2021 with an electrically driven chiller to reduce the heat that is rejected to the Hudson River. Performance data collected by OGS during the summer of 2022 was compared to the three other steam driven machines. Figure 27 shows the data regressions of the electric chiller and the three steam driven chillers at the CACP. It shows that the steam driven chillers reject approximately 2.5 tons of heat for every ton of cooling produced, while the electric

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chiller rejects approximately 1.2 tons of heat for every ton of cooling produced. This represents a 50% reduction in rejected heat from electric chillers vs steam driven chillers.

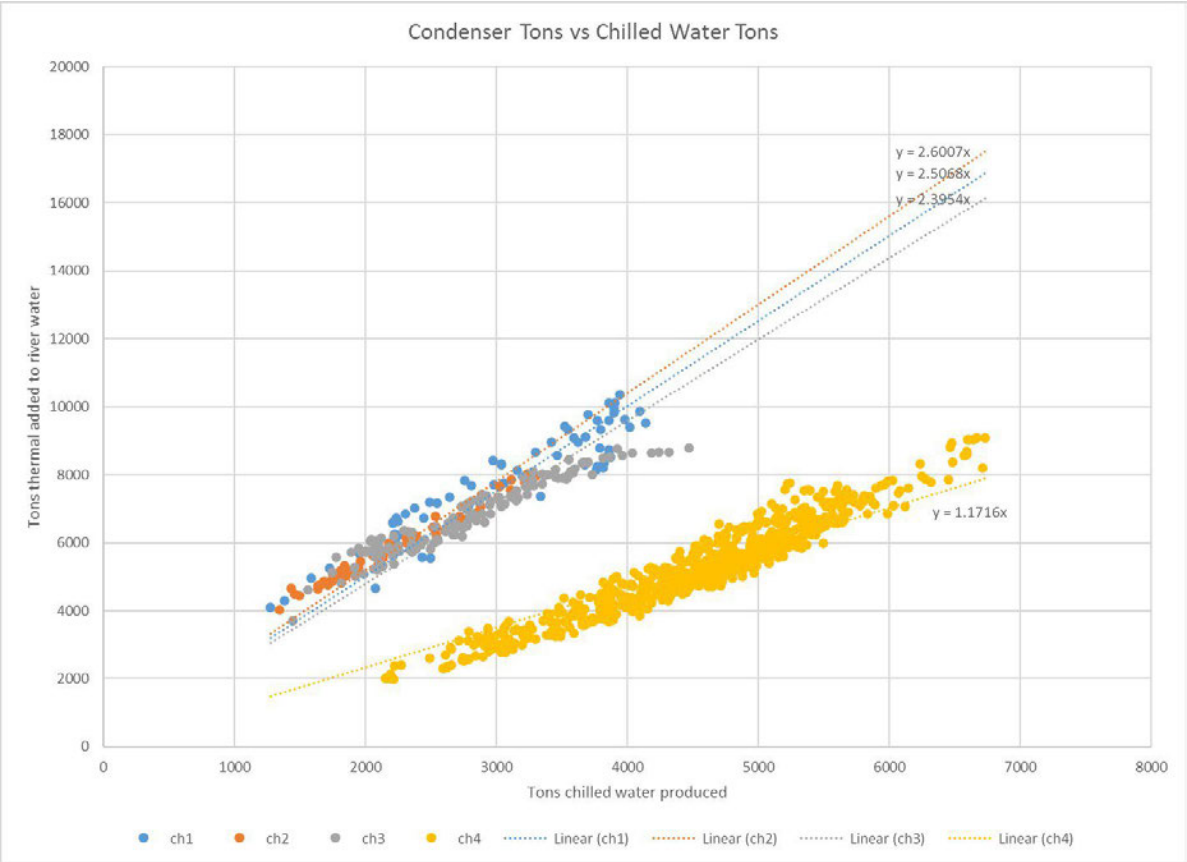

Figure 27. Heat rejected from steam and electric chillers

The current peak chilled water demand is approximately 14,504 tons, of which 6,000 tons comes from the electrically driven chiller. The remaining demand is met with the steam driven chillers. There is an opportunity to switch the remaining steam driven chillers to electrically driven chillers to further reduce the heat that is rejected to the Hudson River. If pursued, compliance with the SPDES permit during reference peaking conditions would be achievable with no other mitigation measures. An all-electric chiller plant would be able to maintain compliance utilizing river water inlet temperatures up to 83°F with the reference cooling load and flow rate. Table 27 summarizes two critical values calculated for the all-electric chiller alternative. The “Reference Day Outlet Temperature” indicates the alternative’s theoretical discharge temperature on the reference day highlighted in this report. The “Max Inlet Temperature for Permit Compliance” indicates the alternative’s theoretical maximum inlet temperature, or river water temperature, to remain within the 2024 permit allowable discharge temperature constraint.

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Table 27. Reference day outlet temperature and maximum inlet temperature for permit compliance for all electric chillers

Case	Reference Day Outlet Temperature (°F)	Max. Inlet Temperature for Permit Compliance (°F)
All Electric Chiller Plant	88.18	83.12

Demand Reduction through Energy Efficiency and Load Reduction

Many energy reduction opportunities were identified along with an associated reduction in future cooling demands as part of the investigation into modernizing the ESP buildings. The ESP buildings were designed in the 1960s and 1970s, and their air handling systems are not as efficient as modern designs. They utilize constant volume systems instead of variable volume systems, introduce more outside air than modern designs, and, in some cases, use systems that are no longer energy code compliant due to excessive simultaneous heating and cooling. The ESP buildings use approximately twice the amount of energy as other similar buildings as cataloged by the 2012 CBECS[20] database.

Figure 28 shows the existing cooling load in 2019 and the expected future cooling load resulting from building renovations and relocation of the health laboratories. A 45% load reduction is expected from the implementation of the efficiency and modernization projects. Using the observed conditions on 8/4/22 as a peak condition, the expected future load would be reduced from 14,504 tons to 7,977 tons.

Assuming the same chillers exist in this future case the electrical chiller would be capable of producing 6,000 tons of that load and the remaining 1,977 tons would be produced by the steam turbine driven chillers. The load that is removed from the steam chillers would be 6,527 tons and this would remove 16,317 tons of heat from the river water or 196 MMBtu/hr.

[20] Commercial Building Energy Consumption Survey

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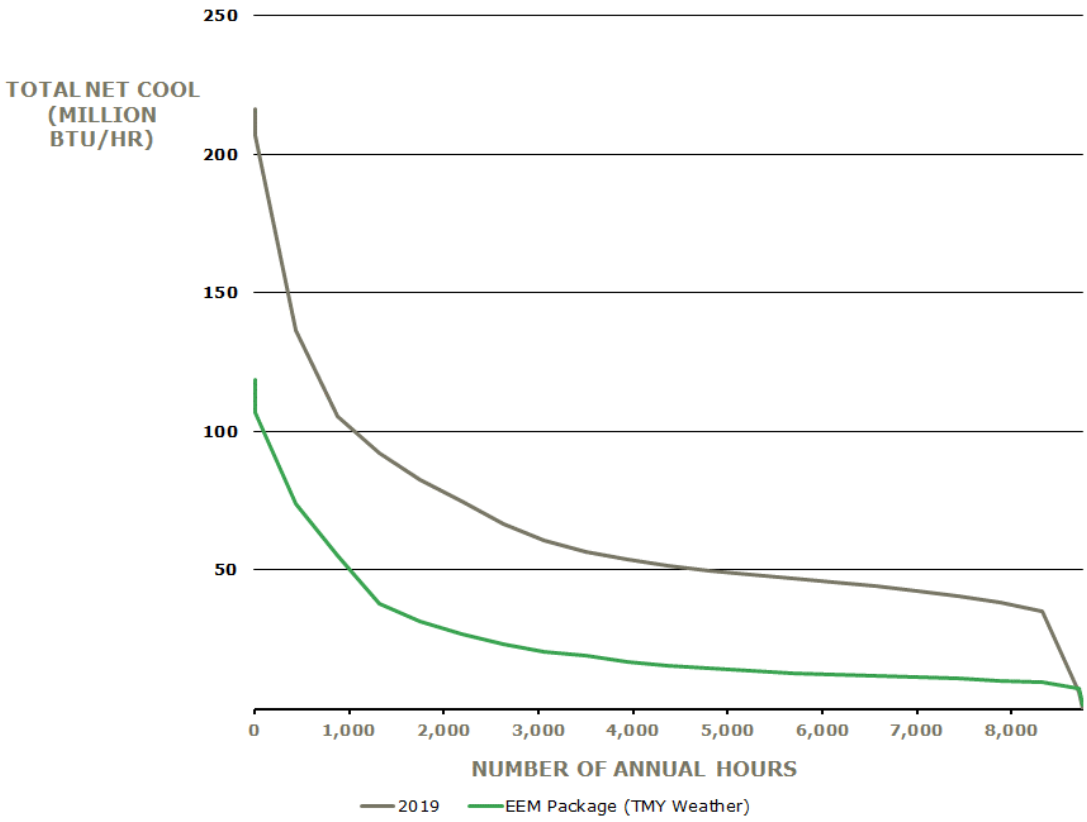

Figure 28. Chilled water load; existing vs future

The first major renovation planned to reduce the overall load is relocating the health laboratory offsite and repurposing this building. Repurposing the health laboratory results in 42% of the total load reduction savings. The new total load on this system will be approximately 11,763 tons.

Table 28. Health lab relocation reference day outlet temperature and maximum inlet temperature for permit compliance

Case	Reference Day Outlet Temperature (°F)	Max. Inlet Temperature for Permit Compliance (°F)
Current Chiller Plant	89.74	81.56
All Electric Chiller Plant	86.88	84.42

Once the additional energy efficient measures are in place, the new total load on the system will be approximately 7,977 tons.

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Table 29. Additional energy efficiency measures reference day outlet temperature and maximum inlet temperature for permit compliance

Case	Reference Day Outlet Temperature (°F)	Max. Inlet Temperature for Permit Compliance (°F)
Current Chiller Plant	86.07	85.23
All Electric Chiller Plant	85.09	86.21

On its own, the implementation of efficiency and modernization measures would maintain compliance with outlet temperature limits during reference day conditions. In conjunction with an all-electric chiller plant, permit compliance would be maintained using river water inlet temperatures up to 86.2F. In both of these cases, the “Max Inlet Temperature for Permit Compliance” is lower than all of the daily average river temperatures observed from 2003-2021.

Load Shifting Using Thermal Energy Storage

The chilled water demand is highly dependent on ambient weather conditions and solar irradiation throughout the day. The highest cooling demand is often in the early afternoon when ambient temperatures and solar gain are high, and the building thermal mass has heated up. Without chilled water storage, the chilled water demand must be met in real time, and the rise in demand translates to a simultaneous rise in chilled water production and the associated thermal discharge to the Hudson River.

If chilled water storage is added to the system, it will allow the decoupling of the demand and the production to reduce the instantaneous peak. This will allow the thermal storage tank to be charged on off-peak periods when electricity is cheaper and then discharged during the electrical peak periods when electricity is the most expensive. This will spread out the heat rejection over time and lead to a move even discharge temperature; reducing the temperature spikes that threaten to exceed the permit.

ESP is considering adding two (2) – one-million-gallon thermal energy storage tanks with one dedicated for chilled water storage. With this design, the thermal energy storage will cover approximately 22% of the current cooling load for approximately three hours. Table 30 shows, for reference day conditions and existing cooling load, the expected river water discharge temperature under various chilled water storage volume sizes.

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Table 30. Thermal energy storage

% CHW Load Covered by TES	Load (Tons) Covered by TES	Covered Duration (Hrs)	Remaining Load From Chillers (Tons)	River Water Discharge Temperature (°F)
100%	14,504	0.69	0.00	81.30
90%	13,054	0.77	1,450.40	82.41
80%	11,603	0.87	2,900.80	83.52
70%	10,153	0.99	4,351.20	84.63
60%	8,702	1.16	5,801.60	85.74
50%	7,252	1.39	7,252.00	86.85
40%	5,802	1.74	8,702.40	87.96
30%	4,351	2.32	10,152.80	89.07
22%	3,136	3.21	11,368.00	90.00
20%	2,901	3.47	11,603.20	90.18
10%	1,450	6.95	13,053.60	91.29
0%	0	0	14,504.00	92.40

D.4 Thermal Energy Modeling

D.4.1 Overview of Hydraulic Modeling

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

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

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D.4.2 Modeling the LTHW Distribution Network

In order to size the new LTHW loop for Empire State Plaza, the software TERMIS was used. TERMIS is a hydraulic modeling software that includes the following capabilities:

- Pipeline design,
- Hydraulic and thermal analyses,
- Operation planning, and
- Creation and analysis of alternative scenarios.

In the context of this project, TERMIS was used to size the new LTHW distribution system to supply heat to the ESP buildings. In order to size the distribution system, the following assumptions were used:

Table 31. Max. allowed velocities dependent on the pipe size

Pipe Nom. Dia [“]	Velocity [ft/s]

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Table 32. Pipe size with corresponding flow rate and thermal capacity

Nom. Dia [”]	Ext. Diameter [mm]	Int. Diameter [mm]	Flow [GPM]	Capacity with ΔT=30°F [kBtu/hr]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

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Table 33. Peak heat capacity by building

Building Name	Total, Heat [kBtu/h]
Agency 1	6,062
Agency 2	5,573
Agency 3	5,781
Agency 4	5,278
Alfred E Smith Office Building	7,613
Capitol	7,747
Corning Tower	32,355
Cultural Education Center	17,920
Health Lab	3,320
Justice Building	6,658
Legislative Building	6,957
Main Platform	29,397
Old Education Building	7,636
Swan St Office Building	10,710
The Egg	1,966
SUM	**154,973**

Two different pipe route alternatives were considered. Alternative 1 and Alternative 2 are shown in Figure 29 and Figure 30, respectively. [redacted]

Alternative 1 consists of a “radial system” spreading out from the energy center. The main advantage of this option is the lower investment compared to the looped system (Alternative 2). The main drawback for Alternative 1 is the lower reliability of heat supply than a looped system. Alternative 2 consists of a “looped system”, with a large diameter main ring connecting most of the buildings. The main advantage of

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this option is the higher reliability of heat supply as compared to a radial system. In case of an issue on a pipe segment of the loop, that section can be shut off, and the buildings can still be supplied from an alternative route via the same loop. The main disadvantage is the higher investment compared to the radial system (Alternative 1) due to the slightly longer trench length and the larger pipe diameters. With a looped system, it is recommended to install sectioning valves making it possible to operate the system as a radial system as standard operation.

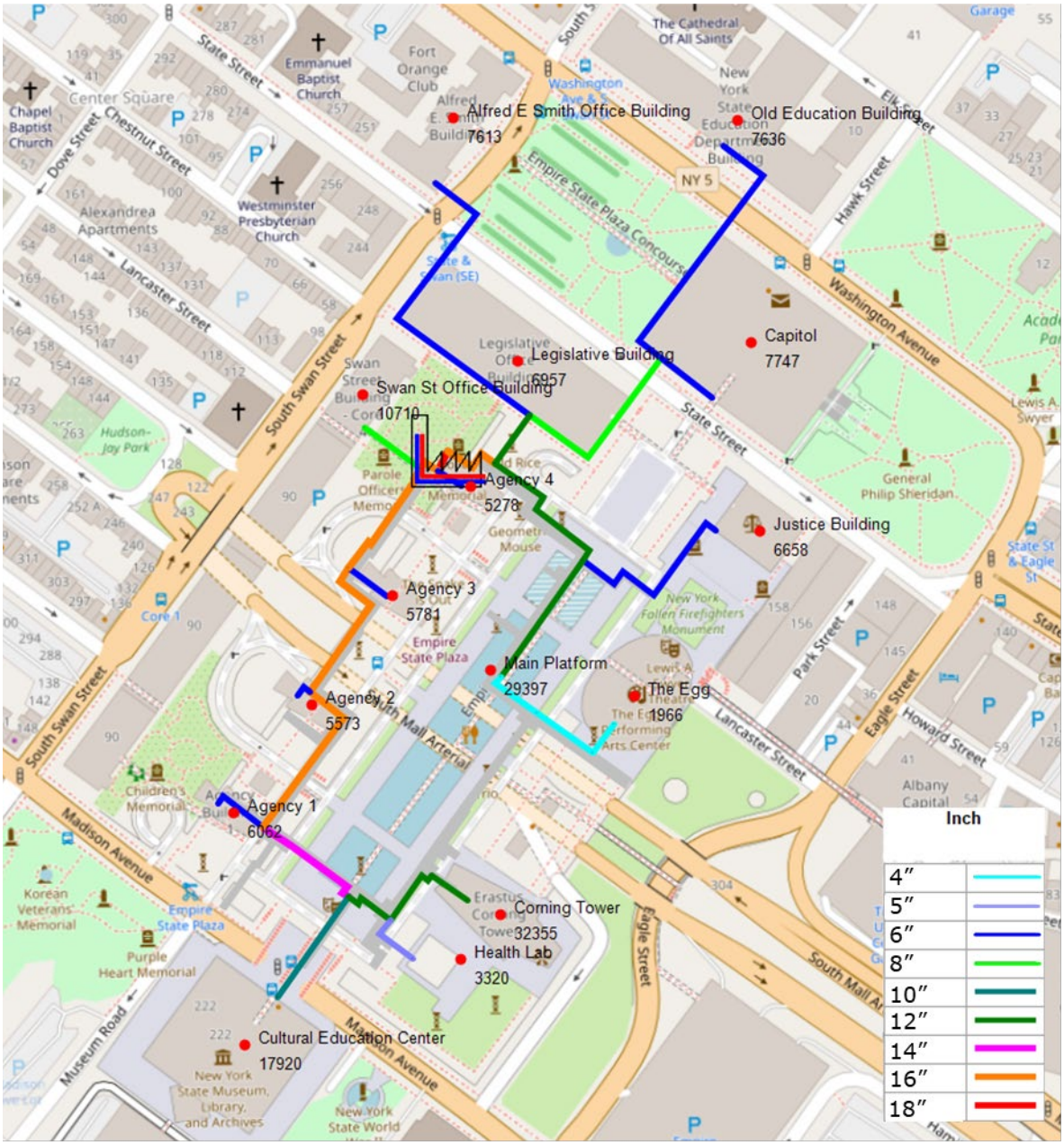

Figure 29. Alternative 1: pipe routing with color-coded pipe size

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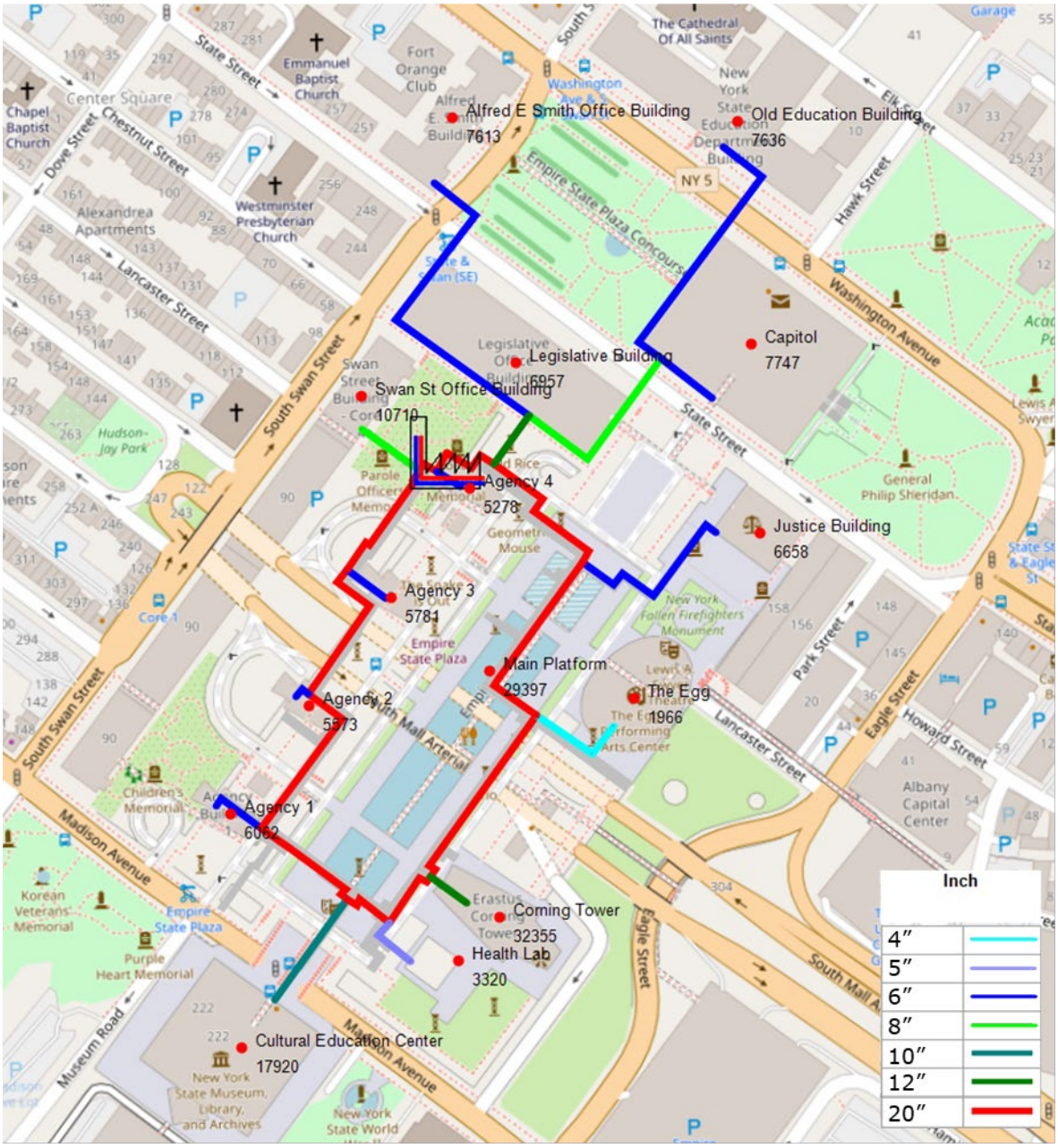

Figure 30. Alternative 2: pipe routing with color-coded pipe size

Alternative 2 was ultimately chosen as the preferred approach and used a basis for cost estimating the LTHW district due to the more robust reliability and flexibility of the solution when compared against Alternative 1.

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D.4.3 energyPRO Modeling

A techno-economic analysis using energyPRO software was conducted to determine the most cost-efficient mix of heating and cooling technologies. The model evaluates the operation of centralized systems, optimizing energy production and storage based on technical, economic, and environmental factors. The layout of an energyPRO model for the Plaza is shown in Figure 31 below.

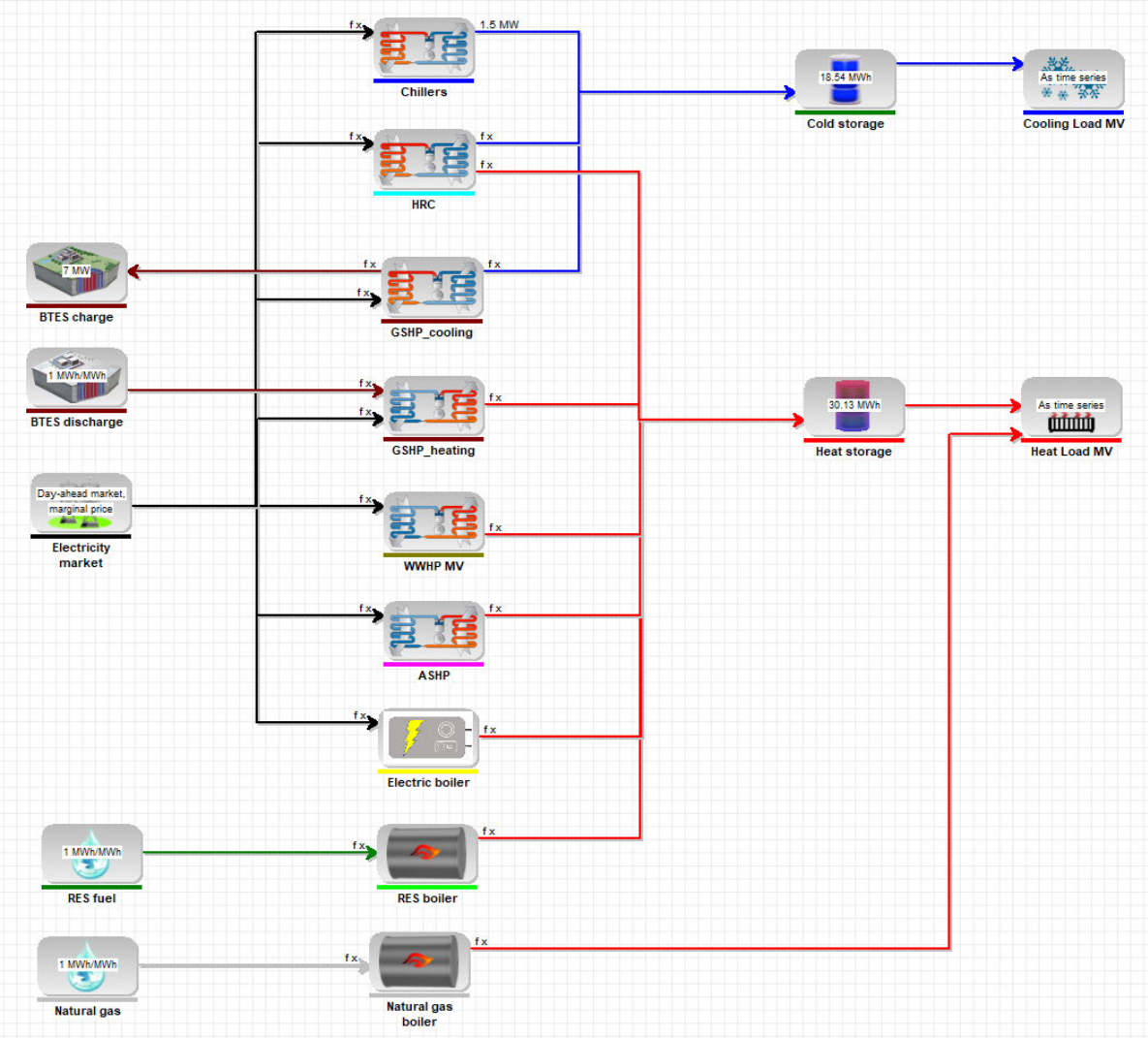

Figure 31. energyPRO Model for ESP

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

- Blue: “cooling energy”
- Red: “heating energy”
- Black: electricity
- Maroon: “heating energy” at a low temperature
- Grey: natural gas

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- Green: biofuel
- Yellow: natural gas

On the right-hand side, the “Cooling Load” and “Heat load and losses” blocks represent the energy demands that must be covered. On the left-hand side are listed the energy sources used, such as electricity, fuels, and geothermal energy.

Aligned vertically in the center of the figure are the different production units. Between production units and energy demands blocks, two short-term energy storages (“Heat storage” and “Cold storage”) work as a buffer between energy supply and energy demand. The presence of thermal storage allows the system to take advantage of lower electricity prices when they occur in the market; operating the electric-drive machines at full capacity to cover instantaneous demand and charging storage(s). During times when the electricity price increases, the stored energy can be discharged to cover the demand, while reducing the output from the energy-production units.

In the model, the two blocks (“BTES charge” and “BTES discharge”) are used to model the seasonal thermal energy storage in applicable scenarios. This is indeed the same identical component, but two components are needed for modeling purposes. The same is true for the two components “GSHP heating” and “GSHP cooling”, which refer to the ground source heat pumps in heating mode (winter operation) and cooling mode (summer operation), respectively.

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

The objective of energyPRO is to optimize the yearly operation of the production units, so that the energy demands (heating and cooling in this case) are covered at the lowest yearly operation cost while also minimizing GHG emissions. Simplifying, energyPRO assigns to each production unit a marginal cost of production in each hour of the year, taking into account relevant external conditions such as ambient temperature (for the ASHP) and electricity price (for electric-driven machines). The units with the lowest marginal cost of production will be called in operation first. If more production capacity is required to cover demand, units with progressively higher marginal costs of production are called in operation.

The optimization process in energyPRO also involves the optimal utilization of the energy storages and technical constraints, such as unavailability periods, and minimum duration of operation.

One of the energyPRO simulation outputs is the hour-by-hour production schedule of the different energy-production-and-conversion units. As an example, the production schedule for a scenario containing HRCs, heat pumps, and peaking boilers is given in graphical form in Figure 32, together with the state of charge of the hot and cold thermal energy storage.

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Note that the x-axis starts on October 1st, on the y-axis energy and power unit are MWh and MW, respectively. These are multiplied by a factor of 3.41 to convert them to MMBtu and MMBtu/h, respectively.

As seen from Figure 32, the HRC has typically the highest priority given the low marginal cost of production (due to cogeneration of useful heating and cooling), heat from the WWHP has second highest priority, and the peaking boiler has the lowest priority. On the cooling side, the water-cooled chillers have lower priority compared to HRC.

It can be seen how energyPRO optimizes the operation of the available technologies, based on the availability of storage capacity and electricity prices. This is better shown in Figure 33, where the operation of the HRC and the chillers is shown together with the state of charge of the thermal storages and the electricity price. In periods with low electricity prices, the HRC and chillers operate as much as possible to cover the simultaneous cooling demand and recharge the thermal energy storage. Conversely, in hours with higher electricity prices, HRC and chiller production is reduced or eliminated, and the demand is covered by discharging the storage.

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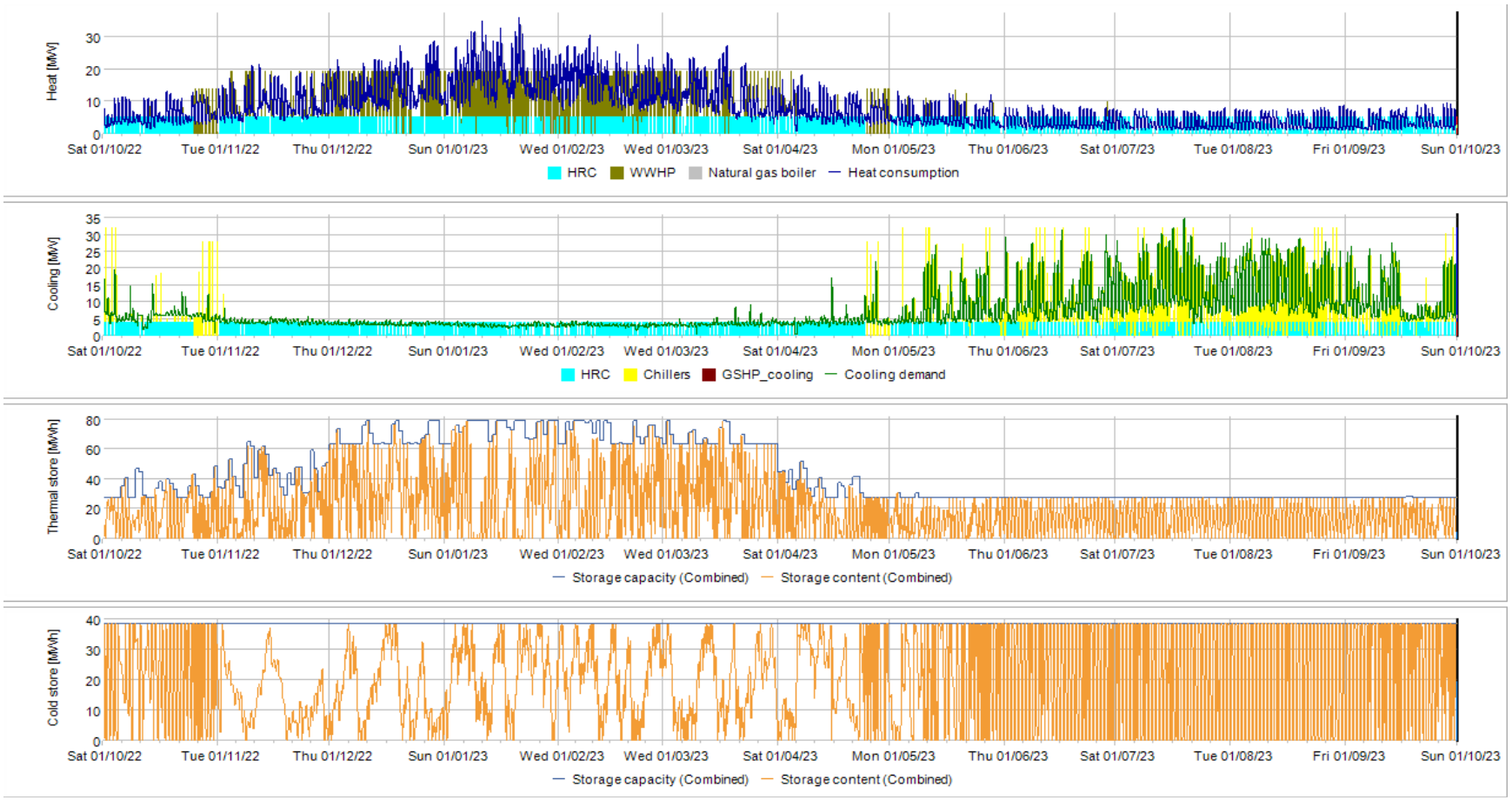

Figure 32. Hour-by-Hour Production Schedule of the Different Production Units Over One Year for Both Heating (1st Diagram from the Top) and Cooling (2nd Diagram), and State of Charge of the Hot (3rd Diagram) and Cold (4th Diagram) Thermal Energy Storage During the Heating and Cooling Seasons. Note that the X-axis Starts on October 1st.

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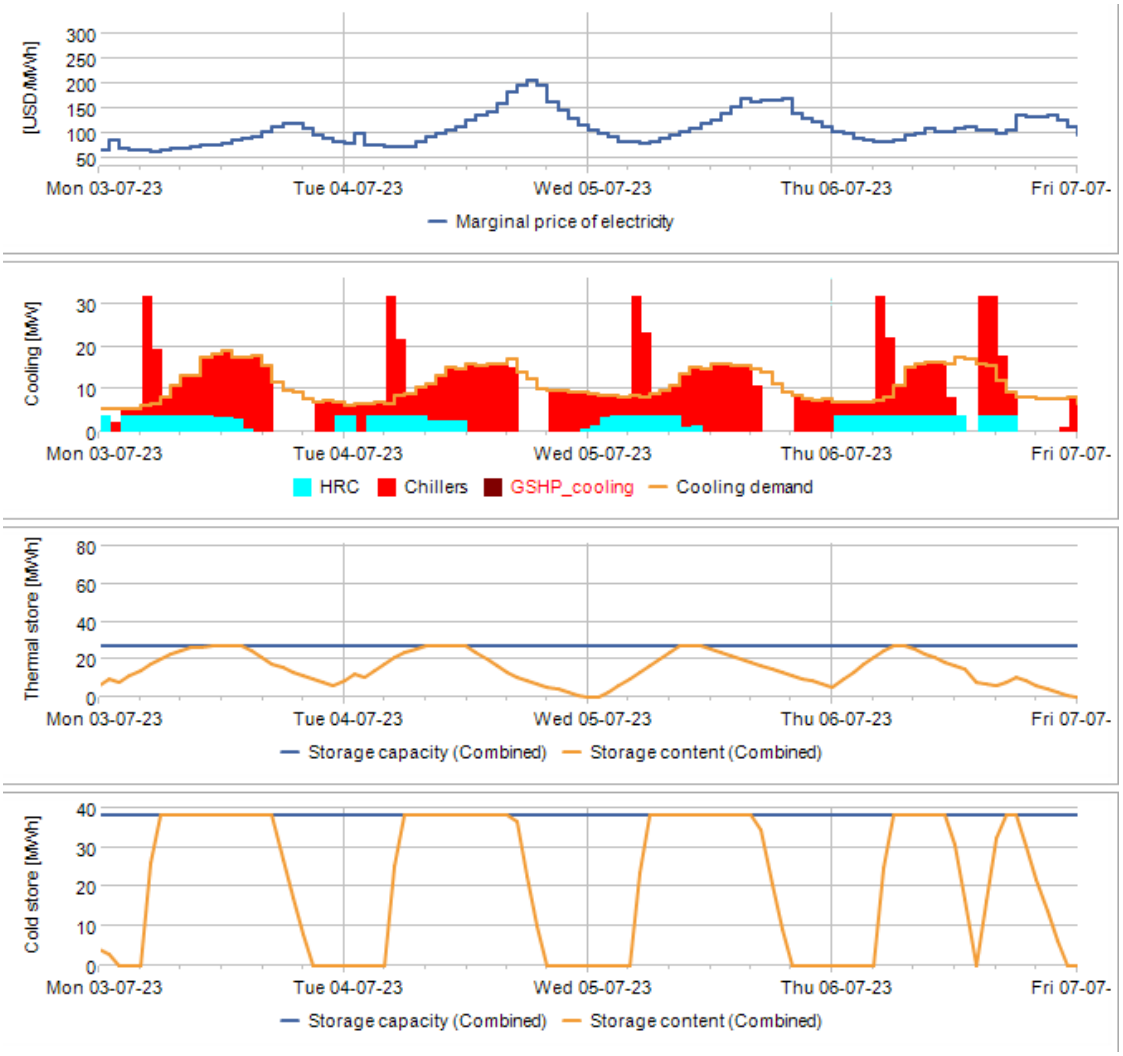

Figure 33. Operation of the Cooling Production Units (2nd Diagram from the Top) in Connection to the Available Storage Capacity of the Hot (3rd Diagram) and Cold (4th Diagram) Storage As Well As the Electricity Price (1st Diagram).

Assumptions

Weather

Albany, NY is located in ASHRAE Climate Zone 5A. The energyPRO model was simulated using Typical Meteorological Year (TMY) weather data from nearby Albany International Airport.

Thermal District Design Temperatures

The district cooling loop is assumed to be operated with a supply and return temperature of 44 °F and 39 °F, respectively.

The district heating loop is assumed to be operated with a supply temperature which is reset dependent on the outdoor temperature. When the outdoor temperature is lower than 20 °F, the supply temperature is

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140 °F; when the outdoor temperature is higher than 50 °F, the supply temperature is 120 °F. At intermediate outdoor temperatures, the supply temperature is linearly interpolated. However, during the winter season (from December 1st to April 1st), the supply temperature is set at least to 134°F, to directly produce domestic hot water (which is assumed to require a temperature at the tap of 125 °F).

The return temperature of the district heating loop is assumed constant and equal to 109 °F.

Heating and Cooling Demand

The heating and cooling demands of ESP used in the energyPRO model are based on the building simulations and include the implementation of the selected EEMs and the repurposing of the Health Laboratory.

When the supply temperature of the district heating network is not high enough to produce domestic hot water (see previous subsection), point-of-use electric heaters are used to top up the last degrees of temperature needed.

The heat losses from the distribution network (as well as from the transmission lines from the wastewater treatment plant in the relevant scenarios) and from the hot thermal energy storage are also added to the central plant heat load.

The “cold” thermal losses from network and storage (heat gains) are neglected, given the low temperature difference between heat transfer fluid and surroundings.

Equipment Performance

Table 34 presents the nominal and average COP values for the thermal energy systems modeled in energryPRO.

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Table 34. energyPRO Equipment Efficiency

Assumptions

Equipment	Nominal COP	Average COP	Source
Fossil Fuel Boilers	0.846	0.846	Historic central plant data
Electric Boilers	0.98	0.98	Engineering assumption
GSHP (heating)	3.2	3.7	Engineering assumption
GSHP (cooling)	4.5	5.5	Engineering assumption
Wastewater Heat Pump (heating)	3.5	4.1	Engineering assumption
Cascade HP (heating)	3.5	2.9	Engineering assumption
Water-Cooled Chiller Plant	4.7	5.7	Engineering assumption

Energy Prices & Tariffs

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

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

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

The overall hourly price used as input to the energyPRO model for the evaluation is shown Figure 34.

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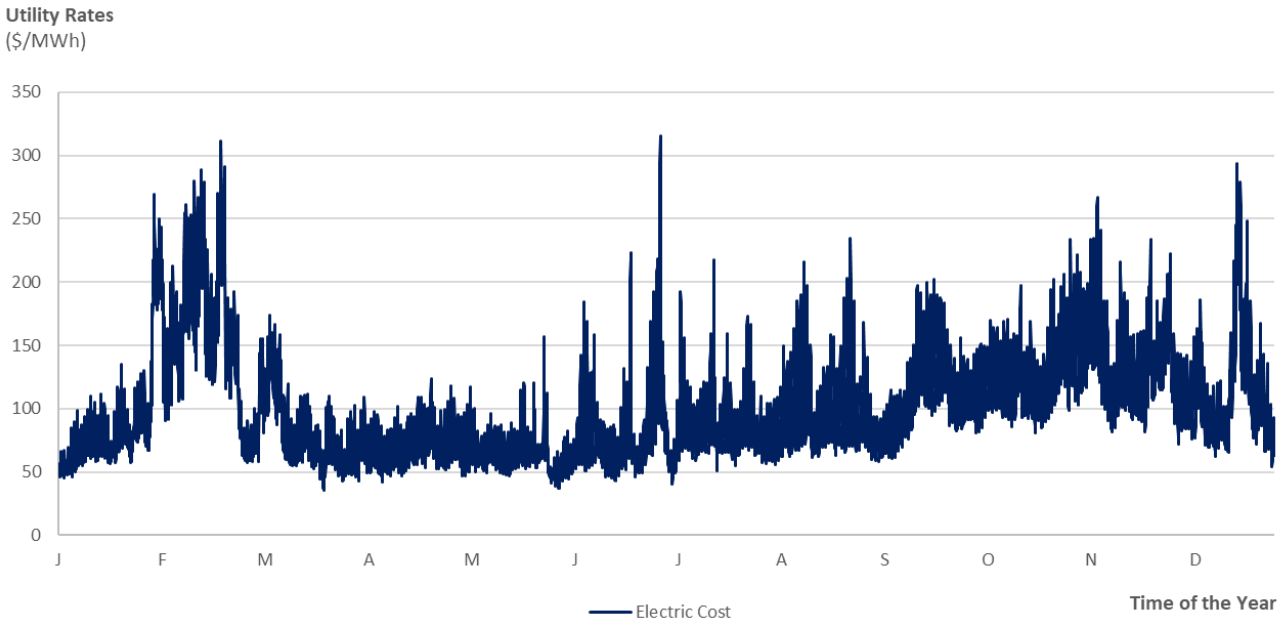

Figure 34. Overall Hourly Electricity Price Used for the Centralized Production Units

Using an hourly blended rate (Figure 34) for electricity instead of explicitly including a separate demand charge has a consequence that can be described using an example.

Consider a centralized cooling production with thermal storage. If an hourly blended rate (Figure 34) is assumed, the optimal operation strategy (lowest operation cost) for operating the electric chillers would be to operate at full capacity in the hours with the lowest electricity prices to charge the thermal storage and then minimize/avoid operation during the hours with the highest electricity price, where the storage tank would be discharged to cover the demand. If the thermal storage charging ends up occurring during times that are not during the peak time window designated by the utility, or if the chiller demand during these times does not contribute to the monthly total electric peak, then the simplification has no consequence; that is not guaranteed. In practice, the thermal storage implementation would be operated to consider monthly demand peaks.

Natural gas rates from Table 16 were escalated to 2025 dollars using the same methodology as described in Section C.1.3; a natural gas rate of $0.469/therm was used for the centralized solution analyses.

D.5 Conceptual Scenario Selection and Initial Screening

The objective of the planning efforts is to develop a group of scenarios to assess centralized energy supply alternatives, and to identify those that will be advanced for further assessment. The scenarios are based on the technologies presented in Section D.2 and consider the aspects below through a combination of quantitative and qualitative screening:

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

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D.5.1 Scenario Variations

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

- Heat recovery chillers (HRCs), GSHPs, ASHPs, industrial heat recovery (IHR) heat pumps, and wastewater heat pumps as baseload technologies
- Natural gas boilers, renewable oil boilers, and electric boilers as peaking technologies
- Tank thermal energy storage (TTES) and borehole thermal energy storage (BTES) solutions
- 4-pipe LTHW and CHW distribution systems
- Production of domestic hot water (centralized and/or local)

Table 35 below presents an initial list of scenarios with chosen combinations of viable technologies as identified in the technology screening process.

Table 35. Initial Scenario Screening List

Scenario	Technologies / sources						
	HRC	**WWHP**	**GSHP**	**IHR**	**ASHP**	**Peak**	**Storage**
1A	Base 1					NG	TTES
1B	Base 1	Base 2				NG	TTES
1C	Base 1		Base 2			NG	TTES + BTES
1C, var 1	Base 1		Base 2			Renew	TTES + BTES
1C, var 2	Base 1		Base 2			Electric	TTES + BTES
1C, var 3	Base 1		Base 2			NG	-
1D	Base 1			Base 2		NG	TTES
1E	Base 1				Base 2	NG	TTES
1F	Base 1	Base 2		Base 3		NG	TTES
2A		Base 1				NG	TTES
2B		Base 1	Base 2			NG	TTES + BTES
2C		Base 1		Base 2		NG	TTES
2D		Base 1			Base 2	NG	TTES
3A			Base 1		Base 2	NG	TTES + BTES

“Base 1” is the acronym for the first baseload technology, and “Base 2” indicates a second baseload technology. The numbers 1 to 3 do not necessarily indicate which baseload technology should have the highest priority, since this priority should be determined from the variable production costs.

The following subsections describe the additional screening that was conducted and reviewed with OGS and NYPA to select variants considered most practical for the Plaza.

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Domestic Hot Water

Domestic hot water (DHW) at the Plaza is mainly produced at the buildings utilizing low-pressure steam from the SASP steam distribution system. For all decarbonization scenarios, DHW production from the proposed LTHW distribution system via building-level heat exchangers was evaluated. In all of these cases, LTHW would be used to heat the domestic hot water up to its design setpoint (minimum of 125°F). As discussed in Section D.4.3, there may be times when the LTHW district supply temperature may not be high enough to accommodate the DHW setpoint (such as during periods of hot water supply temperature reset). In these cases, point-of-use electric heaters would be used to top up the remaining degrees of temperature needed. This approach would be used for each of the decarbonization scenarios, thus there are no variations in DHW production methods amongst the scenarios.

GSHPs Versus ASHPs

Two potential electrification technologies to serve the baseload demands at the Plaza have been considered: GSHPs and ASHPs. The following items were discussed:

- ASHP fan noise: The evaporator of the ASHP is equipped with fans to improve the heat transfer rate. When in operation, the fans create noise. Depending on the context, noise reduction/mitigation may be required, which can be challenging and come at an added cost. However, the fans may be equipped with variable frequency drives to reduce fan speed, which will decrease the noise when operating at reduced speed.
- Land availability for geothermal: A GSHP will require a geothermal heat exchanger and access to the subsurface. Vertical boreholes significantly reduce the space requirements compared to a horizontal geothermal heat exchanger. The process of installing the boreholes will require substantial surface disruption around the building. Once the boreholes are installed, the soil around the area can still be used, but substantial new building construction would not be possible. Parking lots can be a good application for geothermal borefields, particularly when a parking lot is being replaced or added.
- Space availability for the ASHP evaporator: The ASHP evaporators will be located outdoors. Smaller units can be installed on the ground or on the top of buildings, but larger units will require dedicated horizontal space for the installation of the air heat exchanger.
- ASHP performance limitations on cold days: ASHPs experience lower operating efficiencies during colder periods of the year, namely when ambient temperatures are well below freezing. This limitation is driven by how cold the refrigerant within the ASHP system can get, as the refrigerant must be colder than the air in order to accommodate an effective heat transfer. While innovations in ASHP technology have resulted in systems capable of operating at subzero ambient temperatures, the drop-off in operating efficiency and capacity at colder ambient temperatures is still a crucial issue to consider when evaluating baseload technologies.

ASHPs considered in this study are air-to-water heat pumps that use ambient air as the heat source or heat sink to generate hot water or chilled water, respectively. ASHPs use a refrigeration cycle to facilitate this heat transfer between components. ASHPs can be integrated into either a decentralized (building-level) or centralized system, such as a district thermal system. In either arrangement, ASHPs are best sized to contribute toward the annual baseload heating demand. This is due to the heat pump's cost, inverse relationship between capacity and demand, and efficiency degradation for peak demand

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operation. In cold climates, application of ASHPs for heating are often more economical when coupled with the use of more conventional heating technologies, such as electric or gas-fired boilers, for supplemental heat for peak demands.

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

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

Figure 35 below presents a pro/con analysis of ASHPs compared to other technologies. Some of the attributes of ASHPs discussed previously are reiterated in the analysis.

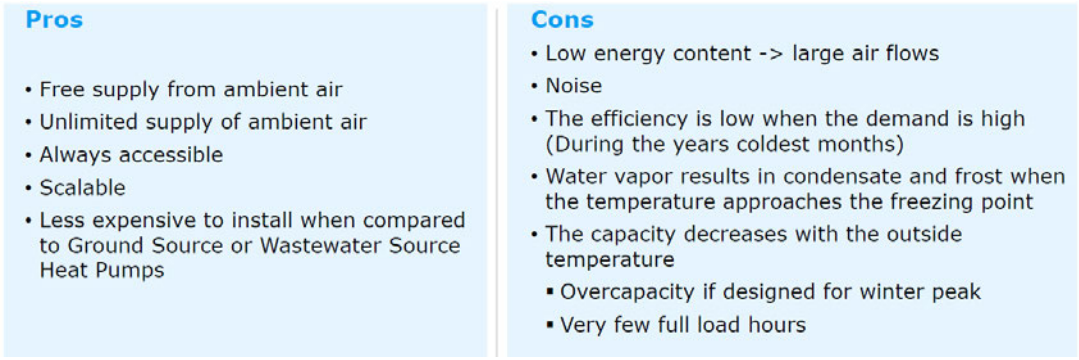

Figure 35. ASHP Pro/Con Chart

GSHPs as considered in this study are water-to-water heat pumps that use the ground as the heat source or heat sink to generate hot water or chilled water, respectively. In the context of vertical closed-loop GSHP technology screened in Section D.2.4, heat is exchanged with the earth via an array of vertical closed-circuit boreholes (the borefield) installed underground. The GSHP systems circulate a water or glycol solution through the borefield on one side and the building or central HW or CHW distribution loop on the other side.

Like ASHPs, GSHPs can be integrated into either a decentralized or centralized system, and they are also often most economical when sized to meet baseload heating demand rather than the entire peak heating demand. This is due, primarily, to their relatively high cost but also due to efficiency degradation

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under peak demand conditions. Despite stable ground temperatures, prolonged intense demand can cause a drop in ground temperatures, reducing the performance of ground source heat pumps. In cold climates, application of GSHPs for heating are often more economical when coupled with the use of more conventional heating technologies, such as electric or gas-fired boilers, for supplemental heat for peak demands.

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

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

Figure 36 below represents a pro/con analysis of GSHPs compared to other technologies. Some of the attributes of GSHPs discussed previously are reiterated in the analysis.

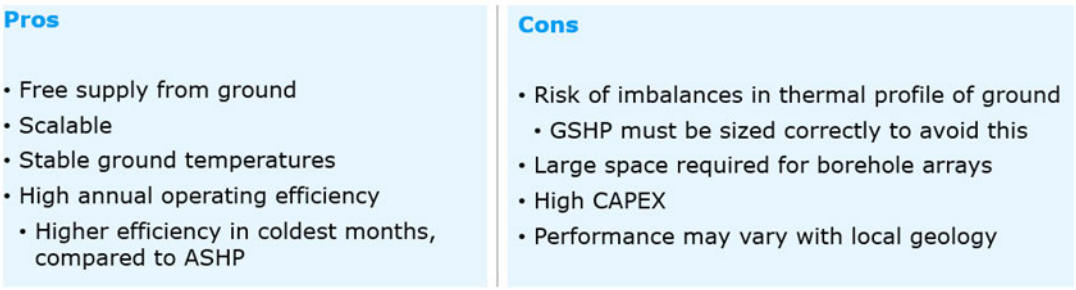

Figure 36. GSHP Pro/Con Chart

Section D.2.4 discusses the potential borefield location and number of boreholes (as well as depths) that were assumed when evaluating GSHPs as a baseload technology.

In conclusion, there are both advantages and disadvantages to GSHP and ASHP technology. As explained later in Section D.5.2, Ramboll optimized the advantages of both technologies by having each technology serve as a baseload technology supplemented with another baseload technology, such as a heat recovery chiller.

D.5.2 Final Scenarios Selected

Through a process of qualitative and quantitative analyses in the technical screening process, Ramboll further reduced the number of scenarios from fourteen (see Table 35) to eight. Table 36 lists the eight final scenarios which advanced to the detailed techno-economic analysis.

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Table 36. Final Scenarios for the Techno-Economic Assessment

Scenario	1A	1B	1C	1C, var 1	1C, var 2	1C, var 3	1E	1F
Approach	Centralized HRC + NG Boiler + TTES	Centralized HRC + WWHP + NG Boiler + TTES	Centralized HRC + GSHP + NG Boiler + TTES+BTES	Centralized HRC + GSHP + Renew. Boiler + TTES+BTES	Centralized HRC + GSHP + Elec. Boiler + TTES+BTES	Centralized HRC + GSHP + NG Boiler w/o TTES	Centralized HRC + ASHP + NG Boiler + TTES	Centralized HRC + WWHP + IHR + NG Boiler + TTES
Total Number of Heated Buildings	18	18	18	18	18	18	18	18
Total Number of Cooled Buildings	17	17	17	17	17	17	17	17
Number of Buildings Connected to District Network	16	16	16	16	16	16	16	16
Total Heat Load (SH + DHW) of All Buildings Covered by District Network, MMBtu/Yr	252,223	252,223	252,223	252,223	252,223	252,223	252,223	252,223
Baseload	HRC	HRC + WWHP	HRC + GSHP	HRC + GSHP	HRC + GSHP	HRC + GSHP	HRC + ASHP	HRC + WWHP + IHR
Peaking	Natural Gas Boiler	Natural Gas Boiler	Natural Gas Boiler	Renewable Oil Boiler	Electric Boiler	Natural Gas Boiler	Natural Gas Boiler	Natural Gas Boiler
DHW	Centralized	Centralized	Centralized	Centralized	Centralized	Centralized	Centralized	Centralized
Space Cooling	HRC, Electric Chiller	HRC, Electric Chiller	HRC, GSHP, Electric Chiller	HRC, GSHP, Electric Chiller	HRC, GSHP, Electric Chiller	HRC, GSHP, Electric Chiller	HRC, ASHP, Electric Chiller	HRC, Electric Chiller
Thermal Storage	TTES	TTES	TTES+BTES	TTES+BTES	TTES+BTES	-	TTES	TTES

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Scenario	1A	1B	1C	1C, var 1	1C, var 2	1C, var 3	1E	1F
Backup Heat	Natural Gas Boiler	Natural Gas Boiler	Natural Gas Boiler	Natural Gas Boiler	Natural Gas Boiler	Natural Gas Boiler	Natural Gas Boiler	Natural Gas Boiler
Borefield Balancing	N/A	N/A	Cooling	Cooling	Cooling	Cooling	N/A	N/A
Location of Borefield	N/A	N/A	Figure 16	Figure 16	Figure 16	Figure 16	N/A	N/A
Distribution Network	4-Pipe	4-Pipe	4-Pipe	4-Pipe	4-Pipe	4-Pipe	4-Pipe	4-Pipe

It would, to a certain extent, be possible to co-produce heating and cooling which would result in a very high efficiency for the heat recovery chiller (HRC). In addition, co-producing heating and cooling would be the only scenario where ESP would not rely on external stakeholders, and the source for heating (the production of chilled water) would be available on site. Therefore, co-production should always be prioritized, and scenarios which do not include HRC were removed (all 2 and 3 scenarios).

Full electrification of the main heating system (aside from backup equipment) is represented in scenario 1C2, as it involves the use of an electric boiler(s) for peak heating. All other scenarios use either natural gas or renewable oil boilers for peaking and are thus not considered to be full electrification scenarios. All scenarios, including 1C2, are equipped with natural gas emergency backup boilers, which are sized to meet the peak heating loads. Scenarios with natural gas boilers as the peaking technology can also consider those same assets as emergency backup boilers. All boilers are located in their respective energy center.

The electrified technologies that are being considered in one or multiple scenarios, in varying capacities, are as follows:

- Heat recovery chillers
- Wastewater heat pumps
- Ground-source heat pumps
- Air-source heat pumps
- Industrial heat recovery heat pumps
- Electric boilers
- Electric chillers

Descriptions of each of these technologies are given in Sections D.2 and D.5.

The **business-as-usual scenario** (in the context of this report, labeled as ‘Baseline 2019’), represents the continuation of existing heating and cooling equipment without compliance with CLCPA requirements. This baseline provides a comparison relative to the proposed modeled scenarios of costs and GHG emissions for the Plaza heating and cooling systems. Technologies will be renewed when they reach the end of their useful lifetime.

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Scenario 1A features one or several heat recovery chillers as the sole baseload heating and cooling technology. All remaining heating load would be covered by natural gas peaking boilers, while all remaining cooling load would be covered by the existing chiller plant. Tank thermal energy storage (TTES) would be utilized under this scenario, with a dedicated hot water storage tank and chilled water storage tank.

Scenario 1B is similar to Scenario 1A but also includes the use of wastewater heat pumps towards baseload heat production (see Section D.2.5).

Scenario 1C features HRCs and GSHPs as baseload heating and cooling technologies. All remaining heating load would be covered by natural gas peaking boilers, while all remaining cooling load would be covered by the existing chiller plant. Both TTES and borehole thermal energy storage (BTES) would be utilized as means of energy storage.

Scenarios 1C1, 1C2, and 1C3 are similar variants that all involve HRCs and GSHPs as baseload heating and cooling technologies. The major difference between the variations is the peak heating technology; natural gas, renewable oil, and electric boiler technology each comprises one of the scenario variants. Scenarios 1C1 and 1C2 also utilize both the GSHP borefield (BTES) and tanks (TTES) as a means of energy storage, while **Scenario 1C3 does not.**

Scenario 1E is similar to Scenario 1B but utilizes ASHPs in lieu of WWHPs for baseload heating.

Scenario 1F features HRCs, WWHPs, and industrial heat recovery heat pumps (IHRs) as a means of baseload heating, while peak heating is covered by natural gas boilers.

D.5.3 Technical Results

Figure 37 and Figure 38 show the annual heating and cooling production (output) from the main technologies in the different scenarios. The heating and cooling demand are the same in all scenarios, but the heating and cooling generated can vary due to different distribution losses between scenarios, and the required input energy to meet the demands (Figure 39) varies due to differing conversion efficiencies of the various production units. Detailed output of the modeling results for the scenarios can be found in Appendix E .

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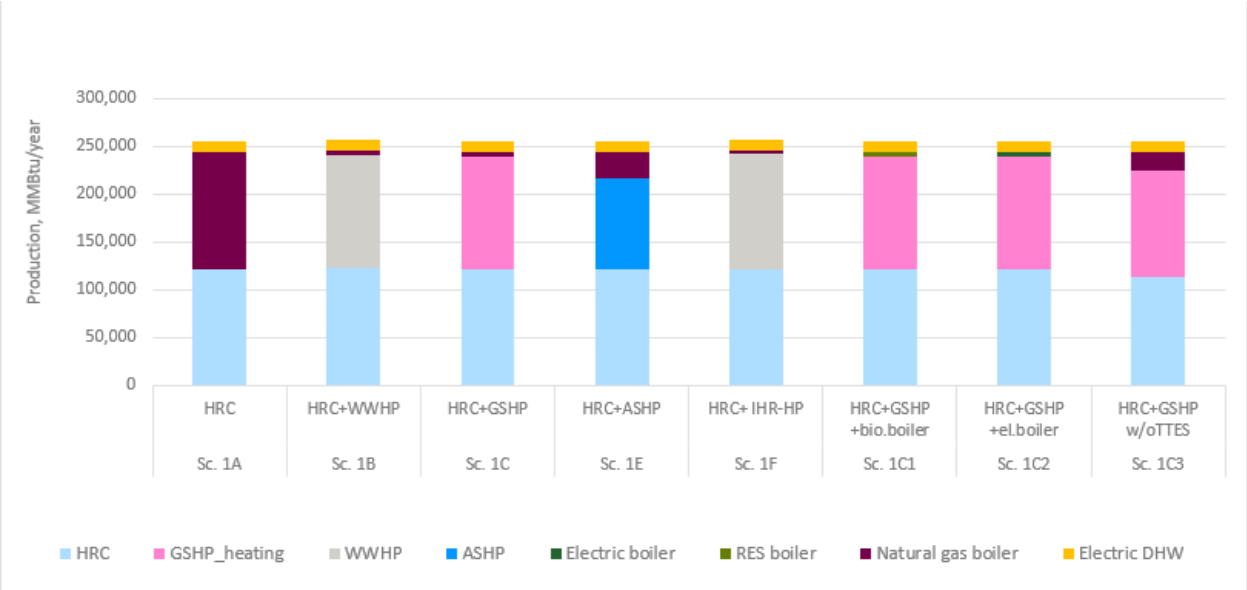

Figure 37. Annual Heating Production

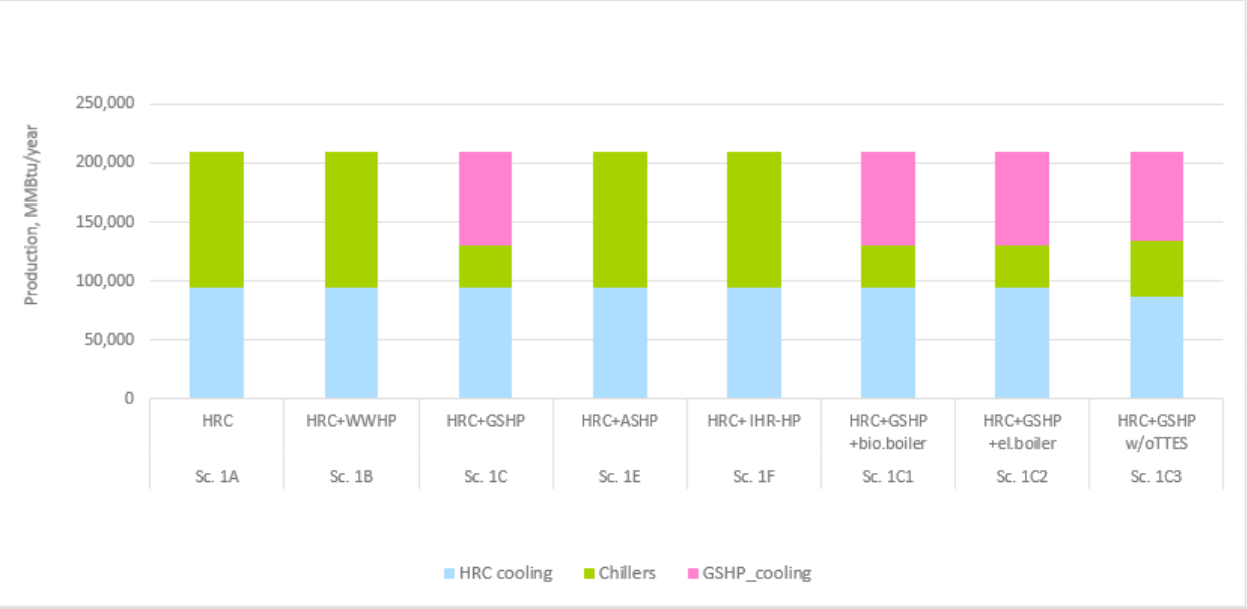

Figure 38. Annual Cooling Production

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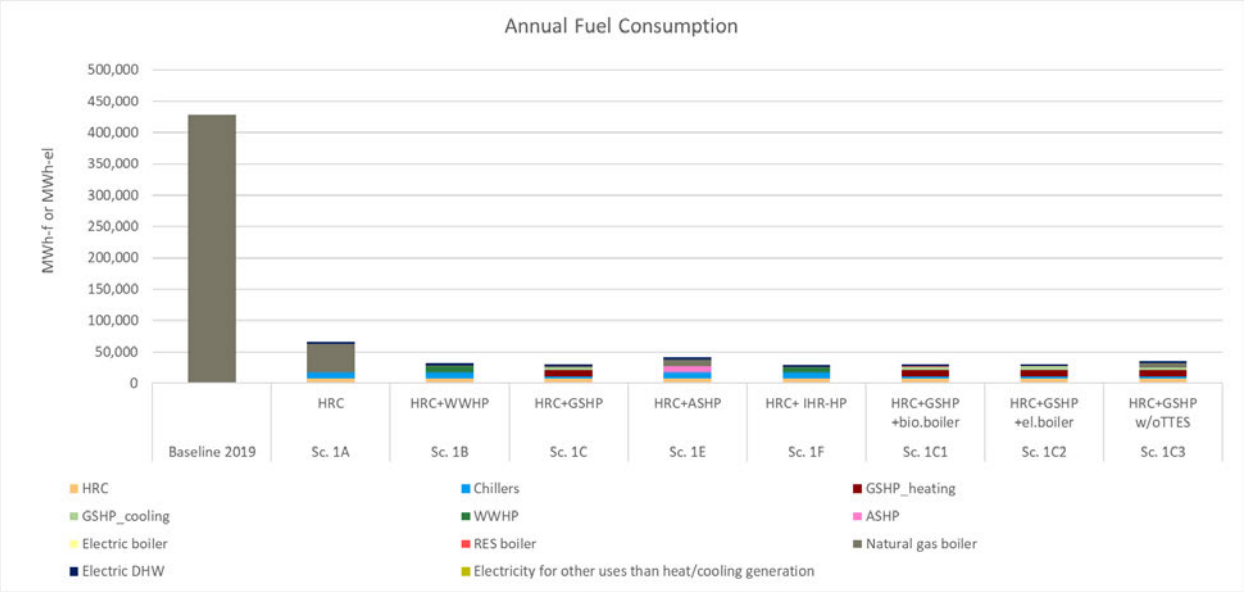

Figure 39. Annual Fuel/Electricity Consumption to Meet Heating and Cooling Demand

Regarding heat production, the HRC produces about 48% of the overall heat production on a yearly basis, with the only exception of Scenario 1C3 (44%), where the absence of the thermal energy storage slightly limits the operation of the HRC.

Regarding cooling production, the HRC produce about 45% of the overall cooling production on a yearly basis, with the only exception of Scenario 1C3, which has a slightly lower share (41%) due to absence of the thermal energy storage.

Table 37 shows the share of heat output from peaking boilers compared to overall heat production. Scenario 1A, which uses only HRC as electrification technology for heat production, shows the highest share of heat production coming from the boilers (almost half of the yearly heat production). Scenario 1E, which uses ASHPs in addition to HRC, shows the next highest boiler contribution to heat at 11%. Because ASHPs have a lower output capacity in the coldest periods, more heat output is required from the boilers to meet the heat demand in the coldest months. Scenario 1C3, which does not have TTES, shows 7% boiler contribution to heat because TTES is not available to store heat pump production which could further offset boiler operation. All other alternative scenarios have very low and quite similar shares of boiler heat production.

Table 37. Share of Heat Output from Peaking Boilers Compared to Overall Heat Production

Scenario	Sc.1A	Sc.1B	Sc.1C	Sc.1E	Sc.1F	Sc.1C1	Sc.1C2	Sc.1C3
Heat share from peaking boilers	48%	2%	2%	11%	1%	2%	2%	7%

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D.6 ESP Electrical Capacity Assessment

D.6.1 Electrical Infrastructure Impacts

Electrification of the Plaza will result in increased electricity use for heating and cooling purposes, as well as an increase in peak electrical load. Figure 5 from Section A shows existing peak demands of nearly 16 MW occurring throughout multiple periods of a typical year. While energy efficiency measures and planned renovations will lower the electrical peak demands and annual electricity consumptions of the Plaza buildings, electrification of the central heating and cooling plants will ultimately result in a net increase in peak demand and annual consumption. Figure 40 summarizes these peak electrical demand impacts by decarbonization scenario.

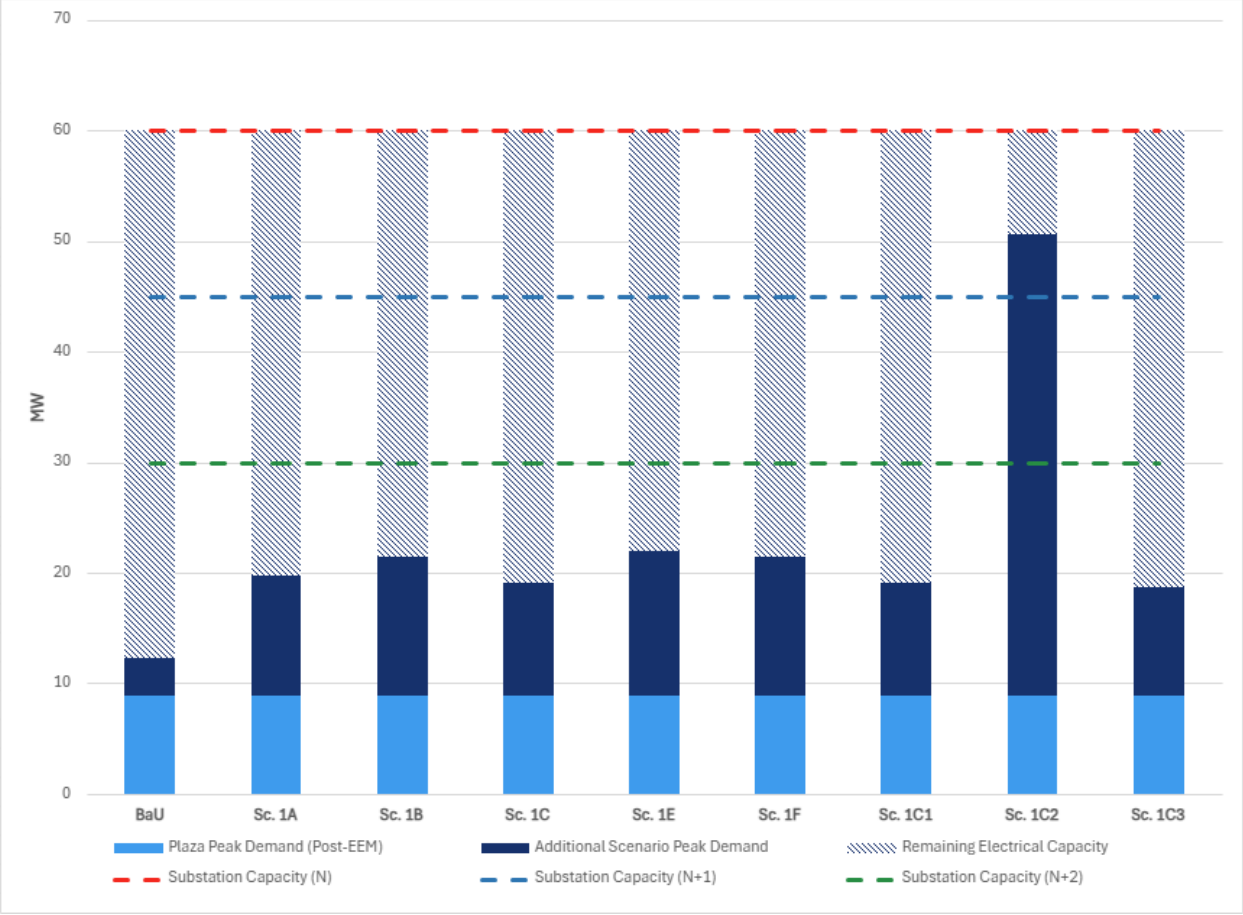

Figure 40. Estimated Plaza Substation Electrical Capacity per Scenario

The main plaza substation as summarized in Section B.1.3 can handle a peak electrical demand of 60 MW with all four transformer banks energized. It is understood, however, that no less than two (x2) transformer banks are preferred to remain open/deenergized during both normal and peak electrical demand periods, thus maintaining an N+2 redundancy at the 34.5kV substation. This equates to roughly 30 MW of peak demand capacity.

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With the exception of decarbonization scenario S1C2, the main plaza substation in its current configuration and condition is expected to sufficiently handle the expected increase in peak electrical demand that would result from the decarbonization scenarios. In these cases, N+2 redundancy would still be maintained, and no direct upgrades would be required at the substation. Further evaluation of each bus on the 13.8kV side of the transformers should be conducted in subsequent design efforts to confirm capacities of the buses (initially understood to be 1200A) before determining power feeder tie-ins that would route to the new electrified heating equipment.

The electrical peak demand for scenario S1C2, which features electric boilers for peak heating, is expected to remain within the total capacity of the main substation but require all four (x4) transformer banks to be energized. This would eliminate the ability for the Plaza to maintain any levels of redundancy across the transformer banks during periods of peak demand. To maintain the preferred N+2 redundancy, a dedicated electrical substation that would serve the loads associated with the electric peaking boiler(s) was included in the cost estimate generated for scenario S1C2 (see Appendix G). Allowances for associated electrical infrastructure upgrades and installations (such as new feeders, panels, etc.) were also included in the cost estimate. Due to the sizeable increase in peak electrical demand anticipated for scenario S1C2, coordination with the local utility (National Grid) would also likely be needed to ensure utility systems upstream of the main plaza substation could accommodate the revised peak loads.

D.7 Proposed Resiliency / Redundancy

D.7.1 Current Resiliency Posture

Heating Network

The existing heating network comprises of the generation of heat at SASP, the thermal distribution system, and the building level heating systems. In the event of a power outage, SASP is able to operate under emergency power, and the thermal distribution system does not require power as steam is transported via its own pressure. The buildings are partially backed up by emergency power and are able to remain heated during an electrical outage. The boilers at SASP are dual fuel, with means to switch to burning fuel oil stores in the event of a natural gas supply disruption.

Comfort Chilled Water Network

The existing chilled water system is comprised of steam and electric chillers at the CACP facility, the chilled water distribution system, and the building level chilled water systems. The CACP facility is not required to operate during an electrical outage and the chilled water pumps are not on emergency power.

Data Center Chilled Water Network

The existing EDP chillers are backed up as critical load by the emergency generator system.

Electrical System

The Plaza currently maintains N+2 redundancy at the four [redacted] feeders and transformer banks that step incoming service from National Grid down to distribution voltage. The four feeders are fed by three different National Grid substations, whereas two National Grid substations could fail and the facility could still be energized.

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As previously described in Section B.4.2, there are two [redacted] emergency power to the Plaza, boiler plant, and EDP chillers in the event of a prolonged electrical outage.

D.7.2 Future Resiliency Posture

Heating Network

It is expected that the heating network would have to operate during a prolonged electrical outage to prevent the heating pipes from freezing, bursting, and causing damage. With an increased focus on electrification of ESP, it is thus advised to have full heating backup from a secondary fuel. Diversified fuel use can support flexibility and cost resiliency. As shown previously in Table 36, natural gas/dual fuel boilers would be featured in all decarbonization scenarios to provide the means of backup heating required.

Select plant auxiliary equipment and the district hot water distribution pumps would need to have the ability to operate on emergency power in order to maintain the heating network during a power outage.

Comfort Chilled Water Network

In the future, it is expected that a similar level of resiliency will be provided for the chilled water system. No comfort cooling is anticipated for emergencies.

Data Center Chilled Water Network

The existing EDP chillers would need to continue to be backed up by the emergency generator system, as is the case today.

Electrical System

In the future, it is anticipated that the electrical infrastructure will remain similar to the current level of resiliency and redundancy. If needed, an additional emergency generator may be required to power the hot water distribution pumps during a prolonged electrical outage.

It is anticipated that electrified heating/cooling systems will be used to heat and cool the Plaza in the future, and fossil fuels will still be used during a prolonged electrical outage. For this reason, the generators do not need to provide enough power to operate beneficial electrification equipment, and N+1 redundancy will not be required for the electric heating and cooling equipment.

Tank Thermal Energy Storage (TTES)

Tank thermal energy storage (TTES) is an important component in an energy system with fluctuating energy prices. TTES involves storing hot or cold water in insulated tanks to help balance energy demand and supply while ultimately reducing peak demand, energy consumption, carbon emissions and costs. The storage makes it possible to disconnect consumption of electricity from the supply of heat. Thereby, it is possible to capture heat when renewable energy is available and supply heat from the TTES when renewable energy is scarce. Section D.2.6 provides a broader discussion of this technology and its application.

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In addition to these benefits, TTES can serve as a crucial resilience measure during power outages. Stored thermal energy can be used to supply heating or cooling to buildings until power is restored. Furthermore, TTES can bridge the gap during startup delays of central backup boilers, ensuring continued thermal supply while the boilers reach operating temperature. By reducing or eliminating the need for warm standby operation, TTES can help avoid the ongoing fuel consumption, emissions, and standby losses associated with keeping backup boilers partially heated. This not only improves overall system efficiency but also lowers operational costs and reduces unnecessary wear on boiler components.

Battery Storage

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

D.8 Conclusion

The analysis presents several critical elements in developing an effective thermal energy strategy.

- The baseload and peaking strategy aims to enhance system performance and manage costs by using technologies such as heat pumps for baseload and existing boilers or electric boilers for peak loads. This approach leverages existing infrastructure to maintain resiliency.
- Reliable backup systems are crucial. Ensuring that the backup fuel supply is non-interruptible and that the technology is familiar to operational staff is vital for maintaining operational reliability
- Performing building upgrades, such as HVAC system replacements and renovations, will not only replace dated building systems that are past the end of their respective useful lives, but will enable the buildings to connect to a more energy efficient low temperature hot water (LTHW) thermal district.

Through qualitative and quantitative screening, Ramboll narrowed approximately 14 scenarios to 8 for detailed analysis. These scenarios include combinations of geothermal and air-source heat pumps, integration of waste heat from wastewater treatment plants and industrial waste heat sources, and a comparison of electric, natural gas, and renewable fuel boilers for peaking. Economic and environmental results are presented in Section E.

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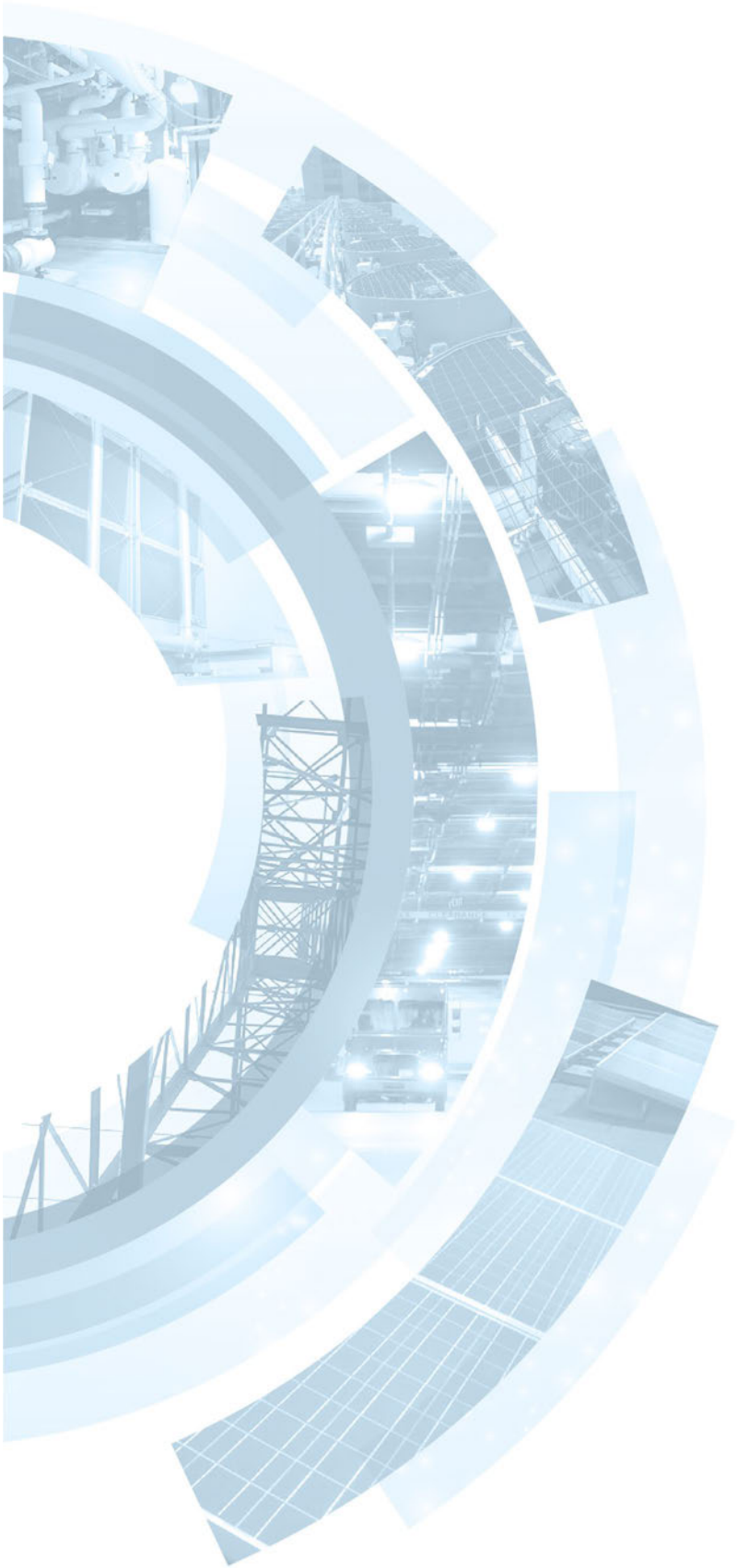

E – Economic and Feasibility Analysis

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Section E – Economic and Feasibility Analysis

The analysis presented in this section was conducted in 2022-2023. The original results were based on 2022 dollars. Costs presented in this section were escalated to 2025 dollars using the historic CPI method[21] discussed previously in Section C.1.3.

E.1 Economic Analysis Results

E.1.1 Main Assumptions

E.1.1.1 Social Cost of carbon

The social costs of greenhouse gases were estimated based on the New York State Department of Environmental Conservation (NYSDEC) document "Establishing a value of carbon"[22] . Table 38 presents the values used to calculate the social costs over the life of the project. The NYSDEC guidance document expresses the values in 2020 dollars. Ramboll calculated the equivalent costs expressed in 2025 dollars based on historical CPI published by the United States Bureau of Labor Statistics[23]. Please note that since the analysis was completed, NYSDEC has updated the guidance document. As a result, the values used in the original analysis may differ from the most current NYSDEC guidance.

Table 38. 2% Average (Central Rate) Social Costs of Carbon, Methane, and Nitrous Oxide

Emissions Year	Carbon			Methane			Nitrous Oxide		
	2020$ per metric ton of CO_2	2022$ per metric ton of CO_2	2025$ per metric ton of CO_2	2020$ per metric ton of CH_4	2022$ per metric ton of CH_4	2025$ per metric ton of CH_4	2020$ per metric ton of N_2O	2022$ per metric ton of N_2O	2025$ per metric ton of N_2O
2020	$121	$137	$150	$2,700	$3,053	$3,346	$42,000	$47,492	$52,056
2021	$123	$139	$152	$2,800	$3,166	$3,470	$43,000	$48,623	$53,296
2022	$124	$140	$153	$2,800	$3,166	$3,470	$44,000	$49,754	$54,535
2023	$126	$142	$156	$2,900	$3,279	$3,594	$45,000	$50,884	$55,774
2024	$128	$145	$159	$2,900	$3,279	$3,594	$45,000	$50,884	$55,774

[21] https://www.bls.gov/regions/mid-atlantic/data/consumerpriceindexhistorical_us_table.htm
2022 average CPI = 292.6
2025 estimated CPI = 320.8
9.61% inflation rate from 2022 to 2025

[22] Establishing a Value of Carbon

[23] https://www.bls.gov/regions/mid-atlantic/data/consumerpriceindexhistorical_us_table.htm
2020 average CPI = 258.8
2022 average CPI = 292.7
13.1% inflation rate from 2020 to 2022

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Emissions Year	Carbon			Methane			Nitrous Oxide		
	2020$ per metric ton of CO_2	2022$ per metric ton of CO_2	2025$ per metric ton of CO_2	2020$ per metric ton of CH_4	2022$ per metric ton of CH_4	2025$ per metric ton of CH_4	2020$ per metric ton of N_2O	2022$ per metric ton of N_2O	2025$ per metric ton of N_2O
2025	$129	$146	$160	$3,000	$3,392	$3,718	$46,000	$52,015	$57,013
2026	$131	$148	$162	$3,100	$3,505	$3,842	$47,000	$53,146	$58,253
2027	$132	$149	$163	$3,100	$3,505	$3,842	$47,000	$53,146	$58,253
2028	$134	$152	$167	$3,200	$3,618	$3,966	$48,000	$54,277	$59,493
2029	$136	$154	$169	$3,300	$3,732	$4,091	$49,000	$55,408	$60,733
2030	$137	$155	$170	$3,400	$3,845	$4,214	$50,000	$56,538	$61,971
2031	$139	$157	$172	$3,400	$3,845	$4,214	$50,000	$56,538	$61,971
2032	$141	$159	$174	$3,500	$3,958	$4,338	$51,000	$57,669	$63,211
2033	$142	$161	$176	$3,600	$4,071	$4,462	$52,000	$58,800	$64,451
2034	$144	$163	$179	$3,600	$4,071	$4,462	$53,000	$59,931	$65,690
2035	$146	$165	$181	$3,700	$4,184	$4,586	$54,000	$61,061	$66,929
2036	$147	$166	$182	$3,800	$4,297	$4,710	$54,000	$61,061	$66,929
2037	$149	$168	$184	$3,900	$4,410	$4,834	$55,000	$62,192	$68,168
2038	$151	$171	$187	$3,900	$4,410	$4,834	$56,000	$63,323	$69,408
2039	$152	$172	$189	$4,000	$4,523	$4,958	$57,000	$64,454	$70,648
2040	$154	$174	$191	$4,100	$4,636	$5,082	$58,000	$65,584	$71,886
2041	$156	$176	$193	$4,200	$4,749	$5,205	$58,000	$65,584	$71,886
2042	$158	$179	$196	$4,200	$4,749	$5,205	$59,000	$66,715	$73,126
2043	$160	$181	$198	$4,300	$4,862	$5,329	$60,000	$67,846	$74,366
2044	$162	$183	$201	$4,400	$4,975	$5,453	$61,000	$68,977	$75,605
2045	$164	$185	$203	$4,500	$5,088	$5,577	$61,000	$68,977	$75,605
2046	$166	$188	$206	$4,500	$5,088	$5,577	$62,000	$70,108	$76,845
2047	$167	$189	$207	$4,600	$5,202	$5,702	$63,000	$71,238	$78,084
2048	$169	$191	$209	$4,700	$5,315	$5,826	$64,000	$72,369	$79,323
2049	$170	$192	$210	$4,800	$5,428	$5,950	$65,000	$73,500	$80,563
2050	$172	$194	$213	$4,800	$5,428	$5,950	$66,000	$74,631	$81,803

E.1.1.2 Staffing Needs and Workforce Development

The need for staffing is dependent on the complexity of the local energy system. The energy system will transition over time from fossil fuel-fired systems to low temperature hot water systems with heat pump

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technology, where combustion fuels are only used for peaking and backup purposes. The operation of the plant will, to a high extent, be automated.

Future operations are expected to be more complicated than today's. With the CLPCA goal of a carbon-free grid by 2040, there will be a broad build out of solar. This will result in more intermittent renewable energy as part of the electric grid and a heightened attention to shifting demand away from hours of limited intermittent renewable electricity in the grid. Daily strategies will include operating the heat pumps at the lowest wholesale day ahead prices for electricity and energy production for thermal storage. In situations with potential high prices for electricity, it may be optimal to use natural gas boilers for energy production. Adopting this operations strategy would need to be done with careful consideration of the emissions that would result from natural gas boiler operation; higher emissions from this strategy may push the Plaza over allowable thresholds of the CLCPA and other state directive goals.

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

E.1.1.3 Technical Lifetime of Assets

Table 39 presents equipment lifetimes that have been assumed for estimating CAPEX. The technical lifetimes are based on values from ASHRAE.[24], discussions with vendors, and previous project experience.

Table 39. Assumed Equipment Technical Lifetime

Item	Technical Lifetime (yr)
Building-Level Installations	
Air Cooled Chiller	15
ASHP	15
Building-Level Tank Thermal Energy Storage	25
Dry Coolers	20
Direct Expansion (DX) Cooling	15
Electric Boilers	15
Electric Radiators	30
Electric Domestic Hot Water Heater	15
Energy Transfer Station (ETS)	25

[24] ASHRAE, *HVAC Applications Handbook*, 2023, Table 4, Chapter 38, " Comparison of Service Life Estimates."

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Item	Technical Lifetime (yr)
Fossil Fuel Boilers	20
Fossil Fuel Domestic Hot Water Heater	15
Geothermal Borefield	40
GSHP	20
Local Domestic Hot Water HP	15
Rooftop Units (RTU)	15
Water Cooled Chiller	20
Distribution System	
Ambient Network	50
Condensate Lines	20
Electrical Infrastructure Upgrades	50
LTW Network	50
Hot Water/Steam Tunnel Network	50
High Temperature Water (HTW) Network (Direct Buried)	35
Medium Temperature Water (MTW) Network (Direct Buried)	30
Steam Lines (Direct Buried)	25
Energy Center	
Air Cooled Chiller	20
Geothermal Borefield	40
Building for Energy Center	50
Dry Coolers	20
Electric Boilers	20
Fossil Fuel Boilers	25
Heat Pump (GSHP, WWHP, Heat Recovery Chiller)	25
Heat Pump (ASHP)	20

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Item	Technical Lifetime (yr)
Tank Thermal Energy Storage (TTES)	30
Water Cooled Chiller	25
Wood Chip Boiler	25

E.1.2 Economic Results

E.1.2.1 CAPEX Estimates

Cost estimating of different technologies was performed by Trophy Point Construction Services & Consulting (Trophy Point). The remaining scenario costs were extrapolated from this cost estimate and previous studies conducted by Ramboll. The full cost estimate with associated breakdown is provided in Appendix G . Note the costs presented in Appendix G are based on 2022 dollars. Costs summarized in this section have been adjusted to 2025 dollars.

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

- General Conditions – 15%
- Overhead & Profit – 10%
- Design Contingency [25] – 20%

Figure 41 presents the CAPEX for the BAU case and the scenario variants divided, respectively, into CAPEX for building-level installations, distribution system, centralized system and other. Additional detail is provided in Appendix G . The CAPEX in the BAU scenario is limited ($458 million), whereas the CAPEX for Scenario 1F, which is the most CAPEX intensive, is approximately $1.36 billion. The CAPEX for the ESP site does include the cost of the EEMs for each scenario as the mechanical upgrades are required to enable decarbonization. This is unique to the ESP project site as other sites do not required the EEMs to be implemented in order to decarbonize.

Comparing Scenario 1C2, which includes electric boilers for peak heating, with natural gas and bio-fuel peaking variants such as Scenarios 1C and 1C1 provides a comprehensive understanding of the cost impact associated with fully electrifying the annual heating load. The additional cost incurred for integrating electric boilers, electrical upgrades, and maintaining backup natural gas boilers ranges between $1.39 M to $2.89 M compared to the natural gas peaking scenarios. In electric scenarios, including a backup natural gas boiler enhances resiliency against extended power outages, whereas natural gas peaking boilers in Scenario 1C inherently serve dual roles as peak heating sources and backup boilers.

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

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Scenario Sc.1F, which involves heat recovery from an offsite location (see Section D.2.5), is the most expensive compared to the other scenarios. Scenario Sc.1A, which only features heat recovery chillers at the CACP and utilizes fossil-fired boilers to cover the remaining heat load, is the least expensive decarbonization scenario from a CAPEX perspective.

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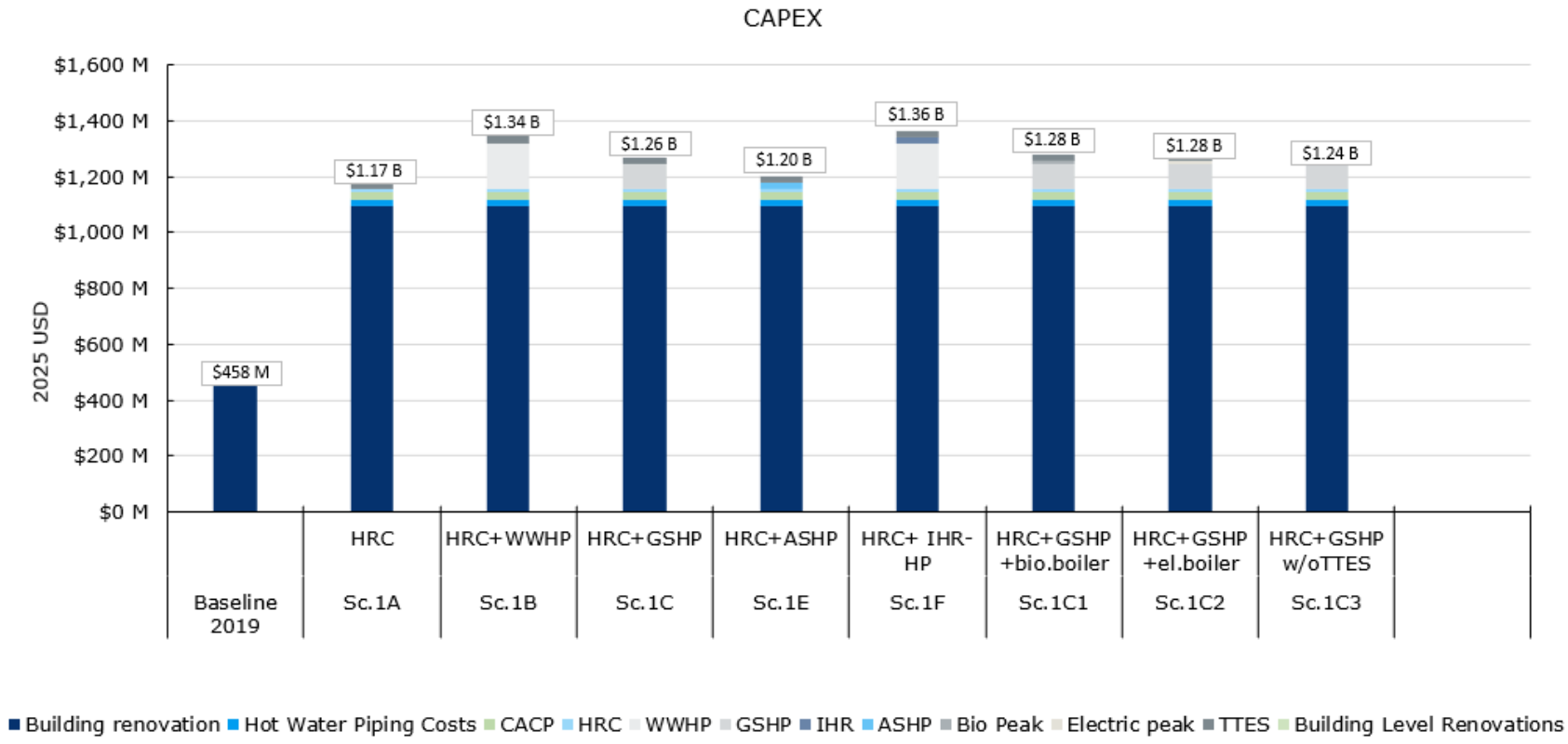

Figure 41. CAPEX for Each Scenario

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E.1.2.2 Cashflow Modeling

Figure 42 provides an overview of the economic performance of the different scenarios in terms of net present value (NPV) over the project lifetime. CAPEX costs, together with the operational costs (OPEX), were fed into a cashflow model which considers the time value of money for the economic evaluation of each scenario. OPEX includes electricity and fuel costs for heating and cooling, operations and maintenance (O&M), and the social cost of carbon (labeled CO2e Emissions Cost in Figure 42).

Assets whose lifetime exceeds the project period are attributed a residual value at the end of the project period to align all costs to that point in time; this shows up in the calculation as a fictitious revenue (incoming cashflow) occurring at the end of the project period. The residual value of the asset is determined by assuming linear depreciation of the asset value (its original CAPEX) over its technical lifetime. For example, an asset with a technical lifetime of 30 years and CAPEX of 3,000,000 USD, installed in the first year of a 20-year project period will retain at the end of the project period a residual value equal to 1/3 of the original CAPEX, i.e., 1,000,000 USD. Conversely, assets whose technical lifetime ends before the end of a 20-year period will require additional investments for replacement or overhaul; these costs and the residual value of the replacements are also included in the cashflow analysis. This approach provides an equitable comparison across the scenarios despite the different technical lifetimes of the assets. The NPV shown in Figure 42 includes the initial CAPEX investment, replacement costs over the project period, and residual value of assets. A year-by-year breakout of the NPV analysis is included in Appendix G that shows the initial investment, annual energy and O&M costs, when replacement costs occur, and the residual value of assets. Note the costs presented in Appendix G are based on 2022 dollars.

The HRC scenario (1A) has the lowest NPV of the decarbonization scenarios. The HRC plus ASHP scenario with natural gas peaking (1E) has a similar NPV but with a slightly lower CO2e emission cost, as less heating hours are being covered by the SASP boilers due to the additional capacity of the ASHPs. The scenario involving industrial heat recovery (1F) has the highest NPV, primarily driven by having the highest CAPEX cost. Despite these observations, the differentiation in total NPV across each scenario is limited. Based exclusively on economics, there is no clear guidance on which scenario is the most favorable.

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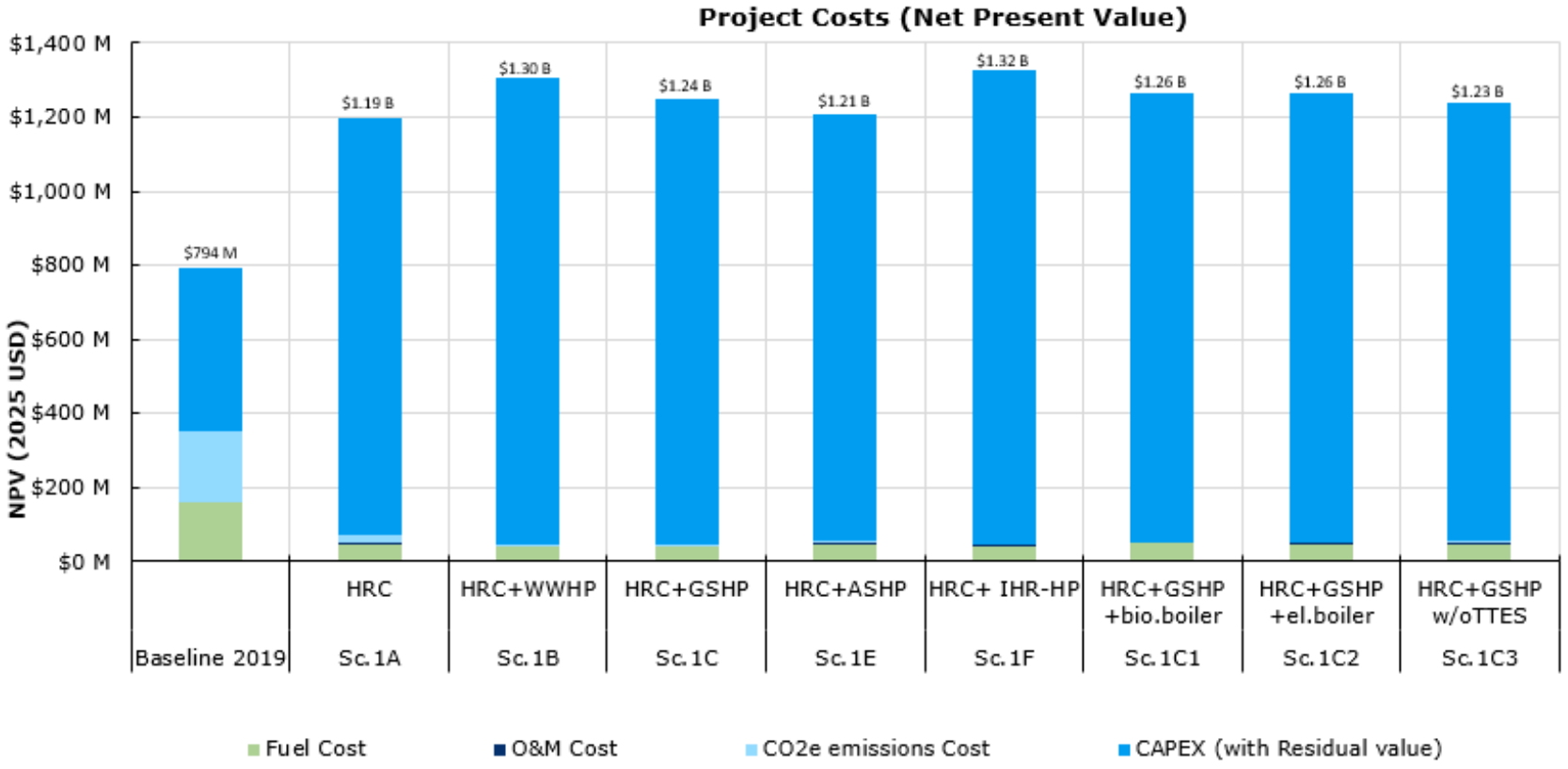

Figure 42. Economic Overview of the Different Scenarios: NPV of the Overall System Cost Over the Project Lifetime

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E.1.3 Environmental Results

Figure 43 shows the CO_2e emissions for the different scenarios together with the overall NPV (CAPEX, OPEX, and residual value). The total NPV is shown with social costs of carbon (green diamond) and without social costs of carbon (yellow dot) for each scenario. The project lifetime social cost of carbon was calculated from the values listed in Table 38, with a projected starting year of 2030. From this representation, the overall NPV of the BAU scenario (with high CO_2e emissions) increases significantly when including the cost of carbon; not so much for the decarbonization scenarios.

It is seen that BAU case has the lowest NPV of the overall system cost ("TOTAL OPEX+CAPEX (with Residual value)") and "TOTAL OPEX+CAPEX (with Residual value & carbon)". However, including a social cost of carbon reduces the difference between the BAU scenario and the other scenarios significantly. In the BAU case, the social cost of carbon increases the NPV of the costs from approximately $603 M to $794 M. All decarbonization scenarios show lower CO_2e emissions and higher NPV of costs compared to the BAU scenario.

All alternatives achieve at least an 85% reduction in CO_2e emissions compared to BAU. This is due to:

- A significant reduction in the share of natural gas use towards the overall energy production in the alternative scenarios
- Beneficial electrification and the progressive decarbonization of the grid electricity over time, in alignment with Executive Order 22 (EO22) goals for 2030 (100% electricity from renewable sources under the Clean Energy Standard (eligible systems)) and CLCPA goals of a 100% carbon free electric grid by 2040

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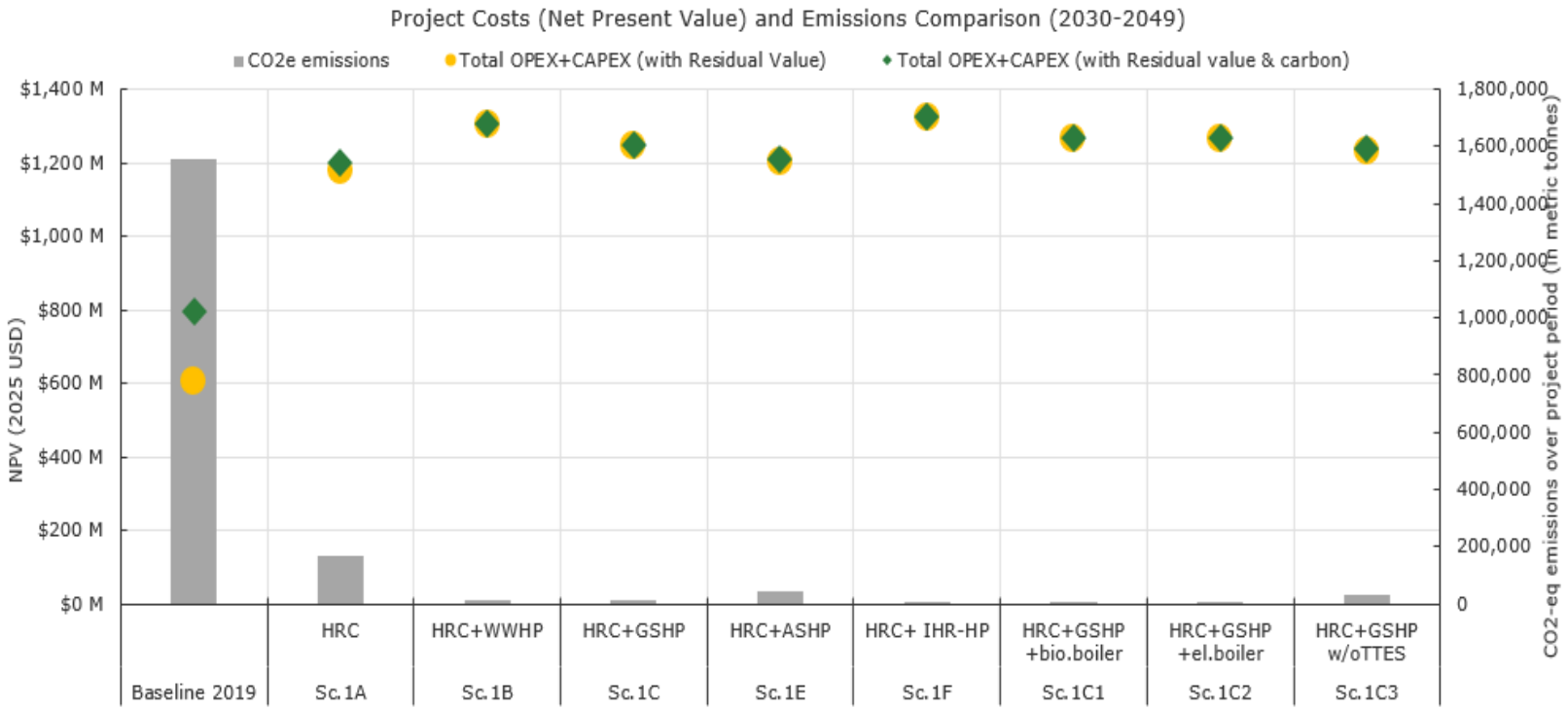

Figure 43. CO_2e Emissions and project NPV for the Different Scenarios

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Figure 44 illustrates the forecasted GHG emissions (CO_2e) trend for the Plaza. Scenario 1C2 was selected for illustrative purposes. The black line represents the BAU scenario, gray shading above the black line represents emission reductions attributed to the electric grid getting cleaner over time. The red line represents the forecasted emissions after energy efficiency, building renovations, and beneficial electrification is implemented. This trend shows that a 100% reduction in GHG emissions can be reached by or before 2050. Scenario 1C2 features electric boilers as peaking assets, which is why the trend for this scenario reaches 100% reduction. All other scenarios that involve natural gas or other peaking boilers can achieve greater than an 85% reduction compared to the 2019 baseline year by or before 2050, which would meet the CLCPA reduction goal.

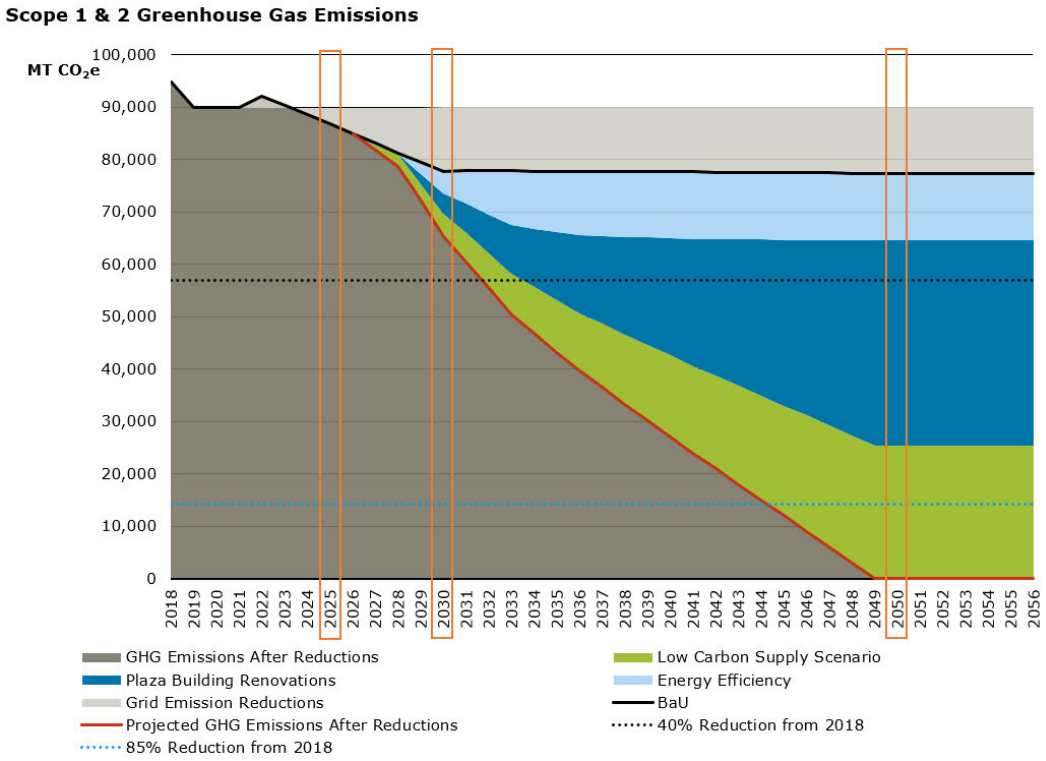

Figure 44. Projected GHG Emissions Trend (Scenario 1C2)

The “shadow price of carbon” is a metric used to evaluate the economic efficiency of reducing carbon emissions. It represents the price of carbon which makes the NPV of each alternative scenario equal to the NPV of the BAU scenario. Essentially, it is the price that balances the financial cost and carbon emissions reduction between the alternative decarbonization scenarios and the BAU scenario. The shadow price is calculated as:

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

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The NPV of costs in the equation above includes:

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

It does not include the social cost of carbon, as this would result in "double counting" of carbon costs. The lower the shadow price of carbon for a scenario, the more cost-efficient the scenario is in reducing carbon emissions. A lower shadow price thus indicates that the scenario achieves carbon reduction at a lower additional cost compared to the BAU scenario.

Table 40 compares the shadow price of carbon for the scenarios. A shadow price of carbon between $518 and $611 per metric ton (MT), would balance the economy between the BAU case and the scenarios.

Table 40. Shadow Price of Carbon Compared to BAU

Scenario	Baseline 2019	Sc.1A	Sc.1B	Sc.1C	Sc.1E	Sc.1F	Sc.1C1	Sc.1C2	Sc.1C3
		HRC	HRC+WWHP	HRC+GSHP	HRC+ASHP	HRC+ IHR-HP	HRC+GSHP +bio. boiler	HRC+GSHP +el. boiler	HRC+GSHP w/oTTES
Shadow Price of carbon (USD/MT)	0	540	595	544	518	611	559	559	540

Table 41 presents the Plaza's projected Scope 1 air quality pollutant emissions in pounds for the project period. The percent reduction relative to the BAU case is also provided. All alternatives achieve at least an 85% reduction in air pollutant emissions compared to BAU, due to a significant decrease in the amount of natural gas combusted on-site. Pollutants considered in this analysis include nitrogen oxides (NOx), sulfur oxides (SOx), and particulate matter (PM). As in the Task 1 report, emissions were calculated using the air quality pollutant emissions factors for stationary sources provided in EPA's *AP-42, Compilation of Air Pollutant Emissions Factors from Stationary Sources*. It is assumed that any natural gas boilers used in the future would have flue gas recirculation systems or low NOx burners.

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Table 41. Projected Scope 1 Air Pollutant Emissions Over Project Period

Scenario		lbs NOx	lbs SOx	lbs PM	Reduction
0	BaU	0	0	0	0
1A	HRC, Natural Gas Peaking	426,964	1,830	23,178	89%
1B	HRC+WWHP, Natural Gas Peaking	18,405	79	999	99%
1C	HRC+GSHP, Natural Gas Peaking	18,313	78	994	99%
1E	HRC+ASHP, Natural Gas Peaking	96,346	413	5,230	97%
1F	HRC+IHR-HP, Natural Gas Peaking	12,153	52	660	99%
1C1	HRC+GSHP+bio.boiler, Renewable Oil Peaking	0	0	0	100%
1C2	HRC+GSHP+el.boiler, Electric Peaking	0	0	0	100%
1C3	HRC+GSHP w/o TTES, Natural Gas Peaking	65,276	280	3,544	98%

Notes:

1. Total PM, inclusive of both condensable and filterable PM, estimated at less than 1.0 micrometer in diameter

The above representations of future air quality pollutant emissions are in part aimed at informing NYPA's efforts to reduce the impact of the facility on the local community. Burning fossil fuels releases air pollutants that can have negative impacts on public health (NOx, SOx, and PM). Table 41 provides estimated emissions of the criteria air pollutants that would be released over the project period. Section A.2.4 identified two disadvantaged communities (DACs) within close proximity to the Sheridan Ave. Steam Plant facing signification socioeconomic challenges. The quantification of air pollutant emissions provides a basis for understanding how future energy generation at the Plaza can reduce localized emissions generation and help improve local air quality.

E.1.4 Conclusions

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

- The CAPEX required for each scenario, a majority of which is driven by building renovation costs, is exerting an outsized effect on total NPVs across all scenarios, such that differences in total NPVs across any of the decarbonization scenarios falls within a margin of error that is typical for cost estimate accuracy ranges of this class.
- The BaU scenario has the lowest NPV, which is primarily from CAPEX attributed to building renovations and system maintenance. This scenario does not meet GHG emission goals.
- Scenario Sc.1A, which only utilizes HRCs for baseload heating, has the lowest upfront CAPEX and lowest NPV total out of all decarbonization scenarios, at $1.17 billion and $1.19 billion, respectively.

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- Scenario Sc.1F, which features HRCs plus industrial heat recovery heat pumps for baseload heating, has the highest CAPEX and highest NPV of all decarbonization scenarios, at $1.36 billion and $1.32 billion, respectively.
- Incorporating the social cost of carbon into total NPVs results in a ~$200 million increase in the total NPV of the BaU case.
- The social cost of carbon has a near-negligible impact on all other decarbonization scenarios, due to the significant reduction in emissions that each scenario achieves.
- The impact that OPEX, cost of carbon, and other components have on total NPV is diminished due to high CAPEX.
- All decarbonization scenarios achieve a GHG emission reduction of at least 85% from 2019 baseline levels. All scenarios but 1A achieve reductions above 95%.
- A value of carbon between $518 and $611 per metric ton would balance the economics between BAU and the decarbonization scenarios.
- Scenario Sc.1E, which integrates HRC and ASHP technology, is the most effective in reducing carbon costs, achieving the lowest carbon cost value among all the scenarios.
- There is no definitive outcome from total NPV comparisons that can favor one scenario over the other, due to the marginal differences in NPV across all scenarios. Other determining factors, such as overall GHG emissions reduction and feasibility of implementation, will have to be considered when determining which scenario to progress forward.

E.2 Phasing and Implementation

The goals of the project focus on a path toward full decarbonization with a desire for near-term emission reductions. The analysis showed that any scenario will be a large project which will require a phased approach and extend beyond a 10-year implementation period. The implementation plan will eliminate fossil fuel use at the Plaza under normal operating conditions. Furthermore, the EO 22 requirement for 100% of electricity used in State operations come from renewable energy by 2030 will ensure that ESP can operate carbon neutral under normal operating conditions after all phases are complete.

E.2.1 Phasing and Sequencing

Based on the scenario assessment presented in Section E.1, **Scenario 1C2** provides the basis for developing the decarbonization action plan, as it offers **full decarbonization** of heating and cooling. **Scenario 1C2** involves:

- Centralized distribution of heating and cooling to ESP buildings
  - Including all plaza buildings plus A.E. Smith Office Building, the Capitol, and the Old Education Building
- 4-pipe distribution
  - LTHW heating system
  - Existing chilled water system
- Central energy plant at CACP
  - Heat recovery chillers (HRCs)
    - 1,200 tons total installed cooling capacity
    - Provides simultaneous heating and cooling
    - Baseload heating and cooling technology

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- Ground-source heat pumps (GSHPs)
  - 914 x 800’ boreholes for borefield
  - 2,850 tons installed heating capacity
  - Baseload heating and cooling technology
- Electric boilers
  - Sized to provide peak heating load, provides 10% of the annual heating load
- Existing steam plant at SASP serves as backup heating
  - Serves as peak heating during transition to full decarbonization
  - Serve strictly as a backup system in the event of an electrical outage once electric boilers are installed

A phased approach is required to achieve the desired carbon reductions. The phases are summarized in Figure 45 along with the anticipated phase timeline and emissions reduction. The following subsections provide more detail of the phases.

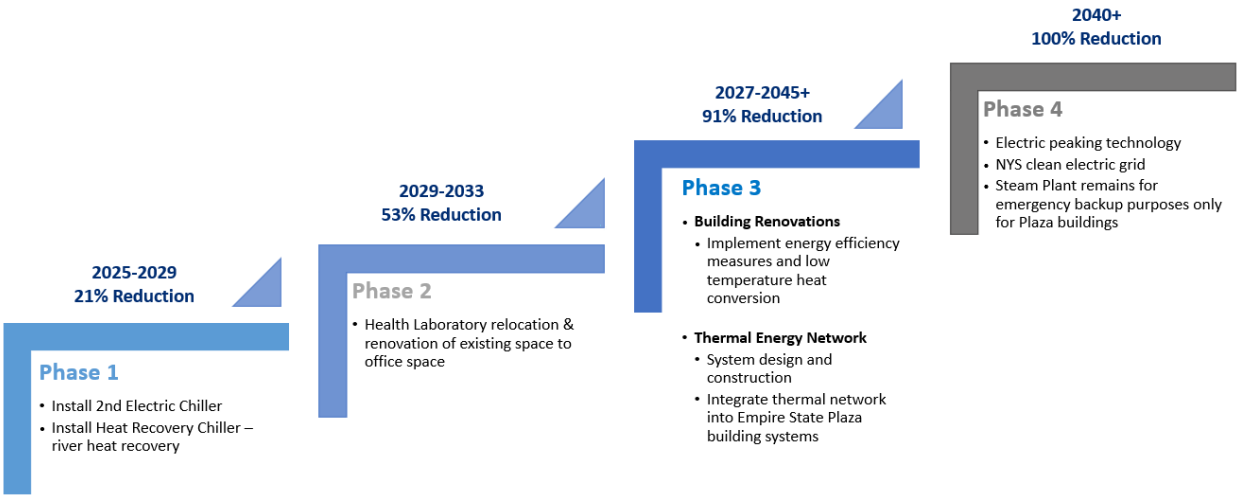

Figure 45. Decarbonization Phasing Plan

Each phase will require further study to refine the scope, cost and code implications for additional work that may be required as each phase is developed. Additional costs may arise as further studies refine the scope and assess building codes and systems not reviewed in this study. Table 42 details the cost and carbon impact associated with each phase shown in Figure 45 above and described in more detail below.

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Table 42. Phased Implementation Cost and Carbon Impact

Phase	Cost (2022 USD)	Cost (2025 USD)	% of Project Cost	% of total carbon reduction
Phase 1	$100,000,000	$245,609,708[26]	19%	21%
Phase 2	$0	$0	0%	32%
Phase 3	$950,000,000	$1,041,292,230	79%	38%
Phase 4	$30,000,000	$32,882,913	2%	9%
Total	**$1.08B**	**$1.32B**	**100%**	**100%**

Phase 1 – Chiller Plant Electrification (2025-2029)

Phase Description: OGS recently replaced Chiller 4 with the site's first electric chiller. It was installed in 2022 and first utilized in 2023. This first phase is to install a second electrical chiller and heat recovery chiller(s) which would allow the site to solely rely on electrical chillers for normal operations and eliminate 40% of the site's natural gas use. Two or three steam driven chillers could remain and would offer fuel diversity, resiliency, and redundancy.

Carbon Impact: At the conclusion of Phase 1 it is anticipated that a 21% reduction of GHG emissions (roughly 19,600 MTCO2e) will be obtained with a direct energy conversion cost estimate of approximately $110M, not including other building rehabilitation costs which were outside the scope of this project[27]. This cost estimate is representative of the costs at the time of this study and escalation would need to be applied for the year when the project is planned.

Phase 2 – Health Laboratory Relocation (2029-2033)

Phase Description: The health laboratories will be relocated from the ESP within the next 10 years. As a result, the building will be repurposed for other uses. While the exact use is not known, it was estimated that the building will be repurposed to an office type use. Other possible uses include storage, additional utility space, or archives.

Carbon Impact: Repurposing the Health Department Laboratory building is estimated to achieve a 32% reduction in GHG emissions itself, equivalent to 30,200 MTCO2e. So, at the completion of Phase 2, the combined GHG emission reduction is estimated at 53%. OGS had previously estimated the cost to repurpose the health laboratory space at approximately $200M, adjusted to $219M in today's dollars. This

[26] Phase 1 costs have been updated to include recently announced funding allocated to building renovations and mechanical upgrades that would supplement the heat recovery chiller installation(s). Announced total in the FY2026 budget is $136M.

[27] An additional $136M of funding as mentioned in the above footnote is directed towards these scopes.

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cost estimate is representative of the costs at the time of this study and escalation would need to be applied for the year when the project is planned.

Phase 3 – Building Renovations and Thermal Energy Network (2027-2045+)

Phase Description (Building Renovations): The building renovations are the most cost intensive aspect of the ESP decarbonization plans, but they are needed as the mechanical systems are over 50 years old, inefficient, and end of life. The replacement also provides an opportunity to redesign the mechanical systems to accept lower temperature hot water from the thermal energy network (approximately 140°F at design conditions); other improvements will also result in a reduced heating and cooling demand as well. Monitoring building-level hot water supply temperatures at the start of this phase, as discussed in Section D.1.6, may help identify which buildings to prioritize when planning these renovations. Review and optimization of existing hot water temperature resets, also described in Section D.1.6, can be completed at the start of this phase as well.

Ramboll estimated that the renovation of the mechanical ventilation system within the buildings will cost approximately $1,041M in today's dollars.

This construction would occur over many years in a phased approach and would require large sections within the buildings to be vacated for the duration of construction. At the end of the project, the overall ventilation load would reduce by approximately 50%, and the buildings would meet or exceed modern energy code standards. It is expected that an additional 25,800 MTCO2e of GHG reductions (28%) be achieved following substantial completion of the building renovations.

Given the scale and depth of these required renovations to the mechanical systems, OGS has determined that additional improvements to other supporting systems and building elements are necessary to comply with modern building codes. Estimates of the costs of these improvements were not developed by Ramboll within the scope of this study and therefore are not presented within this report.

Phase Description (Thermal Energy Network): In parallel with the building renovations, a low temperature thermal energy network will be required to utilize low carbon heat pumps to meet heating loads. This network would consist of the generation equipment and the LTHW distribution system. An additional 10% or 9,400 MTCO2e of GHG reductions is expected following completion of this step.

Low-Temperature Thermal Distribution System

The current steam distribution system would be modified so that the LTHW distribution system can be introduced. The steam distribution system would remain between the SASP and the CACP, but the steam system would end there with a steam to hot water energy transfer station at the CACP.

The LTHW piping would replace the steam distribution system within the utility tunnels under the ESP, and the steam to hot water heat exchangers at each building would be replaced with plate and frame water-to-water heat exchangers at each building.

Thermal Generation Equipment

After the LTHW distribution system is established, beneficial electrification technologies can be introduced to generate the thermal needs and drastically reduce the site's reliance on natural gas.

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This project investigated four main pathways to generate the heat that is needed on site: heat recovery chillers, geothermal heat pumps, wastewater heat pumps, and industrial heat recovery. Heat recovery chillers are recommended to the extent they can be utilized and in conjunction with one or more of the three remaining technologies. All three technologies proved viable, and although Scenario 1C2 uses geothermal heat pumps as its primary baseload technology, it is recommended that all three technologies continue to be considered[28]. Since this is the third phase of implementation, it may be several years before a final approach needs to be chosen. Figure 46 shows the three sources for future consideration.

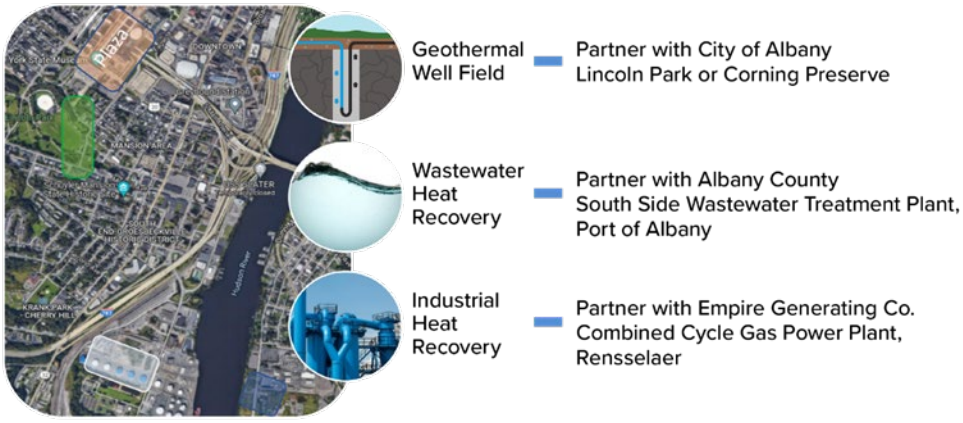

Figure 46. Potential Thermal Energy Network Sources

Carbon Impact: At the conclusion of Phase 3 it is estimated that ESP will achieve approximately a 91% reduction in GHG emissions. The only remaining fossil fuel use will be associated with the thermal peaking need which will still be served by SASP. The estimated cost for Phase 3 was estimated by Ramboll to be approximately $1041M. This cost estimate is representative of the costs at the time of this study and escalation would need to be applied for the year when the project is planned.

Phase 4 – Electrical Peaking for Full Decarbonization (2040+)

Phase Description: The final phase for full decarbonization would eliminate the use of any natural gas under normal operating conditions. This would be achieved by installing electric peaking boilers at the CACP. The Phase 3 supply assets would still operate in the same manner, but when peak heating events occurred, the electric boilers would be called on to make up the difference instead of the fossil fuel boilers. The natural gas system at SASP would remain and serve as a backup system in the event of an electrical outage at the ESP.

Carbon Impact: After the completion of Phase 4, another 8,400 MTCO2e of GHG reductions would collectively achieve a 100% GHG emission reduction for the Plaza under normal operating conditions. Renewable thermal energy systems would be used to generate the heating and cooling for the facility. By 2030, OGS is required to produce or procure renewable electricity; at the completion of Phase 4 (assuming after 2030), ESP would operate carbon neutral. The cost of this phase is estimated to be $33M

[28] Recent conversations between major project stakeholders have identified industrial heat recovery as being less desirable due to the use of fossil fuels at the source. As per Figure 46, the Empire Generating Company's Rensselaer power plant is a combined cycle gas plant.

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for the installation of the electric boilers. This cost estimate is representative of the costs at the time of this study and escalation would need to be applied for the year when the project is planned.

Accelerated Approach:

E.2.2 Barriers to Implementation

Major barriers to implementation of the decarbonization scenarios are expected to include the following:

- High CAPEX
    - The transition away from fossil-fuel-based technologies will require significant upfront investments in large-scale infrastructure. The CAPEX estimates presented in Figure 41 might be daunting for any organization, particularly those reliant on public funding. Decarbonization projects can be difficult to justify to stakeholders because the return on investment will not be realized in the near-term and funds may have to be redirected from other important areas to meet budgetary needs. The Plaza will likely need to employ a range of financing strategies to tackle these hurdles.
- Variable federal funding opportunities
    - Adding to the potential financial obstacles, funding opportunities that are sponsored by the federal government might vary under different presidential administrations, due to the trending politicization of climate change and decarbonization. In 2024, the DOE, the Environmental Protection Agency (EPA), and other federal agencies provided grants, tax credits, rebates, and numerous other incentives to support decarbonization projects. There may be federal reevaluation and resizing of certain agencies and programs. New York State has a more established commitment to decarbonization and is less likely to implement significant reductions in funding availability at the state level, but some State programs are dependent on federal support.
- Grid-level electrical impacts for electric peaking technologies
    - As previously described, prioritizing heat pump technology as the primary means of baseload heating and utilizing natural gas or renewable fuel-fired boilers as means of peak heating would remain within the Plaza's electrical capacity and maintain N+2 redundancy at the main substations. Utilizing electric peaking boilers, however, requires dedicated electrical infrastructure and would more than triple the current peak demands of the Plaza. Coordination with the local utility (National Grid) will be needed as decarbonization efforts continue at the Plaza to ensure these high demands can be met by the grid.
- Labor and material shortages
    - Recent years have seen shortages in skilled labor, semiconductors, and other materials and personnel essential for the implementation of a decarbonization scenario. Global geopolitical, economic, and social conflicts continue to cause supply chain disruptions. The sooner the project planning phases can begin, the sooner ESP will be able to assess local labor and material availability and how it may impact project goals.
- Complex permitting processes
    - A variety of permits will need to be obtained during the phases of the project. These could include building and zoning permits issued by the local government, environmental permits issued by state agencies, and electrical permits issued by the utility, among

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others. Given the complexity and scale of decarbonization projects, the process of applying for all necessary permits is likely to be lengthy and labor intensive. Delays could impact project goals. ESP should engage with local permitting experts and authorities in the earliest stages of the planning process.

- Stakeholder engagement
    - Baseload heating options such as GSHPs, WWHPs, and IHR heat pumps would involve tapping-into heat sources & sinks on sites outside the property lines of ESP, which would require OGS-owned infrastructure (borefields, piping, pumps, etc) be installed on land parcels not owned by the agency. Coordination with the appropriate stakeholders (such as local municipalities, other state agencies, private entities, etc.) would need to be had before efforts associated with progressing any of the aforementioned baseload heating options are progressed further.
- Limited space availability
    - The Plaza is an aesthetically centric complex with limited space availability within the site property for land intensive installations such as GSHP borefields. ASHPs, which require arrays of air coolers to be installed in outdoor locations, could yield noise issues and would require architectural means to hide the air coolers from sight within the Plaza. Additional consideration for locations of major heating and cooling equipment will need to be had as planning and design efforts progress.
- Construction-related disruptions
    - Major construction projects have the potential to temporarily cause significant disruption to the Plaza and surrounding community. This might include noise, dust, traffic detours, safety risks, diminished aesthetic appeal, and power outages. Local geography, accessibility, and coincident Plaza events and activities should be carefully considered in the next stages of the planning process to minimize disruption and ensure safety.

E.2.3 Implementation Considerations

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

- Heat pumps
    - The US market for heat pumps is changing rapidly with higher efficiency and/or higher potential supply temperature regularly becoming available, and additional options are expected to grow pending future energy code updates. Many heat pumps with higher efficiency and temperature exist today on the European market and, therefore, it is anticipated that similar units will be introduced in the US from the main vendors. ESP will want to monitor market maturity and technology advancements to help inform design and installation decisions and timing.
- Building HVAC
    - Monitor supply and return temperature and assess measures to increase the delta T for hot water and chilled water.
    - Ensure building hot water and chilled water loops have outdoor temperature reset implemented.
- Accelerated Decarbonization

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- While proposed as LTHW-producing peak heating assets in Scenario 1C2's approach, further evaluation of electric boilers as steam-producing heating assets could accelerate the Plaza's decarbonization timeline by deploying these assets in an earlier phase and covering a greater portion of the heating load.
  - Steam electric boilers could be installed and serve heat to the Plaza prior to the conversion of the Plaza's thermal network from steam to LTHW.

E.2.4 Funding Source and Incentive Program Potential

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

- NYSERDA
  - https://www.nyserda.ny.gov/All-Programs#category=schools-colleges-universities
  - Community Heat Pump Systems (PON 4614)
  - NY-Sun Commercial / Industrial Incentive Program (PON 3082)
  - Carbon Challenge and Carbon Neutral Community Economic Development programs
- Inflation Reduction Act
  - Established new credit delivery mechanisms that enables state, local, Tribal governments, non-profit organizations, U.S. territories, and other entities to take advantage of clean energy tax credits
  - RMI developed a list that breaks out Inflation Reduction Act programs and incentives: RMI IRA break down by incentive
  - Production Tax Credit for Electricity from Renewables

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

- DSIRE: https://programs.dsireusa.org/system/program/ny
- U.S. DOE: https://www.energy.gov/eere/funding/eere-funding-opportunities

E.3 Key Takeaways and Recommended Next Steps

Table 43 provides a summary of important topics and associated aspects that surfaced during the planning process. These inform the complexities and challenges that will need to be considered and managed as part of the Plaza's energy transition. These aspects intersect to influence and balance carbon reduction, energy efficiency, flexibility, resiliency, and redundancy in a pragmatic and cost-effective manner.

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Table 43. Key Takeaways from the Planning Process

Electrical Demand Impact	Natural Gas Peaking Benefits	Building Improvements	Infrastructure Scenarios	Emission Reduction
• No major electrical upgrades are anticipated for nonelectric peaking scenarios • A separate, dedicated substation would be required to serve electric peaking boilers in full-electrification scenarios • Significant emergency/stand-by power requirements, without nonelectric-based backup • High CAPEX with relatively small carbon emissions reduction to electrify peak load in addition to baseload	• Flexibility • Redundancy for emergency • Bridging fuel (while electric utility infrastructure catches up) • More manageable CAPEX • May align with future NYS plans of transitioning from natural gas to renewable natural gas (RNG) and hydrogen • Reuse of existing infrastructure and backup power assets	• Address steam use in buildings • Enables connection to LTHW (140°F) system • Increases energy efficiency and lowers heating & cooling demands • Renovation approval and timing • Hazardous materials impact • High CAPEX, but replaces aging and obsolete HVAC systems that are due for replacement • Long duration projects	• Further evaluation of baseload options (WWHP vs IHR vs GSHP) • Permitting, other obstacles to utilizing offsite heat sources	• 85% reduction is achievable without 100% electrification

E.3.1 Recommended Next Steps

Ramboll has identified the following recommended next steps to help ESP prioritize projects that can influence future system designs and demonstrate progress towards their goals:

- **Building Level Recommendations**
  - Implement the EEMs including the building renovations and transition to lower supply water temperatures
  - Prioritize energy efficiency as part of the repurposing of the Health Labs
- **Central Utility Recommendations**

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  - Convert from a steam-based heating network to a low temperature hot water heating network
  - Retain the SASP and transition the facility from the primary heating asset to a peaking asset and ultimately a resiliency asset
  - Convert at least two more steam driven chillers to electric driven chillers
  - Repair the Ross valve in the CACP
  - Install two additional vertical turbine pumps at the RPS
- **Renewable Electricity**
  - Continue to develop off site solar projects
  - Procure renewable electricity beyond what can be produced through solar development in compliance with Executive Order No. 22
- **Long Term Decarbonization**
  - Leverage heat recovery chillers to the extent possible
  - Continue to evaluate the options for geothermal, wastewater heat recovery, and industrial heat recovery and implement the most favorable at the time of implementation
  - Monitor market developments and advancements in heat pump technology and U.S. market availability
  - Leverage tank thermal energy storage to maximize heat recovery, limit electrical peaks, and minimize electrical costs

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F – Distributed Energy Resources

NEW YORK STATE | NY Power Authority

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Section F – Distributed Energy Resources

F.1 Distributed Energy Resources

F.1.1 Potential for Renewable Electricity Generation

ESP has the potential to implement PV solar arrays to reduce its monthly electrical bill, while also contributing to the Plaza's decarbonization to help meet the various NYS carbon reduction targets and directives. Utilizing PVWatts[29], Ramboll conducted a solar assessment to identify buildings within the Plaza that are good candidates for rooftop solar installations. Figure 47 below shows the solar "heat map" utilized to identify potential buildings for rooftop solar installations within Empire State Plaza. Architecturally relevant buildings such as The Egg were omitted from this evaluation for aesthetic purposes.

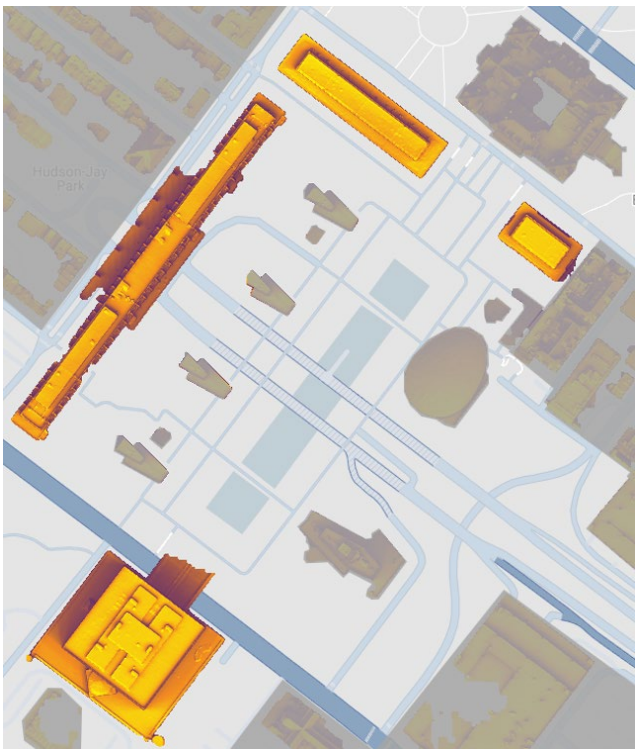

Figure 47. Solar "heat map" for rooftop solar at Empire State Plaza .[30]

[29] Online calculator supported by the US Dept. of Energy's National Renewable Energy Laboratory (NREL). https://pvwatts.nrel.gov/

[30] Google. (2024). Solar potential for buildings at Empire State Plaza. Project Sunroof. https://sunroof.withgoogle.com/building/42.67829924205623/-73.80894732350036/#?f=buy

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PV Watts was utilized to estimate potential output of the rooftop areas. For demonstrative purposes, Figure 48 below shows the potential power output of the Legislative Office Building (LOB) if the roof was utilized for rooftop solar installations.

Figure 48: PVWatts power output estimate for the Legislative Office Building at Empire State Plaza

National Grid maintains a PV hosting capacity data portal that identifies the capacity local substations and electrical feeders have available for accommodating the back feed of electricity supplied by customer-installed PV assets, such as rooftop solar panels. While the database identifies PV hosting capacities of several substations and feeders surrounding ESP, it does not contain information for the four (x4) 34.5 kV underground feeders that directly serve the Plaza (#38 Riverside, #35 Riverside, #36 Menands, #37 Delaware). Due to this, it was not possible to assess how much PV capacity the utility-level electrical infrastructure serving ESP is capable of hosting. Coordination with the local utility should be had by ESP prior to the implementation of any onsite PV projects that may have the ability to back feed to the local power grid. Energy storage systems (e.g., battery storage) may also be considered as viable options should it be determined that the feeders and/or substation lack the needed hosting capacity during periods of peak output by solar systems.

Utilizing the data collected from PVWatts, Table 44 was developed to show the estimated power generation capability associated with implementing rooftop systems at select buildings within ESP. The buildings with a significant number of rooftop obstructions and shading were excluded from this analysis.

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Table 44: PVWatts Assessment of Rooftop Solar Array for ESP Buildings

Building	System Capacity (kWdc)	Sq ft	kWh/yr produced
Swan Street Building	690	71,064	829,502
Justice Abrams Building	120	8,643	146,184
Cultural Education Center	783	56,157	949,409
Legislative Office Building	280	22,217	334,745

The buildings listed in Table 44 are ideal candidates for implementing rooftop solar due to minimal shading and relatively unobstructed rooftop spaces.

F.1.2 Factors to Consider for Solar Options

- The estimated system capacity is based on a PVWatts analysis with NYS average parameters inputted. A more detailed solar analysis should be conducted in subsequent planning and design efforts to confirm the system capacity.
- Prices can vary based on various site parameters such permitting and labor costs.

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G – Transportation Electrification

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Section G – Transportation Electrification

G.1 Introduction

Transportation plays a critical role in the functionality and sustainability efforts of employees, impacting both personal travel to and from work (Scope 3 emissions) and the operation of state-owned fleet vehicles (Scope 1 emissions). This section provides an investigation of the infrastructure and planning needed to electrify transportation resources to reduce Greenhouse Gas (GHG) emissions from both commuting and fleet-owned transportation. The emissions from these transportation activities constitute a significant portion of the Plaza's overall carbon footprint.

G.2 Current Commuting Alternatives

Empire State Plaza (ESP) and the surrounding area offer a variety of transportation options and services for employees. These include walking, cycling, utilizing bus services, and participating in car-sharing programs. Choosing these alternative transportation methods over commuting individually in gasoline fueled vehicles can help reduce Scope 3 emissions.

Walking

Empire State Plaza, located in the heart of downtown Albany and spanning approximately 98 acres, offer a variety of walking opportunities both indoors and outdoors. The Empire State Plaza Concourse features a network of interconnected buildings and tunnels that provide a convenient and weather-protected environment for walking, making it especially suitable during inclement weather. In addition to the indoor concourse, the Plaza also includes several designated outdoor walking routes with varying lengths to accommodate different preferences and fitness levels. Together, these options make Empire State Plaza a versatile and accessible destination for year-round walking.

Bicycling

Empire State Plaza offers several options to support biking. Free-standing bike racks are available outside each building for secure parking. In addition, the CDPHP Cycle! a bike-sharing program provides smart bikes that can be rented and returned at various locations around Albany and the Capital Region.

Bus Services

The Capital District Transportation Authority (CDTA) provides bus service to the Empire State Plaza through several routes, including 214, 224, 233, 519, 530, and NX. These services operate from 6.00 am to 6.40 pm on weekdays, 7.20 am to 10.40 pm on Saturdays, and 7.30 am to 6.16 pm on Sundays. However, some routes do not operate on weekends, and certain express routes offer limited service, primarily during evening hours. This network offers a convenient public transit option for accessing the Plaza, with varying schedules depending on the day and route. Figure 49 below shows the route of the bus service at the Plaza.

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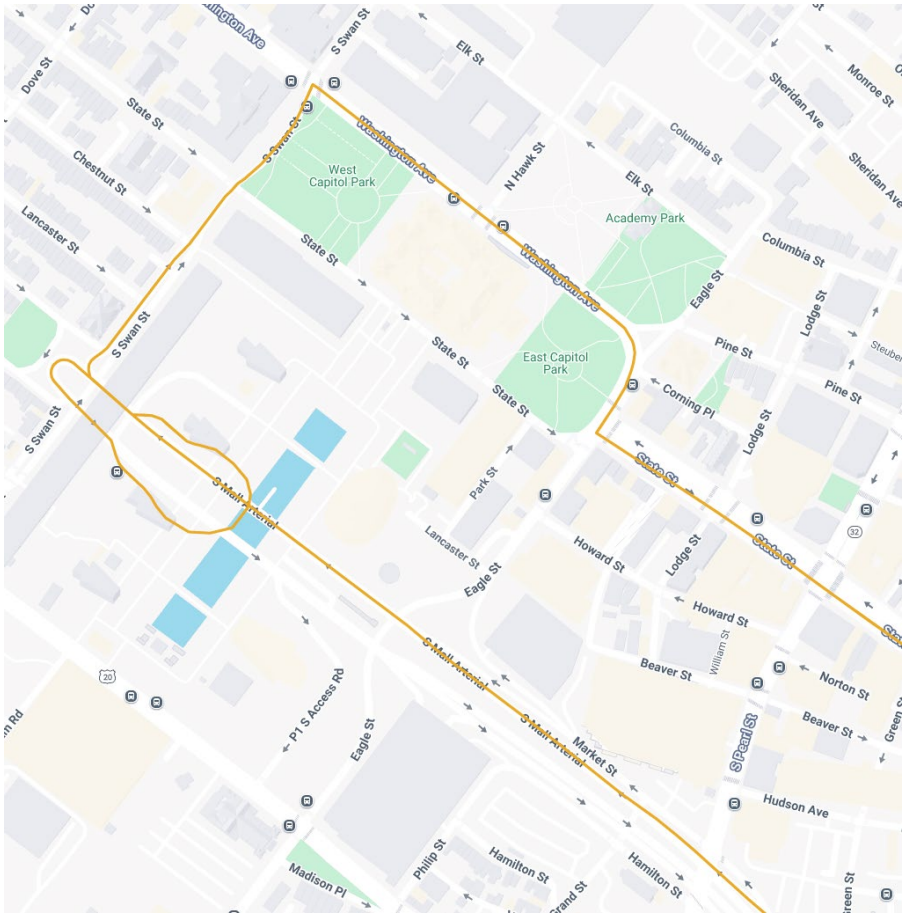

Figure 49. Bus Service Route at Empire State Plaza.[31]

Carpool Program

The Empire State Plaza offers a carpool program for state employees to promote sustainable commuting and reduce parking demand. Eligible employees can form carpools of 2–4 members and receive reduced parking rates, designated carpool spaces, and occasional day passes for solo commuting. The program is managed through the Employee Parking Profile and includes specific guidelines to ensure proper use.

G.3 Fleet Vehicles

The complex facilities manage a fleet of vehicles to support various operational, maintenance, and administrative needs. These fleets typically comprise a range of vehicles including maintenance trucks, security vehicles, and staff cars for administrative purposes. The purpose of these vehicles is to ensure the smooth running of the complex activities, facilitate response to emergencies, and support the broader

[31] https://www.cdta.org/schedules-stop-detail?stop_id=10868

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logistical requirements. The list of all light-duty and heavy-duty vehicles that are used on the Empire State Plaza complex is presented in Appendix H .

G.3.1 Existing Conditions

G.3.1.1 Vehicle Infrastructure and Electric Vehicle Charging Stations

The Plaza offers designated parking facilities for employees. Major parking structures include the East Parking Garage, which provides convenient access to the Plaza via a tunnel and entrances from Philip Street and Eagle Street; the P2-North and P2-South garages located beneath the Plaza; and the P3 level, which includes the P3-South Garage and P3-North, the latter potentially serving as a visitor lot. Additional surface parking areas include the Madison Avenue East lot (formerly the Cathedral Lot), the pastures Lot, the Swan and Elk Street Lot, and the Sheridan Hollow Garage. Several of these locations are equipped with Level 2 electric vehicle (EV) charging stations, including 12 ports at the East Garage, 4 at the P-2 North Garage, 4 at the P-2 South Garage, 6 at the P-3 North Garage, 2 at the Madison Avenue East lot, and 7 at the Sheridan Hollow Garage. In addition, there are 10 Level 2 charging ports located at the Plaza that are reserved for the Legislature and Executive's ramp. Protocols and costs for the existing charging program used by employees are detailed on the OGS website[32].

There are ongoing projects in collaboration with NYPA to significantly expand EV charging infrastructure at both the Plaza and the East Parking Garage (EPG). The following EV charging projects shown in Table 45 are currently in varying levels of planning and/or design:

Table 45. List of EV Charging Projects

Location	# Ports	# Ports (Future)	Port Type
P-2 North Garage	15	15	L2
P-2 South Garage	15	15	L2
P-1 South Garage	4	0	DCFC
East Garage	20	20	L2
East Garage	2	2	DCFC

[32] Employee Zero Emissions Vehicle Charging Program | Office of General Services

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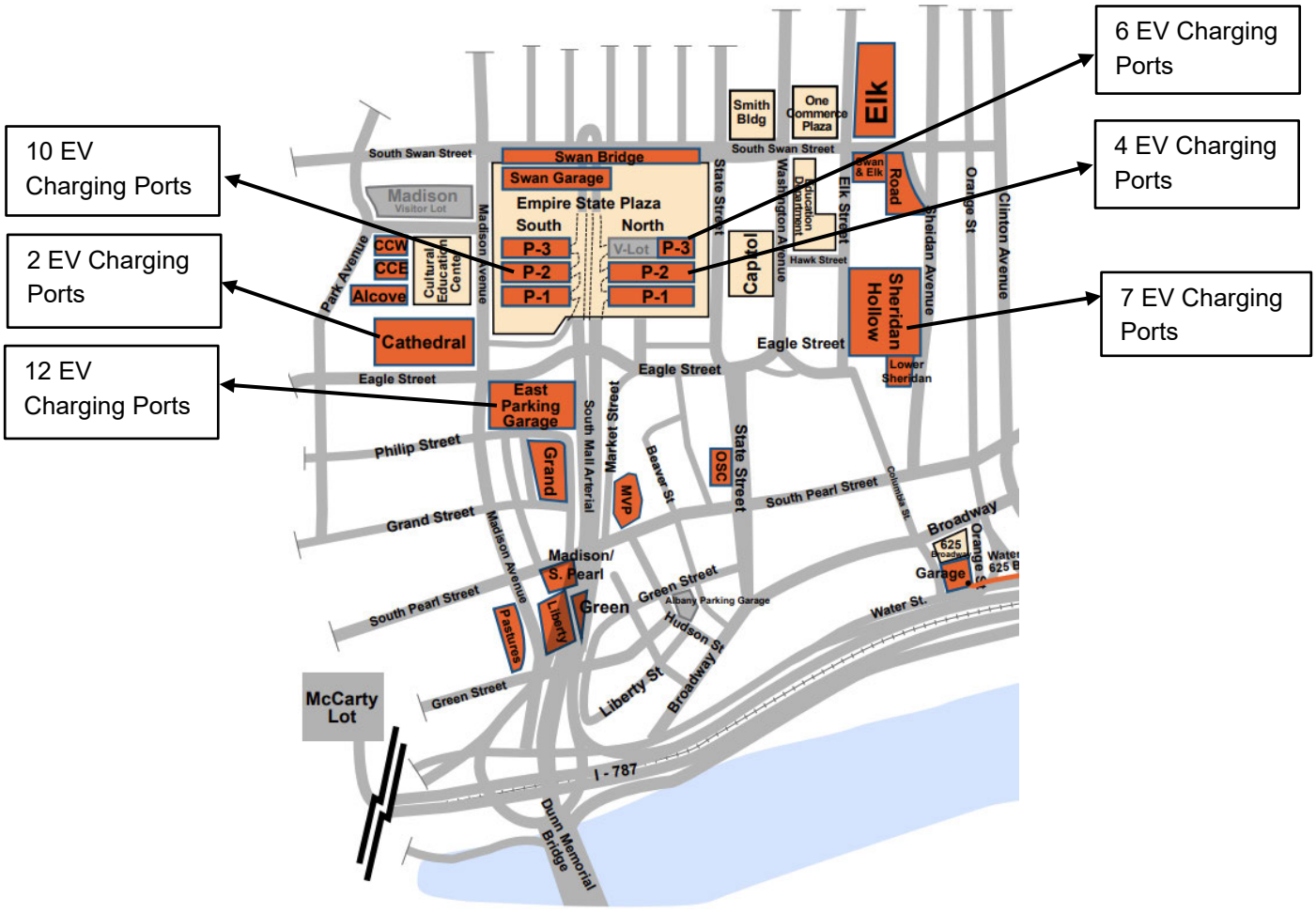

Figure 50. Existing EV Charging Stations.[33, 34]

G.3.1.2 Fuel Usage and Emissions

The 2023 fuel usage, along with the estimated corresponding GHG emissions are presented in Table 46 below. It is assumed that fleet vehicle usage is consistent year-to-year. Refer to Section A.2 for emissions factors.

Table 46. Fuel Usage, Cost and Emissions

Fuel Source	Usage (gallons)	Total Mileage	Usage (MMBtu)[35]	Total Cost ($)	CO2 emissions (MT CO2e)[36]
Gasoline	8,215	107,509	987	$24,329	42.05
Diesel Fuel	6,274	69,364	862	$20,944	54.58

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G.3.2 Fleet Electrification

As directed by EO 22, 100% of the Plaza's light-duty non-emergency fleet vehicles are required to be Zero Emission Vehicles (ZEVs) by 2035. In addition, 100% of the medium- and heavy-duty fleet vehicles are required to be ZEVs by 2040. The drive to electrify the Plaza's fleet vehicles is not only state-mandated, but a critical move towards sustainability, cutting carbon emissions significantly. It requires a well-planned shift from gas-powered to electric vehicles, adhering to the complex's green objectives and involving a transition of service vehicles and fleet cars to eco-friendlier electric options. This change underlines the complex's commitment to clean energy and responsible environmental management.

The shift to electric vehicles (EVs) on Plaza complex promises both environmental and financial gains. EVs contribute to substantial reductions in carbon emissions, promote a quieter and more cost-effective transport solution and are better for local air quality; they also provide visible evidence of the complex's commitment to sustainability. Establishing robust fleet electric vehicle supply equipment (EVSE) includes strategically locating fleet vehicle charging stations and upgrading power systems to accommodate their usage, reinforcing the complex's commitment to green practices and energy independence.

The development of EV infrastructure at the complex may also pave the way for broader EV adoption by the community. With a strong network of charge points, the complex could continue to foster a green transport ethos and promote the use of electric vehicles among the complex employees and facilities staff. The continuation of the fleet electrification and EVSE rollout would underscore the complex's dedication to an environmentally sustainable building and offer a flexible framework to accommodate emerging EV technologies and the escalating need for eco-friendly transport options.

G.3.2.1 EV Considerations

The complex currently has a fleet of 62 light duty vehicles and 17 heavy duty vehicles. Of the 79 fleet vehicles, three already use electric power: one hybrid Battery Electric Vehicle (BEV) and two hybrid Plug-in Electric Vehicles (PHEVs). The vehicle types and their electrification uses are further described in Appendix H and in the sections below.

G.3.2.2 Light Duty Vehicles

Light-duty vehicles (LDV) are those with a gross vehicle weight rating (GVWR) of 8,500 lbs or less, as defined by the EPA. Electrification in the context of LDVs denotes the transition from conventional internal combustion engine (ICE) vehicles, which utilize gasoline or diesel, to those equipped with electric batteries or hybrid propulsion systems. The push for LDVs to be electrified primarily stems from the

[33] https://ogs.ny.gov/parking/downtown-albany-garages-and-lots

[34] https://ogs.ny.gov/zero-emission-vehicles-infrastructure-0

[35] The energy content of gasoline is estimated at 120,333 Btu/gallon and that of diesel fuel is estimated at 137,381 Btu/gallon.

[36] MOVES4 data downloaded from the Bureau of Transportation Statistics, https://www.bts.gov/content/estimated-national-average-vehicle-emissions-rates-vehicle-vehicle-type-using-gasoline-and. Values presented are national averages for the 2023 calendar year. Vehicle electric consumption was not available.

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urgent requirement to curtail greenhouse gas emissions, enhance air quality, diminish noise pollution, and minimize reliance on fossil fuels.

The primary zero emission electric alternative for LDVs is Battery Electric Vehicles (BEVs). Plug-In Hybrid Electric Vehicles (PHEVs) could also be a suitable option and can use the same charging infrastructure.

G.3.2.2.1 Heavy Duty & Agricultural Vehicles

Heavy duty vehicles are those with a GVWR greater than 8,500 lbs, as defined by the EPA. Electrification of heavy-duty vehicles and agricultural equipment is an important future step toward sustainability and innovation in electrification. Battery electric options for heavy duty vehicles and equipment are becoming increasingly available and affordable. Additional strategies to be considered for the reduction of emissions associated with heavy-duty vehicles include:

- **No Idling:** Avoid prolonged idling to reduce fuel consumption and emissions. Turn off the engine when stationary for extended periods.
- **Regular Maintenance:** Conduct regular maintenance checks on vehicles to optimize engine performance and fuel efficiency.
- **Fuel- Efficient Engines:** Invest in vehicles equipped with fuel-efficient engines and technologies, such as automatic transmissions and hybrid systems.
- **Hybrid Vehicles**: Combining electric and diesel technologies can improve efficiency and reduce emissions.
- **Biofuels**: Utilizing biodiesel, renewable diesel, or other biofuels allows organizations to maintain existing diesel engines while reducing their carbon footprint and promoting renewable energy sources.
- **Compressed Natural Gas**: CNG vehicles can provide a cleaner alternative to traditional diesel, with lower emissions.
- **Hydrogen Fuel Cells**: While still in development, hydrogen fuel cells offer a promising zero-emission option for heavy-duty applications.

G.3.2.3 EV Charging Infrastructure Considerations

The global shift towards low-carbon vehicle solutions is marked by a range of innovative refueling and recharging methods. When developing EV charging infrastructure onsite, it is essential to consider several factors to ensure efficiency and reliability. This section outlines the various types of available charging infrastructures.

G.3.2.3.1 EV Charging Configurations

EV charging configurations are divided into three primary types: manual plug-ins, automatic plug-in, and wireless. These categories are illustrated in Figure 51 below. In campus environments, manual plug-ins are often the most practical option. The advantages, limitations, and impacts of this approach are discussed in this section. Automatic plug-in and wireless configurations are not considered further in this study due to their significantly higher capital costs and the potential need for vehicle modifications.

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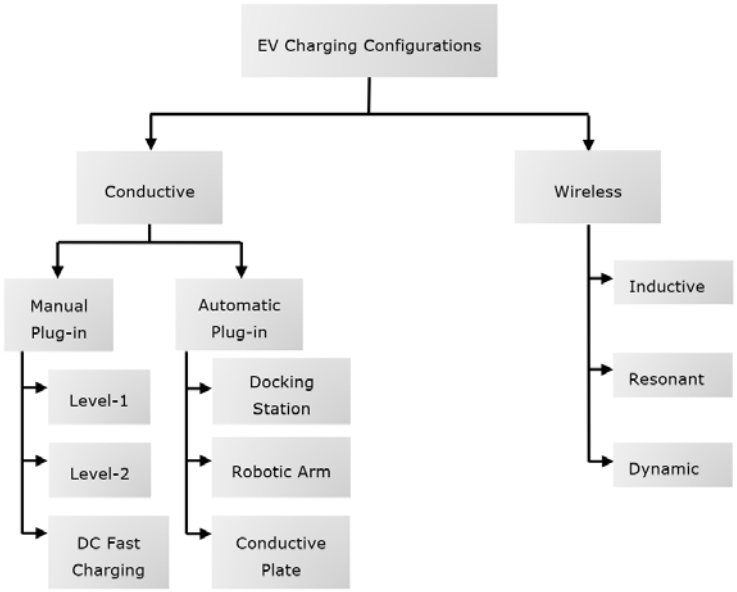

Figure 51. Categories of EV Charging Configurations

Manual Plug-in Charging

Manual plug-in charging requires physically connecting the charging cable to the vehicle's port. This widely accepted and popular method accommodates nearly all EV types on the market. Compared to other charging options, the initial investment for manual plug-in facilities is lower. From an infrastructure perspective, setting up this configuration mainly involves routing cables between power cabinets and charging points. Automatic plug-in and wireless configurations typically involve specialized hardware, software, and installation costs that are significantly higher than standard wired connections.

There are three main levels of manual plug-in charging:

- Level 1 charging involves a standard 120V AC power source, charging at lower power levels where slow charging is acceptable. Due to the limited charging speed, this level is generally not practical for fleet operations.
- Level 2 charging operates with a 240V AC power source, requiring dedicated charging stations or wall-mounted chargers. This is the most common choice for fleet charging and can be strategically distributed across the Plaza to support light-duty vehicles.
- Level 3, or DC Fast Charging (DCFC), provides a quicker charging experience at higher power levels by bypassing the onboard charger to directly charge the vehicle's battery. Level 3 chargers typically run on a 480V power source and most likely require significant electrical upgrades. This level is ideal for heavy-duty vehicles that require fast charging. However, due to the significant power demand, Level 3 charging can substantially impact ESP's electric demand and requires careful planning.

The Department of Energy provides a guide on fleet electrification steps for federal fleets, which serves as a valuable reference for designing fleet EVSE. Based on the Fleet Electrification Step 10: Complete

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Site Assessment and Design EVSE[37], which sources the General Services Administration's (GSA's) Public Building Service (PBS) P100 Facilities Standards[38], the number of chargers needed at the facility can be estimated based on the available parking spaces. The "quantity and configuration of chargers and ports must be designed to accommodate tenant vehicle usage and locations" as follows:

- Lots with fewer than five fleet vehicles: A minimum of two charging ports must be installed.
- Lots with 5 to 15 fleet vehicles: A minimum of four charging ports must be installed.
- Lots with more than 15 fleet vehicles: Charging ports must represent at least 30% of the total planned federal fleet vehicles.

The exact number of chargers needed will be dependent on the level of charging selected and the usage patterns of the fleet vehicles. Infrastructure requirements are discussed further in Section G.3.2.4.

G.3.2.3.2 EV Charging Patterns

EV charging relies on multiple connected parties and can be divided into three main types based on different needs: overnight charging, high-power fast charging, and opportunity charging (charging whenever possible). These charging choices are important for operations as they directly affect costs, efficiency, and system reliability.

Overnight Charging
Overnight charging is commonly used for light and heavy-duty vehicles that stay parked for long periods, usually overnight when they are not in use. This method allows the battery to charge at a lower power level over a longer time, making it possible to charge during lower grid demand and benefit from off-peak electricity rates.

High-Power Fast Charging
High-power charging is increasingly popular for short, fast charging sessions, especially for heavy-duty vehicles and those in transit. Rapidly charging the EV battery is an attractive option; however, it can accelerate battery wear, shorten the battery's lifespan and impact the Plaza's electrical demand. It's also essential to note that not all EVs have charging systems designed to support high-power charging safely and efficiently.

Opportunity Charging
Opportunity charging refers to charging electric vehicles in short periods of downtime at regular intervals, using both fast and slow options to meet different needs. Site designs should consider how vehicles are used and include features for this type of charging. These sessions usually last a few hours, providing partial charges to extend the vehicle's range. It is also important for site operations to consider electricity rates and demands to offer the best pricing for EV users. When combined with high-power charging, opportunity charging can help streamline operations and align with how traditional vehicles are used.

[37] Department of Energy Fleet Electrification Step 10: https://www.energy.gov/femp/fleet-electrification-step-10-complete-site-assessment-and-design-evse

[38] U.S. General Services Administration P100 Facilities Standards for the Public Building Service: https://www.gsa.gov/system/files/P100%202022%20Addendum%20Final_.pdf

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G.3.2.3.3 EV Charging Adopting Standards

EV charging standards include key areas like connector types, site requirements, and grid specifications. These standards are essential to ensure that electric vehicles and charging stations are compatible, safe, and able to communicate with each other.

Connector Standards

There are several charging standards for EV connectors, designed to ensure compatibility between charging stations and electric vehicles, considering development timelines and locations. The Combined Charging System (CCS) is widely used and supports both AC and DC charging, using a single connector with extra DC pins for fast charging. New standards, like Megawatt Charging System and the GB/T standard, are being developed for even higher power charging. Tesla has its own Supercharger network and connector, originally used only for Tesla vehicles. However, starting in 2023, the North American Charging Standard (NACS), which was originally used only by Tesla, has been adopted by other manufacturers to improve compatibility and access. All connectors must meet IEC 61851 and SAE J1772 standards, and they should support the Open Charge Point Protocol (OCPP) for communication. Any connectors considered for installation at the Plaza should also be evaluated based on current project funding source requirements (if applicable) and compatibility with commonly used EVs at the complex.

Figure 52 showcases the connectors available for manual conductive charging and high-power charging.

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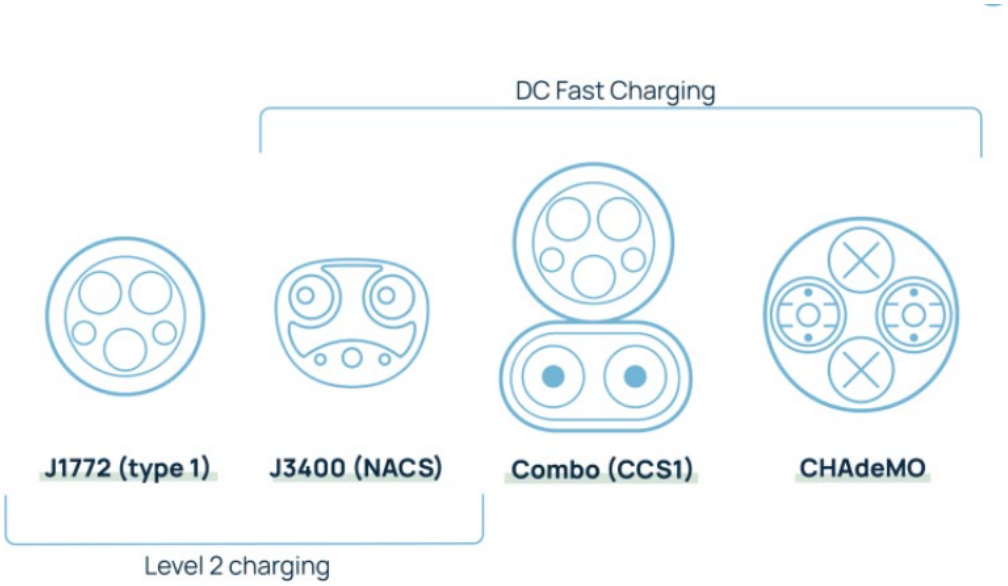

Figure 52. Different Connectors Available for Manual Conductive Charging.[39]

Grid Integration Standard

A key part of setting up EV charging infrastructure is grid integration. Standards for integrating EV charging with the electrical grid are crucial for ensuring efficient and reliable operations. These standards enable communication, interoperability, and smart management of charging stations.

Grid-associated standards help maintain stability, promote the use of renewable energy, and improve overall grid management. They support load balancing and the integration of EV charging with renewable energy sources.

Grid integration standards applicable to the Plaza are evolving but notably include the New York State Standardized Interconnection Requirements (SIR). The SIR provides guidance for large-scale EV charging projects, and those with smart chargers, on-site generation, and/or on-site storage, on how they can effectively connect with the grid. Some financial incentive programs, such as the National Grid Make-Ready Program, are also designed to streamline coordination with the utility.

EV charging infrastructure should be developed as an integrated component of Empire State Plaza's energy systems. By aligning EV charging with on-site renewables, energy storage, and demand management strategies, the Plaza can minimize fossil-based electricity use and foster an approach to vehicle electrification that supports, not strains, its electrical system and directly advances its decarbonization and resilience goals.

[39] https://www.flo.com/en-ca/insights/ev-connectors-do-all-evs-use-the-same-plug/

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G.3.2.3.4 EV Charging Infrastructure Maintenance

Effective installation and maintenance of EV charging infrastructure is vital for maintaining reliability and efficiency in electric vehicle charging. Hence, the following planning considerations and periodic inspections should be incorporated into the Plaza's EV program:

- Warranty terms, service agreements, and support expectations should be clearly defined during procurement and incorporated into broader EV planning efforts to maintain long-term operational reliability.
- Software requirements should also be addressed in the early project stage, with attention to centralized management, cost oversight, cybersecurity, data standardization, and scalability to accommodate network growth or additional sites.
- Physical inspections are necessary to identify and resolve issues such as vandalism, wear and tear, or technical faults.
- All charger systems require computational capability to operate, and thus software updates for networked chargers fall under regular maintenance to support the latest feature upgrades and compliance with security measures.
- Proactive maintenance practices like periodic cleaning, tightening of electrical connections, and testing of safety systems can be termed as preventive maintenance for EV charging infrastructure.
- Adequate staffing should be planned for all aspects of the EV charging program, including facilities, IT, and administrative functions. Staff must be trained in operations, maintenance, and software management, and staffing levels should be adjusted as the network expands.
- EV charging policies should establish clear priorities and scheduling for fleet versus employee vehicles, preventing conflicts while meeting operational needs. Energy consumption and costs should be tracked separately, policies communicated clearly, and rules designed to scale.

G.3.2.4 Impacts & Considerations

To fully electrify ESP's vehicle fleet, it is essential to understand the energy requirements in kilowatt-hours (kWh) and power demand in kilowatts (kW). The amount of energy required to electrify the vehicles depends on factors like the number of vehicles, average driving distance, and energy efficiency of the vehicles.

From the fleet vehicle list and the annual gasoline and diesel consumption provided by the complex, the total energy consumption for a fully electrified complex fleet (i.e., a scenario in which all current gasoline and diesel use is replaced by electricity) can be estimated. Table 47 below outlines the current fuel consumption of each vehicle type and their projected kWh consumption if converted to electric. The equivalent EV energy consumption in kWh per mile for various vehicle types is estimated using references for all-electric vehicles provided by the U.S. Department of Energy, as noted in Table 47.

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Table 47. EV Annual Energy Requirements

EPA MOVES Category	Existing Usage (Gallons)	Existing Fleet Miles per Gallon (MPG)[40]	US DOE AFDC Category	Equivalent Annual Mileage[1]	Equivalent EV kWh per Mile[41]	EV Annual kWh[2]
Gasoline, Light-duty Vehicle	2,938	24.4	Van	23,893	0.30	7,168
			SUV	35,839	0.36	12,902
			Pickup	5,973	0.45	2,688
			Sedan	5,973	0.34	2,031
Gasoline, Light-duty truck	5,277	17.8	Van	26,301	0.30	7,890
			Pickup	67,631	0.45	30,434
Diesel, Light-duty truck	3,635	23.4	Pickup	85,069	0.45	38,281
Diesel, Heavy-duty truck	2,639	20.1	Vocational/Cab Chassis	53,040	0.39	19,469
Total: Gasoline	**8,215**	**-**	**-**	**165,609**	-	**63,113**
Total: Diesel	**6,274**	**-**	**-**	**138,109**	-	**57,750**

Notes:

1. The equivalent annual mileage is determined by multiplying the total fuel consumption by the fleet's average miles per gallon.
2. The annual electric consumption for electric vehicles (EVs), expressed in kilowatt-hours (kWh), is derived as the product of three parameters: (i) the Equivalent Annual Mileage, (ii) the EV- specific energy consumption rate (kWh per mile) sourced from the U.S. DOE Alternative Fuels Data Center (AFDC), and (iii) the proportional representation of each vehicle category within the existing fleet.

Currently, there are no electric vehicle options available for heavy-duty pickup trucks, such as the Ford F-250 or Chevrolet Silverado 2500 HD. As a result, Table 47 does not consider electric replacements for these vehicle types within the fleet. However, alternative fuel options are available. For example, renewable diesel (a fuel chemically similar to petroleum diesel) can be used as a direct replacement in existing diesel engines without any vehicle or infrastructure modifications. Unlike biodiesel, which may require blending and compatibility considerations, renewable diesel meets the same ASTM D975 fuel specification as conventional diesel and is approved by many engine manufacturers for use at 100% concentration (R100). This makes it a practical low-carbon alternative for heavy-duty diesel vehicles where electrification is not yet feasible.

[40] Average fuel economies downloaded from the Department of Energy's Alternative Fuels Data Center, https://afdc.energy.gov/data/10309

[41] Average electric vehicle kW per mile taken from US DOE Alternative Fuels Data Center (AFDC) https://afdc.energy.gov/vehicles/search

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It is assumed that either Level 2 or Level 3 EV chargers will be installed for fleet vehicles and that, based on the information presented in Table 47, fleet vehicles average fewer than 50 miles per day and can be charged overnight. With most EVs on the market having an all-electric range of over 150 miles (and most light-duty EVs having a range of 200-400 miles), no more than one charging station per three fleet vehicles would be needed. In this case, vehicles could alternate charging ports/spots at the stations as necessary.

A typical Level 2 charging station might have two ports with a combined 22-kW capacity, and a typical low-power DCFC charging station might have a single port with a 75-kW capacity. A single two-port Level 2 station could serve twelve LDVs (six per port) and a single one-port low-power DCFC station could serve three HDVs (three per port). In this scenario, 12 LDV charging ports and 6 HDV charging ports with a combined capacity of 582 kW would be required to meet the needs of the Empire State Plaza fleet. Assuming a diversity factor of 2[42, 43], the estimated peak electric demand resulting from fleet EV charging would be 291 kW.

A typical mid-power DCFC charging station might have a single port with a 100-kW capacity, and a typical high-power DCFC charging station might have a single port with a 300-kW capacity. A single one-port mid-power DCFC station could serve nine LDVs (nine per port) and a single one-port high-power DCFC station could serve three HDVs (three per port). In this scenario, 7 LDV charging ports and 6 HDV charging ports with a combined capacity of 2500 kW would be required to meet the needs of the Empire State Plaza fleet. Assuming a diversity factor of 2, the estimated peak electric demand resulting from fleet EV charging would be 1250 kW.

Estimated peak electric demands from both EV charging scenarios (lower-power and higher-power) would be sufficiently served by the 34.5kV main Plaza substation evaluated in Section D.6. The distribution of future EV charging stations across the Plaza and adjacent owned properties, however, would need to be further determined and coordinated as certain lots and other sites that are good candidates for charging stations may not receive electrical service from the main Plaza substation. Subsequent planning and design efforts associated with charging station installations will need to consider where the electrical service of an identified charging area would come from, in addition to the capacity and condition of the respective electrical infrastructure for that area. A comparison of the EV infrastructure requirements in these two scenarios is presented in Figure 53.

[42] Finn Silber, Stefan Scheubner, Alexandra Märtz, Analysis of the simultaneity factor of fast-charging sites using Monte-Carlo simulation, *International Journal of Electrical Power & Energy Systems, Volume 155, Part B*, 2024, 109540, ISSN 0142-0615, https://doi.org/10.1016/j.ijepes.2023.109540.

[43] Hecht C, Figgener J, Sauer DU. Simultaneity Factors of Public Electric Vehicle Charging Stations Based on Real-World Occupation Data. *World Electric Vehicle Journal*. 2022; 13(7):129. https://doi.org/10.3390/wevj13070129

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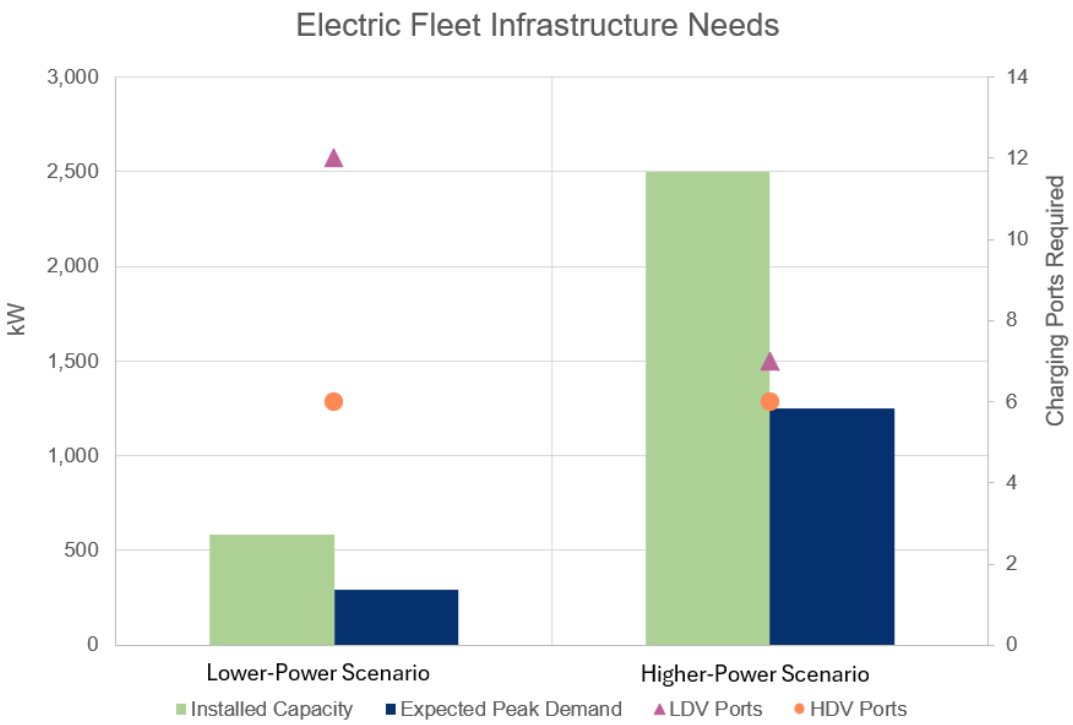

Figure 53. Comparison of potential EV Infrastructure Needs for Level 2 and Level 3 Charging

G.3.2.5 Funding Sources

Securing appropriate funding sources is essential for the successful execution of the project. OGS is currently funding the expansion of ports for state agencies. Additional funding sources could involve exploring state or federal incentives, utility rebates, or private sector partnerships. Funding sources are highly time-sensitive and must be re-evaluated during the implementation planning phase. A list of current programs is provided as a reference:

- Federal Opportunities:
  - Department of Transportation - Rebuilding American Infrastructure with Sustainability and Equity (RAISE)
  - Department of Energy grants
- State Programs
  - New York State Energy Research and Development Authority (NYSERDA): Offers rebates and incentives for installing public and private EV charging stations through the Charge Ready NY program.
- Utility Incentives
  - Various programs including the New York Joint Utilities Make-Ready Program, Fleet Advisory Services, Load Management Technologies Incentive Program (LMTIP), and potential demand charge rebate programs.

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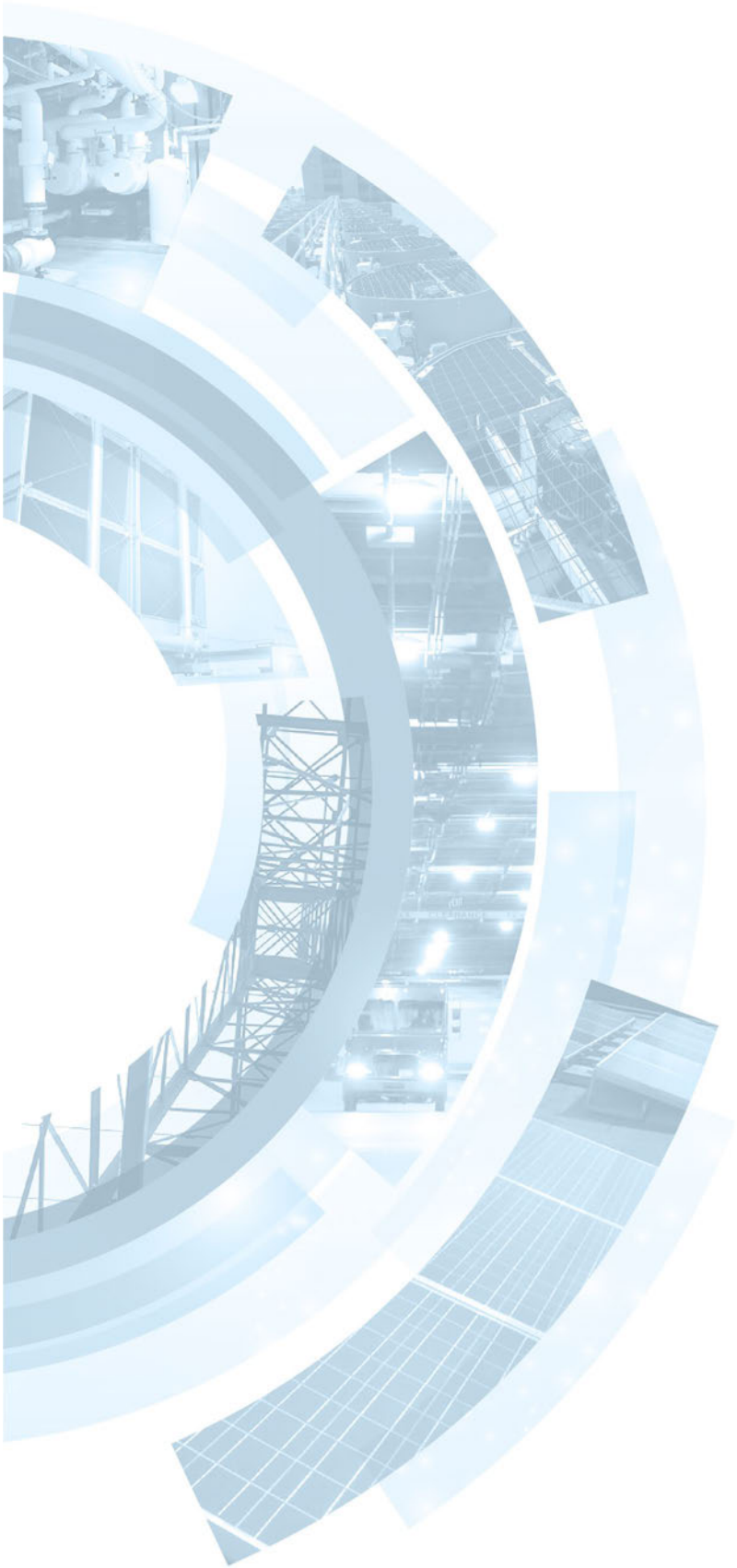

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Section H – Appendices

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Appendix A – Preliminary Energy-Use Analysis

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Energy Use Analysis and Benchmarking Profile

All Fuels Summary

Empire State Plaza

Complex Total

Building Data			
Gross Area (SF): 12,933,812		% Heated: 68%	% Cooled: 68%
Building Type(s)	**Year(s) of Construction**	**Year(s) of Renovation**	**Operating Schedule**
36% Government office 4% Laboratory 9% Entertainment/culture 4% Library 1% Social/meeting 47% Other	NA	NA	M-F 8 a.m. - 5 p.m. Unoccupied Weekends

Benchmark Comparisons		
Site EUI	**Source EUI**	
74.9	112.0	Weighted CBECS Comparison
146.6	219.2	Average
145.6	217.7	Weather Normalized
149.4	223.5	Jan 2018 to Dec 2018
143.7	215.0	Jan 2019 to Dec 2019
143.3	214.4	Jan 2020 to Dec 2020

Total Energy Profile

	Month	Average		Weather Normalized		Jan 2018 to Dec 2018		Jan 2019 to Dec 2019		Jan 2020 to Dec 2020	
		MMBtu	Cost	MMBtu	Cost	MMBtu	Cost	MMBtu	Cost	MMBtu	Cost
	Jan	196,256	$ 1,587,288	198,790	$ 1,212,829	196,893	$ 2,161,527	195,618	$ 1,551,095	164,397	$ 869,728
	Feb	158,773	$ 993,089	177,571	$ 1,111,672	150,777	$ 1,117,558	166,769	$ 1,141,463	155,401	$ 697,420
	Mar	163,092	$ 1,068,395	156,471	$ 1,011,083	165,359	$ 1,221,508	160,825	$ 1,198,343	148,645	$ 694,376
	Apr	139,577	$ 879,874	132,446	$ 896,580	148,708	$ 1,078,291	130,445	$ 937,160	136,325	$ 587,185
	May	125,428	$ 813,359	135,846	$ 912,939	128,967	$ 934,549	121,890	$ 829,331	129,657	$ 673,416
	Jun	140,745	$ 904,834	150,075	$ 980,891	146,561	$ 1,076,940	134,930	$ 943,623	154,875	$ 744,029
	Jul	192,212	$ 1,185,490	178,402	$ 1,116,142	196,709	$ 1,435,947	187,714	$ 1,218,376	195,298	$ 925,979
	Aug	188,227	$ 1,160,537	165,917	$ 1,056,533	197,799	$ 1,419,085	178,654	$ 1,179,471	176,958	$ 842,546
	Sep	147,405	$ 849,345	138,014	$ 923,294	153,735	$ 1,096,751	141,075	$ 717,567	151,413	$ 743,187
	Oct	130,076	$ 780,858	129,072	$ 880,491	129,713	$ 1,042,401	130,439	$ 643,760	137,356	$ 664,513
	Nov	151,710	$ 928,688	144,900	$ 955,916	154,432	$ 1,126,525	148,988	$ 851,493	142,045	$ 740,388
	Dec	162,334	$ 1,052,306	175,347	$ 1,101,066	162,905	$ 1,253,665	161,763	$ 927,897	161,389	$ 949,469
	Annual	**1,895,835**	**$12,204,064**	**1,882,852**	**$12,159,435**	**1,932,559**	**$14,964,748**	**1,859,110**	**$12,139,580**	**1,853,758**	**$ 9,132,236**
Total	Site EUI	146.6 kBtu/SF		145.6 kBtu/SF		149.4 kBtu/SF		143.7 kBtu/SF		143.3 kBtu/SF	
	ECI	0.94 $/SF		0.94 $/SF		1.16 $/SF		0.94 $/SF		0.71 $/SF	
	Utility Cost	6.44 $/MMBtu		6.46 $/MMBtu		7.74 $/MMBtu		6.53 $/MMBtu		4.93 $/MMBtu	
Electric	Site EUI	31.0 kBtu/SF		31.0 kBtu/SF		31.4 kBtu/SF		30.7 kBtu/SF		29.9 kBtu/SF	
		9.1 kWh/SF		9.1 kWh/SF		9.2 kWh/SF		9.0 kWh/SF		8.8 kWh/SF	
	Demand/SF	1.72 W/SF		1.67 W/SF		1.78 W/SF		1.66 W/SF		1.59 W/SF	
	ECI	0.511 $/SF		0.512 $/SF		0.596 $/SF		0.482 $/SF		0.437 $/SF	
	Utility Cost	0.056 $/kWh		0.056 $/kWh		0.065 $/kWh		0.054 $/kWh		0.050 $/kWh	
		16.48 $/MMBtu		16.48 $/MMBtu		19.02 $/MMBtu		15.69 $/MMBtu		14.62 $/MMBtu	
Natural Gas	Site EUI	115.6 kBtu/SF		114.5 kBtu/SF		118.1 kBtu/SF		113.1 kBtu/SF		113.4 kBtu/SF	
		1.156 Therms/SF		1.145 Therms/SF		1.181 Therms/SF		1.131 Therms/SF		1.134 Therms/SF	
	ECI	0.432 $/SF		0.429 $/SF		0.561 $/SF		0.457 $/SF		0.269 $/SF	
	Utility Cost	0.374 $/Therm		0.374 $/Therm		0.475 $/Therm		0.404 $/Therm		0.237 $/Therm	
		3.74 $/MMBtu		3.74 $/MMBtu		4.75 $/MMBtu		4.04 $/MMBtu		2.37 $/MMBtu	
Central CHW	Site EUI	0.0 kBtu/SF		0.0 kBtu/SF		0.0 kBtu/SF		0.0 kBtu/SF		0.0 kBtu/SF	
		0.000 kBtu/SF		0.000 kBtu/SF		0.000 kBtu/SF		0.000 kBtu/SF		0.000 kBtu/SF	
	ECI	0.000 $/SF		0.000 $/SF		0.000 $/SF		0.000 $/SF		0.000 $/SF	
	Utility Cost	N/A $/kBtu		N/A $/kBtu		N/A $/kBtu		N/A $/kBtu		N/A $/kBtu	
		N/A $/MMBtu		N/A $/MMBtu		N/A $/MMBtu		N/A $/MMBtu		N/A $/MMBtu	
Central Steam	Site EUI	0.0 kBtu/SF		0.0 kBtu/SF		0.0 kBtu/SF		0.0 kBtu/SF		0.0 kBtu/SF	
		0.000 lb/SF		0.000 lb/SF		0.000 lb/SF		0.000 lb/SF		0.000 lb/SF	
	ECI	0.000 $/SF		0.000 $/SF		0.000 $/SF		0.000 $/SF		0.000 $/SF	
	Utility Cost	N/A $/lb		N/A $/lb		N/A $/lb		N/A $/lb		N/A $/lb	
		N/A $/MMBtu		N/A $/MMBtu		N/A $/MMBtu		N/A $/MMBtu		N/A $/MMBtu	

Notes:

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

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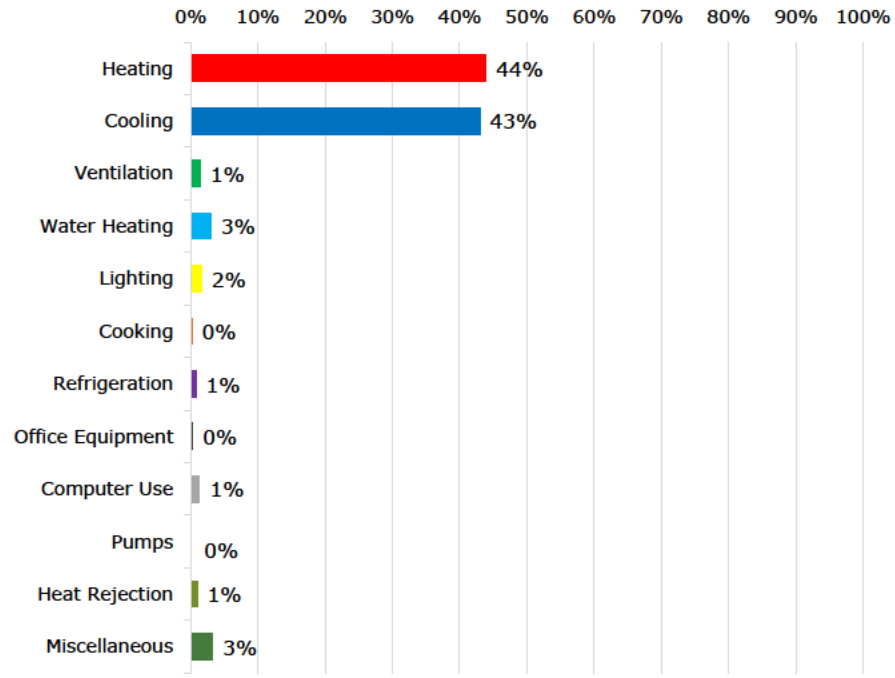
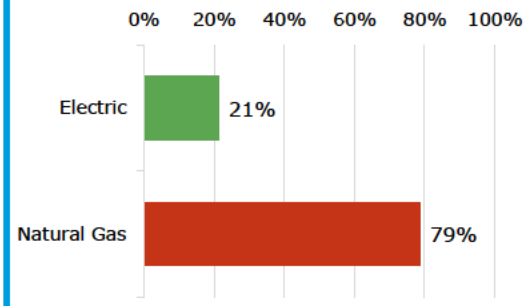
Energy Use Analysis and Benchmarking Profile | **All Fuels Summary**

Empire State Plaza | **Complex Total**

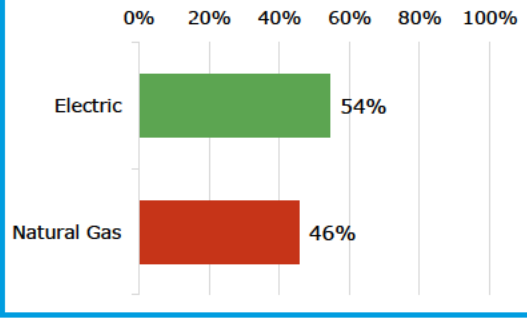
Weather Normalized Total End Use Energy Allocation



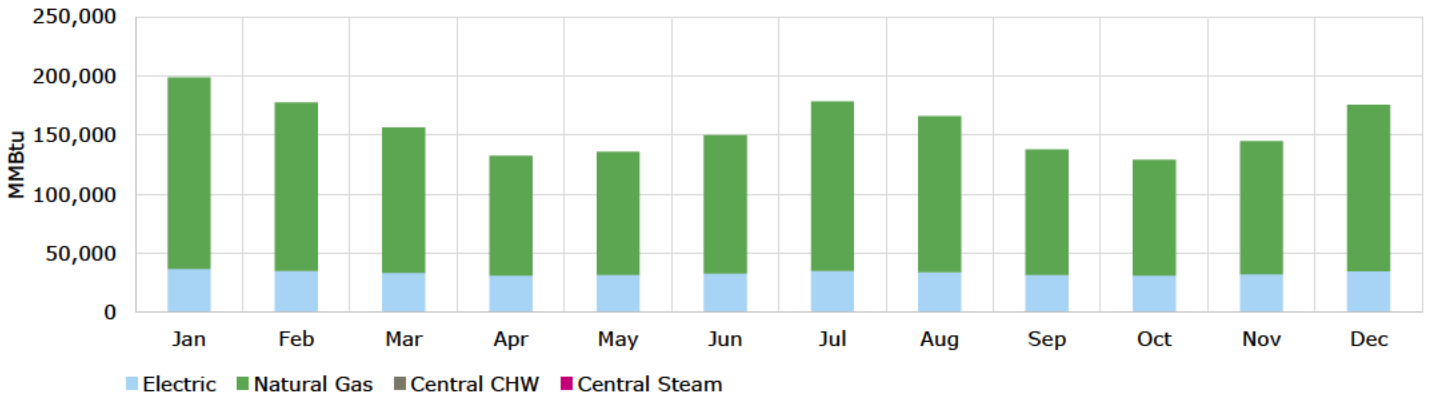
Weather Normalized Total Energy Use



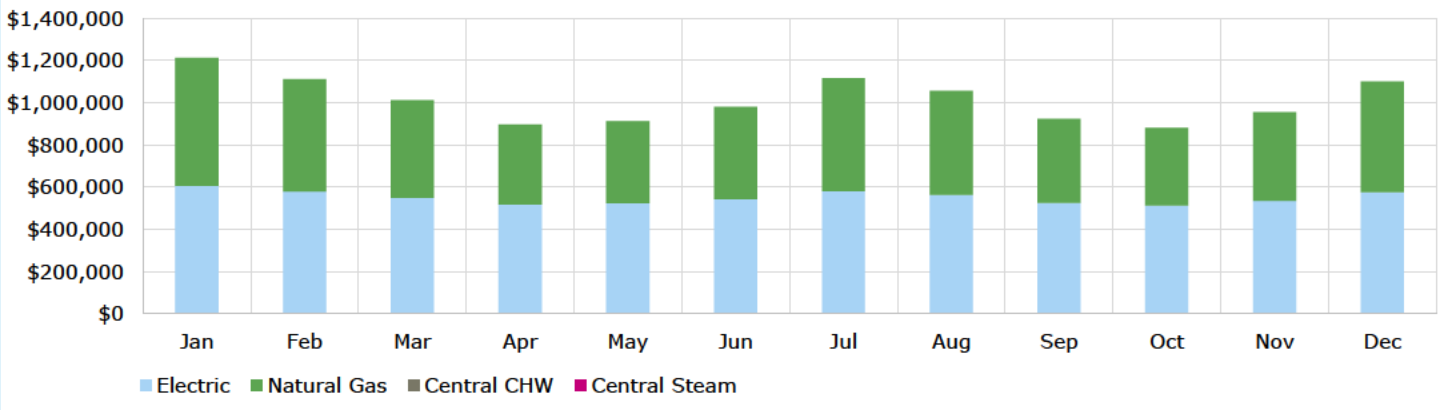
Weather Normalized Total Energy Cost



Weather Normalized Total Energy Use



Weather Normalized Total Energy Cost



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Energy Use Analysis and Benchmarking Profile

Empire State Plaza

Electric Summary

Complex Total

Utility Account Information			
Component	**Provider**	**Account Number**	**Rate Class**
Electric Delivery	National Grid	Multiple	Multiple
Electric Supply	National Grid	Multiple	

Electric Energy Profile

Month	Average					Weather Normalized				
	kWh	kW	Total Cost	CDD	HDD	kWh	kW	Total Cost	CDD	HDD
Jan	10,475,703	21,505	$ 886,093	1	880	10,791,238	21,546	$ 606,857	0	1,089
Feb	9,599,092	21,029	$ 481,644	1	685	10,290,386	20,860	$ 578,691	0	834
Mar	10,559,915	20,880	$ 551,583	2	549	9,792,422	20,183	$ 550,687	4	574
Apr	9,337,857	19,390	$ 475,338	21	284	9,226,071	19,448	$ 518,838	37	233
May	9,367,723	20,507	$ 463,634	224	42	9,309,766	19,753	$ 523,545	191	26
Jun	9,431,148	20,187	$ 510,629	429	0	9,648,321	20,367	$ 542,584	311	4
Jul	10,677,055	22,214	$ 618,577	651	0	10,321,735	21,555	$ 580,454	525	0
Aug	10,579,726	21,702	$ 591,383	512	0	10,024,962	21,033	$ 563,764	432	0
Sep	9,506,756	20,977	$ 494,470	277	15	9,361,363	19,847	$ 526,446	210	22
Oct	9,256,747	19,702	$ 491,476	51	164	9,146,339	19,334	$ 514,354	33	198
Nov	9,193,851	18,998	$ 498,123	3	496	9,519,201	19,803	$ 535,322	0	442
Dec	9,593,461	18,743	$ 549,230	0	735	10,237,876	20,788	$ 575,738	0	808
Annual	**117,579,035**	**22,214**	**$ 6,612,181**	**2,172**	**3,851**	**117,669,681**	**21,555**	**$ 6,617,279**	**1,743**	**4,232**
KPIs	9.1 kWh/SF	1.72 W/SF	0.51 $/SF			9.1 kWh/SF	1.67 W/SF	0.51 $/SF		
Load Factor	60%					62%				
Blended Rates	0.056 $/kWh					0.056 $/kWh				

Electric Energy Profile

Month	Jan 2018 to Dec 2018					Jan 2019 to Dec 2019					Jan 2020 to Dec 2020				
	kWh	kW	Total Cost	CDD	HDD	kWh	kW	Total Cost	CDD	HDD	kWh	kW	Total Cost	CDD	HDD
Jan	10,670,205	22,443	$ 1,366,553	0	974	10,281,202	20,568	$ 750,335	0	962	9,896,804	19,018	$ 492,425	3	705
Feb	9,723,378	22,068	$ 504,514	4	621	9,474,806	19,991	$ 503,860	0	760	9,347,443	18,920	$ 423,932	0	674
Mar	10,821,512	21,981	$ 584,260	0	637	10,298,318	19,779	$ 608,494	2	611	9,720,552	18,548	$ 418,153	4	400
Apr	9,317,639	19,720	$ 550,209	3	399	9,358,075	19,060	$ 485,771	55	200	8,687,423	16,511	$ 356,924	5	252
May	9,301,698	20,518	$ 491,579	297	7	9,433,748	20,497	$ 439,322	139	43	8,861,095	17,778	$ 434,927	237	75
Jun	9,466,047	18,963	$ 555,673	397	0	9,396,248	21,412	$ 493,179	406	0	9,402,025	20,077	$ 481,458	484	1
Jul	10,794,944	23,070	$ 704,887	672	0	10,559,166	21,358	$ 563,487	650	0	10,953,928	20,599	$ 603,396	630	0
Aug	10,727,634	22,391	$ 682,172	612	0	10,431,819	21,012	$ 559,792	503	0	10,617,969	20,310	$ 534,324	421	0
Sep	9,772,510	21,754	$ 544,437	362	3	9,241,003	20,200	$ 441,372	272	0	9,436,761	19,166	$ 493,961	198	43
Oct	9,279,723	20,106	$ 588,426	78	200	9,233,772	19,297	$ 418,912	50	88	8,948,171	17,680	$ 450,707	24	203
Nov	9,232,538	19,288	$ 547,314	1	530	9,155,163	18,708	$ 487,513	0	536	8,405,794	17,642	$ 416,845	8	423
Dec	9,746,520	19,137	$ 594,849	0	690	9,440,402	18,350	$ 475,943	0	760	9,088,592	17,650	$ 547,993	0	756
Annual	**118,854,349**	**23,070**	**$ 7,714,872**	**2,426**	**4,061**	**116,303,721**	**21,412**	**$ 6,227,981**	**2,077**	**3,960**	**113,366,559**	**20,599**	**$ 5,655,046**	**2,014**	**3,532**
KPIs	9.2 kWh/SF	1.78 W/SF	0.60 $/SF			9.0 kWh/SF	1.66 W/SF	0.48 $/SF			8.8 kWh/SF	1.59 W/SF	0.44 $/SF		
Load Factor	59%					62%					63%				
Blended Rates	0.065 $/kWh					0.054 $/kWh					0.050 $/kWh				

Notes:

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

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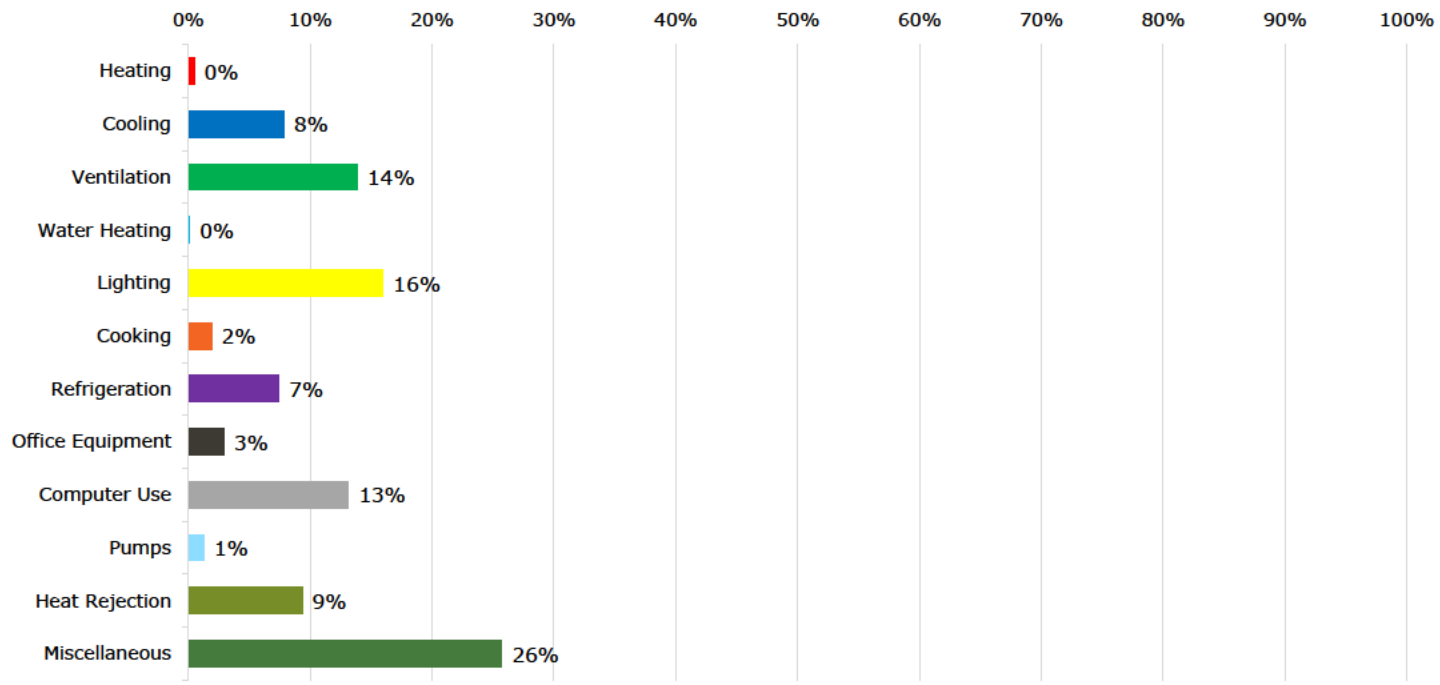
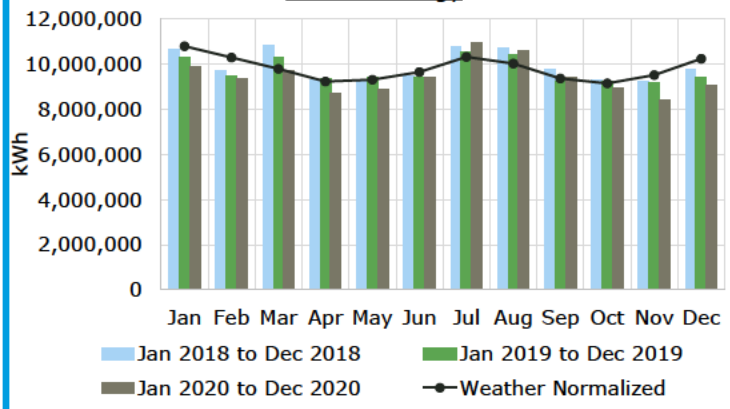
Energy Use Analysis and Benchmarking Profile — **Electric Summary**

Empire State Plaza — **Complex Total**

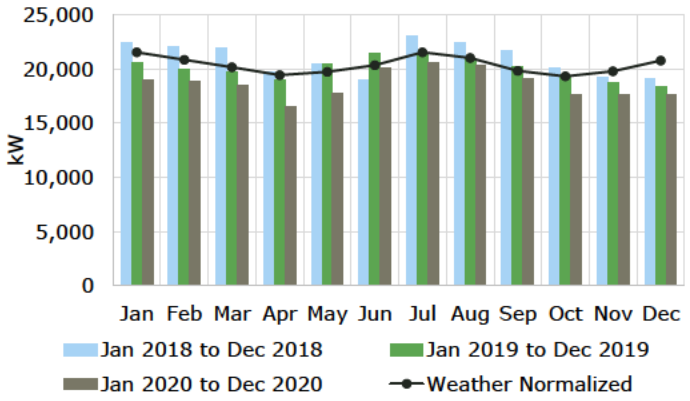
Electric End Use Energy Allocation



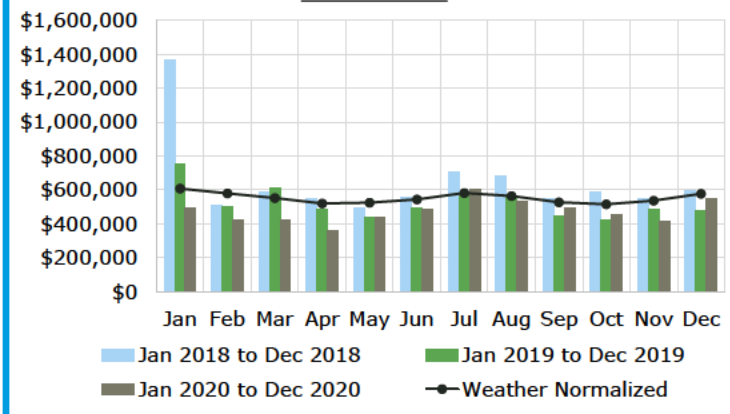
Electric Energy



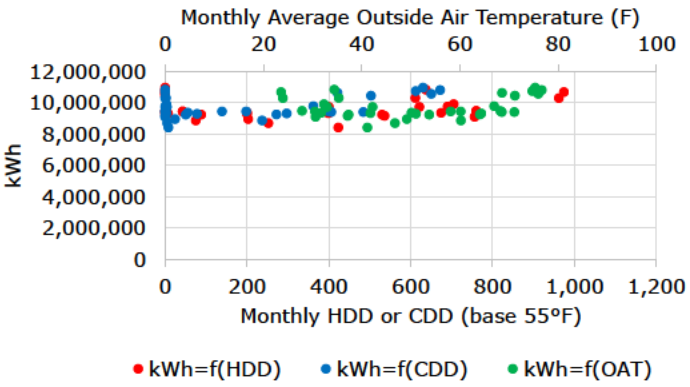
Electric Demand



Electric Cost



Electric Energy vs HDD/CDD/OAT



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Energy Use Analysis and Benchmarking Profile

Natural Gas Summary

Empire State Plaza

Complex Total

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

Natural Gas Energy Profile

Month	Average				Weather Normalized			
	Therms	Total Cost	CDD	HDD	Therms	Total Cost	CDD	HDD
Jan	1,605,127	$ 701,195	1	880	1,619,702	$ 605,972	0	1,089
Feb	1,260,209	$ 511,445	1	685	1,424,605	$ 532,981	0	834
Mar	1,270,618	$ 516,811	2	549	1,230,592	$ 460,396	4	574
Apr	1,077,158	$ 404,537	21	284	1,009,668	$ 377,742	37	233
May	934,657	$ 349,725	224	42	1,040,813	$ 389,395	191	26
Jun	1,085,661	$ 394,205	429	0	1,171,553	$ 438,308	311	4
Jul	1,557,816	$ 566,913	651	0	1,431,841	$ 535,688	525	0
Aug	1,521,289	$ 569,154	512	0	1,317,122	$ 492,769	432	0
Sep	1,149,679	$ 354,875	277	15	1,060,735	$ 396,848	210	22
Oct	984,919	$ 289,382	51	164	978,647	$ 366,137	33	198
Nov	1,203,404	$ 430,565	3	496	1,124,205	$ 420,594	0	442
Dec	1,296,014	$ 503,077	0	735	1,404,151	$ 525,328	0	808
Annual	**14,946,549**	**$ 5,591,883**	**2,172**	**3,851**	**14,813,634**	**$ 5,542,157**	**1,743**	**4,232**
KPIs	1.156 Therms/SF	0.432 $/SF			1.145 Therms/SF	0.429 $/SF		
Blended Rates	0.374 $/Therm	3.74 $/MMBtu			0.374 $/Therm	3.74 $/MMBtu		

Natural Gas Energy Profile

Month	Jan 2018 to Dec 2018				Jan 2019 to Dec 2019				Jan 2020 to Dec 2020			
	Therms	Total Cost	CDD	HDD	Therms	Total Cost	CDD	HDD	Therms	Total Cost	CDD	HDD
Jan	1,604,865	$ 794,975	0	974	1,605,390	$ 800,759	0	962	1,306,288	$ 377,303	3	705
Feb	1,176,009	$ 613,045	4	621	1,344,410	$ 637,603	0	760	1,235,076	$ 273,488	0	674
Mar	1,284,363	$ 637,248	0	637	1,256,872	$ 589,850	2	611	1,154,786	$ 276,223	4	400
Apr	1,169,166	$ 528,082	3	399	985,150	$ 451,389	55	200	1,066,834	$ 230,261	5	252
May	972,293	$ 442,969	297	7	897,021	$ 390,009	139	43	994,233	$ 238,488	237	75
Jun	1,142,627	$ 521,268	397	0	1,028,696	$ 450,444	406	0	1,227,955	$ 262,570	484	1
Jul	1,598,766	$ 731,060	672	0	1,516,865	$ 654,889	650	0	1,579,227	$ 322,583	630	0
Aug	1,611,968	$ 736,913	612	0	1,430,610	$ 619,679	503	0	1,407,293	$ 308,222	421	0
Sep	1,203,913	$ 552,314	362	3	1,095,444	$ 276,195	272	0	1,192,149	$ 249,226	198	43
Oct	980,505	$ 453,976	78	200	989,332	$ 224,848	50	88	1,068,251	$ 213,806	24	203
Nov	1,229,306	$ 579,211	1	530	1,177,502	$ 363,981	0	536	1,133,642	$ 323,543	8	423
Dec	1,296,501	$ 658,816	0	690	1,295,527	$ 451,954	0	760	1,303,783	$ 401,476	0	756
Annual	**15,270,280**	**$ 7,249,876**	**2,426**	**4,061**	**14,622,817**	**$ 5,911,599**	**2,077**	**3,960**	**14,669,517**	**$ 3,477,189**	**2,014**	**3,532**
KPIs	1.181 Therms/SF	0.561 $/SF			1.131 Therms/SF	0.457 $/SF			1.134 Therms/SF	0.269 $/SF		
Blended Rates	0.475 $/Therm	4.75 $/MMBtu			0.404 $/Therm	4.04 $/MMBtu			0.237 $/Therm	2.37 $/MMBtu		

Notes:

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

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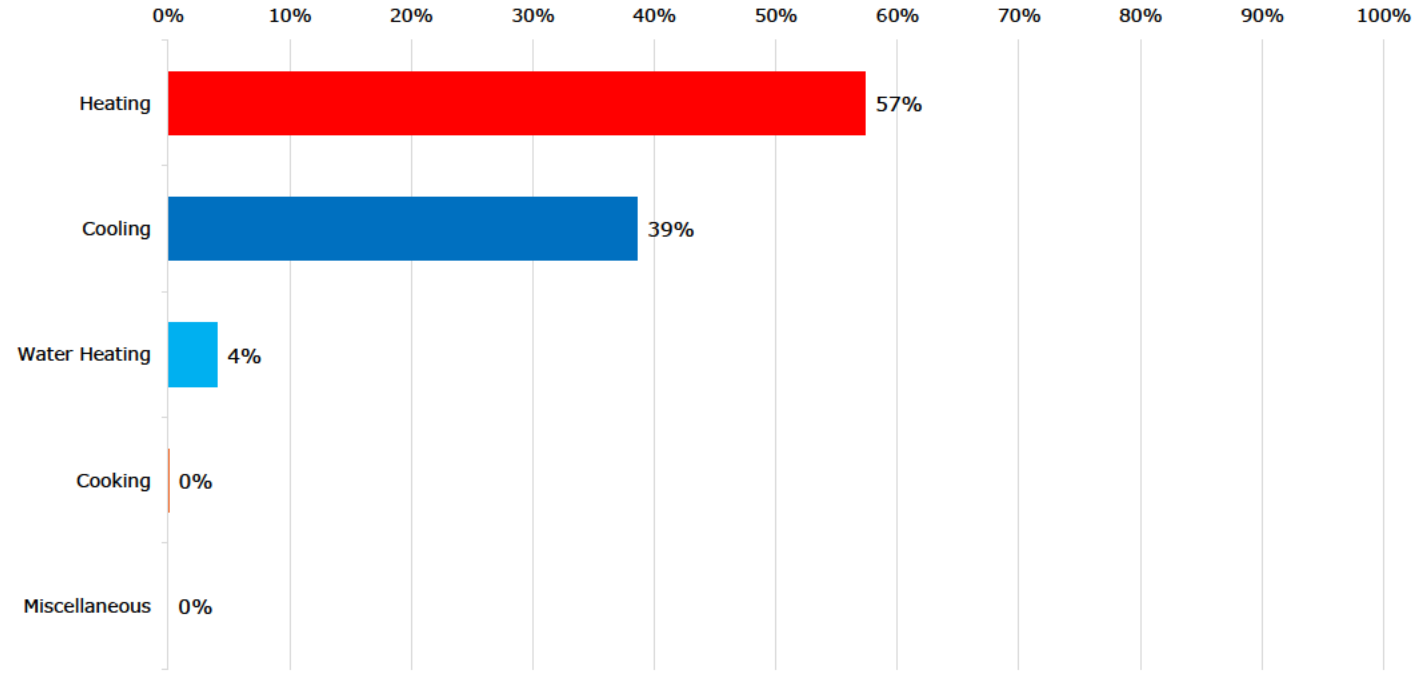
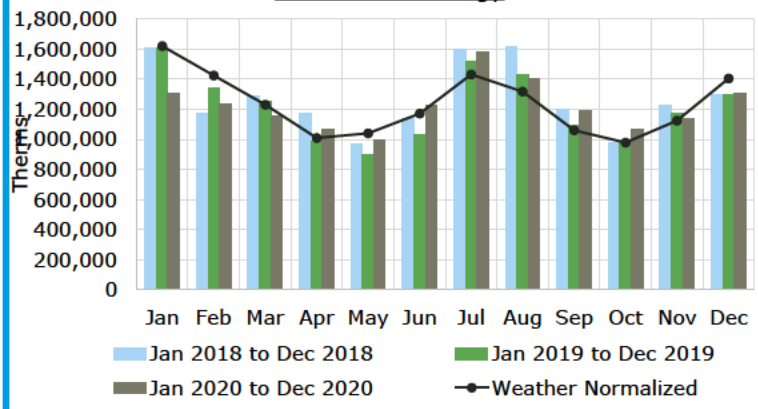
Energy Use Analysis and Benchmarking Profile | **Natural Gas Summary**

Empire State Plaza | **Complex Total**

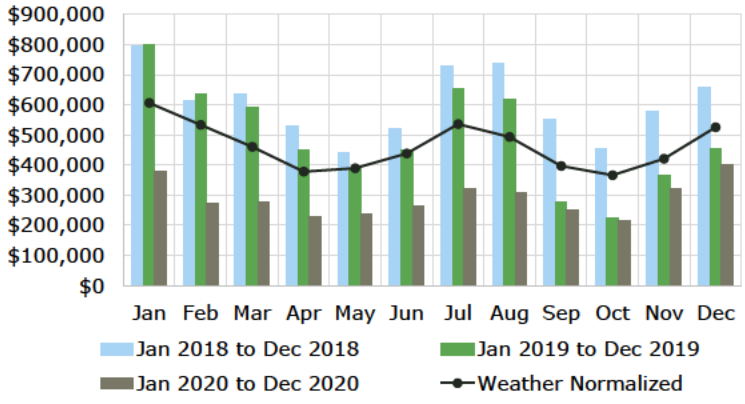
Natural Gas End Use Energy Allocation



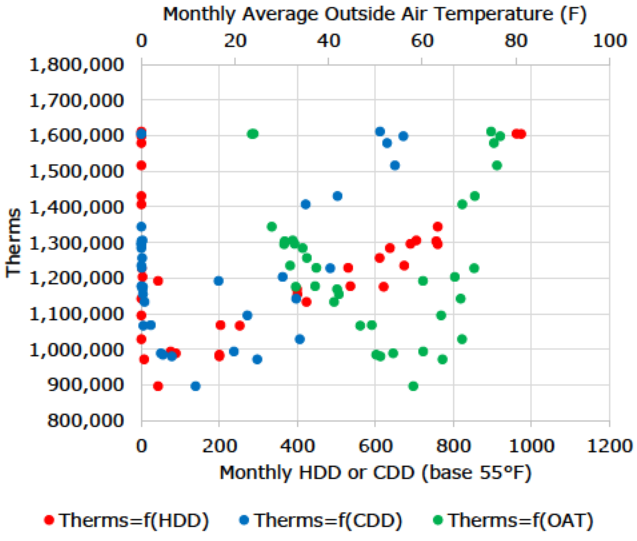
Natural Gas Energy



Natural Gas Cost



Natural Gas vs HDD/CDD/OAT



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Energy Use Analysis and Benchmarking Profile

Building Summary

Empire State Plaza

EUI

Building	Gross Area (SF)	Weather Normalized EUI					CBECS Building Type	Weighted CBECS Comparison (kBtu/SF)	Notes
		Electricity (kBtu/SF)	Natural Gas (kBtu/SF)	Chilled Water (kBtu/SF)	Steam (kBtu/SF)	Total (kBtu/SF)			
Legislative Office Building	650,348	27.8	0.0	21.6	56.4	105.7	100% Government office	72.8	1
Justice Building	261,177	35.9	0.0	18.2	68.9	123.0	90% Government office 10% Courthouse/probation office	73.2	1
Agency Building 1	198,196	17.2	0.0	27.3	77.4	121.9	100% Government office	72.8	1
Agency Building 2	198,196	17.7	0.0	22.0	84.6	124.3	100% Government office	72.8	1
Agency Building 3	198,196	16.3	0.0	27.0	102.8	146.1	100% Government office	72.8	1
Agency Building 4	198,196	14.2	0.0	28.3	100.7	143.2	100% Government office	72.8	1
Corning Tower	927,423	24.4	0.0	14.2	100.5	139.1	100% Government office	72.8	1
Cultural Education Center (Museum)	1,582,504	28.9	0.0	53.2	23.3	105.4	67% Entertainment/culture 33% Library	87.5	1
Health Department Laboratory	485,210	115.7	0.0	344.9	521.9	982.5	100% Laboratory	230.4	1
Meeting Center (The Egg)	159,362	96.7	0.0	82.5	257.0	436.2	50% Entertainment/culture 50% Social/meeting	76.4	1
Swan Street Office Building	842,727	29.3	0.0	19.6	64.2	113.1	100% Government office	72.8	1
Main Platform	3,878,694	18.2	0.0	11.1	51.2	80.5	25% Enclosed mall 75% Other	71.6	1
Central Air Conditioning Plant (CACP)	144,261	205.6	0.0	0.0	3712.7	3918.3	100% Other	107.3	1
East Parking Garage	715,610	2.7	0.0	0.0	0.0	2.7	100% Vacant	7.8	2
Alfred E Smith Office Building	598,866	31.4	0.0	13.5	60.3	105.1	100% Government office	72.8	3
Capitol	572,025	24.7	0.0	29.4	81.6	135.8	100% Government office	72.8	3
Executive Residence	30,000	47.6	153.1	0.0	0.0	200.7	50% Government office 50% Other	90.1	4
Sheridan Avenue Steam Plant (SASP)	77,350	38.2	18685.3	0.0	0.0	18723.5	100% Other	107.3	5
Sheridan Parking Garage	450,000	2.6	0.0	0.0	0.0	2.6	100% Vacant	7.8	6
River Front Pump Station	15,471	2166.0	0.0	0.0	0.0	2166.0	100% Other	107.3	7
Old State Education Building	750,000	29.4	0.1	101.9	75.7	207.1	80% Government office 20% Social/meeting	70.8	3
Complex Total	**12,933,812**	**31.0**	**114.5**	**0.0**	**0.0**	**145.6**	**Weighted CBECS Comparison**	**74.9**	**-**

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Overall Notes:

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

Building Specific Notes:

1 Electric service from Main Plaza. Chilled water from CACP. Steam from SASP.
2 Electric service from Main Plaza.
3 Separate electric service. Chilled water from CACP. Steam from SASP.
4 Electric service from Main Plaza. Separate natural gas service.
5 Separate electric service. Separate natural gas service.
6 Electric service from SASP
7 Separate electric service.

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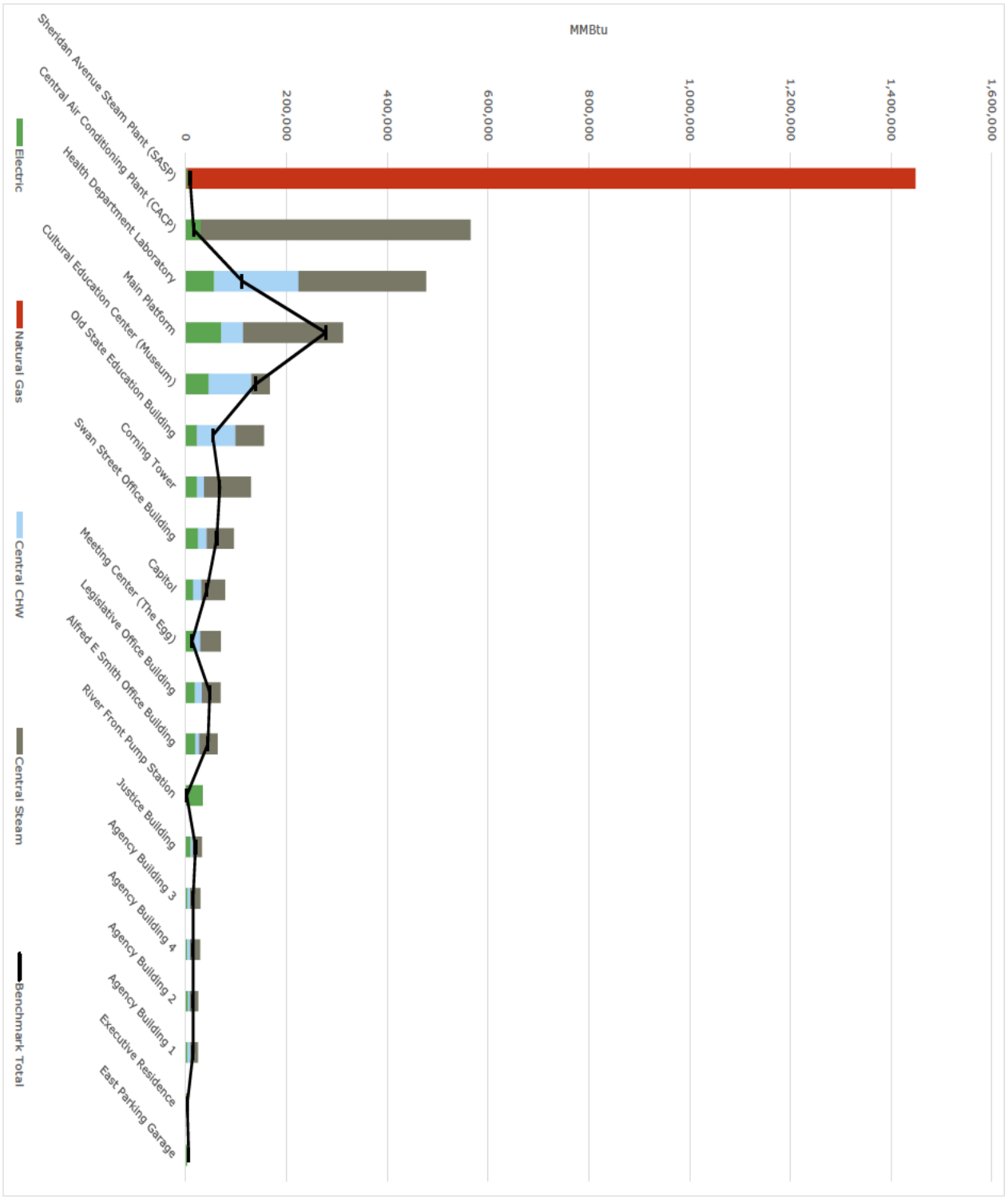
Energy Use Analysis and Benchmarking Profile | **Building Summary**

Empire State Plaza | **Total Energy Chart**



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Energy Use Analysis and Benchmarking Profile | **Building Summary**

Empire State Plaza | **EUI Chart**

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Appendix B – Building Assessment Reports

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RAMBOLL

Empire State Plaza | EEM Opportunity Matrix (DRAFT)

Potential Energy Efficiency Measure →

| Campus | Building Occupant | GSF | Gut Rehab Scheduled | Envelope | | | | Lighting | | | | | HVAC Equipment | | | | | | | | | | | | | | | | | | | | | | | | | HVAC Controls | | | | | | | | | | | | | | | | | | | | | | | | | | | DHW | | O&M | | |
|---|---|---

		Energy Conservation Measure							
		Building Envelope		HVAC Upgrades			HVAC Controls		
Building	GSF	Replace Single Pane Windows with High Performance Windows	Replace Double Pane Windows with High Performance Windows	AHU Modernization [1]	Energy Recovery	Laboratory VAV Exhaust/Supply	Install Occupancy-Based HVAC Controls	Additional Zone Controls on FTR	Laboratory DCV
Agency Building 1	198,196		•	•			•		
Agency Building 2	198,196		•	•			•		
Agency Building 3	198,196		•	•			•		
Agency Building 4	198,196		•	•			•		
Corning Tower	927,423		•	•			•		
Health Laboratory	485,210		•		•	•	•		•
Health Lab Repurpose (Office Space)			•	•			•		
Swan Street Building	842,727	•	•	•			•	•	
The Egg	159,362	•	•	•			•		
CEC	1,582,504	•	•	•			•	•	
JOB	261,177		•	•			•	•	
LOB	650,348		•	•			•	•	
Main Platform	3,878,694			•			•		
Total	**9,580,229**	**3**	**12**	**12**	**1**	**1**	**13**	**4**	**1**

Notes:
1. AHU Modernization is a complete replacement of existing air handling units, ductwork, and terminal devices, and includes:
   - Demand controlled ventilation (DCV) where required by code
   - Energy recovery where required by code
   - Direct digital controls (DDC)
   - Opportunity for deep energy retrofit solutions such as dedicated outdoor air systems with energy recovery, chilled beams, etc.

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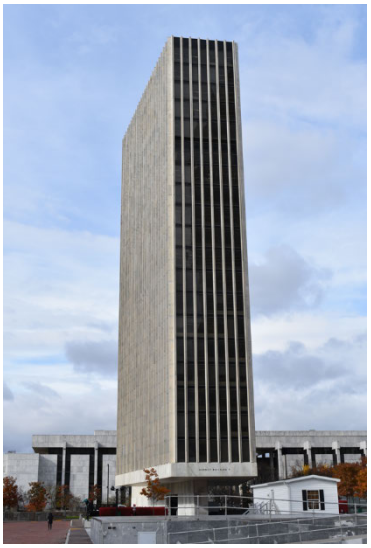
EMPIRE STATE PLAZA | AGENCY BUILDING 1 BUILDING ASSESSMENT



Building Description

Building Name:	Agency Building 1
Year Constructed:	1974
No. of Floors:	20 + basement and concourse level
Est. GSF:	198,196

Major Renovations

- Roof Replacement (2016)

Functional Description

Agency Building 1 is one of four identical government office buildings (numbered 1 through 4) that primarily house offices for the NYS Department of Civil Service, Division of Budget, Department of Public Service, Division of Tax Appeals, and Division of Human Rights.

Number of Occupants

The approximate number of building occupants during the audit was around 360 people which is well below maximum occupancy mostly due to the COVID-19 pandemic with people working from home. A 30% increase in occupants is anticipated towards the end of 2022.

Occupancy Patterns

The offices are typically occupied from 8:00 a.m. to 5:00 p.m. on weekdays and largely unoccupied on weekends.

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Space Function Summary

Table 1. Space Function Summary (Estimated)

	Office
Original Intended Use	Office
Gross Floor Area (GSF)	198,196
% of Total GSF	100%
% Heated	100%
% Cooled	100%
Number of Occupants	360
Typical Occupancy Pattern	M-F 8 a.m. – 5 p.m.
Principal HVAC Type	AHUs serving core spaces & as primary air to perimeter induction units
Principal Lighting Type	Fluorescent T8

Building Envelope

Roof

- Roof is a typical flat roof with white membrane waterproofing and stormwater management throughout. No roof deficiencies were observed. There was no roof ponding. The roof was recently replaced around 2016 with unknown insulation.

Exterior Walls

- Exterior walls are original to the building and marble-faced. The building is steel-framed with unknown insulation

Windows

- Double-glazed floor-to-ceiling fixed, non-operable windows with aluminum frames are typical of all perimeter spaces. Window-to-wall ratio is estimated to be 80%. Windows have been gradually replaced on an individual basis as they fail and are otherwise original to the building.

Exterior Doors

- Four (4) glass doors at the main ground-level entry vestibule are single-glazed, aluminum framed. Significant air gaps were observed (worn weatherstripping).
- There is also one (1) revolving door in the entry vestibule, also all glass and single glazed

Air Infiltration/Leakage

- No large concerns

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- Some worn weatherstripping near main entryway doors

Utilities

Electricity

- Electricity is supplied to the plaza through [redacted] feeders from National Grid
- [redacted] high voltage primary distribution transformers step down the voltage [redacted] and distribution switchgear supplies power to substations throughout the plaza
- Various electrical rooms house the building's main switchgear [redacted] and various disconnect switches
- Various transformers convert to distribution voltages (480V, 120V)

Natural Gas

- The building does not have a natural gas service

District Steam

- The building is supplied by high pressure steam (HPS) from the Sheridan Avenue Steam Plant (SASP) at around 150 psig. There are various pressure reducing stations that convert to medium pressure steam (MPS) ~ 60 psig and low pressure steam (LPS) ~10 psig.
- MPS and LPS are used to generate heating hot water (HHW) for induction units and reheat coils. LPS is generally used for domestic hot water (DHW) production.

District Chilled Water

- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations

Metering

Utility Feeds and Meters

- The Plaza has one main National Grid utility account meter under SC-3A Transmission and Delivery Service tariff

Submeters

- Agency Building 1 has numerous submeters that are aggregated to provide the total building electric consumption
- Chilled water blending stations are submetered to continuously monitor thermal energy. The Main Platform contains multiple blending stations that provide chilled water to equipment in various mechanical/electrical rooms (MER).
- Steam flow is submetered to continuously monitor thermal energy. HPS is metered just prior to the pressure reducing stations.
- All electric and thermal submeter data is automatically collected by OGS' Web Enabled Advanced Metering (WEAM) system

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Lighting

Interior Fixture Types

- Linear T8 fluorescent fixtures are most prevalent
- An LED conversion project is in progress, but no interior LED fixtures were observed during the visit

Interior Lighting Controls

- Some occupancy sensors were observed in mechanical spaces
- Interior lighting is generally manually switched ON/OFF with minimal controls

Exterior Lighting

- LED lighting fixtures observed on the roof (level 21) and on the ground for façade uplighting
- Exterior lighting is scheduled through building automation system, and typically operate from 4:15 p.m. to 11:30 a.m. every day

HVAC

Central Heating System

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- HPS is supplied to the building around 150 psig. There are various pressure reducing stations that convert to MPS ~ 60 psig and LPS ~10 psig. LPS is used to generate heating hot water (HHW) and domestic hot water (DHW) through shell and tube heat exchangers.
  - One (1) shell and tube heat exchanger (HX-15-1) generates HHW using LPS for induction units and air handling unit preheat and reheat heating coils
  - Condensate from the heat exchangers and piping is collected in condensate receivers located in the MERs and pumped back to the SASP
  - Condensate pumps have VFDs
- Two (2) 10 hp, 300 GPM pumps (P-15-3 & P-15-4) supply HHW to air handling unit (AHU) coils for the second floor spaces and above. Mechanical room unit heaters also run off of this HHW system.
  - These pumps are *not* driven by VFDs
  - Only one pump operates at any time, with the other on standby
- Two (2) 40 hp, 800 GPM pumps (P-15-1 & P-15-2) supply HHW or CHW (2-pipe configuration) to the perimeter induction units
  - These pumps are controlled by VFDs in response to differential pressure across the loop
  - Only one pump operates at any time, with the other on standby
- HHW supply temperature is reset based on outdoor air temperature and varies by loop. HHW supply temperature at colder outdoor air temperatures, generally, ranges from 160°F to 190°F.

Central Cooling System

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations
- Two (2) 15 hp, 425 GPM pumps (P-3B-1 & P-3B-2) supply CHW to the building's AHU cooling coils.
  - Both pumps are controlled by VFDs in response to differential pressure across the loop.

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  - Only one pump operates at any time, with the other on standby
- CHWP1-22B and CHWP1-22A (HP unknown) are on VFDs and supply CHW for units located in MER-15, 4-2, 4-3, and 4-4
  CHWP1-26B and CHWP1-26A (20HP each) are on VFDs and supply CHW for units located in MER-1 and 4-5

Air Handling Units

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- The building is conditioned with [redacted] air handling unit systems designated typically by the following:
  [redacted]
  - The AHUs supply heating, cooling, and ventilation air to each floor. Distribution for core spaces is through drop ceilings with linear slot diffusers.
  - Each air handler has preheat and cooling coils at a minimum. Each unit originally included a steam humidifier section but these are no longer in use and are largely abandoned in place. AHUs serving core zones have reheat coils. AHUs serving perimeter spaces have zone-level heating and cooling at the induction units. Conditioned air is supplied to some areas with duct-mounted hot water reheat coils that are controlled to maintain zone temperatures at setpoint.
  - The supply air fan motors range from 5hp to 50hp, but most are typically 50hp. Return air fan motors average around 10hp. These motors are typically NEMA premium and appear to have been replaced within the last ~10 years. Exhaust fans are described below.
  - Most supply and return fan motors have VFDs to vary airflow
    - Supply fan VFD speed is reset based on outdoor air temperature, as shown in the schedule below. The return fan tracks the supply fan VFD speed.

OA Temperature (°F)	Fan Speed (%)	OA Temperature (°F)	Fan Speed (%)
90 to 95	100	35 to 40	60
85 to 90	100	30 to 35	70
80 to 85	95	25 to 30	70
75 to 80	90	20 to 25	70
70 to 75	80	15 to 20	80
65 to 70	80	10 to 15	80
60 to 65	70	5 to 10	80
55 to 60	60	0 to 5	80
50 to 55	60	-5 to 0	80
45 to 50	60	-10 to -5	80

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OA Temperature (°F)	Fan Speed (%)
40 to 45	60

OA Temperature (°F)	Fan Speed (%)

Exhaust Systems

- All exhaust systems and components date to the original construction and are generally past the end of their useful life
- This building has [redacted] exhaust systems that remove air from the building
  - Fans range from 3/4hp to 10hp and typically average 5hp. They are mostly NEMA Premium motors
  - None of these motors are on VFDs
  - No energy recovery was observed

Zone Heating/Cooling

- Common ductwork serving core zones contain duct-mounted reheat coils, 1 per floor
- Induction Units along perimeter of every floor utilize a two-pipe loop for either cooling or heating
  - There is one induction unit per window, per floor. Primary air is provided by AHUs
  - The changeover temperature between heating and cooling mode is set at 60F

HVAC Controls

Building Automation System

- Honeywell Enterprise Building Integrator (EBI) building automation system (BAS) is used for monitoring, direct digital control (DDC), and energy management of HVAC systems
- All valves, dampers, and other control devices have pneumatic actuators with electric to pneumatic transducers that convert the BAS control signal to a proportional pneumatic pressure

Operating Schedules

- HVAC systems are typically in occupied mode [redacted] on weekdays and are typically scheduled OFF on weekends with a temperature minimum of 55F. Heating equipment cycles ON in OFF mode if space temperatures fall below 55F
- Exhaust systems follow a similar schedule

Energy Saving Control Strategies

- Building HVAC equipment is generally scheduled to run during occupied hours and only cycles during unoccupied hours if space temperatures falls below 55F
- Each AHU is controlled by some combination of the following:
  - The supply air temperature (SAT) is reset based on OAT
  - The supply and return fan speeds are controlled based on OAT. Fan speed is 60% between 35F and 60F OAT, ramping up to 100% at 85F and above, and ramping up to 80% at 20F and below.
- Hot water temperature reset schedule ranging from 125F @45F OAT and above to 180F @15F OAT and below, ramped linearly in between

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- Air-side economizer mode is activated when outdoor air conditions are ideal for cooling operation, but many of the dampers are not functional

Domestic/Service Water Heating

Domestic Water Heaters
- A semi-instantaneous domestic hot water system uses LPS to generate hot water
- Some electric resistance storage hot water heaters were observed but noted they did not serve the Agency buildings and instead served nearby stores in the plaza central mall area

DHW Load
- The DHW load comes from bathroom hand sinks and janitor closets

Piping and Ductwork

Piping Systems/Insulation
- Various steam, CHW, and HW pipes were uninsulated or missing large amounts of insulation
- Many issues appear to have been identified and have tags indicating that repairs are scheduled and/or in progress
- Several piping system leaks (including steam leaks) were observed but were generally tagged for future repair

Air Distribution Systems/Insulation
- Ductwork insulation is generally in good shape or tagged where deficient

Equipment Insulation
- Heat exchangers were mostly insulated when necessary. Most deficiencies were tagged.

Piping and Ductwork Leaks
- Few, if any, leaks were identified in piping and ductwork during the building walk-through

Miscellaneous Loads and Specialty Systems

Plug Loads

- The building has typical office plug loads such as computers, monitors, laptops, printers, small kitchen appliances in break rooms, and task lighting
- IT Server racks are the only other significant plug load, but most were single or double racks at most. No data centers were found in this building
- Air compressors for pneumatic controls were observed in some mechanical rooms, but are no longer in operation

Renewable Energy Systems

- None observed

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Mission Critical Systems

- Camera security systems
- Emergency power is supplied by emergency generators at the SASP

Water Systems

- No major water using systems related to Hudson River and municipal sources of water are used in building HVAC processes

Initial Hazardous Materials Assessment

- Asbestos is present in structural fire proofing above ceiling tiles and on the concrete floors. Both areas have been marked with stickers indicating the hazard.

Potential Energy Efficiency Measures (EEMs)

- Consolidate office spaces between Corning Tower and the four Agency buildings so that more unoccupied floors and AHUs can be operated in unoccupied mode
- Replace all major AHUs, corresponding ductwork, and terminal reheat coils
  - Multizone AHUs should consider the following features:
    - Multizone variable air volume (VAV) systems with VAV terminal boxes and hot water reheat coils
    - Supply fan motors controlled by VFDs to maintain duct static pressure setpoint
    - Duct static pressure reset controls
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
  - Single zone AHUs should consider the following features:
    - Temperature based control of supply fan VFD speed. The supply fan speed and discharge temperature would be controlled to satisfy the space temperature setpoint.
    - Demand controlled ventilation on units with high ventilation loads
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
- Consider alternative HVAC systems for deep energy retrofits, such as
  - Dedicated outdoor air systems (DOAS) with energy recovery and DCV
  - Active chilled beams
  - Water-source heat pumps in lieu of induction units
- Install occupancy-based controls on tenant HVAC systems to allow for automatic setback of space temperature setpoints in unoccupied zones during normal occupied mode periods. This measure would also provide occupied mode setpoints during unoccupied mode periods when the zone is occupied (*e.g.*, during nighttime housekeeping).
- Implement differential pressure reset on variable speed pumping systems
- BAS Optimization—survey existing BAS to identify opportunities for improved operations and energy savings (e.g., sequence of operation changes, operating schedules, setpoints, reset schedules)

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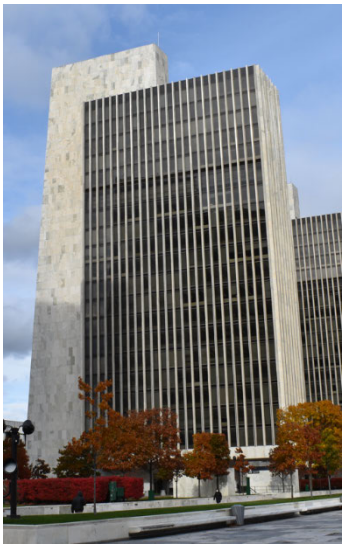
EMPIRE STATE PLAZA | AGENCY BUILDING 2 BUILDING ASSESSMENT



Building Description

Building Name:	Agency Building 2
Year Constructed:	1974
No. of Floors:	20 + basement and concourse level
Est. GSF:	198,196

Major Renovations

- Roof Replacement (2016)

Functional Description

Agency Building 2 is one of four identical government office buildings (numbered 1 through 4) that primarily house offices for numerous New York State agencies including, but not limited to:

- Office of Administrative and Information Technology Services (ITS) Unit
- Division of Tax Appeals
- Division of Human Rights
- Office of Commission Operations & Municipal Assistance
- Office of Human Resources & Administrative Planning
- Office of Staffing Services/Career Mobility
- Division of Veterans' Affairs
- Public Employment Relations Board (PERB)
- Office of The Inspector General
- Unified Court System Office of Court Administration
- NYS Office of the Attorney General
- Governor's Office of Employee Relations
- Office of the Aging

Number of Occupants

The approximate number of building occupants during the audit was around 360 people which is well below maximum occupancy mostly due to the COVID-19 pandemic with people working from home. A 30% increase in occupants is anticipated towards the end of 2022.

Occupancy Patterns

The offices are typically occupied from 8:00 a.m. to 5:00 p.m. on weekdays and largely unoccupied on weekends.

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Space Function Summary

Table 1. Space Function Summary (Estimated)

	Office
Original Intended Use	Office
Gross Floor Area (GSF)	198,196
% of Total GSF	100%
% Heated	100%
% Cooled	100%
Number of Occupants	360
Typical Occupancy Pattern	M-F 8 a.m. – 5 p.m.
Principal HVAC Type	AHUs serving core spaces & as primary air to perimeter induction units
Principal Lighting Type	Fluorescent T8

Building Envelope

Roof

- Roof is a typical flat roof with white membrane waterproofing and stormwater management throughout. No roof deficiencies were observed. There was no roof ponding. The roof was recently replaced around 2016 with unknown insulation type or amount.

Exterior Walls

- Exterior walls are original to the building and marble-faced. The building is steel-framed with unknown insulation.

Windows

- Double-glazed floor-to-ceiling fixed, non-operable windows with aluminum frames are typical of all perimeter spaces. Window-to-wall ratio is estimated to be 80%. Windows have been gradually replaced on an individual basis as they fail and are otherwise original to the building.

Exterior Doors

- Four (4) glass doors at the main ground-level entry vestibule are single-glazed, aluminum framed. Significant air gaps were observed (worn weatherstripping).
- There is also one (1) revolving door in the entry vestibule, also all glass and single glazed.

Air Infiltration/Leakage

- No large concerns

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- Some worn weatherstripping near main entryway doors

Utilities

Electricity

- Electricity is supplied to the plaza through [redacted] separate [redacted] feeders from National Grid
- [redacted] high voltage primary distribution transformers step down the voltage [redacted] and distribution switchgear supplies power to substations throughout the plaza
- Various electrical rooms house the building's main switchgear [redacted] and various disconnect switches
- Various transformers convert to distribution voltages (480V, 120V)

Natural Gas

- The building does not have a natural gas service

District Steam

- The building is supplied by high pressure steam (HPS) from the Sheridan Avenue Steam Plant (SASP) at around 150 psig. There are various pressure reducing stations that convert to medium pressure steam (MPS) ~ 60 psig and low pressure steam (LPS) ~10 psig.
- MPS and LPS are used to generate heating hot water (HHW) for induction units and VAV reheat boxes. LPS is generally used for domestic hot water (DHW) production.

District Chilled Water

- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations

Metering

Utility Feeds and Meters

- The Plaza has one main National Grid utility account meter under SC-3A Transmission and Delivery Service tariff

Submeters

- Agency Building 2 has numerous submeters that are aggregated to provide the total building electric consumption
- Chilled water blending stations are submetered to continuously monitor thermal energy. The Main Platform contains multiple blending stations that provide chilled water to equipment in various mechanical/electrical rooms (MER).
- Steam flow is submetered to continuously monitor thermal energy. HPS is metered just prior to the pressure reducing stations.
- All electric and thermal submeter data is automatically collected by OGS' Web Enabled Advanced Metering (WEAM) system

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Lighting

Interior Fixture Types

- Linear T8 fluorescent fixtures are most prevalent
- An LED conversion project is in progress, but no interior LED fixtures were observed during the visit

Interior Lighting Controls

- Some occupancy sensors were observed in mechanical spaces
- Interior lighting is generally manually switched ON/OFF with minimal controls

Exterior Lighting

- LED lighting fixtures observed on the roof (level 21) and on the ground for façade uplighting
- Exterior lighting is scheduled through building automation system, and typically operate from 4:15 p.m. to 11:30 a.m. every day

HVAC

Central Heating System

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- HPS is supplied to the building around 150 psig. There are various pressure reducing stations that convert to MPS ~ 60 psig and LPS ~10 psig. LPS is used to generate heating hot water (HHW) and domestic hot water (DHW) through shell and tube heat exchangers.
  - One (1) shell and tube heat exchanger (HX-15-1) generates HHW using LPS for induction units and air handling unit preheat and reheat heating coils
  - Condensate from the heat exchangers and piping is collected in condensate receivers located in the MERs and pumped back to the SASP
  - Condensate pumps have VFDs
- Two (2) 10 hp, 300 GPM pumps (P-15-3 & P-15-4) supply HHW to air handling unit (AHU) coils for the second floor spaces and above. Mechanical room unit heaters also run off of this HHW system.
  - These pumps are *not* driven by VFDs
  - Only one pump operates at any time, with the other on standby
- Two (2) 40 hp, 800 GPM pumps (P-15-1 & P-15-2) supply HHW or CHW (2-pipe configuration) to the perimeter induction units
  - These pumps are controlled by VFDs in response to differential pressure across the loop
  - Only one pump operates at any time, with the other on standby
- HHW supply temperature is reset based on outdoor air temperature and varies by loop. HHW supply temperature at colder outdoor air temperatures, generally, ranges from 160°F to 190°F.

Central Cooling System

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations
- Two (2) 15 hp, 425 GPM pumps (P-3B-1 & P-3B-2) supply CHW to the building's AHU cooling coils.
  - Both pumps are controlled by VFDs in response to differential pressure across the loop.

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  - Only one pump operates at any time, with the other on standby
- CHWP1-22B and CHWP1-22A (HP unknown) are on VFDs and supply CHW for units located in MER-15, 4-2, 4-3, and 4-4
  CHWP1-26B and CHWP1-26A (20HP each) are on VFDs and supply CHW for units located in MER-1 and 4-5

Air Handling Units

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- The building is conditioned with [redacted] variable air volume reheat (VAVRH) systems designated typically by the following:
  [redacted]
  - The AHUs supply heating, cooling, and ventilation air to each floor. Distribution for core spaces is through drop ceilings with linear slot diffusers.
  - Each air handler has preheat and cooling coils at a minimum. Each unit originally included a steam humidifier section but these are no longer in use and are largely abandoned in place. AHUs serving core zones have reheat coils. AHUs serving perimeter spaces have zone-level heating and cooling at the induction units. Conditioned air is supplied to some areas with duct-mounted hot water reheat coils that are controlled to maintain zone temperatures at setpoint.
  - The supply air fan motors range from 5hp to 50hp, but most are typically 50hp. Return air fan motors average around 10hp. These motors are typically NEMA premium and appear to have been replaced within the last ~10 years. Exhaust fans are described below.
  - Most supply and return fan motors have VFDs to vary airflow
    - Supply fan VFD speed is reset based on outdoor air temperature, as shown in the schedule below. The return fan tracks the supply fan VFD speed.

OA Temperature (°F)	Fan Speed (%)	OA Temperature (°F)	Fan Speed (%)
90 to 95	100	35 to 40	60
85 to 90	100	30 to 35	70
80 to 85	95	25 to 30	70
75 to 80	90	20 to 25	70
70 to 75	80	15 to 20	80
65 to 70	80	10 to 15	80
60 to 65	70	5 to 10	80
55 to 60	60	0 to 5	80
50 to 55	60	-5 to 0	80

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OA Temperature (°F)	Fan Speed (%)
45 to 50	60
40 to 45	60

OA Temperature (°F)	Fan Speed (%)
-10 to -5	80

Exhaust Systems

- All exhaust systems and components date to the original construction and are generally past the end of their useful life
- This building has [redacted] exhaust systems that remove air from the building
  - Fans range from 3/4hp to 10hp and typically average 5hp. They are mostly NEMA Premium motors
  - None of these motors are on VFDs
  - No energy recovery was observed

Zone Heating/Cooling

- Common ductwork serving core zones contain duct-mounted reheat coils, 1 per floor
- Induction Units along perimeter of every floor utilize a two-pipe loop for either cooling or heating
  - There is one induction unit per window, per floor. Primary air is provided by AHUs
  - The changeover temperature between heating and cooling mode is set at 60F

HVAC Controls

Building Automation System

- Honeywell Enterprise Building Integrator (EBI) building automation system (BAS) is used for monitoring, direct digital control (DDC), and energy management of HVAC systems
- All valves, dampers, and other control devices have pneumatic actuators with electric to pneumatic transducers that convert the BAS control signal to a proportional pneumatic pressure

Operating Schedules

- HVAC systems typically run in occupied mode [redacted] on weekdays and are typically scheduled OFF on weekends with a temperature minimum of 55F. Heating equipment cycles ON in OFF mode if space temperatures fall below 55F
- Exhaust systems follow a similar schedule

Energy Saving Control Strategies

- Building HVAC equipment is generally scheduled to run during occupied hours and only cycles during unoccupied hours if space temperatures falls below 55F
- Each AHU is controlled by some combination of the following:
  - The supply air temperature (SAT) is reset based on OAT
  - The supply and return fan speeds are controlled based on OAT. Fan speed is 60% between 35F and 60F OAT, ramping up to 100% at 85F and above, and ramping up to 80% at 20F and below.
- Hot water temperature reset schedule ranging from 125F @45F OAT and above to 180F @15F OAT and below, ramped linearly in between

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- Air-side economizer mode is activated when outdoor air conditions are ideal for cooling operation, but many of the dampers are not functional

Domestic/Service Water Heating

Domestic Water Heaters
- A semi-instantaneous domestic hot water system uses LPS to generate hot water

DHW Load
- The DHW load comes from bathroom hand sinks and janitor closets

Piping and Ductwork

Piping Systems/Insulation
- Various steam, CHW, and HW pipes were uninsulated or missing large amounts of insulation
- Many issues appear to have been identified and have tags indicating that repairs are scheduled and/or in progress
- Several piping system leaks (including steam leaks) were observed but were generally tagged for future repair

Air Distribution Systems/Insulation
- Ductwork insulation is generally in good shape or tagged where deficient

Equipment Insulation
- Heat exchangers were mostly insulated when necessary. Most deficiencies were tagged.

Piping and Ductwork Leaks
- Few, if any, leaks were identified in piping and ductwork during the building walk-through

Miscellaneous Loads and Specialty Systems

Plug Loads

- The building has typical office plug loads such as computers, monitors, laptops, printers, small kitchen appliances in break rooms, and task lighting
- IT Server racks are the only other significant plug load, but most were single or double racks at most. No data centers were found in any of the buildings.
- Air compressors for pneumatic controls were observed in some mechanical rooms, but are no longer in operation

Renewable Energy Systems

- None observed

Mission Critical Systems

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- Camera security systems
- Emergency power is supplied by emergency generators at the SASP

Water Systems

- No major water using systems related to Hudson River and municipal sources of water are used in building HVAC processes

Initial Hazardous Materials Assessment

- Asbestos is present in structural fire proofing above ceiling tiles and on the concrete floors. Both areas have been marked with stickers indicating the hazard.

Potential Energy Efficiency Measures (EEMs)

- Consolidate office spaces between Corning Tower and the four Agency buildings so that more unoccupied floors and AHUs can be operated in unoccupied mode
- Replace all major AHUs, corresponding ductwork, and terminal reheat coils
  - Multizone AHUs should consider the following features:
    - Multizone variable air volume (VAV) systems with VAV terminal boxes and hot water reheat coils
    - Supply fan motors controlled by VFDs to maintain duct static pressure setpoint
    - Duct static pressure reset controls
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
  - Single zone AHUs should consider the following features:
    - Temperature based control of supply fan VFD speed. The supply fan speed and discharge temperature would be controlled to satisfy the space temperature setpoint.
    - Demand controlled ventilation on units with high ventilation loads
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
- Consider alternative HVAC systems for deep energy retrofits, such as
  - Dedicated outdoor air systems (DOAS) with energy recovery and DCV
  - Active chilled beams
  - Water-source heat pumps in lieu of induction units
- Install occupancy-based controls on tenant HVAC systems to allow for automatic setback of space temperature setpoints in unoccupied zones during normal occupied mode periods. This measure would also provide occupied mode setpoints during unoccupied mode periods when the zone is occupied (*e.g.*, during nighttime housekeeping).
- Implement differential pressure reset on variable speed pumping systems
- BAS Optimization—survey existing BAS to identify opportunities for improved operations and energy savings (e.g., sequence of operation changes, operating schedules, setpoints, reset schedules)

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EMPIRE STATE PLAZA | AGENCY BUILDING 3 BUILDING ASSESSMENT

Building Description

Building Name:	Agency Building 3
Year Constructed:	1974
No. of Floors:	20 + basement and concourse level
Est. GSF:	198,196

Major Renovations

- Roof Replacement (2016)

Functional Description

Agency Building 3 is one of four identical government office buildings (numbered 1 through 4) that primarily house offices for the NYS Department of Public Service.

Number of Occupants

The approximate number of building occupants during the audit was around 360 people which is well below maximum occupancy mostly due to the COVID-19 pandemic with people working from home. Agency building 3 is expecting about a 30% increase in occupants towards the end of 2022.

Occupancy Patterns

The offices are typically occupied from 8:00 a.m. to 5:00 p.m. on weekdays and largely unoccupied on weekends.

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Space Function Summary

Table 1. Space Function Summary (Estimated)

	Office
Original Intended Use	Office
Gross Floor Area (GSF)	198,196
% of Total GSF	100%
% Heated	100%
% Cooled	100%
Number of Occupants	360
Typical Occupancy Pattern	M-F 8 a.m. – 5 p.m.
Principal HVAC Type	AHUs serving core spaces & as primary air to perimeter induction units
Principal Lighting Type	Fluorescent T8

Building Envelope

Roof

- Roof is a typical flat roof with white membrane waterproofing and stormwater management throughout. No roof deficiencies were observed. There was no roof ponding. The roof was recently replaced around 2016 with unknown insulation type and amount.

Exterior Walls

- Exterior walls are original to the building and marble-faced. The building is steel-framed with unknown insulation type or amount.

Windows

- Double-glazed floor-to-ceiling fixed, non-operable windows with aluminum frames are typical of all perimeter spaces. Window-to-wall ratio is estimated to be 80%. Windows have been gradually replaced on an individual basis as they fail and are otherwise original to the building.

Exterior Doors

- Four (4) glass doors at the main ground-level entry vestibule are single-glazed, aluminum framed. Significant air gaps were observed (worn weatherstripping).
- There is also one (1) revolving door in the entry vestibule, also all glass and single glazed

Air Infiltration/Leakage

- No large concerns

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- Some worn weatherstripping near main entryway doors

Utilities

Electricity

- Electricity is supplied to the plaza through [redacted] separate [redacted] feeders from National Grid
- [redacted] high voltage primary distribution transformers step down the voltage [redacted] and distribution switchgear supplies power to substations throughout the plaza
- Various electrical rooms house the building's main switchgear [redacted] and various disconnect switches
- Various transformers convert to distribution voltages (480V, 120V)

Natural Gas

- The building does not have a natural gas service

District Steam

- The building is supplied by high pressure steam (HPS) from the Sheridan Avenue Steam Plant (SASP) at around 150 psig. There are various pressure reducing stations that convert to medium pressure steam (MPS) ~ 60 psig and low pressure steam (LPS) ~10 psig.
- MPS and LPS are used to generate heating hot water (HHW) for induction units and VAV reheat boxes. LPS is generally used for domestic hot water (DHW) production.

District Chilled Water

- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations

Metering

Utility Feeds and Meters

- The Plaza has one main National Grid utility account meter under SC-3A Transmission and Delivery Service tariff

Submeters

- Agency Building 3 has numerous submeters that are aggregated to provide the total building electric consumption
- Chilled water blending stations are submetered to continuously monitor thermal energy. The Main Platform contains multiple blending stations that provide chilled water to equipment in various mechanical/electrical rooms (MER).
- Steam flow is submetered to continuously monitor thermal energy. HPS is metered just prior to the pressure reducing stations.
- All electric and thermal submeter data is automatically collected by OGS' Web Enabled Advanced Metering (WEAM) system

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Lighting

Interior Fixture Types

- Linear T8 fluorescent fixtures are most prevalent
- An LED conversion project is in progress, but no interior LED fixtures were observed during the visit

Interior Lighting Controls

- Some occupancy sensors were observed in mechanical spaces
- Interior lighting is generally manually switched ON/OFF with minimal controls

Exterior Lighting

- LED lighting fixtures observed on the roof (level 21) and on the ground for façade uplighting
- Exterior lighting is scheduled through building automation system, and typically operate from 4:15 p.m. to 11:30 a.m. every day

HVAC

Central Heating System

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- HPS is supplied to the building around 150 psig. There are various pressure reducing stations that convert to MPS ~ 60 psig and LPS ~10 psig. LPS is used to generate heating hot water (HHW) and domestic hot water (DHW) through shell and tube heat exchangers.
  - One (1) shell and tube heat exchanger (HX-15-1) generates HHW using LPS for induction units and air handling unit preheat and reheat heating coils
  - Condensate from the heat exchangers and piping is collected in condensate receivers located in the MERs and pumped back to the SASP
  - Condensate pumps have VFDs
- Two (2) 10 hp, 300 GPM pumps (P-15-3 & P-15-4) supply HHW to air handling unit (AHU) coils for the second floor spaces and above. Mechanical room unit heaters also run off of this HHW system.
  - These pumps are *not* driven by VFDs
  - Only one pump operates at any time, with the other on standby
- Two (2) 40 hp, 800 GPM pumps (P-15-1 & P-15-2) supply HHW or CHW (2-pipe configuration) to the perimeter induction units
  - These pumps are controlled by VFDs in response to differential pressure across the loop
  - Only one pump operates at any time, with the other on standby
- HHW supply temperature is reset based on outdoor air temperature and varies by loop. HHW supply temperature at colder outdoor air temperatures, generally, ranges from 160°F to 190°F.

Central Cooling System

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations
- Two (2) 15 hp, 425 GPM pumps (P-3B-1 & P-3B-2) supply CHW to the building's AHU cooling coils.
  - Both pumps are controlled by VFDs in response to differential pressure across the loop.

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  - Only one pump operates at any time, with the other on standby
- CHWP1-22B and CHWP1-22A (HP unknown) are on VFDs and supply CHW for units located in MER-15, 4-2, 4-3, and 4-4
  CHWP1-26B and CHWP1-26A (20HP each) are on VFDs and supply CHW for units located in MER-1 and 4-5

Air Handling Units

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- The building is conditioned with [redacted] variable air volume reheat (VAVRH) systems designated typically by the following:
  [redacted]
  - The AHUs supply heating, cooling, and ventilation air to each floor. Distribution for core spaces is through drop ceilings with linear slot diffusers.
  - Each air handler has preheat and cooling coils at a minimum. Each unit originally included a steam humidifier section but these are no longer in use and are largely abandoned in place. AHUs serving core zones have reheat coils. AHUs serving perimeter spaces have zone-level heating and cooling at the induction units. Conditioned air is supplied to some areas with duct-mounted hot water reheat coils that are controlled to maintain zone temperatures at setpoint.
  - The supply air fan motors range from 5hp to 50hp, but most are typically 50hp. Return air fan motors average around 10hp. These motors are typically NEMA premium and appear to have been replaced within the last ~10 years. Exhaust fans are described below.
  - Most supply and return fan motors have VFDs to vary airflow
    - Supply fan VFD speed is reset based on outdoor air temperature, as shown in the schedule below. The return fan tracks the supply fan VFD speed.

OA Temperature (°F)	Fan Speed (%)	OA Temperature (°F)	Fan Speed (%)
90 to 95	100	35 to 40	60
85 to 90	100	30 to 35	70
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70 to 75	80	15 to 20	80
65 to 70	80	10 to 15	80
60 to 65	70	5 to 10	80
55 to 60	60	0 to 5	80
50 to 55	60	-5 to 0	80

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OA Temperature (°F)	Fan Speed (%)
45 to 50	60
40 to 45	60

OA Temperature (°F)	Fan Speed (%)
-10 to -5	80

Exhaust Systems

- All exhaust systems and components date to the original construction and are generally past the end of their useful life
- This building has [redacted] exhaust systems that remove air from the building
  - Fans range from 3/4hp to 10hp and typically average 5hp. They are mostly NEMA Premium motors
  - None of these motors are on VFDs
  - No energy recovery was observed

Zone Heating/Cooling

- Common ductwork serving core zones contain duct-mounted reheat coils, 1 per floor
- Induction Units along perimeter of every floor utilize a two-pipe loop for either cooling or heating
  - There is one induction unit per window, per floor. Primary air is provided by AHUs
  - The changeover temperature between heating and cooling mode is set at 60F

HVAC Controls

Building Automation System

- Honeywell Enterprise Building Integrator (EBI) building automation system (BAS) is used for monitoring, direct digital control (DDC), and energy management of HVAC systems
- All valves, dampers, and other control devices have pneumatic actuators with electric to pneumatic transducers that convert the BAS control signal to a proportional pneumatic pressure

Operating Schedules

- HVAC systems typically run in occupied mode [redacted] on weekdays and are typically scheduled OFF on weekends with a temperature minimum of 55F. Heating equipment cycles ON in OFF mode if space temperatures fall below 55F
- Exhaust systems follow a similar schedule

Energy Saving Control Strategies

- Building HVAC equipment is generally scheduled to run during occupied hours and only cycles during unoccupied hours if space temperatures falls below 55F
- Each AHU is controlled by some combination of the following:
  - The supply air temperature (SAT) is reset based on OAT
  - The supply and return fan speeds are controlled based on OAT. Fan speed is 60% between 35F and 60F OAT, ramping up to 100% at 85F and above, and ramping up to 80% at 20F and below.
- Hot water temperature reset schedule ranging from 125F @45F OAT and above to 180F @15F OAT and below, ramped linearly in between
- Air-side economizer mode is activated when outdoor air conditions are ideal for cooling operation, but many of the dampers are not functional

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Domestic/Service Water Heating

Domestic Water Heaters
- A semi-instantaneous domestic hot water system uses LPS to generate hot water

DHW Load
- The DHW load comes from bathroom hand sinks and janitor closets

Piping and Ductwork

Piping Systems/Insulation
- Various steam, CHW, and HW pipes were uninsulated or missing large amounts of insulation
- Many issues appear to have been identified and have tags indicating that repairs are scheduled/in progress
- Several piping system leaks (including steam leaks) were observed but were generally tagged for future repair

Air Distribution Systems/Insulation
- Ductwork insulation is generally in good shape or tagged where deficient

Equipment Insulation
- Heat exchangers were mostly insulated when necessary. Most deficiencies were tagged.

Piping and Ductwork Leaks
- Few, if any leaks were identified in piping and ductwork during the building walk-through

Miscellaneous Loads and Specialty Systems

Plug Loads

- The building has typical office plug loads such as computers, monitors, laptops, printers, small kitchen appliances in break rooms, and task lighting
- IT Server racks are the only other significant plug load, but most were single or double racks at most. No data centers were found in any of the buildings.
- Air compressors for pneumatic controls were observed in some mechanical rooms, but are no longer in operation

Renewable Energy Systems

- None observed

Mission Critical Systems

- Camera security systems
- Emergency power is supplied by emergency generators at the SASP

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Water Systems

- No major water using systems related to Hudson River and municipal sources of water are used in building HVAC processes

Initial Hazardous Materials Assessment

- Asbestos is present in structural fire proofing above ceiling tiles and on the concrete floors. Both areas have been marked with stickers indicating the hazard.

Potential Energy Efficiency Measures (EEMs)

- Consolidate office spaces between Corning Tower and the four Agency buildings so that more unoccupied floors and AHUs can be operated in unoccupied mode
- Replace all major AHUs, corresponding ductwork, and terminal reheat coils
  - Multizone AHUs should consider the following features:
    - Multizone variable air volume (VAV) systems with VAV terminal boxes and hot water reheat coils
    - Supply fan motors controlled by VFDs to maintain duct static pressure setpoint
    - Duct static pressure reset controls
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
  - Single zone AHUs should consider the following features:
    - Temperature based control of supply fan VFD speed. The supply fan speed and discharge temperature would be controlled to satisfy the space temperature setpoint.
    - Demand controlled ventilation on units with high ventilation loads
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
- Consider alternative HVAC systems for deep energy retrofits, such as
  - Dedicated outdoor air systems (DOAS) with energy recovery and DCV
  - Active chilled beams
  - Water-source heat pumps in lieu of induction units
- Install occupancy-based controls on tenant HVAC systems to allow for automatic setback of space temperature setpoints in unoccupied zones during normal occupied mode periods. This measure would also provide occupied mode setpoints during unoccupied mode periods when the zone is occupied (*e.g.*, during nighttime housekeeping).
- Implement differential pressure reset on variable speed pumping systems
- BAS Optimization—survey existing BAS to identify opportunities for improved operations and energy savings (e.g., sequence of operation changes, operating schedules, setpoints, reset schedules)

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EMPIRE STATE PLAZA | AGENCY BUILDING 4 BUILDING ASSESSMENT

Building Description

Building Name:	Agency Building 4
Year Constructed:	1974
No. of Floors:	20 + basement and concourse level
Est. GSF:	198,196

Major Renovations

- Roof Replacement (2016)

Functional Description

Agency Building 4 is one of four identical government office buildings (numbered 1 through 4) that primarily house offices for numerous New York State agencies including, but not limited to:

- Division of Veterans' Affairs
- Public Employment Relations Board
- Office of The Inspector General
- Unified Court System Office of Court Administration
- Majority Conference Services (State Senate)
- Senate Finance Committee
- Executive Chamber
- Department of Labor

Number of Occupants

The approximate number of building occupants during the audit was around 360 people which is well below maximum occupancy mostly due to the COVID-19 pandemic with people working from home. A 30% increase in occupants is anticipated towards the end of 2022.

Occupancy Patterns

The offices are typically occupied from 8:00 a.m. to 5:00 p.m. on weekdays and largely unoccupied on weekends. There are some weekend hours for the State Senate, primarily when it is in-session.

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Space Function Summary

Table 1. Space Function Summary (Estimated)

	Office
Original Intended Use	Office
Gross Floor Area (GSF)	198,196
% of Total GSF	100%
% Heated	100%
% Cooled	100%
Number of Occupants	360
Typical Occupancy Pattern	M-F 8 a.m. – 5 p.m.
Principal HVAC Type	AHUs serving core spaces & as primary air to perimeter induction units
Principal Lighting Type	Fluorescent T8

Building Envelope

Roof

- Roof is a typical flat roof with white membrane waterproofing and stormwater management throughout. No roof deficiencies were observed. There was no roof ponding. The roof was recently replaced around 2016 and insulation type and amount is unknown.

Exterior Walls

- Exterior walls are original to the building and marble-faced. The building is steel-framed with unknown insulation type or amount.

Windows

- Double-glazed floor-to-ceiling fixed, non-operable windows with aluminum frames are typical of all perimeter spaces. Window-to-wall ratio is estimated to be 80%. Windows have been gradually replaced on an individual basis as they fail and are otherwise original to the building.

Exterior Doors

- Four (4) glass doors at the main ground-level entry vestibule are single-glazed, aluminum framed. Significant air gaps were observed (worn weatherstripping).
- There is also one (1) revolving door in the entry vestibule, also all glass and single glazed

Air Infiltration/Leakage

- No large concerns
- Some worn weatherstripping near main entryway doors

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Utilities

Electricity

- Electricity is supplied to the plaza through [redacted] separate [redacted] feeders from National Grid
- Four high voltage primary distribution transformers step down the voltage [redacted] and distribution switchgear supplies power to substations throughout the plaza
- Various electrical rooms house the building's main switchgear [redacted] and various disconnect switches
- Various transformers convert to distribution voltages (480V, 120V)

Natural Gas

- The building does not have a natural gas service

District Steam

- The building is supplied by high pressure steam (HPS) from the Sheridan Avenue Steam Plant (SASP) at around 150 psig. There are various pressure reducing stations that convert to medium pressure steam (MPS) ~ 60 psig and low pressure steam (LPS) ~10 psig.
- MPS and LPS are used to generate heating hot water (HHW) for induction units and VAV reheat boxes. LPS is generally used for domestic hot water (DHW) production.

District Chilled Water

- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations

Metering

Utility Feeds and Meters

- The Plaza has one main National Grid utility account meter under SC-3A Transmission and Delivery Service tariff

Submeters

- Agency Building 3 has numerous submeters that are aggregated to provide the total building electric consumption
- Chilled water blending stations are submetered to continuously monitor thermal energy. The Main Platform contains multiple blending stations that provide chilled water to equipment in various mechanical/electrical rooms (MER).
- Steam flow is submetered to continuously monitor thermal energy. HPS is metered just prior to the pressure reducing stations.
- All electric and thermal submeter data is automatically collected by OGS' Web Enabled Advanced Metering (WEAM) system

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Lighting

Interior Fixture Types

- Linear T8 fluorescent fixtures are most prevalent
- An LED conversion project is in progress, but no interior LED fixtures were observed during the visit

Interior Lighting Controls

- Some occupancy sensors were observed in mechanical spaces
- Interior lighting is generally manually switched ON/OFF with minimal controls

Exterior Lighting

- LED lighting fixtures observed on the roof (level 21) and on the ground for façade uplighting
- Exterior lighting is scheduled through building automation system, and typically operate from 4:15 p.m. to 11:30 a.m. every day

HVAC

Central Heating System

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- HPS is supplied to the building around 150 psig. There are various pressure reducing stations that convert to MPS ~ 60 psig and LPS ~10 psig. LPS is used to generate heating hot water (HHW) and domestic hot water (DHW) through shell and tube heat exchangers.
  - One (1) shell and tube heat exchanger (HX-15-1) generates HHW using LPS for induction units and air handling unit preheat and reheat heating coils
  - Condensate from the heat exchangers and piping is collected in condensate receivers located in the MERs and pumped back to the SASP
  - Condensate pumps have VFDs
- Two (2) 10 hp, 300 GPM pumps (P-15-3 & P-15-4) supply HHW to air handling unit (AHU) coils for the second floor spaces and above. Mechanical room unit heaters also run off of this HHW system.
  - These pumps are *not* driven by VFDs
  - Only one pump operates at any time, with the other on standby
- Two (2) 40 hp, 800 GPM pumps (P-15-1 & P-15-2) supply HHW or CHW (2-pipe configuration) to the perimeter induction units
  - These pumps are controlled by VFDs in response to differential pressure across the loop
  - Only one pump operates at any time, with the other on standby
- HHW supply temperature is reset based on outdoor air temperature and varies by loop. HHW supply temperature at colder outdoor air temperatures, generally, ranges from 160°F to 190°F.

Central Cooling System

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations
- Two (2) 15 hp, 425 GPM pumps (P-3B-1 & P-3B-2) supply CHW to the building's AHU cooling coils.
  - Both pumps are controlled by VFDs in response to differential pressure across the loop.

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  - Only one pump operates at any time, with the other on standby
- CHWP1-22B and CHWP1-22A (HP unknown) are on VFDs and supply CHW for units located in MER-15, 4-2, 4-3, and 4-4
  CHWP1-26B and CHWP1-26A (20HP each) are on VFDs and supply CHW for units located in MER-1 and 4-5

Air Handling Units

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- The building is conditioned with [redacted] variable air volume reheat (VAVRH) systems designated typically by the following:
  [redacted]
  - The AHUs supply heating, cooling, and ventilation air to each floor. Distribution for core spaces is through drop ceilings with linear slot diffusers.
  - Each air handler has preheat and cooling coils at a minimum. Each unit originally included a steam humidifier section but these are no longer in use and are largely abandoned in place. AHUs serving core zones have reheat coils. AHUs serving perimeter spaces have zone-level heating and cooling at the induction units. Conditioned air is supplied to some areas with duct-mounted hot water reheat coils that are controlled to maintain zone temperatures at setpoint.
  - The supply air fan motors range from 5hp to 50hp, but most are typically 50hp. Return air fan motors average around 10hp. These motors are typically NEMA premium and appear to have been replaced within the last ~10 years. Exhaust fans are described below.
  - Most supply and return fan motors have VFDs to vary airflow
    - Supply fan VFD speed is reset based on outdoor air temperature, as shown in the schedule below. The return fan tracks the supply fan VFD speed.

OA Temperature (°F)	Fan Speed (%)	OA Temperature (°F)	Fan Speed (%)
90 to 95	100	35 to 40	60
85 to 90	100	30 to 35	70
80 to 85	95	25 to 30	70
75 to 80	90	20 to 25	70
70 to 75	80	15 to 20	80
65 to 70	80	10 to 15	80
60 to 65	70	5 to 10	80
55 to 60	60	0 to 5	80
50 to 55	60	-5 to 0	80

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OA Temperature (°F)	Fan Speed (%)
45 to 50	60
40 to 45	60

OA Temperature (°F)	Fan Speed (%)
-10 to -5	80

Exhaust Systems

- All exhaust systems and components date to the original construction and are generally past the end of their useful life
- This building has [redacted] exhaust systems that remove air from the building
  - Fans range from 3/4hp to 10hp and typically average 5hp. They are mostly NEMA Premium motors
  - None of these motors are on VFDs
  - No energy recovery was observed

Zone Heating/Cooling

- Common ductwork serving core zones contain duct-mounted reheat coils, 1 per floor
- Induction Units along perimeter of every floor utilize a two-pipe loop for either cooling or heating
  - There is one induction unit per window, per floor. Primary air is provided by AHUs
  - The changeover temperature between heating and cooling mode is set at 60F

HVAC Controls

Building Automation System

- Honeywell Enterprise Building Integrator (EBI) building automation system (BAS) is used for monitoring, direct digital control (DDC), and energy management of HVAC systems
- All valves, dampers, and other control devices have pneumatic actuators with electric to pneumatic transducers that convert the BAS control signal to a proportional pneumatic pressure

Operating Schedules

- HVAC systems typically run in occupied mode [redacted] on weekdays and are typically scheduled OFF on weekends with a temperature minimum of 55F. Heating equipment cycles ON in OFF mode if space temperatures fall below 55F
- Exhaust systems follow a similar schedule

Energy Saving Control Strategies

- Building HVAC equipment is generally scheduled to run during occupied hours and only cycles during unoccupied hours if space temperatures falls below 55F
- Each AHU is controlled by some combination of the following:
  - The supply air temperature (SAT) is reset based on OAT
  - The supply and return fan speeds are controlled based on OAT. Fan speed is 60% between 35F and 60F OAT, ramping up to 100% at 85F and above, and ramping up to 80% at 20F and below.
- Hot water temperature reset schedule ranging from 125F @45F OAT and above to 180F @15F OAT and below, ramped linearly in between
- Air-side economizer mode is activated when outdoor air conditions are ideal for cooling operation, but many of the dampers are not functional

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Domestic/Service Water Heating

Domestic Water Heaters
- A semi-instantaneous domestic hot water system uses LPS to generate hot water

DHW Load
- The DHW load comes from bathroom hand sinks and janitor closets

Piping and Ductwork

Piping Systems/Insulation
- Various steam, CHW, and HW pipes were uninsulated or missing large amounts of insulation
- Many issues appear to have been identified and have tags indicating that repairs are scheduled/in progress
- Several piping system leaks (including steam leaks) were observed but were generally tagged for future repair

Air Distribution Systems/Insulation
- Ductwork insulation is generally in good shape or tagged where deficient

Equipment Insulation
- Heat exchangers were mostly insulated when necessary. Most deficiencies were tagged.

Piping and Ductwork Leaks
- Few, if any leaks were identified in piping and ductwork during the building walk-through

Miscellaneous Loads and Specialty Systems

Plug Loads

- The building has typical office plug loads such as computers, monitors, laptops, printers, small kitchen appliances in break rooms, and task lighting
- IT Server racks are the only other significant plug load, but most were single or double racks at most. No data centers were found in any of the buildings.
- Air compressors for pneumatic controls were observed in some mechanical rooms, but are no longer in operation

Renewable Energy Systems

- None observed

Mission Critical Systems

- Camera security systems
- Emergency power is supplied by emergency generators at the SASP

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Water Systems

- No major water using systems related to Hudson River and municipal sources of water are used in building HVAC processes

Initial Hazardous Materials Assessment

- Asbestos is present in structural fire proofing above ceiling tiles and on the concrete floors. Both areas have been marked with stickers indicating the hazard.

Potential Energy Efficiency Measures (EEMs)

- Consolidate office spaces between Corning Tower and the four Agency buildings so that more unoccupied floors and AHUs can be operated in unoccupied mode
- Replace all major AHUs, corresponding ductwork, and terminal reheat coils
  - Multizone AHUs should consider the following features:
    - Multizone variable air volume (VAV) systems with VAV terminal boxes and hot water reheat coils
    - Supply fan motors controlled by VFDs to maintain duct static pressure setpoint
    - Duct static pressure reset controls
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
  - Single zone AHUs should consider the following features:
    - Temperature based control of supply fan VFD speed. The supply fan speed and discharge temperature would be controlled to satisfy the space temperature setpoint.
    - Demand controlled ventilation on units with high ventilation loads
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
- Consider alternative HVAC systems for deep energy retrofits, such as
  - Dedicated outdoor air systems (DOAS) with energy recovery and DCV
  - Active chilled beams
  - Water-source heat pumps in lieu of induction units
- Install occupancy-based controls on tenant HVAC systems to allow for automatic setback of space temperature setpoints in unoccupied zones during normal occupied mode periods. This measure would also provide occupied mode setpoints during unoccupied mode periods when the zone is occupied (*e.g.*, during nighttime housekeeping).
- Implement differential pressure reset on variable speed pumping systems
- BAS Optimization—survey existing BAS to identify opportunities for improved operations and energy savings (e.g., sequence of operation changes, operating schedules, setpoints, reset schedules)

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EMPIRE STATE PLAZA | CORNING TOWER BUILDING ASSESSMENT

Building Description

Building Name: Corning Tower

Year Constructed: 1974

No. of Floors: 44

Est. GSF: 927,423

Major Renovations

- Roof Replacement (2021)

Functional Description

The Erastus Corning Tower, also known as the Mayor Erastus Corning 2nd Tower or simply the Corning Tower, is a state office building for the NYS Office of General Services and NYS Department of Health at Empire State Plaza. It is the tallest skyscraper in the state of NY outside of New York City.

Number of Occupants

The approximate number of building occupants during the audit was around 1,600 people which is a reduced occupancy due to COVID-19 with people working from home. Full, normal occupancy is closer to 2,700 people.

Occupancy Patterns

The offices are typically occupied from 7:00 a.m. to 6:00 p.m. on weekdays and largely unoccupied on weekends. Some employees prefer to come in closer to 6:30 am and others prefer to leave later in the day around 6:30pm, but general office hours are 8:00 a.m. to 5:00 p.m. weekdays only. Cleaning staff typically works until 10:30pm.

Space Function Summary

Table 1. Space Function Summary (Estimated)

	Office	Cafe
Original Intended Use	Office	Cafeteria
Gross Floor Area (GSF)	915,423	~12,000
% of Total GSF	98.7%	1.3%
% Heated	100%	100%
% Cooled	100%	100%

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	Office	Cafe
Number of Occupants	1,585/2,655	15/45
Typical Occupancy Pattern	M-F 7 a.m. – 6 p.m.	M-F 7 a.m. – 3 p.m.
Principal HVAC Type	AHUs serving core spaces & as primary air to perimeter induction units	AHUs serving core spaces & as primary air to perimeter induction units
Principal Lighting Type	Fluorescent T8	Fluorescent T8

Building Envelope

Roof

- Typical flat roof with white waterproof membrane and stormwater management throughout. No roof deficiencies were observed. There was no roof ponding. The roof was recently replaced in 2021 but insulation type and levels are unknown.

Exterior Walls

- Exterior walls are original to the building and marble faced. The building is steel-framed but insulation type and levels are unknown.

Windows

- Double-glazed floor-to-ceiling fixed, non-operable windows with aluminum frames are typical of all perimeter spaces. Window-to-wall ratio is estimated to be 0.90.

Exterior Doors

- Exterior doors are glass, single-glazed, aluminum framed

Air Infiltration/Leakage

- No large concerns identified during time of walkthrough

Utilities

Electricity

- Electricity is supplied to the plaza through [redacted] separate [redacted] feeders from National Grid
- [redacted] high voltage primary distribution transformers step down the voltage [redacted] and distribution switchgear supplies power to substations throughout the plaza
- Various electrical rooms house the building's main switchgear [redacted] and various disconnect switches
- Various transformers convert to distribution voltages (480V, 120V)

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Natural Gas
- The building does not have a natural gas service

District Steam
- The building is supplied by high pressure steam (HPS) from the Sheridan Avenue Steam Plant (SASP) at around 150 psig. There are various pressure reducing stations that convert to medium pressure steam (MPS) ~ 60 psig and low pressure steam (LPS) ~10 psig.
- MPS and LPS is used to generate heating hot water (HHW) for induction units, AHU preheat and reheat coils and zonal reheat boxes. LPS is generally used for domestic hot water (DHW) production.

District Chilled Water
- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations

Metering

Utility Feeds and Meters
- The Plaza has one main National Grid utility account meter under SC-3A Transmission and Delivery Service tariff

Submeters
- Numerous submeters are aggregated to provide the total building electric consumption
- Chilled water blending stations are submetered to continuously monitor thermal energy. The Main Platform contains multiple blending stations that provide chilled water to equipment in various mechanical/electrical rooms (MER).
- Steam flow is submetered to continuously monitor thermal energy. HPS is metered just prior to the pressure reducing stations.
- All electric and thermal submeter data is automatically collected by OGS' Web Enabled Advanced Metering (WEAM) system

Lighting

Interior Fixture Types
- Linear T8 fluorescent fixtures are most prevalent
- An LED conversion project is in progress, but no interior LED fixtures were observed during the visit

Interior Lighting Controls
- Some occupancy sensors were observed in mechanical spaces
- Interior lighting is generally manually switched ON/OFF with minimal controls

Exterior Lighting
- LED lighting fixtures observed on the roof (level 21) and on the ground for façade uplighting
- Exterior lighting is scheduled through building automation system, and typically operate from 4:15 p.m. to 11:30 a.m. every day

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HVAC

Central Heating System

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- HPS is supplied to the building around 150 psig. There are various pressure reducing stations that convert to MPS ~ 60 psig and LPS ~10 psig. LPS is used to generate heating hot water (HHW) and domestic hot water (DHW) through shell and tube heat exchangers.
  - Seven (7) shell and tube heat exchangers (HX-1 through HX-7) generate HHW via steam for induction units and air handling unit preheat and reheat heating coils.
  - Condensate from the heat exchangers and piping is collected in condensate receivers located in the MERs and pumped back to the SASP
- Eight (8) 7.5 hp pumps supply HHW for AHU preheat and reheat coils, and unit heaters. Pumps generally serve the floors above them.
  - P-B-5 & P-B-6 (SB) are 230 GPM each and located on the B-level
  - P-15-5 & P-15-6 (SB) are 250 GPM each and located on the 15th floor mechanical room
  - P-30-3 & P-30-4 (SB) are 250 GPM each and located on the 30th floor mechanical room
  - P-43-1 & P-43-2 (SB) are 300 GPM each and located on the 43rd floor mechanical room
  - These pumps are *not* driven by VFDs
  - Only one pump operates at any time, with the other on standby (SB)
- Six (6) pumps supply HHW or CHW (2-pipe configuration) to the perimeter induction units in the 15 floors above them
  - P-B-1 & P-B-2 (SB) are 1,250 GPM, 50 HP each and located on the B-level
  - P-15-3 & P-15-4 (SB) are 1,350 GPM, 75 HP each and located on the 15th floor mechanical room
  - P-30-1 & P-30-2 (SB) are 1,060 GPM, 40 HP each and located on the 30th floor mechanical room
  - These pumps are driven by VFDs
  - Only one pump operates at any time, with the other on standby (SB)

Central Cooling System

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- Chilled water is supplied to the building from the central ESP chilled water plant (below Agency 4) without the use of plate and frame heat exchangers, via a "blending station"
- Four (4) chilled water pumps supply CHW to AHU cooling coils
  - P-B-3 & P-B-4 (SB) are 680 GPM, 25 HP each and located on the B-level and serve floors B-15
  - P-15-1 & P-15-2 (SB) are 2,250 GPM, 125 HP each and located on the 15th floor mechanical room and serve floors 16-43
  - Only one pump operates at any time, with the other on standby

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Air Handling Units

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- The building is conditioned with [redacted] AHU systems.
  - [redacted]

Exhaust Systems

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- There are [redacted] exhaust systems that remove air from the building and serve various mechanical, electrical, toilet, or janitor rooms
  - Fans range from 1hp to 10hp and average 3hp. They are mostly NEMA Premium motors.
  - None of these motors are on VFDs
  - No energy recovery was observed

Zone Heating/Cooling

- Duct-mounted reheat hot water coils serve individual building floor interior zones to maintain space temperature at setpoint. It is estimated about 3-4 coils per floor and around 150 total reheat coils in the building
- Induction Units along perimeter of every floor utilize a two-pipe loop for either cooling or heating. There is one induction unit per window, per floor. Primary air is provided by AHUs.

HVAC Controls

Building Automation System

- Honeywell Enterprise Building Integrator (EBI) building automation system (BAS) is used for monitoring, direct digital control (DDC), and energy management of HVAC systems
- All valves, dampers, and other control devices have pneumatic actuators with electric to pneumatic transducers that convert the BAS control signal to a proportional pneumatic pressure

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Operating Schedules

- HVAC systems are typically in occupied mode [redacted] on weekdays and are typically scheduled OFF on weekends with a temperature minimum of 55F. Heating equipment cycles ON in OFF mode if space temperatures fall below 55F
- Exhaust systems follow a similar schedule

Energy Saving Control Strategies

- Building HVAC equipment is generally scheduled to run during occupied hours and only cycles during unoccupied hours if space temperatures fall below 55F
- Each AHU is controlled by some combination of the following:
  - The supply air temperature (SAT) is reset based on OAT
  - The supply and return fan speeds are controlled based on OAT. Fan speed is 60% between 35F and 60F OAT, ramping up to 100% at 85F and above, and ramping up to 80% at 20F and below
- Hot water temperature reset based on OAT
- Air-side economizer mode is activated when outdoor air conditions are ideal for cooling operation

Domestic/Service Water Heating

Domestic Water Heaters

- A semi-instantaneous domestic hot water system uses LPS to generate hot water

DHW Load

- The DHW load comes from bathroom hand sinks and janitor closets

Piping and Ductwork

Piping Systems/Insulation

- Various steam, CHW, and HW pipes were uninsulated or missing large amounts of insulation
- Many issues appear to have been identified and have tags indicating that repairs are scheduled/in progress
- Several piping system leaks (including steam leaks) were observed but were generally tagged for future repair

Air Distribution Systems/Insulation

- Ductwork insulation is generally in good shape or tagged where deficient

Equipment Insulation

- Heat exchangers were mostly insulated where necessary. Most deficiencies were tagged.

Piping and Ductwork Leaks

- Few, if any leaks were identified in piping and ductwork during the building walk-through

Miscellaneous Loads and Specialty Systems

Plug Loads

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- The building has typical office plug loads such as computers, monitors, laptops, printers, small kitchen appliances in break rooms, and task lighting
- IT Server racks were single or double rack configuration
  - No data centers were discovered through the walkthrough
- The café has typical cooking and refrigeration loads.

Renewable Energy Systems

- None observed

Mission Critical Systems

- Camera security systems
- Emergency power is supplied by emergency generators at the SASP

Water Systems

- No major water using systems related to Hudson River and municipal sources of water are used in building HVAC processes

Initial Hazardous Materials Assessment

- Asbestos is present in structural fire proofing above ceiling tiles and on the concrete floors. Both areas have been marked with stickers indicating the hazard.

Potential Energy Efficiency Measures (EEMs)

- Replace all major AHUs, corresponding ductwork, and terminal reheat coils
  - Multizone AHUs should consider the following features:
    - Multizone variable air volume (VAV) systems with VAV terminal boxes and hot water reheat coils
    - Supply fan motors controlled by VFDs to maintain duct static pressure setpoint
    - Duct static pressure reset controls
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
  - Single zone AHUs should consider the following features:
    - Temperature based control of supply fan VFD speed. The supply fan speed and discharge temperature would be controlled to satisfy the space temperature setpoint.
    - Demand controlled ventilation on units with high ventilation loads
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
- Consider alternative HVAC systems for deep energy retrofits, such as
  - Dedicated outdoor air systems (DOAS) with energy recovery and DCV
  - Active chilled beams
  - Water-source heat pumps in lieu of induction units

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- Implement air-side energy recovery, enthalpy wheel type including both latent and sensible recovery
- Consolidate office spaces between Corning Tower and the four Agency buildings so that more unoccupied floors and AHUs can be operated in unoccupied mode.

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EMPIRE STATE PLAZA | HEALTH LABORATORY BUILDING ASSESSMENT

Building Description

Building Name: HEALTH LABORATORY

Year Constructed: 1974

No. of Floors: 5

Est. GSF: 485,210

Major Renovations

- None

Functional Description

The Wadsworth Center Biggs Laboratory (Health Laboratory) is part of a science-based community committed to protecting and improving the health of New Yorkers through laboratory analysis, investigations, research, as well as laboratory certification and educational programs. Biggs Laboratory at Empire State Plaza is one of five (5) labs under the Wadsworth Center umbrella.

Number of Occupants

The approximate number of building occupants is 230 people.

Occupancy Patterns

The offices and laboratories are typically occupied from 8:00 a.m. to 4:00 p.m. on weekdays and largely unoccupied on weekends.

Space Function Summary

Table 1. Space Function Summary (Estimated)

	Office	Laboratory	Library
Original Intended Use	Office	Laboratory	Library
Gross Floor Area (GSF)	121,302	339,647	24,260
% of Total GSF	25%	70%	5%
% Heated	100%	100%	100%
% Cooled	100%	100%	100%
Number of Occupants	50	178	2

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	Office	Laboratory	Library
Typical Occupancy Pattern	M-F 8 a.m. – 4 p.m.	M-F 7 a.m. – 5 p.m.	M-F 8 a.m. – 4 p.m.
Principal HVAC Type	CAV	CAV	CAV
Principal Lighting Type	Fluorescent T8	Fluorescent T8	Fluorescent T8

Building Envelope

Roof

- The observation deck (a walkable area of the plaza) doubles in function as the roof for the health lab building
- The roof of this building is comprised of concrete walkways, grass & soil natural areas, and interior floor for the Corning Tower footprint above
- No improvements since original construction
- Insulation type and levels are unknown
- Some water leakage issues observed

Exterior Walls

- There is not a large amount of exterior wall as building is primarily underground/embedded into a hill
- The Southeast and Southwest exterior wall construction consists of stone veneer and fenestration
- The courtyard is primarily curtainwall
- The Southeast wall is partially underground; only the top two floors are exposed to ambient conditions
- The Southwest wall is partially underground; mainly just the top floor is exposed
- Insulation type and levels are unknown

Windows

- Double-glazed curtainwall in courtyard area; metal-framed fixed windows dating to the original building construction
- Double-glazed aluminum-framed fixed windows in the library

Exterior Doors

- Courtyard glass doors are double-glazed, aluminum-framed. Metal doors for access to the loading dock and parking garages. No other exterior doors are present except from the interior/underground concourse area.
- The building has pressurization issues, with portions of the building excessively positively or negatively pressurized, as noted by huge volumes of air movement at entry/exit doors. Maintenance staff noted it is not uncommon for interior glass entryway doors to crack or blow in from the high pressure/suction differential

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Air Infiltration/Leakage

- Mechanical room in "88" level showing signs of excessive infiltration which has been partially remedied by being filled with spray foam. Staff noted air handling unit coils may freeze when OA temperatures are low, in part due to OA infiltration near the units. Air infiltration and exfiltration is exacerbated by building pressurization issues.

Utilities

Electricity

- The [redacted] electrical room [redacted]
- Various [redacted]
- Electricity is metered at building-level

Natural Gas

- Natural gas has been disconnected [redacted]

District Steam

- The building is supplied by [redacted] There are various pressure reducing stations that convert to [redacted].
- LPS is used to generate heating hot water (HHW) – both preheat and reheat. LPS is also used for domestic hot water (DHW). [redacted]
- Steam was previously used for humidification but staff noted that the humidification system is no longer active. All corresponding steam equipment is abandoned in place and inactive.

District Chilled Water

- Chilled water is supplied directly to the building [redacted]

Metering

Utility Feeds and Meters

- The Plaza has one main National Grid utility account meter under SC-3A Transmission and Delivery Service tariff

Submeters

- Agency Building 1 has numerous submeters that are aggregated to provide the total building electric consumption
- Chilled water blending stations are submetered to continuously monitor thermal energy. The Main Platform contains multiple blending stations that provide chilled water to equipment in various mechanical/electrical rooms (MER).
- Steam flow is submetered to continuously monitor thermal energy. HPS is metered just prior to the pressure reducing stations.
- All electric and thermal submeter data is automatically collected by OGS' Web Enabled Advanced Metering (WEAM) system

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Lighting

Interior Fixture Types
- Linear T8 fluorescent fixtures are most prevalent
- An LED conversion project is in progress, but no interior LED fixtures were observed during the visit

Interior Lighting Controls
- Some occupancy sensors were observed in mechanical spaces
- Interior lighting is generally manually switched ON/OFF with minimal controls

Exterior Lighting
- None observed

HVAC

Central Heating System
- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- HPS is supplied to the building around 150 psig. There are various pressure reducing stations that convert to MPS ~ 60 psig and LPS ~10 psig. LPS is used to generate heating hot water (HHW) and domestic hot water (DHW) through shell and tube heat exchangers.
  - Two (2) shell and tube heat exchangers (HX-2, HX-3) generate HHW preheat from the LPS for AHU heating coils
  - Two (2) shell and tube heat exchangers (HX-4, HX-5) generate HHW reheat from the LPS for AHU heating coils
  - Condensate from the heat exchangers and piping is pumped back to the campus central heating plant
- Three (3) 30 hp, 1,250 GPM pumps (P-9, P-10, P-21) supply HHW to HW preheat coils
  - These pumps are attached to VFDs but the VFDs are not in use
  - Only one pump operates at any time, with the other on standby
- Three (3) 15 hp, 400 GPM pumps (P-11, P-12, P-22) supply HHW to HW reheat coils
  - These pumps are attached to VFDs but the VFDs are not in use
  - Only one pump operates at any time, with the other on standby
- HHW supply temperature is reset based on outdoor air temperature and varies by loop. HHW supply temperature at colder outdoor air temperatures, generally, ranges from 160°F to 190°F.

Central Cooling System
- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations
- Three (3) 125 hp, 3,150 GPM pumps (CHWP-1, CHWP-2, CHWP-3) supply CHW to the building's AHU cooling coils
  - All three pumps are controlled by VFDs in response to differential pressure across the loop
  - Only one pump operates at any time, with the other two on standby

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- Condensing water used to cool laboratory processes is cooled via plate and frame heat exchanger (HX-1A)
  - This heat exchanger uses CHW from the CACP
  - Condensing water cooled from 61F to 57F as observed from temperature gauges with "max 80 from hot packs" and "min 60" written on HX-1A.

Air Handling Units

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- Building energy consumption is very high. A large component of building energy is due to the AHU systems and operation:
  - 100% outside air drives heating and cooling energy
  - Constant volume units drive fan energy
  - High flowrates due to laboratory requirements for high air changes and pressurization
  - 24/7/365 operation
  - High cooling load
- The building is conditioned by [redacted]

Exhaust Systems

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- [redacted] exhaust systems directly remove air from the building and maintain a negative pressure differential
  - Fans range from [redacted]. They are mostly [redacted] motors.
  - None of these motors are on VFDs
  - No energy recovery was observed
- All fume hoods that were observed were noted 24/7/365 operation by laboratory staff
  - It is estimated around 10-15 fume hoods were observed during the walkthrough
- Exhaust fans are ducted to a common underground header and which is then ducted through the [redacted]
- These fan HPs and CFMs were not observed during the walkthrough

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Zone Heating/Cooling

- Hot water reheat coils serve individual building zones to maintain space temperature at setpoint. There is no setback schedule for zone thermostat settings.

HVAC Controls

Building Automation System

- Honeywell Enterprise Building Integrator (EBI) building automation system (BAS) is used for monitoring, direct digital control (DDC), and energy management of HVAC systems
- All valves, dampers, and other control devices have pneumatic actuators with electric to pneumatic transducers that convert the BAS control signal to a proportional pneumatic pressure

Operating Schedules

- HVAC supply air systems run 24/7/365
- Exhaust systems (including fume hoods) operate 24/7/365

Energy Saving Control Strategies

- Hot water temperature reset schedule for HW reheat loop ranges from 120F @60F OAT and above to 160F @20F OAT and below, ramped linearly in between

Domestic/Service Water Heating

Domestic Water Heaters

- A semi-instantaneous domestic hot water system uses LPS to generate hot water

DHW Load

- The DHW load comes from bathroom hand sinks, showers, janitor closets, and laboratory processes including, but not limited to, glassware washing

Piping and Ductwork

Piping Systems/Insulation

- Most piping systems observed during the walk-through appeared to be well insulated
- Small sections of steam pipes and equipment were uninsulated but tagged for future insulation work

Air Distribution Systems/Insulation

- [redacted] observed during the walk-through. AHUs are oriented in a circular pattern so that [redacted]

Equipment Insulation

- Heat exchangers and pumps were mostly insulated when necessary. Some heat exchangers (a small LPS heat exchanger specifically) had torn insulation and often had nearby piping uninsulated.

Piping and Ductwork Leaks

- Majority of piping and ductwork was not leaking during the building walk-through

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- In one case there was a fire sprinkler system leaking onto an air handling unit, causing the AHU to rust

Miscellaneous Loads and Specialty Systems

Laboratory Equipment

- The building has high process and plug loads as observed during the walkthrough [redacted]
- Around [redacted] throughout the building and still in use.
    - These rooms are part of the original building design and appear to be unrenovated
    - Some rooms may be functional but many appear to be in various states of disrepair
    - [redacted]
    - Many rooms have [redacted]
    - Some rooms are dedicated to heating only, others are cooling only. Some have humidity controls and others are designated for [redacted].
    - Cooling is achieved via direct expansion (DX) which utilizes a refrigerant and a compressor driven by electricity
    - Heating utilizes steam from the building steam supply [redacted]
- Both steam (MPS) and electric autoclaves are used for cleaning and sterilizing lab equipment and glassware.
    - [redacted]

Plug Loads

- Non-laboratory plug loads in the building offices include computers, monitors, laptops, chargers, printers, small appliances and desk lamps

Fabrication Shop

- There is a fabrication shop with various drill presses, sheet metal cutters, sheet metal bending devices, a sawdust collection system and saws

Renewable Energy Systems

- None observed

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Mission Critical Systems

- The entire building is considered mission critical for the most part, [redacted]
- Security camera systems are mission critical
- Some laboratory equipment [redacted]
- [redacted]

Water Systems

- Building personnel noted water using systems related to Hudson River and Municipal Sources of water used to be used in HVAC processes in the past, but none now. These systems are abandoned in place.

Initial Hazardous Materials Assessment

- Building maintenance staff noted previous asbestos abatement project, but likely have not eliminated all sources as there were a few locations still posted with asbestos warnings – for example, [redacted]

Potential Energy Efficiency Measures (EEMs)

- Replace all major AHUs, corresponding ductwork, and terminal reheat coils
  - Multizone AHUs should consider the following features:
    - Multizone variable air volume (VAV) systems with VAV terminal boxes and hot water reheat coils
    - Supply fan motors controlled by VFDs to maintain duct static pressure setpoint
    - Duct static pressure reset controls
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
  - Single zone AHUs should consider the following features:
    - Temperature based control of supply fan VFD speed. The supply fan speed and discharge temperature would be controlled to satisfy the space temperature setpoint.
    - Demand controlled ventilation on units with high ventilation loads
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
- Consider alternative HVAC systems for deep energy retrofits, such as
  - Dedicated outdoor air systems (DOAS) with energy recovery and DCV
  - Active chilled beams
  - Water-source heat pumps in lieu of induction units

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- Install a run-around loop to recover heat from laboratory exhaust and reject it into the building HHW loop for AHU preheat and reheat coils
- Install [redacted]
- Control HHW loop VFD speed based on [redacted]
  - Any three-way valves would need to be replaced with two-way valves or converted to two-way by capping the return leg
- Implement SAT reset controls based on OAT
- Install Aircuity demand controlled ventilation (DCV) system to reduce occupied and unoccupied mode air change rates in the laboratories

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EMPIRE STATE PLAZA | SWAN STREET BUILDING
BUILDING ASSESSMENT

Building Description

Building Name: Swan Street Building

Year Constructed: 1965

No. of Floors: 5 AG, 2-4 BG

Est. GSF: 842,727

Major Renovations

- Roof Replacement (2016)

Functional Description

Swan Street Building is a government office building that primarily houses the New York State Department of Motor Vehicles (DMV) and the Information Technology Service (ITS).

Number of Occupants

The current approximate number of building occupants is 2,000 people, split about 50/50 between the DMV and ITS.

Occupancy Patterns

The offices are typically occupied from 7:00 a.m. to 5:00 p.m. on weekdays and mostly unoccupied on weekends. It is not uncommon to have employees working overtime on weekends.

Space Function Summary

Table 1. Space Function Summary (Estimated)

	Office	Cafeteria	Post Office
Original Intended Use	Office	Cafeteria	Storage/Post Office
Gross Floor Area (GSF)	674,182	42,136	126,409
% of Total GSF	80%	5%	15%
% Heated	100%	100%	100%
% Cooled	100%	100%	100%
Number of Occupants	1900	15	85

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	Office	Cafeteria	Post Office
Typical Occupancy Pattern	M-F 7 a.m. – 5 p.m.	M-F 11 a.m. – 2:30 p.m.	M-F 7 a.m. – 5 p.m.
Principal HVAC Type	CAV with Hot Water Reheat	CAV with Hot Water Reheat	Liebert Specialized AC Units
Principal Lighting Type	Fluorescent T8	Fluorescent T8	Fluorescent T8

Building Envelope

Roof

- Typical flat roof with white waterproof membrane and stormwater management throughout
- No insulation type or roof deficiencies were observed
- There was no roof ponding
- The roof was recently replaced around 2016

Exterior Walls

- Exterior walls appear to be original to the building and are faced on the exterior with marble Architectural drawings show concrete block walls, indicating that the exterior walls are likely uninsulated

Windows

- Double-glazed floor-to-ceiling fixed, non-operable windows are aluminum frame and typical of all perimeter spaces. Window-to-wall ratio is estimated to be 0.38.
- Connecting bridges between Cores 1&2 and Cores 3&4 are single-glazed, aluminum framed curtainwall

Exterior Doors

- Glass doors are double glazed, aluminum frame. Metal doors are used for access to the loading dock and parking garages.

Air Infiltration/Leakage

- No large concerns identified during walkthrough. Building occupants noted that windows are not particularly drafty.

Utilities

Electricity

- The electrical room [redacted] houses the building's main switchgear and various disconnects
- Various transformers [redacted]

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Natural Gas
- Cafeteria staff reported that some cafeteria cooking equipment uses natural gas. No other natural gas equipment was identified in the building, nor was a gas meter located.

District Steam
- The building is supplied by High Pressure Steam (HPS) at around 150 PSI. There are various pressure reducing devices that convert to Medium Pressure Steam (MPS) ~ 60 PSI and Low Pressure Steam (LPS) ~10 PSI.
- LPS and MPS is used to generate heating hot water (HHW) for finned-tube radiation, AHU heating coils and VAV reheat boxes. LPS is generally used for domestic hot water (DHW) production.

District Chilled Water
- Chilled water is supplied to the building from the central CHW plant located in the bottom of Agency Building 4 via a "blending station"

Metering

Utility Feeds and Meters
- The Plaza has one main National Grid utility account meter under SC-3A Transmission and Delivery Service tariff

Submeters
- Chilled water blending stations are submetered to continuously monitor thermal energy. The Main Platform contains multiple blending stations that provide chilled water to equipment in various mechanical/electrical rooms (MER).
- Steam flow is submetered to continuously monitor thermal energy. HPS is metered just prior to the pressure reducing stations.
- All electric and thermal submeter data is automatically collected by OGS' Web Enabled Advanced Metering (WEAM) system

Lighting

Interior Fixture Types
- Linear T8 fluorescent fixtures are most prevalent
- An LED conversion project is in progress, but no interior LED fixtures were observed during the visit

Interior Lighting Controls
- Some occupancy sensors were observed in mechanical spaces. Interior lighting is generally manually switched ON/OFF with minimal controls.
  Many occupants commented that they prefer low lighting levels and therefore turn the lights off

Exterior Lighting
- LED fixtures observed in covered areas under the two connecting bridges
- Exterior lighting is scheduled through building automation system, and typically operate from 4:15 p.m. to 11:30 a.m. every day

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HVAC

Central Heating System

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- HPS is supplied to the building around 150 psig. There are various pressure reducing stations that convert to MPS ~ 60 psig and LPS ~10 psig. LPS is used to generate heating hot water (HHW) and domestic hot water (DHW) through shell and tube heat exchangers.
  - One (1) shell and tube heat exchanger (HE-1) generates HHW for finned tube radiation
  - One (1) shell and tube heat exchanger (HE-2) generates HHW for AHU heating coils
  - One (1) shell and tube heat exchanger (HE-3) generates glycol HHW for an exterior in-slab snowmelt system
  - Condensate from the heat exchangers and piping is collected in condensate receivers located in the MERs and pumped back to the SASP
  - Condensate pumps have VFDs
- Three (3) 10 hp, 260 GPM pumps (P-6, P-7, P-16) supply HHW to zone finned-tube radiation found along most perimeter spaces and in the connecting bridges
  - These pumps are attached to VFDs
  - Only one pump operates at any time, with the other on standby
- Two (2) 30 hp, 1,085 GPM pumps (P-8, P-9) supply HHW to HW coils in the AHUs and mechanical room unit heaters
  - These pumps are *not* attached to VFDs
  - Only one pump operates at any time, with the other on standb.
- Two (2) 1 hp, 30 GPM pumps (P-10, P-11) supply HHW mixed with glycol for the slab snowmelt system
  - These pumps are *not* attached to VFDs
  - Only one pump operates at any time, with the other on standby
- HHW supply temperature is reset based on outdoor air temperature and varies by loop. HHW supply temperature at colder outdoor air temperatures, generally, ranges from 160°F to 190°F.

Central Cooling System

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations
- Four CHW pumps serve the building:
  - Two (2) 40 hp, 1,265 GPM pumps (P-1 & P-2) supply CHW to the building's AHU cooling coils
    - Both pumps are controlled by VFDs in response to differential pressure across the loop
    - Only one pump operates at any time, with the other on standby
  - Two (2) 15 hp, 610 GPM pumps (P-3 & P-4) supply CHW to the building's AHU cooling coils
    - Both pumps are controlled by VFDs in response to differential pressure across the loop
    - Only one pump operates at any time, with the other on standby

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Air Handling Units

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- The building is conditioned with [redacted]

Exhaust Systems

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- [redacted] exhaust systems directly remove air from the building
  - Fans range from 3/4hp to 2hp and average 1hp. They are mostly NEMA Premium motors.
  - None of these motors are on VFDs
  - No energy recovery was observed

Zone Heating/Cooling

- The building was originally designed with an open floorplan. There were very large areas of the building uninterrupted by interior walls. Interior walls were added over time to separate different office uses. This has resulted in poor air distribution and issues with occupant comfort and has made it challenging to determine how best to operate the AHUs for maximum occupant satisfaction.
- Hot water reheat coils serve some individual building zones to maintain space temperature at setpoint
- Hot water perimeter finned-tube radiation is controlled based on outdoor air temperature reset

HVAC Controls

Building Automation System

- Honeywell Enterprise Building Integrator (EBI) building automation system (BAS) is used for monitoring, direct digital control (DDC), and energy management of HVAC systems
- All valves, dampers, and other control devices have pneumatic actuators with electric to pneumatic transducers that convert the BAS control signal to a proportional pneumatic pressure

Operating Schedules

- HVAC systems on average run [redacted] on weekdays and Saturdays, and are typically OFF on Sundays
- Exhaust systems follow a similar schedule

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Energy Saving Control Strategies

- Building HVAC equipment is generally scheduled to run during occupied hours and only cycles during unoccupied hours if space temperatures fall below 55F
- SAT controlled based on outdoor air temperature
- Airside economizer mode is used when outdoor air conditions are ideal for cooling operation
- Some AHUs show CO2 return air sensors on BAS, but the operable status of this control is unknown
- Hot water baseboard radiation is activated on a fixed setpoint of 60F outdoor air temperature and HHW supply temperature is reset based on outdoor air temperature and varies by loop
- Some air handlers use optimum start/stop to meet scheduled setpoints

Domestic/Service Water Heating

Domestic Water Heaters

- A semi-instantaneous domestic hot water system uses LPS to generate hot water

DHW Load

- The DHW load comes from bathroom hand sinks, showers, janitor closets, and the cafeteria/kitchen

Piping and Ductwork

Piping Systems/Insulation

- Various steam, CHW, and HW pipes were uninsulated or missing large amounts of insulation
- Many issues appear to have been identified and have tags indicating that repairs are scheduled/in progress

Air Distribution Systems/Insulation

- Ductwork insulation is generally in good shape or tagged where deficient

Equipment Insulation

- Heat exchangers are mostly insulated where necessary. Most deficiencies were tagged.

Piping and Ductwork Leaks

- Few, if any leaks were identified in piping and ductwork during the building walk-through

Miscellaneous Loads and Specialty Systems

Plug Loads

- The building has typical office plug loads such as computers, monitors, laptops, printers, small kitchen appliances in break rooms, and task lighting
- Printing operations in basement of ITS
- Post Office DMV mailing area specialty equipment & sorting
- Command Center of ITS has higher-than-average computer loads with large LCD displays for live data
- Kitchen equipment and refrigeration present in cafeteria

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Renewable Energy Systems

- None observed

Mission Critical Systems

- Camera security systems
- Emergency generators not located at building and instead located at a separate standalone location.
- ITS Data Center servers are located off-site. However, corresponding local computer controls are mission critical and on UPS. The ITS "Command Center" is located in the building as well.
- DMV "Inserting Unit" post office area and associated equipment is identified as mission critical.
- Canadian Bank Note area in which driver's licenses are produced is identified as mission critical and was inaccessible during the building walkthrough for security reasons

Water Systems

- No major water using systems related to Hudson River and municipal sources of water are used in building HVAC processes

Initial Hazardous Materials Assessment

- Building maintenance staff noted asbestos containing material is present in the building's HVAC piping and air handling unit insulation and in progress of removal

Potential Energy Efficiency Measures (EEMs)

- Replace all major AHUs, corresponding ductwork, and terminal reheat coils
  - Multizone AHUs should consider the following features:
    - Multizone variable air volume (VAV) systems with VAV terminal boxes and hot water reheat coils
    - Supply fan motors controlled by VFDs to maintain duct static pressure setpoint
    - Duct static pressure reset controls
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
  - Single zone AHUs should consider the following features:
    - Temperature based control of supply fan VFD speed. The supply fan speed and discharge temperature would be controlled to satisfy the space temperature setpoint.
    - Demand controlled ventilation on units with high ventilation loads
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
- Consider alternative HVAC systems for deep energy retrofits, such as
  - Dedicated outdoor air systems (DOAS) with energy recovery and DCV
  - Active chilled beams
  - Water-source heat pumps in lieu of induction units
- Implement air-side energy recovery, enthalpy wheel type including both latent and sensible recovery

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- Window replacement, especially at the location of the single-pane windows in connecting bridges between Cores 1&2 and 3&4
- Snowmelt slab heating systems is currently always activated if outdoor air temperatures are below 60F. Instead, activate during OA temperatures below 40F and combine with in-slab moisture sensors.

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EMPIRE STATE PLAZA | THE EGG BUILDING ASSESSMENT

Building Description

Building Name: The Egg

Year Constructed: 1978

No. of Floors: 5 AG, 3 BG

Est. GSF: 159,362

Major Renovations

- Roof Replacement (2019)
- Elevator Replacement (2014)

Functional Description

The Egg is a performing arts center with two main theaters. It was "established to present quality performances, accessible to all citizens of New York State, highlighting the unique and extraordinary artists from New York State, across the country and around the globe."

Number of Occupants

There are two main theaters in this building. Hart Theatre seats 980 people and spans floors 3 & 4. Swyer Theatre seats 440 people and spans floors 2 & 3.

Occupancy Patterns

The building is almost entirely unoccupied except for events in the two theatres. Various performers and stage assistant personnel may occupy the building during the day leading up to an evening event. During the typical busy season (Spring through Fall), the building typically has events up to 5 days per week.

Space Function Summary

Table 1. Space Function Summary (Estimated)

	Performing Arts Center
Original Intended Use	Performing Arts Center
Gross Floor Area (GSF)	159,362
% of Total GSF	100%
% Heated	100%
% Cooled	100%
Number of Occupants	1,420

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	Performing Arts Center
Typical Occupancy Pattern	W-Sun 7pm – 11pm
Principal HVAC Type	CAV with Hot Water Reheat
Principal Lighting Type	Recessed cans – CFL and incandescent

Building Envelope

Roof

- Roof is a unique convex and curved custom white roof. There are ports for exhaust that exit through the roof. The roof was recently replaced around 2019 but insulation type and levels are unknown.

Exterior Walls

- Exterior walls are original to the building and made entirely of solid concrete, typically 3.5 feet thick with no insulation

Windows

- The building is nearly windowless. Single-glazed floor-to-ceiling fixed, non-operable, aluminum-framed windows are in the main lobby. No other fenestration is present in the building.

Exterior Doors

- Glass doors in the entry lobby are double-glazed, aluminum framed

Air Infiltration/Leakage

- No large concerns found during walkthrough other than some gaps in entranceway doors where weatherstripping is typically located

Utilities

Electricity

- The upper mechanical and electrical room houses the building’s main switchgear and various disconnects
- Various transformers convert to distribution voltages (480V, 208V, 120V)

Natural Gas

- The building does not have a natural gas service

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District Steam

- The building is supplied by high pressure steam (HPS) from the Sheridan Avenue Steam Plant (SASP) at around 150 psig. There are various pressure reducing stations that convert to medium pressure steam (MPS) ~ 60 psig and low pressure steam (LPS) ~10 psig.
- LPS is used to generate heating hot water (HHW) for finned-tube, preheat, and reheat coils. LPS is generally used for domestic hot water (DHW) production.

District Chilled Water

- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations

Metering

Utility Feeds and Meters

- The Plaza has one main National Grid utility account meter under SC-3A Transmission and Delivery Service tariff

Submeters

- Chilled water blending stations are submetered to continuously monitor thermal energy. The Main Platform contains multiple blending stations that provide chilled water to equipment in various mechanical/electrical rooms (MER).
- Steam flow is submetered to continuously monitor thermal energy. HPS is metered just prior to the pressure reducing stations.
- All electric and thermal submeter data is automatically collected by OGS' Web Enabled Advanced Metering (WEAM) system

Lighting

Interior Fixture Types

- Mostly recessed can fixtures, CFL and incandescent
- An LED conversion project is in progress but no interior LED fixtures were observed during the visit

Interior Lighting Controls

- Some occupancy sensors were observed in mechanical spaces
- Interior lighting is generally manually switched ON/OFF with minimal controls

Exterior Lighting

- Pole-mounted LED lighting fixtures for façade uplighting. Some continuation of recessed can fixtures from the lobby to the underside of the building just outside of the main entrance.

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HVAC

Central Heating System

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- The building is supplied by high pressure steam (HPS) from the Sheridan Avenue Steam Plant (SASP) at around 150 psig. There are various pressure reducing stations that convert to medium pressure steam (MPS) ~ 60 psig and low pressure steam (LPS) ~10 psig.
    - LPS is used to generate heating hot water (HHW) and domestic hot water (DHW) through shell and tube heat exchangers.
- One (1) shell and tube heat exchanger (HX-1) generates HHW for AHU hot water coils
- Four (4) shell and tube heat exchangers (HE-1-4) are used for combination preheat and cooling coils, where either cooling or heating may be called for
    - Condensate from the heat exchangers and piping is pumped back to the campus central heating plant
- Two (2) 10 hp, 275 GPM pumps (HWP-1 & HWP-2) supply HHW to HW coils in the building AHUs and mechanical room unit heaters
    - These pumps are not driven by VFDs
    - Only one pump operates at any time, with the other on standby
- HHW supply temperature is reset based on outdoor air temperature and varies by loop. HHW supply temperature at colder outdoor air temperatures, generally, ranges from 160°F to 190°F.

Central Cooling System

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations
- Two (2) 25 hp, 545 GPM pumps (CHWP-1A, CHWP-1B) supply chilled water for AHU cooling coils
    - These pumps are not driven by VFDs
    - Only one pump operates at any time, with the other on standby

Air Handling Units

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- The building is conditioned with [redacted]

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- The supply air fan motors range from 5hp to 30hp, and average around 10hp. Return air fan motors range from 1.5hp to 20hp and average around 5hp. These motors are typically NEMA premium and appear to have been replaced within the last ~10 years. Exhaust fans are described below.
- The are no VFDs on any of the supply, return, or exhaust fans
- Most air handling units have connections and devices for steam humidification which are no longer in use and are abandoned in place

Exhaust Systems

- Major systems and equipment date to the original construction with various retrofits, are generally in poor condition, and have exceeded their useful life
- [redacted] exhaust systems remove air from the building and serve various mechanical rooms, toilet rooms, each auditorium, and the projector rooms
- Fans range from 1hp to 5hp and typically average 1.5hp. They are mostly NEMA Premium motors.
- None of these motors are on VFDs
- No energy recovery was observed

Zone Heating/Cooling

- Reheat coils serve some individual building zones, however these are duct-mounted

HVAC Controls

Building Automation System

- Honeywell Enterprise Building Integrator (EBI) building automation system (BAS) is used for monitoring, direct digital control (DDC), and energy management of HVAC systems
- All valves, dampers, and other control devices have pneumatic actuators with electric to pneumatic transducers that convert the BAS control signal to a proportional pneumatic pressure

Operating Schedules

- HVAC systems on average, run [redacted] on weekdays and Saturdays, and are typically OFF on Sundays unless there's an event
- Exhaust systems follow a similar schedule

Energy Saving Control Strategies

- Building HVAC equipment is generally scheduled to run during occupied hours and only cycles during unoccupied hours if space temperatures fall below 55F
- Outdoor air temperature reset controls are used for supply air temperature for both cooling and heating
- Air-side economizer mode is used when outdoor air conditions are ideal for cooling operation
- Some air handlers use optimum start/stop to meet scheduled setpoints
- Preheat coil air temperature reset schedule based on OAT
- Hot water temperature reset schedule ranging from 140F @60F OAT and above to 190F @20F OAT and below, ramped linearly in between

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Domestic/Service Water Heating

Domestic Water Heaters

- A semi-instantaneous domestic hot water system uses LPS to generate hot water
- This building also has a "domestic water cooler" which uses electricity and a one-way (cooling only) air source heat pump to cool incoming potable water for various drinking fountains in the building. Heat is rejected into the surrounding mechanical room in the upper MER.

DHW Load

- The DHW load comes from bathroom hand sinks and janitor closets

Piping and Ductwork

Piping Systems/Insulation

- Insulation is generally in good shape with no major concerns. A handful of areas of HW piping could use insulation but is considered minor.

Air Distribution Systems/Insulation

- Ductwork insulation is generally in good shape or tagged where deficient

Equipment Insulation

- Heat exchangers are insulated where necessary

Piping and Ductwork Leaks

- Few, if any leaks were identified in piping and ductwork during the building walk-through

Miscellaneous Loads and Specialty Systems

Plug Loads

- The building has typical plug loads for a performing arts center including:
- Stage lighting and associated DMX control boards
- Audio mixing, amplification, and controls and all associated speakers, microphones, and input devices
- Mechanical pit area stage lift for retracting pit area into the floor
- 4 elevators

Renewable Energy Systems

- None observed

Mission Critical Systems

- Camera security systems
- Emergency power is supplied by emergency generators at the SASP

Water Systems

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- No major water using systems related to Hudson River and municipal sources of water are used in building HVAC processes

Initial Hazardous Materials Assessment

- Building maintenance staff noted asbestos containing material is suspected in the building floor tiles

Potential Energy Efficiency Measures (EEMs)

- Replace all major AHUs, corresponding ductwork, and terminal reheat coils
  - Multizone AHUs should consider the following features:
    - Multizone variable air volume (VAV) systems with VAV terminal boxes and hot water reheat coils
    - Supply fan motors controlled by VFDs to maintain duct static pressure setpoint
    - Duct static pressure reset controls
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
  - Single zone AHUs should consider the following features:
    - Temperature based control of supply fan VFD speed. The supply fan speed and discharge temperature would be controlled to satisfy the space temperature setpoint.
    - Demand controlled ventilation on units with high ventilation loads based on zone CO2 levels or occupancy-counters, especially for large events where occupancy is counted and scheduled
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
- Consider alternative HVAC systems for deep energy retrofits, such as
  - Dedicated outdoor air systems (DOAS) with energy recovery and DCV
  - Active chilled beams
  - Water-source heat pumps in lieu of induction units
- Implement air-side energy recovery, enthalpy wheel type including both latent and sensible recovery
- Opportunities for mechanical equipment operating schedule refinement based on an actual and continually updated event schedule
- Lobby window replacement

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EMPIRE STATE PLAZA | CULTURAL EDUCATION CENTER (MUSEUM) BUILDING ASSESSMENT

Building Description

Building Name: Cultural Education Center (Museum)

Year Constructed: 1976

No. of Floors: 11+ basement, concourse level, and penthouse

Est. GSF: 1,582,504

Major Renovations

- 20+ years ago: Carousel Addition
- 2000: Eleventh-Floor Renovation
- 2006: Grand Stair Repairs
- 2016: Lighting Upgrade
- Ongoing: Gallery Renovations

Functional Description

The Cultural Education Center (CEC) houses the New York State Museum, State Library and State Archives. The building consists of exhibition spaces, storage spaces, event spaces, auditoriums, a gift shop, offices, conference rooms, labs and research centers. The public has access to the Museum at the concourse level, street level via Madison Avenue, and first, second and fourth floors. The public has access to the Archives and Library on the seventh and eleventh floor.

Number of Occupants

The approximate number of building employees is 300 people. Prior to the COVID pandemic, about 500,000 people visited the Museum each year. The Library and Archives are also open to visitors.

Occupancy Patterns

The building is typically occupied from 8:30 a.m. to 6:00 p.m. on weekdays and weekends. Large events, such as wedding receptions and press conferences, are often held in the Fourth Floor Terrace Gallery and the Clark Auditorium. Other smaller event spaces are also available for rent. Visiting hours for each CEC institution are listed in the table below.

Table 1. CEC Public Visitation Hours

Institution	Hours Open to Public
Museum	Tuesday through Sunday, 9:30 a.m. to 5:00 p.m.
Library	Monday through Friday, 9:30 a.m. to 5:00 p.m.
Archives	Monday through Friday, 10:00 a.m. to 4:00 p.m. (by appointment only)

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Space Function Summary

Table 2. Space Function Summary (Estimated)

	Office	Storage & Mech. Space	Library & Archives	Museum	Research Space
Original Intended Use	Office	Storage & Mech. Space	Library & Archives	Museum	Research Space
Gross Floor Area (GSF)	316,501	158,250	633,002	316,501	158,250
% of Total GSF	20%	10%	40%	20%	10%
% Heated	100%	100%	100%	100%	100%
% Cooled	100%	100%	100%	100%	100%
Number of Occupants	250	-	50-500	100	50
Typical Occupancy Pattern	M-F 6 a.m. to 6 p.m.	-	Irregular	T-Su 9 a.m. to 5 p.m.	Sa-Su 9 a.m. to 5 p.m.
Principal HVAC Type	Constant Volume AHU	Constant Volume AHU	Constant Volume AHU	Constant Volume AHU	Constant Volume AHU
Principal Lighting Type	Fluorescent T8/T12	Fluorescent T8/T12	Fluorescent T8/T12	Fluorescent T8/T12	LED panels

Building Envelope

Roof

- Built-up flat roof with marble chips
- Three elevated sections of penthouse roof (one higher, two lower), uninsulated
- Two layers of 2" rigid insulation

Exterior Walls

- The predominant exterior wall construction consists of concrete masonry with unknown insulation
- The building is encased with large marble panels. Repairs and replacements for some of these panels were designed by Simpson Gumpertz & Heger in 2006. Recently, one of the marble panels fell and crashed into the upper terrace on the ninth floor. Newer repairs are in progress.

Windows

- The more recently built carousel enclosure has double glazed, metal frame fixed windows
- The Terrace Gallery has large single glazed, metal frame fixed windows dating to the original construction

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- To address concerns of sunlight damaging museum exhibits, window films were applied to the fourth-floor windows. The film was removed after causing some windows to crack.
- The remaining floors have double glazed, metal frame windows dating to the original construction. The windows were originally operable but were recently sealed and fixed in place to mitigate infiltration.

Exterior Doors
- The Madison Avenue entrance has swinging doors and rotary entrances with bronze glazing

Air Infiltration/Leakage
- No noticeable signs of excessive infiltration

Utilities

Electricity
- Electricity is supplied to the plaza through [redacted] separate [redacted] feeders from National Grid
- [redacted] high voltage primary distribution transformers step down the voltage [redacted] and distribution switchgear supplies power to substations throughout the plaza
- The plaza distribution power is stepped down [redacted] to 480/277 V at various substations which supply power to the buildings

Natural Gas
- The building has no natural gas service

District Steam
- High pressure steam (HPS) at 150 psig is supplied to the building from the Sheridan Avenue Steam Plant (SASP) and reduced to medium pressure steam (MPS, about 40 psig) and low pressure steam (LPS, about 10 psig) at the building through pressure reducing stations
- MPS is used for clean steam generation
- LPS is used to generate heating hot water (HHW) and domestic hot water (DHW) through multiple shell and tube heat exchangers
- On the eleventh floor, LPS is used in steam coils for desiccant reactivation

District Chilled Water
- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations

Metering

Utility Feeds and Meters
- The Plaza has one main National Grid utility account meter under SC-3A Transmission and Delivery Service tariff

Submeters
- The building is submetered for electricity

[redacted]

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- Chilled water blending stations are submetered to continuously monitor thermal energy. The CEC contains two blending stations that provide chilled water to equipment in various mechanical/electrical rooms (MER).
- Steam flow is submetered to continuously monitor thermal energy. HPS is metered just prior to the pressure reducing stations.
- All electric and thermal submeter data is automatically collected by OGS's Web Enabled Advanced Metering (WEAM) system

Lighting

Interior Fixture Types

- Approximately 18,000 U-bend (T8 and T12) fixtures were replaced with custom 2'x2' LED panels in 2016-18. A significant number of older fixtures remain, particularly in the basements and on floors 1-4, 9 and 10.

Interior Lighting Controls

- Lighting schedule is controlled through the building automation system
- The new LED panels have integrated occupancy sensors

Exterior Lighting

- Exterior floodlights turn on between 4:15 p.m. and 11:30 p.m. every day. Exterior lighting is scheduled through the building automation system.

HVAC

Central Heating System

- High pressure steam is piped from the SASP to the building where it is reduced to low pressure steam. The LPS is used to generate heating hot water (HHW) and domestic hot water (DHW) through shell and tube heat exchangers.
  - Multiple shell and tube heat exchangers generate HHW from the LPS for AHU heating coils and reheat coils
  - Condensate from the heat exchangers is collected in condensate receivers located in the MERs and pumped back to the SASP. Condensate pumps have variable frequency drives (VFD).
- Multiple pumps circulate HHW from the shell and tube heat exchangers to heating coils in various MERs
  - Smaller horsepower pumps (typically less than 10 hp) are constant flow
  - Larger horsepower pumps (typically 10 hp or greater) are controlled by VFDs in response to differential pressure across the loop
- Peak HHW supply temperatures, generally, range from 160°F to 190°F

Central Cooling System

- Chilled water (CHW) is supplied to the building from the central chilled water plant through blending stations that serve two CHW loops
  - Secondary pumps circulate CHW from the blending stations to cooling coils in various MERs
  - The pumps are controlled by VFDs in response to differential pressure across the loop

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Air Handling Units

- Major systems and equipment date to the original construction, are generally in poor condition, and have exceeded their useful life
- There are [redacted]

Exhaust Systems

- Larger exhaust fans serve the truck service area, utility tunnel and larger MERs
- Smaller exhaust fans serve miscellaneous spaces in the building, such as elevators, staircases, bathrooms and the smaller MERs

Zone Heating/Cooling

- Constant volume terminal boxes with hot water reheat coils serve individual building zones to maintain space temperature at setpoint
- VAV terminal boxes with hot water reheat coils serve individual zones on the third floor to maintain space temperature at setpoint
- Two pipe fan coil units provide perimeter heating and cooling
- The carousel enclosure has a separate HVAC system located in the nearby ceiling and radiant floor heating

HVAC Controls

Building Automation System

- Honeywell Enterprise Building Integrator (EBI) building automation system (BAS) is used for monitoring, direct digital control (DDC), and energy management of HVAC systems

[redacted]

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- All valves, dampers, and other control devices have pneumatic actuators with electric to pneumatic transducers that convert the BAS control signal to a proportional pneumatic pressure

Operating Schedules

- HVAC systems are typically scheduled to operate in occupied mode [redacted] but the schedules were extended to operate an additional two hours in the morning and evening. It is unclear if space temperature is setback during unoccupied periods, or if the systems can cycle on to meet unoccupied mode setpoints.

Energy Saving Control Strategies

- HHW supply temperature is reset based on outdoor air temperature. Reset schedule varies by loop.
- Enthalpy economizer controls exist on all major air handling units, but many of the dampers are not functional
- Supply air temperature is reset based on outdoor air temperature on some units. Reset schedule varies by unit.

Domestic/Service Water Heating

Domestic Water Heaters

- Multiple semi-instantaneous domestic water heaters (DWH-A) generate DHW from LPS for the building's plumbing fixtures

DHW Load

- The DHW load comes from toilet hand sinks and janitor closets

Piping and Ductwork

Piping Systems/Insulation

- Piping systems observed during the walk-through appeared to be well insulated

Air Distribution Systems/Insulation

- Ductwork was not accessible to observe insulation levels

Equipment Insulation

- Heat exchangers and tanks are well insulated

Piping and Ductwork Leaks

- No obvious piping or ductwork leaks were observed during the building walk-through

Miscellaneous Loads and Specialty Systems

Plug Loads

- The building has typical office plug loads such as computers, monitors, laptops, chargers, printers, and desk lamps
- Large screens and projectors are located in the lobby, auditoriums and meeting rooms

[redacted]
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Compressed Air

- Compressed air for pneumatic actuators is piped to the MERs from the CACP
- Air compressors for pneumatic controls were observed in some mechanical rooms, but are no longer in operation

Exhibit Pumps

- Pumps to recirculate museum exhibit pool and waterfall water

Renewable Energy Systems

- No renewable energy systems exist

Mission Critical Systems

- No mission critical systems exist in the CEC
- Emergency power is supplied by emergency generators at the SASP to life safety systems in each building
  - These systems include some lighting, limited elevator motors, freeze protection, fire pumps and limited computer server areas

Water Systems

- No major water using systems related to Hudson River and municipal sources of water are used in building HVAC processes

Initial Hazardous Materials Assessment

- Asbestos is reportedly present in structural fire proofing above ceiling tiles

Potential Energy Efficiency Measures (EEMs)

- Replace all major AHUs, corresponding ductwork, and terminal reheat coils
  - Multizone AHUs should consider the following features:
    - Multizone variable air volume (VAV) systems with VAV terminal boxes and hot water reheat coils
    - Supply fan motors controlled by VFDs to maintain duct static pressure setpoint
    - Duct static pressure reset controls
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
  - Single zone AHUs should consider the following features:
    - Temperature based control of supply fan VFD speed. The supply fan speed and discharge temperature would be controlled to satisfy the space temperature setpoint.
    - Demand controlled ventilation on units with high ventilation loads, such as the auditorium and theater
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils

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        - Electric actuators for direct digital control
    - Consider alternative HVAC systems for deep energy retrofits, such as
        - Dedicated outdoor air systems (DOAS) with energy recovery
        - Active chilled beams
- Install occupancy-based controls on HVAC systems to allow for automatic setback of space temperature setpoints in unoccupied zones during normal occupied mode periods. This measure would also provide occupied mode setpoints during unoccupied mode periods when the zone is occupied (*e.g.*, during nighttime housekeeping).
- Implement differential pressure reset on variable speed pumping systems
- BAS Optimization—survey existing BAS to identify opportunities for improved operations and energy savings (*e.g.,* sequence of operation changes, operating schedules, setpoints, reset schedules).
- Install destratification fans on the fourth floor
- Replace single pane windows on the fourth-floor terrace with double pane windows

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EMPIRE STATE PLAZA | JUSTICE ABRAMS BUILDING
BUILDING ASSESSMENT

Building Description

Building Name: Justice Abrams Building

Year Constructed: 1972

No. of Floors: 9 + concourse and basement levels

Est. GSF: 261,177

Major Renovations

- Bathrooms
- 2021: LED retrofit

Functional Description

The Justice Abrams Building is a 9-story building which houses office spaces, judge's chambers, and courtrooms. The first three floors serve the Attorney General and have restricted access.

Number of Occupants

The approximate number of building employees is 350 people. The courtrooms can accommodate up to 1,800 people.

Occupancy Patterns

The building is open on weekdays from 7:45 a.m. to 5:15 p.m. It is typically occupied between the hours of 8:30 a.m. and 5 p.m. on weekdays. The building systems are scheduled to remain on two hours before the building opens and two hours after the building closes. The building may be opened on the weekends upon special request, but that is not typical.

Space Function Summary

Space Function	Office	Courthouse
Original Intended Use	Office	Courthouse
Gross Floor Area (GSF)	235,059	26,118
(%)	90%	10%
% Floor Area Heated	100%	100%
% Floor Area Cooled	100%	100%
Number of Occupants	350	Transient
Typical Occupancy Pattern	M-F 7:45 a.m. – 5:15 p.m.	M-F 7:45 a.m. – 5:15 p.m.
Typical Building Systems Operating Hours	M-F 6 a.m. – 7 p.m.	M-F 6 a.m. – 7 p.m.

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Principal HVAC Type	Dual Duct AHU	Constant Volume AHU
Principal Lighting Type	LED	LED

*LED retrofitting project for entire building started 11/17/21

Building Envelope

Roof
- The roof is the original roof, no renovations have been done
- No equipment on the roof

Exterior Walls
- Mass wall construction with marble finish
- Unknown wall insulation

Windows
- Single glazed, metal frame fixed windows dating to the original construction

Exterior Doors
- Swinging double doors with bronze glazing

Air Infiltration/Leakage
- No noticeable signs of excessive infiltration

Utilities

Electricity
- Electricity is supplied to the plaza through [redacted] feeders from National Grid
- [redacted] high voltage primary distribution transformers step down the voltage [redacted] and distribution switchgear supplies power to substations throughout the plaza
- The plaza distribution power is stepped down [redacted] to 480/277 V at various substations which supply power to the buildings

Natural Gas
- The building has no natural gas service

District Steam
- High pressure steam (HPS) at 150 psig is supplied to the building from the Sheridan Avenue Steam Plant (SASP) and reduced to medium pressure steam (MPS, about 40 psig) and low pressure steam (LPS, about 5 psig) at the building through pressure reducing stations
- LPS is used to generate heating hot water (HHW) and domestic hot water (DHW) through multiple shell and tube heat exchangers

[redacted]
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District Chilled Water

- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations

Metering

Utility Feeds and Meters

- The Plaza has one main National Grid utility account meter under SC-3A Transmission and Delivery Service tariff

Submeters

- Each building is submetered for electricity
- Chilled water blending stations are submetered to continuously monitor thermal energy. The Justice building contains one blending station located in mechanical equipment room (MER) P2 East that provides chilled water to equipment in the other MERs.
- Steam flow is submetered to continuously monitor thermal energy. HPS is metered just prior to the pressure reducing stations.
- All electric and thermal submeter data is automatically collected by OGS's Web Enabled Advanced Metering (WEAM) system

Lighting

Interior Fixture Types

- LED retrofit project is in progress to replace all lighting in the building. This process began on 11/17/21 for this building and is scheduled to be completed in January 2022.

Interior Lighting Controls

- Lighting schedule is determined by the building automation system.
- No occupancy sensors in corridors or offices
- All lights turn off automatically when building closes as set by the building automation system. If someone is working after-hours, they must send a request to the building manager for the lighting to be turned on.

Exterior Lighting

- Exterior floodlights turn on between 4:15 p.m. and 11:30 p.m. every day. Exterior lighting is scheduled through the building automation system.

HVAC

Central Heating System

- HVAC equipment is located in three main mechanical rooms; located on Garage Level 2 (P2 East – MER 2), above the 8th Floor (Penthouse), and adjacent to the Annex (MER 4, former storage area converted to office space)
- High pressure steam is piped to the mechanical room on Garage level 2 (P2 East) from the central steam plant. HPS is converted to medium pressure steam (MPS) and low-pressure steam (LPS) through separate pressure reducing stations.

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  - MPS goes to a large heat exchanger to convert to hot water to be pumped to the rest of the building
  - LPS goes to multiple smaller heat exchangers for the same purpose
  - Condensate pumps from the heat exchangers in P2 East return condensate back to the central steam plant
- Peak HHW supply temperatures, generally, range from 160°F to 190°F
- Hot water is supplied from P2 East to the rest of the building through four constant flow loops.
- Control board upgrades are in progress in each of the mechanical rooms

Central Cooling System

- Chilled water (CHW) is supplied to the building from the central chilled water plant through a blending station in P2 East mechanical room
  - Secondary pumps circulate CHW from the blending stations to cooling coils in various MERs
  - Chilled water pumps are controlled by VFDs in response to differential pressure across the loop

Air Handling Units

- Major systems and equipment date to the original construction, are generally in poor condition, and have exceeded their useful life
- There are [redacted]

OA Temperature (°F)	Fan Speed (%)
[redacted]	[redacted]

OA Temperature (°F)	Fan Speed (%)
[redacted]	[redacted]

- Multizone dual duct units serve most of the building, and, generally, have a cold deck, hot deck, supply fan, and return fan. AHUs with larger amounts of design outdoor air have preheat coils.

[redacted]

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- [redacted]

Exhaust Systems
- Multiple exhaust fans and an exhaust air plenum are located in the P2 East and Penthouse mechanical rooms
- Exhaust fans serve mechanical/electrical rooms, elevator shafts, and toilets

Zone Heating/Cooling
- Fin tube radiation (FTR) heats perimeter spaces. Four loops serve the North, South, East, and West exposures of the building. Each loop has dedicated constant speed pumps and separate supply temperature reset schedules.
- Space temperature sensors on each floor control valves that supply hot water to FTR on that floor. Each exposure has a separate temperature sensor.
- Constant volume mixing boxes blend air from the hot and cold ducts to maintain space temperature
- Space temperature set points are controlled in the building automation system.
- The Annex is its own zone served by equipment in the adjacent mechanical room, MER 4. This area was built as a storage area but was converted to office space. Reportedly this area does not have a lot of air circulation and typically hot hallways.

HVAC Controls

Building Automation System
- Honeywell Enterprise Building Integrator (EBI) building automation system (BAS) is used for monitoring, direct digital control (DDC), and energy management of HVAC systems
- All valves, dampers, and other control devices have pneumatic actuators with electric to pneumatic transducers that convert the BAS control signal to a proportional pneumatic pressure

Operating Schedules
- HVAC systems are typically scheduled to operate [redacted] on weekdays. They typically do not operate on weekends unless specifically requested through OGS.
- [redacted] the schedules were extended to operate an additional two hours in the morning and evening. It is unclear if space temperature is setback during unoccupied periods, or if the systems can cycle on to meet unoccupied mode setpoints

Energy Saving Control Strategies
- HW supply temperature reset based on outdoor air temperature

[redacted]

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- AHU hot and cold deck discharge temperature setpoints are reset based on outdoor air temperature. Reset schedule varies by unit.
- BAS operators often change the AHU discharge temperature setpoints and reset schedules in response to occupant comfort complaints
- Supply and return fan speeds are reset based on outside air temperature
- Enthalpy economizer controls exist on all major air handling units, but many of the dampers are not functional

Domestic/Service Water Heating

Domestic Water Heaters
- Multiple semi-instantaneous domestic water heaters (DWH-A) generate DHW from LPS for the building's plumbing fixtures

DHW Load
- The DHW load comes from toilet hand sinks, kitchenettes, and janitor closets

Piping and Ductwork

Piping Systems/Insulation
- Piping systems observed during the walk-through appeared to be well insulated

Air Distribution Systems/Insulation
- Ductwork was not accessible to observe insulation levels

Equipment Insulation
- Heat exchangers and tanks are well insulated

Piping and Ductwork Leaks
- No obvious piping or ductwork leaks were observed during the building walk-through

Miscellaneous Loads and Specialty Systems

Plug Loads
- The building has typical office plug loads such as computers, monitors, laptops, chargers, printers, and desk lamps
- The building has two small data centers and a copy room

Compressed Air
- Compressed air for pneumatic actuators is piped to the MERs from the CACP
- Air compressors for pneumatic controls were observed in some mechanical rooms, but are no longer in operation

Data Center
- Data center located on the second floor
- Conditioned by two Liebert units

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Renewable Energy Systems

- No renewable energy systems exist

Mission Critical Systems

- Emergency power is supplied by emergency generators at the SASP to life safety systems in each building
  - These systems include some lighting, limited elevator motors, freeze protection, fire pumps and limited computer server areas

Water Systems

- No major water using systems related to Hudson River and municipal sources of water are used in building HVAC processes

Initial Hazardous Materials Assessment

- Asbestos is reportedly present in structural fire proofing above ceiling tiles

Potential Energy Efficiency Measures (EEMs)

- Add additional zone controls to FTR. Ramboll observed instances where the FTR was overheating the space due to lack of zone control, and the dual duct AHUs were providing cold air to cool the space to meet the space temperature setpoint.
- Replace all major AHUs, corresponding ductwork, and terminal reheat coils
  - Multizone AHUs should consider the following features:
    - Multizone variable air volume (VAV) systems with VAV terminal boxes and hot water reheat coils
    - Supply fan motors controlled by VFDs to maintain duct static pressure setpoint
    - Duct static pressure reset controls
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
  - Single zone AHUs should consider the following features:
    - Temperature based control of supply fan VFD speed. The supply fan speed and discharge temperature would be controlled to satisfy the space temperature setpoint.
    - Demand controlled ventilation on units with high ventilation loads, such as courtrooms
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
  - Consider alternative HVAC systems for deep energy retrofits, such as
    - Dedicated outdoor air systems (DOAS) with energy recovery
    - Active chilled beams
- Install occupancy-based controls on HVAC systems to allow for automatic setback of space temperature setpoints in unoccupied zones during normal occupied mode periods. This measure would

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also provide occupied mode setpoints during unoccupied mode periods when the zone is occupied (*e.g.*, during nighttime housekeeping).

- Implement differential pressure reset on variable speed pumping systems
- BAS Optimization—survey existing BAS to identify opportunities for improved operations and energy savings (*e.g.,* sequence of operation changes, operating schedules, setpoints, reset schedules).
- Add discriminator controls to reset the hot deck discharge air temperature based on mixing box request for hot deck air flow
- Convert dual duct systems to variable air volume systems

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EMPIRE STATE PLAZA | LEGISLATIVE OFFICE BUILDING BUILDING ASSESSMENT

Building Description

Building Name: Legislative Office Building

Year Constructed: 1972

No. of Floors: 11 + basement, concourse level, and penthouse

Est. GSF: 650,248

Major Renovations

- 2021: LED retrofit

Functional Description

The Legislative Office Building houses government offices (notably the Senate and the Assembly), common spaces/lobby areas, meeting rooms, and hearing rooms.

Number of Occupants

The approximate number of building occupants is 1,000 people. There are two smaller hearing rooms which house approximately 250 occupants, and a larger hearing room which houses up to 550 occupants.

Occupancy Patterns

The building is open on weekdays from 9 a.m. – 5 p.m.

Space Function Summary

Table 1. Space Function Summary (Estimated)

Space Function	Office	Hearing Rooms
Original Intended Use	Office	Meeting Rooms
Gross Floor Area (GSF)	617,831	32,517
(%)	95%	5%
% Floor Area Heated	100%	100%
% Floor Area Cooled	100%	100%
Number of Occupants	1,000	1,050
Typical Occupancy Pattern	M-F 9 a.m. - 5 p.m.	M-F 9 a.m. - 5 p.m.
Typical Building Systems Operating Hours	M-F 5:30 a.m. – 7 p.m.	M-F 5:30 a.m. – 7 p.m.*
Principal HVAC Type	Dual Duct AHU	Constant Volume AHU

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Principal Lighting Type	LED	LED

*Systems that serve hearing rooms only operate during scheduled meeting times

Building Envelope

Roof
- The roof is the original roof, no major renovations have been done
- No equipment on the roof

Exterior Walls
- Concrete block walls with a 4" marble façade
- 1" layer of unspecified insulation

Windows
- Single glazed, metal frame fixed windows dating to the original construction

Exterior Doors
- Swinging double doors with bronze glazing

Air Infiltration/Leakage
- No noticeable signs of excessive infiltration

Utilities

Electricity
- Electricity is supplied to the plaza through [redacted] feeders from National Grid
- [redacted] high voltage primary distribution transformers step down the voltage [redacted] and distribution switchgear supplies power to substations throughout the plaza
- The plaza distribution power is stepped down [redacted] to 480/277 V at various substations which supply power to the buildings

Natural Gas
- The building has no natural gas service

District Steam
- High pressure steam (HPS) at 150 psig is supplied to the building from the Sheridan Avenue Steam Plant (SASP) and reduced to low pressure steam (LPS) at the building (about 10 psig) through pressure reducing stations
- LPS is used to generate heating hot water (HHW) and domestic hot water (DHW) through multiple shell and tube heat exchangers

District Chilled Water
- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations

[redacted]
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Metering

Utility Feeds and Meters

- The Plaza has one main National Grid utility account meter under SC-3A Transmission and Delivery Service tariff

Submeters

- Each building is submetered for electricity
- Chilled water blending stations are submetered to continuously monitor thermal energy. The Legislative Office Building contains two chilled water blending stations.
- Steam flow is submetered to continuously monitor thermal. HPS is metered just prior to the pressure reducing stations.
- All electric and thermal submeter data is automatically collected by OGS's Web Enabled Advanced Metering (WEAM) system

Lighting

Interior Fixture Types

- An LED retrofit project is in progress to replace all lighting in the building. This lighting project is about is about 85% completed in the Legislative Office Building as of 11/18/21.

Interior Lighting Controls

- Lighting schedule is controlled through the building automation system
- No occupancy sensors in corridors or offices
- Majority of mechanical equipment room (MER) light fixtures utilize integrated occupancy sensors
- All lights turn off automatically when building closes as set by the building automation system. If someone is working after-hours, they must send a request to the building manager for the lighting to be turned on.

Exterior Lighting

- Exterior lighting and Plaza floodlights turn on between 4:15 p.m. – 11:30 p.m. every day. Exterior lighting is scheduled through the building automation system.

HVAC

Central Heating System

- High pressure steam is piped from the SASP to the building where it is reduced to low pressure steam. The LPS is used to generate heating hot water (HHW) and domestic hot water (DHW) through shell and tube heat exchangers.
  - Multiple shell and tube heat exchangers generate HHW from the LPS for AHU heating coils and reheat coils
  - Condensate from the heat exchangers is collected in condensate receivers located in the MERs and pumped back to the SASP. Condensate pumps have variable frequency drives (VFD).
- Multiple pumps circulate HHW from the shell and tube heat exchangers to heating coils in various MERs
  - Smaller horsepower pumps (typically less than 10 hp) are constant flow

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  - Larger horsepower pumps (typically 10 hp or greater) are controlled by VFDs in response to differential pressure across the loop
- Peak HHW supply temperatures, generally, range from 160°F to 190°F

Central Cooling System

- Chilled water (CHW) is supplied to the building from the central chilled water plant through blending stations that serve multiple CHW loops
  - Secondary pumps circulate CHW from the blending stations to cooling coils in various MERs
  - Larger horsepower pumps are controlled by VFDs in response to differential pressure across the loop

Air Handling Units

- Major systems and equipment date to the original construction, are generally in poor condition, and have exceeded their useful life
- There are [redacted]

OA Temperature (°F)	Fan Speed (%)	OA Temperature (°F)	Fan Speed (%)
[redacted]	[redacted]	[redacted]	[redacted]

- [redacted]

[redacted]

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- [redacted]

Exhaust Systems

- Exhaust fans serve mechanical/electrical rooms, elevator shafts, staircases, toilets, and an exercise room

Zone Heating/Cooling

- Fin tube radiation (FTR) heats perimeter spaces. Two loops serve the North and South exposures of the building. Each loop has dedicated constant speed pumps and separate supply temperature reset schedules.
- Constant volume mixing boxes blend air from the hot and cold ducts to maintain space temperature. AHU cold and hot deck discharge temperature setpoints are set based on a reset schedule.
- BAS operators often change the AHU discharge temperature setpoints in response to occupant comfort complaints.
- Space temperature set points are controlled in the building automation system

HVAC Controls

Building Automation System

- Honeywell Enterprise Building Integrator (EBI) building automation system (BAS) is used for monitoring, direct digital control (DDC), and energy management of HVAC systems
- All valves, dampers, and other control devices have pneumatic actuators with electric to pneumatic transducers that convert the BAS control signal to a proportional pneumatic pressure

Operating Schedules

- HVAC systems are typically scheduled to operate [redacted] on weekdays. They typically do not operate on weekends unless specifically requested through OGS.
- [redacted] the schedules were extended to operate an additional two hours in the morning and evening. It is unclear if space temperature is setback during unoccupied periods, or if the systems can cycle on to meet unoccupied mode setpoints.
- Single zone AHUs serving the hearing rooms are typically off except for scheduled events, OGS must be contacted to schedule units

Energy Saving Control Strategies

- HW supply temperature reset based on outdoor air temperature
- Supply air temperature is reset based on outdoor air temperature on some units. Reset schedule varies by unit.
- There are no zone level controls for the FTR. The FTR loops are activated when the outdoor air temperature falls below 60°F. The HW supply temperature is reset based on outdoor air temperature.
- Supply and return fan speeds are reset based on outside air temperature

[redacted]
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- Enthalpy economizer controls exist on all major air handling units, but many of the dampers are not functional

Domestic/Service Water Heating

Domestic Water Heaters
- Multiple semi-instantaneous domestic water heaters (DWH-A) generate DHW from LPS for the building's plumbing fixtures

DHW Load
- The DHW load comes from toilet hand sinks, kitchenettes, and janitor closets

Piping and Ductwork

Piping Systems/Insulation
- Piping systems observed during the walk-through appeared to be well insulated

Air Distribution Systems/Insulation
- Ductwork was not accessible to observe insulation levels

Equipment Insulation
- Heat exchangers and tanks are well insulated

Piping and Ductwork Leaks
- No obvious piping or ductwork leaks were observed during the building walk-through

Miscellaneous Loads and Specialty Systems

Plug Loads
- The building has typical office plug loads such as computers, monitors, laptops, chargers, printers, and desk lamps, as well as mini fridges, microwaves, and space heaters
- The building has a data center with two Libert units

Renewable Energy Systems

- No renewable energy systems exist

Mission Critical Systems

- Emergency power is supplied by emergency generators at the SASP to life safety systems in each building
  - These systems include some lighting, limited elevator motors, freeze protection, fire pumps and limited computer server areas

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Water Systems

- No major water using systems related to Hudson River and municipal sources of water are used in building HVAC processes

Initial Hazardous Materials Assessment

- Asbestos is reportedly present in structural fire proofing above ceiling tiles

Potential Energy Efficiency Measures (EEMs)

- Add zone controls to FTR. Ramboll observed instances where the FTR was overheating the space due to lack of zone control, and the dual duct AHUs were providing cold air to cool the space to meet the space temperature setpoint.
- Replace all major AHUs, corresponding ductwork, and terminal reheat coils
  - Multizone AHUs should consider the following features:
    - Multizone variable air volume (VAV) systems with VAV terminal boxes and hot water reheat coils
    - Supply fan motors controlled by VFDs to maintain duct static pressure setpoint
    - Duct static pressure reset controls
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
  - Single zone AHUs should consider the following features:
    - Temperature based control of supply fan VFD speed. The supply fan speed and discharge temperature would be controlled to satisfy the space temperature setpoint.
    - Demand controlled ventilation on units with high ventilation loads, such as the hearing rooms
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
  - Consider alternative HVAC systems for deep energy retrofits, such as
    - Dedicated outdoor air systems (DOAS) with energy recovery
    - Active chilled beams
- Install occupancy-based controls on HVAC systems to allow for automatic setback of space temperature setpoints in unoccupied zones during normal occupied mode periods. This measure would also provide occupied mode setpoints during unoccupied mode periods when the zone is occupied (*e.g.*, during nighttime housekeeping).
- Implement differential pressure reset on variable speed pumping systems
- BAS Optimization—survey existing BAS to identify opportunities for improved operations and energy savings (*e.g.,* sequence of operation changes, operating schedules, setpoints, reset schedules).
- Add discriminator controls to reset the hot deck discharge air temperature based on mixing box request for hot deck air flow
- Convert dual duct systems to variable air volume systems

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EMPIRE STATE PLAZA | MAIN PLATFORM BUILDING ASSESSMENT

Building Description

Building Name: Main Platform

Year Constructed: Approximately 1970

No. of Floors: 1 + parking levels

Est. GSF: 3,878,694

Major Renovations

- 1994: Cafeteria Renovation
- 1997: Parking Garage Rehab
- 2019: Electric Vehicle Charging Stations

Functional Description

The Main Platform is comprised of the concourse, commercial space, food court, a large convention hall with multiple meeting rooms, and New York State Agency office space. Each building on the plaza is accessible through the concourse. There are three levels of parking below the Main Platform. While the platform is mostly underground, there is street level access at Madison Avenue.

Number of Occupants

The Main Platform is mainly transient occupancy.

Occupancy Patterns

The concourse is accessible 24/7, while the rest of the spaces in the Main Platform are based on the tenant, typically normal business hours 8 a.m. to 4 p.m.

Space Function Summary

Table 1. Space Function Summary (Estimated)

	Parking	Mixed Use Property
Original Intended Use	Parking	Mixed Use Property
Gross Floor Area (GSF)	2,909,021	969,674
% of Total GSF	75%	25%
% Heated	0%	100%
% Cooled	0%	100%
Number of Occupants	-	Transient
Typical Occupancy Pattern	M-F 6 a.m. to 6 p.m.	M-F 7 a.m. to 5 p.m.

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	Parking	Mixed Use Property
Principal HVAC Type	Ventilation Only	Constant Volume AHU
Principal Lighting Type	Fluorescent T8/Super T8	Fluorescent T8/Super T8

Building Envelope

Roof

- There is no roof exposed to exterior conditions. The Main Platform is underground, directly below the exterior plaza. It is unclear from the original drawings if the ceiling is insulated.

Exterior Walls

- From the original construction drawings, exterior walls are poured concrete with a layer of 1" unknown insulation, metal furring, and plaster and wire lath finish on the interior

Windows

- Metal frame storefront windows at the Madison entranceway and bus turn entranceway dating to the original construction

Exterior Doors

- Metal frame swinging doors and rotary doors at the Madison entranceway and bus turn entranceway dating to the original construction

Air Infiltration/Leakage

- No noticeable signs of excessive infiltration

Utilities

Electricity

- Electricity is supplied to the plaza through [redacted] feeders from National Grid
- [redacted] high voltage primary distribution transformers step down the voltage [redacted] and distribution switchgear supplies power to substations throughout the plaza
- The plaza distribution power is stepped down [redacted] to 480/277 V at various substations which supply power to the buildings

Natural Gas

- The building has no natural gas service

District Steam

- High pressure steam (HPS) at 150 psig is supplied to the building from the Sheridan Avenue Steam Plant (SASP) and reduced to low pressure steam (LPS) at the building (about 10 psig) through pressure reducing stations
- LPS is used to generate heating hot water (HHW) and domestic hot water (DHW) through multiple shell and tube heat exchangers

[redacted]

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District Chilled Water

- Chilled water is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations

Metering

Utility Feeds and Meters

- The Plaza has one main National Grid utility account meter under SC-3A Transmission and Delivery Service tariff

Submeters

- The main platform has numerous submeters that are aggregated to provide the total building electric consumption
- Chilled water blending stations are submetered to continuously monitor thermal energy. The Main Platform contains multiple blending stations that provide chilled water to equipment in various mechanical/electrical rooms (MER).
- Steam flow is submetered to continuously monitor thermal energy. HPS is metered just prior to the pressure reducing stations.
- All electric and thermal submeter data is automatically collected by OGS's Web Enabled Advanced Metering (WEAM) system

Lighting

Interior Fixture Types

- The interior lighting system is mainly comprised of linear T8 fluorescent fixtures.

Interior Lighting Controls

- Lighting is scheduled through building automation system
- Occupancy sensors were observed in mechanical spaces

Exterior Lighting

- All exterior lights at the Plaza have been recently replaced with LED technology
- Exterior lighting is scheduled through building automation system, and typically operate from 4:15 p.m. to 11:30 p.m. every day.

HVAC

Central Heating System

- High pressure steam is piped from the SASP to the building where it is reduced to low pressure steam. The LPS is used to generate heating hot water (HHW) and domestic hot water (DHW) through shell and tube heat exchangers.
  - Multiple shell and tube heat exchangers generate HHW from the LPS for AHU heating coils and reheat coils
  - Condensate from the heat exchangers is collected in condensate receivers located in the MERs and pumped back to the SASP. Condensate pumps have variable frequency drives (VFD).

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- Multiple pumps circulate HHW from the shell and tube heat exchangers to heating coils in various MERs.
  - Smaller horsepower pumps (typically less than 10 hp) are constant flow
  - Larger horsepower pumps (typically 10 hp or greater) are controlled by VFDs in response to differential pressure across the loop
- HHW supply temperature is reset based on outdoor air temperature and varies by loop. Peak HHW supply temperatures, generally, range from 160°F to 190°F.

Central Cooling System

- Chilled water (CHW) is supplied to the building from the central chilled water plant through blending stations that serve multiple CHW loops
  - Secondary pumps circulate CHW from the blending stations to cooling coils in various MERs
  - Larger horsepower pumps are controlled by VFDs in response to differential pressure across the loop

Air Handling Units

- Major systems and equipment date to the original construction, are generally in poor condition, and have exceeded their useful life
- There are [redacted]

OA Temperature (°F)	Fan Speed (%)
[redacted]	[redacted]

OA Temperature (°F)	Fan Speed (%)
[redacted]	[redacted]

[redacted]

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- [redacted]

Exhaust Systems

- The parking garage is ventilated by numerous supply and exhaust fans controlled by VFDs. [redacted]

[redacted]

- Each location has carbon monoxide (CO) and nitrous oxide (NOx) sensors. When the sensors are reading above the setpoint limit, fans come on individually at 30% speed until the sensor is below the setpoint. If the sensor is still reading above the setpoint, all fans in that group will increase by 5% increments until the levels fall below the setpoint.
- Garage ventilation supplied through a large intake air shaft [redacted] and exhausted through a smaller air shaft

Zone Heating/Cooling

- Constant volume terminal boxes with hot water reheat coils serve individual building zones to maintain space temperature at setpoint.
- Zone reheat discharge temperature is reset based on space temperature, as shown in the typical reset scheme below

[redacted]

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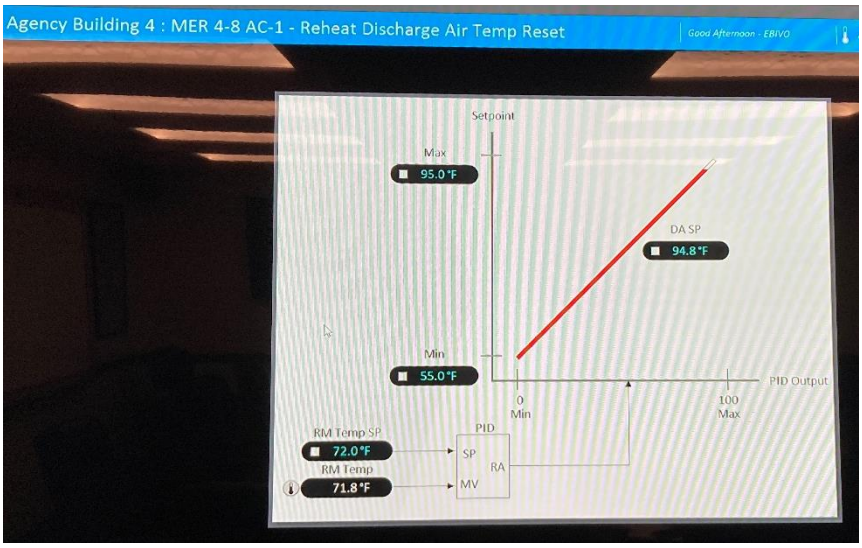

HVAC Controls

Building Automation System

- Honeywell Enterprise Building Integrator (EBI) building automation system (BAS) is used for monitoring, direct digital control (DDC), and energy management of HVAC systems
- All valves, dampers, and other control devices have pneumatic actuators with electric to pneumatic transducers that convert the BAS control signal to a proportional pneumatic pressure

Operating Schedules

- HVAC systems are typically scheduled to operate in occupied mode [redacted], but the schedules were extended to operate an additional two hours in the morning and evening. It is unclear if space temperature is setback during unoccupied periods, or if the systems can cycle on to meet unoccupied mode setpoints.

Energy Saving Control Strategies

- HHW supply temperature is reset based on outdoor air temperature. Reset schedule varies by loop.
- Supply air temperature is reset based on outdoor air temperature on some units. Reset schedule varies by unit.
- BAS operators often change the AHU discharge temperature setpoints and reset schedules in response to occupant comfort complaints
- Enthalpy economizer controls exist on all major air handling units, but many of the dampers are not functional

Domestic/Service Water Heating

Domestic Water Heaters

- Multiple semi-instantaneous domestic water heaters (DWH-A) generate DHW from LPS for the building's plumbing fixtures.

[redacted]
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DHW Load
- The DHW load comes from toilet hand sinks, janitor closets and multiple food court vendors.

Piping and Ductwork

Piping Systems/Insulation
- Piping systems observed during the walk-through appeared to be well insulated

Air Distribution Systems/Insulation
- Ductwork was not accessible to observe insulation levels

Equipment Insulation
- Heat exchangers and tanks are well insulated

Piping and Ductwork Leaks
- No obvious piping or ductwork leaks were observed during the building walk-through

Miscellaneous Loads and Specialty Systems

Plug Loads
- Retail tenants have point of sale equipment, signs, and computers
- Tenant office space has typical office plug loads such as computers, monitors, laptops, chargers, printers, and desk lamps
- There are multiple food court vendors with kitchen equipment
- Pumps for the outdoor plaza reflecting pools

Compressed Air
- Compressed air for pneumatic actuators is piped to the MERs from the CACP
- Air compressors for pneumatic controls were observed in some mechanical rooms, but are no longer in operation

Ice Rink
- During the winter months, the Plaza has an outdoor ice rink.
- Two 125-ton York chillers with R-22 refrigerant generate chilled glycol for ice making. The chillers are in the CACP.

Renewable Energy Systems

- No renewable energy systems exist

Mission Critical Systems

- No mission critical systems exist in the Main Platform
- Emergency power is supplied by emergency generators at the SASP to life safety systems in each building

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  - These systems include some lighting, limited elevator motors, freeze protection, fire pumps and limited computer server areas

Water Systems

- No major water using systems related to Hudson River and municipal sources of water are used in building HVAC processes

Initial Hazardous Materials Assessment

- Asbestos is reportedly present in structural fire proofing above ceiling tiles

Potential Energy Efficiency Measures (EEMs)

- Replace all major AHUs, corresponding ductwork, and terminal reheat coils
  - Multizone AHUs should consider the following features:
    - Multizone variable air volume (VAV) systems with VAV terminal boxes and hot water reheat coils
    - Supply fan motors controlled by VFDs to maintain duct static pressure setpoint
    - Duct static pressure reset controls
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
  - Single zone AHUs should consider the following features:
    - Temperature based control of supply fan VFD speed. The supply fan speed and discharge temperature would be controlled to satisfy the space temperature setpoint.
    - Demand controlled ventilation on units with high ventilation loads, such as the concourse and convention hall AHUs
    - Enthalpy economizer controls
    - Two-way valves on all AHU and terminal reheat coils
    - Electric actuators for direct digital control
  - Consider alternative HVAC systems for deep energy retrofits, such as
    - Dedicated outdoor air systems (DOAS) with energy recovery
    - Active chilled beams
- Install occupancy-based controls on tenant HVAC systems to allow for automatic setback of space temperature setpoints in unoccupied zones during normal occupied mode periods. This measure would also provide occupied mode setpoints during unoccupied mode periods when the zone is occupied (*e.g.*, during nighttime housekeeping).
- Implement differential pressure reset on variable speed pumping systems
- BAS Optimization—survey existing BAS to identify opportunities for improved operations and energy savings (*e.g.,* sequence of operation changes, operating schedules, setpoints, reset schedules).

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EMPIRE STATE PLAZA | ALFRED E. SMITH OFFICE BUILDING | BUILDING ASSESSMENT

Building Description

Building Name: Alfred E. Smith Office Building

Year Constructed: 1928

No. of Floors: 33 + Basement + Cellar

Est. GSF: 598,866

Recent Building Upgrades
- AHU VFDs replacement
- NYPA LED retrofit (scheduled for 2025, currently in 90% design phase)

Functional Description
Alfred E. Smith Office Building serves as office space for several NYS agencies, including NYS Division of Criminal Justice Services, NYS Liquor Authority, NYS Commission of Correction, NYS Department of State Office, NYS Office for the Prevention of Domestic Violence, NYS Office of Victim Services, NYS Senate, NYS Assembly, etc.

Occupancy Patterns
The building is typically occupied from 6 a.m. to 6 p.m. on weekdays

Building Envelope

Roof
- Copper roof at the top of the structure
- Built-up roof with concrete deck on floors 11 and 21
- Roof insulation type and levels not accessible during walk-through

Exterior Walls
- Metal frame with blocks
- Exterior wall insulation type and levels not accessible during walk-through

Floors/Foundation
- Concrete above unconditioned crawlspace (often referred to as "the cellar")

Windows
- Most areas have metal-framed with thermal break, double-glazed operable windows with internal blinds

Doors
- Building main entrance has 4 doors

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- Two sets of single-glazed swinging doors
  - Two revolving doors
- One set of double-glazed swinging doors on each side and at the back of the building
- One automatic overhead door at the back of the building

Air Infiltration/Leakage
- No excessive air infiltration/leakage was observed during the walk-through

Utilities

Electricity
- Electricity is supplied to the plaza through four [redacted] feeders from National Grid
  - [redacted] primary distribution transformers step down the incoming voltage to [redacted]
  - Various electrical rooms house the building's main switchgear from an incoming [redacted] feed and various disconnect switches
    - Several building-level transformers further step down the [redacted] service to distribution voltages [redacted]

District Steam
- The building is supplied by high-pressure steam (HPS) from the Sheridan Avenue Steam Plant (SASP) at around 150 psig. There are various pressure reducing stations that convert to medium-pressure steam (MPS) at ~60 psig and low-pressure steam (LPS) at ~10 psig.
- MPS and LPS are used to generate heating hot water (HW) for induction units and AHU coils. LPS is generally used for domestic hot water (DHW) production.
- Condensate pumps are located throughout the building in the mechanical rooms (MERs), circulating condensate to a collection tank in the cellar
  - Three pairs of constant speed 15-HP condensate pumps circulate condensate from the collection tank back to the SASP

District Chilled Water
- District chilled water (CHW) is supplied directly to the building from the Central Air Conditioning Plant (CACP) through blending stations

Metering

Submeters
- Electricity, district steam, and district CHW are metered at the building level

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Lighting

Interior Fixture Types

Table 1. Interior Lighting Fixtures

Fixture Type	Lamp Type	Area Served	Estimated % Area
Cove light	Linear T5 fluorescent	Office, hallway	45
9" recessed can	CFL plug-in bulbs	Office, hallway, conference rooms	45
4' pendant shop light	Linear T5 fluorescent	MERs, 32nd and 33rd floor	7
Decorative pendant	CFL plug-in bulbs	Lobby	3

Interior Lighting Controls

- Interior lighting is controlled mainly via the Building Automation System (BAS)
  - Interior lights turn on and off daily according to the schedule programmed in the BAS
  - There is a manual timer on each floor that can be used to override the schedule
  - Additional occupancy sensors located in conference rooms

Exterior Lighting

- Building-mounted exterior lighting consists of wall-mount light-emitting diode (LED) wall packs, LED lighting for special events, and pendant/pedestal lights with CFL bulbs
  - Exterior lighting at the main entrance was on during the walkthrough, which occurred during the daytime

Exterior Lighting Controls

- Building-mounted exterior lighting is controlled via timeclock
- Special event LED lights are controlled manually

HVAC

Central Heating System

- Building receives district steam from the SASP
  - Steam valves are manually turn off during the summer
- Three shell-and-tube heat exchangers HE-1, HE-2, HE-3 convert LPS to heating hot water (HW)
  - These three heat exchangers are connected to a two-pipe system with seasonal changeover
    - Shares two-pipe system with chilled water (CHW) heat exchangers
  - Three pumps P-6, P-7, and P-8, circulate HW and/or secondary CHW to perimeter induction units serving Zone 1 (Northwest perimeter, 1st to 20th floor) and Zone 2 (Southeast perimeter, 1st to 20th floor)
- Three shell-and-tube heat exchangers HE-4, HE-5, HE-6 convert LPS to heating HW
  - These three heat exchangers are also connected to a two-pipe system with seasonal changeover
    - Shares two-pipe system with chilled water (CHW) heat exchangers
  - Three pumps P-9, P-10, and P-11 circulate HW and/or secondary CHW to perimeter induction units serving Zone 3 (North perimeter, 1st to 11th floor) and Zone 4 (South perimeter, 1st to 11th floor)

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- Two shell-and-tube heat exchangers HE-7 and HE-8 convert LPS to heating HW
  - These two heat exchangers are connected to a two-pipe system with seasonal changeover
    - Shares two-pipe system with chilled water (CHW) heat exchangers
  - Two pumps, P-4 and P-5, circulate HW and/or secondary CHW to perimeter induction units serving Zone 5, which covers 22nd to 33rd floor perimeter spaces
- One shell-and-tube heat exchanger HE-9 converts LPS to heating HW
  - One pump, P-1, circulates HW to bathroom fin tube radiation units between 1st and 11th floor
- One shell-and-tube heat exchanger HE-10 converts LPS to heating HW
  - Two pumps, P-2 and P-2A, circulate HW to convectors and fin tube radiation units between 12th and 33rd floors
- Piping insulation observations
  - No missing and damaged heating system piping insulation observed during walk-through
- Equipment insulation observations
  - No missing or damaged equipment insulation observed during walk-through
- Piping leak observations
  - No piping leaks observed during walk-through

Table 2. Heating System Heat Exchangers

Tag	Type	Service
HE-1, HE-2, HE-3	Shell-and-tube, LPS to HW	Two-pipe system, serves Zone 1 and Zone 2 perimeter cabinet system
HE-4, HE-5, HE-6	Shell-and-tube, LPS to HW	Two-pipe system, serves Zone 3 and Zone 4 perimeter cabinet system
HE-7, HE-8	Shell-and-tube, LPS to HW	Two-pipe system, serves Zone 5 perimeter cabinet system
HE-9	Shell-and-tube, LPS to HW	Fin tube radiation, 1st to 11th floor
HE-10	Shell-and-tube, LPS to HW	Fin tube radiation, 12th to 33rd floor

Table 3. Heating System Pumps

Tag	Service	Motor HP	GPM	Head (ft)	Control
P-6	HW/CHW	10	750	108	Lead/Lag, VFD
P-7	HW/CHW	30	575	121	Lead/Lag, VFD
P-8	HW/CHW	10	750	108	Lead/Lag, VFD
P-9	HW/CHW	25	450	110	Lead/Lag, VFD
P-10	HW/CHW	30	575	-	Lead/Lag, VFD
P-11	HW/CHW	30	575	105	Lead/Lag, VFD
P-4, P-5	HW/CHW	15	-	-	Lead/Lag, VFD
P-1	HW	-	-	-	Lead/Lag, VFD
P-2, P-2A	HW	3	-	-	Lead/Lag

Central Cooling System

- Building receives central CHW from the CACP via the blending station located in the cellar

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  - Two pumps, P-1 and P-2, boost CHW from the plaza primary CHW loop to the building, which supplies CHW to the two-pipe systems and the AHU coils
- Four plate-and-frame heat exchangers HE-20, HE-21, HE-22, and HE-23 generate secondary CHW
  - These four heat exchangers are part of the two-pipe system that serves Zone 1 and Zone 2 perimeter induction system via pumps P-6, P-7, and P-8 as described in Central Heating System above
- Four plate-and-frame heat exchangers HE-24, HE-25, HE-26, and HE-27 generate secondary CHW
  - These four heat exchangers are part of the two-pipe system that serves Zone 3 and Zone 4 perimeter induction system via pumps P-9, P-10, and P-11 as described in Central Heating System above
- Two plate & frame heat exchangers HE-28 and HE-29 generate secondary CHW
  - These two heat exchangers are part of the two-pipe system that serves Zone 5 perimeter induction system via pumps P-4 and P-5 as described in Central Heating System above
- Piping insulation observations
  - No missing or damaged piping insulation observed during walk-through
- Equipment insulation observations
  - No missing or damaged equipment insulation observed during walk-through
- Piping leak observations
  - No leaking observed during walk-through

Table 4. Cooling System Heat Exchangers

Tag	Type	Service
HE-20, HE-21, HE-22, HE-23	Plate-and-frame, CHW to sec CHW	Two-pipe system, serves Zone 1 and Zone 2 perimeter cabinet system
HE-24, HE-25, HE-26, HE-27	Plate-and-frame, CHW to sec CHW	Two-pipe system, serves Zone 3 and Zone 4 perimeter cabinet system
HE-28, HE-29	Plate-and-frame, CHW to sec CHW	Two-pipe system, serves Zone 5 perimeter cabinet system

Table 5. Cooling System Pumps

Tag	Service	Motor HP	GPM	Head (ft)	Control
P-1, P-2	Primary CHW	125	3100	110	Lead/Lag, VFD

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Air Handling Units

- Control strategy
  - All dampers and control valves associated with the AHUs are electric actuated
  - [redacted]

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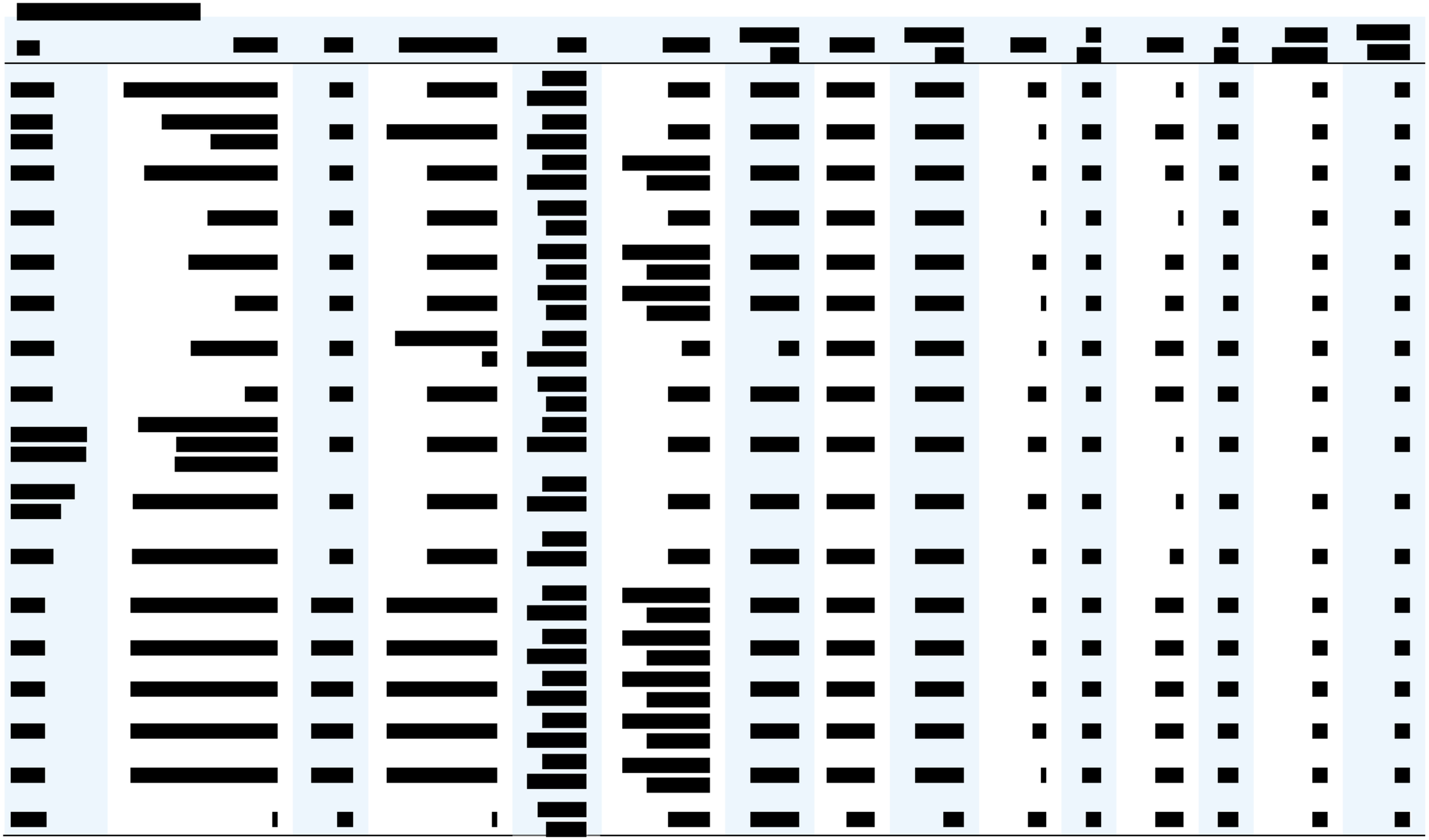

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Exhaust Systems
- Constant speed exhaust fans serve various spaces
- TX2 serves bathrooms on all floors
  - EF-CN-1 and EF-CN-2 serve CAPNET room
  - EF-TR-1 serves trash room
  - EF-PS-1 serves print storage
  - TX-21-1 and TX-21-2 serve washrooms
  - Several other exhaust fans were observed to serve mechanical spaces during walkthrough

Zone Heating/Cooling
- Perimeter induction system serves perimeter office spaces on most floors
  - Heating HW and CHW supplied to the induction system has supply temperature reset controls based on OAT and space temperature for summer and winter, daytime and nighttime
- Finned tube radiators serve bathroom on all floors
  - Heating HW has supply temperature reset controls based on OAT
- Diffusers serve core hallway, office space, and conference room
- Split units serve radio room and elevator machine rooms
- Fan coil units serve telecom rooms, cellar electrical room, and the lobby
- Steam unit heaters serve space heating to MERs

HVAC Controls

Building Automation System
- Honeywell EBI building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of the central heating systems and air handling units

Operating Schedules
- Most AHUs are scheduled to operate [redacted] on weekdays
- PAC units are scheduled to operate [redacted] on weekdays
- AHU-5A is scheduled to operate 24/7 (for the fingerprint office)

Domestic/Service Water Heating

Domestic Water Heaters
- Three Patterson-Kelly steam semi-instantaneous water heaters provide domestic HW to the building
  - Each heater has a fractional circulation pump
  - Two domestic HW pumps DHWP-1, DHWP-2 are both 7.5HP and controlled by VFDs

DHW Load
- Bathroom hand sinks
- Break room kitchenette sinks

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Miscellaneous Loads

Plug Loads

- Offices: computers or laptops, desk phones, desk lamps, printers, etc.
- Conference rooms: computers or laptops, monitors, projectors, etc.
- Breakrooms: microwaves, refrigerators, coffee machines, etc.
- Café: coffee machine, commercial beverage fridges, ice freezer, etc.
- Security check point: computers, turnstiles, etc.

Elevators

- Sixteen Otis elevators, ranging 38-47HP, serve the building
  - Four of them serve 1st-11th floor (low-rise section)
  - Six of them serve 1st, 11th-20th floor (mid-rise section)
  - Six of them serve 1st, 20th-31st floor (high-rise section)
- One freight elevator serves between the basement and the 31st floor
- One freight elevator serves between the basement and the 28th floor

Specialty Systems

Air Compressors

- One air compressor supplies compressed air to control systems in the building

Dehumidifiers

- Two dehumidifiers serve the building, controlled by the BAS
  - Bry-Air dehumidifiers (tag DH-1)
    - Model MP-600, serial no. 2005E7719
    - 600 CFM, heater input 14.1 kW
    - 1-hp process blower motor and reactivation blower motor

Domestic Cold Water Booster Pumps

- Three domestic water pumps DCWP-1, DCWP-2, DCWP-3 circulate domestic cold water to the building
  - All three pumps are 30HP and controlled by VFDs
  - Three additional fractional recirculation pumps in the loop

Potential Energy Efficiency Measures (EEMs)

No Cost/Low-Cost Measures

- Retro-commissioning of HVAC systems and controls
  - Optimize HW and CHW supply temperature reset control
  - Optimize supply air temperature reset controls
- Implement pump differential pressure reset controls on the induction system HW and CHW pumps P-4 to P-11

Capital Measures

- Continue replacing interior light fixtures with LED light fixtures as per the NYPA LED Retrofit project
- Replace exterior light fixtures with LED fixtures

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- Install variable frequency drives (VFD) on AHU-B4 and AHU-B5 supply and return fans
- Convert constant volume single-zone (CVSZ) systems AHU-B16 and AHU-L1 to single-zone variable air volume (VAV) systems by installing VFDs on the system and implementing a temperature-based control scheme to modulate airflow
  - Implement demand control ventilation in the lobby served by AHU-L1
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Consider replacing direct steam heating coils and perimeter steam units with hot water

O&M Measures

- Repair missing insulation and leaking on PAC-5 CHW coil
- Turn off exterior lights during daytime
- Participate in a steam trap survey and repair program
- Change any remaining v-belt fan drives to cogged belt fan drives

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EMPIRE STATE PLAZA| NYS CAPITOL | BUILDING ASSESSMENT

Building Description

Building name: NYS Capitol Bldg.

Year Constructed: 1867, not finished until 1899

No. of floors: 7 total- 5 main floors, 1 basement, 1 small storage room attic

Est. GSF: 572,025

Recent building upgrades

- Planned renovation for the staircase and entranceway on east side of the building
- CHW HX upgrade
- NYPA lighting project to convert all metal halide exterior lights to LED

Functional description

The New York state Capitol building is the home of the New York state government. The building is part of the Empire State Plaza complex and is on State Street. It holds a Senate and Assembly Chambers and is primarily office and conference spaces. There are also museum spaces and grand staircases that are commonly shown for tours.

Occupancy patterns

- Building is open to the public 7:00am to 7:00pm, Monday through Friday
  - Typically occupied by employees from 9:00am to 7:00pm
  - [redacted]
- Occupancy patterns change from January to June when the legislature is in session

General notes

Building envelope

Roof

- Shingles/shake
- Insulation type and levels not accessible during walkthrough

Exterior walls

- Stone walls, granite, and marble
- Insulation type and levels not accessible during walkthrough

Floors/foundation

- Concrete (above conditioned space)

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Windows

- Single-paned windows throughout
  - Some are operable with casement or hopper style
  - Employees are encouraged to leave them shut
- Stain glass windows in 3rd floor senate and assembly chambers

Doors

- Swinging and revolving
- Wood, Metal, Glass

Air infiltration/leakage

- Some air infiltration was observed through poorly sealed windows

Building envelope notes

- Corridors have approximately 15-20 foot-tall ceilings
- Chambers have roughly 40 foot-tall ceilings

Utilities

Electricity

[redacted]

- Electricity is stepped down to 120/208 V

District Steam

- 150 psig high-pressure steam (HPS) generated at the Sheridan Ave Steam Plant (SASP) enters the building [redacted] is reduced to medium-pressure steam (MPS) for heat exchangers (HXs) and low-pressure steam (LPS) for steam heating coils in air handling units (AHUs), steam radiators, and other zone equipment for space heating
- Steam is also utilized by domestic hot water (DHW) heat exchangers, [redacted]

District Chilled Water (CHW)

- Chilled water (CHW) generated at the Central Air Conditioning Plant (CACP) [redacted] and serves plate and frame heat exchangers [redacted] to supply the CHW cooling coils in AHUs and fan coil units (FCUs) throughout the building.
  [redacted]

City Water

- Two (2x) city water feeds into the building
- One (1x) high pressure feed – older system
- One (1x) low pressure feed – newer system
  - Load is mainly for hand sinks, utility sinks.

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Metering

Utility Feeds and Meters

- The two city water feeds into the building feature a meter owned by the local water authority

Submeters

- Electricity, district steam, district chilled water are metered at the building level
  - The electric submeter is located in the main basement mechanical room
  - Locations of other submeters were not noted during the building walkthrough

Lighting

Interior fixture types

Table 1. Interior lighting fixtures

Fixture type	Lamp type	Area served	Estimated % area
Decorative pendant/chandelier	Fluorescent bulbs	Corridors	20
Recessed	Compact Fluorescents (CFL)	Corridors	20
Indirect hanging fixture	T8 Fluorescent	Offices	40
Indirect hanging fixture	LED	Offices	20

Interior lighting controls

- Manual switch controls all lights
- All on during the day and turned off at night
- Many unoccupied rooms had lights on, many lights were observed to be out

Exterior lighting

- NYPA lighting project began in 2021 to convert metal halide lights to LED

Table 2. Exterior lighting fixtures

Fixture type	Lamp type	Area served
Decorative streetlamp	Compact Fluorescent (CFL)	Sidewalks and steps
Flood lamps	LED	Façade lighting

Exterior lighting controls

- The plaza site exterior lighting is scheduled through the BAS

HVAC

Central heating system

- District steam enters the building [redacted] where it is reduced to MPS and LPS for building distribution
- MPS pressure setpoint reset based on LPS valve position
  - At a LPS 10% valve position, the MPS pressure set point is 18 psig

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        - The MPS pressure setpoint increases linearly until the LPS valve position reaches 70% where the MPS pressure setpoint is fixed at 22 psig
        - At the time of walk-through, LPS valve position was 100% with a MPS pressure setpoint of 22 psig and 10 psig LPS setpoint
    - 5th floor also has a separate pressure reducing valve (PRV) station with reset based on outdoor air (OA) temperature
        - The pressure setpoint decreases linearly as temperature increases. The pressure reduces from 6 psig at 0° F to 4 psig at temperatures 60° F and above.
- MPS supplies two (2x) heat exchangers (HX), HX-1, HX-2 located in the basement MER
- Shell and tube, MPS-to-heating hot water (HW)
    - Two (x2) pneumatic steam valves on each
    - Three (x3) HW pumps (one is disconnected) on VFD control
        - HW pumping system is enabled at 65°F; HWP-3 only runs when OA temp is below 20°F
        - Services FCUs, and some HW heating coils in AHUs
- LPS is utilized by domestic hot water (DHW) heaters, air handling unit (AHU) heating coils, unit heaters, fan coil units (FCUs), and HX-3 for the radiant floor loop
- HPS, MPS and LPS alarms visible on BAS
- Hot water reset
    - The hot water setpoint decreases linearly as the outside air temperature increases
        - At an OA temperature of 10° F and below, the HW supply setpoint is 170° F and decreases linearly to 80° F for OA temperatures 60° F and above
- Piping insulation observations
    - Missing and damaged insulation was observed on some steam piping in the mechanical rooms during the walk-through
- Equipment insulation observations
    - Damaged insulation was observed in some heat exchangers during the walk-through
- Piping leak observations
    - No pipe leaking was observed on the heating side of the system

Table 3. Heating system heat exchangers

Tag	Type	Service	Notes
HX-1	Shell and Tube, Steam-to-HW	AHU coils, FCUs	MPS, P-1 feeding the system
HX-2	Shell and Tube, Steam-to-HW	AHU coils, FCUs	MPS, P-2 feeding the system
HX-3	Shell and Tube, Steam-to-HW	HWS radiant floor loop	LPS, Not observed during site-walkthrough

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Table 4. Heating system pumps

Tag	Service	Pump motor HP	Pump control	GPM	Head (ft)	Notes
P-1	HX-1	25	VFD	--	--	Located in large MER in basement
P 2	HX-2	25	VFD	--	--	Identical to P-1
P-3	HX-1/2	25	VFD	--	--	Disconnected
Superheat pump	HW	Fractional	On/off	--	--	One of two
HX-1 Condensate pump 1	HX-1	2	On/off	--	--	Packaged pump system with condensate tank
HX-2 Condensate pump 2	HX-2	2	On/off	--	--	Identical to condensate pump 1
CR-1	HX-1 system	Fractional	On/off	--	--	Packaged pump system with condensate tank
CR-2	HX-2 system	Fractional	On/off	--	--	Identical to CR-1
DHW HX - Condensate pump 1	DHW HX-1	2	On/off	--	--	Packaged pump system with condensate tank
DHW HX - Condensate pump 2	DHW HX-2	2	On/off	--	--	Identical to condensate pump 1
DHW HX - CR-1	DHW HX-1 system	Fractional	On/off	--	--	Packaged pump system with condensate tank
DHW HX - CR-2	DHW HX-2 system	Fractional	On/off	--	--	Identical to DHW HX- CR-1
HWP-1	HW from Convertor-1/2		VFD	--	--	Not noted during site walkthrough
HWP-2	HW from Convertor-1/2		VFD	--	--	Not noted during site walkthrough, Identical to HWP-1
HWP-3	HW from Convertor-1/2		VFD	--	--	Not noted during site walkthrough, Identical to HWP-1

Central cooling system

- District CHW serves plate & frame heat exchangers [redacted] to generate building-level CHW
  - One CHW HX operates as the lead, the others are staged into operation as necessary to maintain the secondary CHW differential pressure setpoint

[redacted]

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[redacted]

- Chilled water reset
  - The CHW setpoint decreases linearly as the return water temperature increases and is offset by the OA temperature
    - At a return water temperature of 50° F and below, the CHW supply setpoint is 55° F and decreases linearly to 42.4° F for CHW return temperatures 56° F and above
      - If the OA temperature is 20° F or below, 3° F will be added to the CHW set point, and if the OA temperature is 90° F or higher, 0° F will be added to the setpoint from above
- Piping insulation observations
  - Damaged insulation was observed on some CHW piping in the mechanical rooms during the walk-through
- Equipment insulation observations
  - Damaged insulation was observed on some heat exchangers during the walk-through
- Piping leak observations
  - Significant leaking on PWP-1
  - Some water was observed on the mechanical room floor around CHW systems

Table 5. Cooling system heat exchangers

Tag	Type	Service	Size	Units	Notes
EDP CHW HX	Plate and frame (Water-Water)	EDP (Electric Data Processing)	--	--	Torn insulation, Located in Room 12
CHW HX-1	Plate and frame (Water-Water)	CHW for building	--	--	Located in Room 9
CHW HX-2	Plate and frame (Water-Water)	CHW for building	--	--	Located in Room 12
CHW HX-3	Plate and frame (Water-Water)	CHW for building	--	--	Located in Room 11
CHW HX-4	Plate and frame (Water-Water)	CHW for building	--	--	Located in Room 10

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Table 6. Cooling system pumps

Tag	Service	Pump motor HP	Pump control	GPM	Head (ft)	Notes
PWP-1	Primary CHWS	15	VFD	450	75	Located in Room 9, significant leaking
PWP-2	Primary CHWS	15	VFD	450	75	Located in Room 12
PWP-3	Primary CHWS	15	VFD	450	75	Located in Room 11
PWP-4	Primary CHWS	15	VFD	450	75	Located in Room 10
SCWP-1	Secondary CHWS	30	VFD	450	155	Located in Room 9
SCWP-2	Secondary CHWS	30	VFD	450	155	Located in Room 12
SCWP-3	Secondary CHWS	30	VFD	450	155	Located in Room 11
SCWP-4	Secondary CHWS	30	VFD	450	155	Located in Room 10
PP-EDP	CHW supply pump for EDP CHW HX	-	VFD	-	-	Located in ceiling, Room 12
SP-EDP	CHW return pump from EDP CHW HX	-	On/off	-	-	Located in ceiling, Room 12

Air handling units

- There are [redacted]

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Exhaust systems

- Small exhaust systems provide general building exhaust
    - Located in basement mechanical rooms, rooftop and other MERs throughout the building

Zone heating/cooling

- Most spaces in building are conditioned by the AHUs
  - Diffusers distribute air received from AHUs
- Additional perimeter heating is provided via radiators
  - Radiators are steam with pneumatic-controlled valves
- Variable air volume (VAV) boxes serve some spaces on 2nd and 3rd floors
  - Governor's office wing is served by several VAV boxes
- One zone in this wing has an electric reheat unit
- Two (x2) pipe & four pipe fan coil units (FCU) also provide additional zone conditioning
  - Mostly located below windows
    - Significant condensation on windows was observed during the walkthrough
  - All have integral controllers (off/low/medium/high)
  - Units are mostly a mix of steam and hot water heating coils
- Four (x4) FCUs service the four corners of the basement
  - All on on/off switches
  - Nameplates not accessible during site walkthrough
- Window AC units located in basement maintenance offices
- Elevator rooms are supplied by dedicated ductless-split systems
  - Mechanical room for elevator 7/8 served by mini-split system with roof top condensing unit
- Occupants contact building managers to request space temperature adjustments

HVAC controls

Controls/building automation system

- Honeywell EBI building automation system (BAS) used for monitoring, direct digital control (DDC), and energy management of all HVAC systems in the building

Operating schedules

- Summer/winter and occupancy schedules are used in a majority of the building's HVAC systems
  - AHUs and zone heating/cooling equipment feature temperature setbacks dictated by programmed occupancy schedules set in the BAS
  - [redacted]

Domestic/service water heating

Domestic water heaters

- Two (x2) domestic hot water heaters
  - LPS to HW, semi-instantaneous water heater
  - One (x1) is a 1000 L capacity heater

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- Nameplate not visible on the other unit

Table 7. Domestic Hot Water Table

Tag	Type	Service	Capacity	Notes
DHW HX #1	Steam-to-HW	-	1000 L	Plate and Frame
DHW HX #2	Steam-to-HW	-	-	Plate and Frame

DHW load

- Bathroom hand sinks

Miscellaneous loads

Plug loads

- Printers, coffee makers, minifridges, computers, desk phones, desk lamps, vacuums, toaster ovens, portable fans, display monitors, vending machines

Elevators

Table 8. Elevators

Type	Qty	Motor HP	Floor served
Hydraulic	6	40 HP	Concourse to 5th floor,
Hydraulic	2	-	Basement to 5th floor
Hydraulic	1	-	Governor's office, floors 1-2

Specialty systems

Air Compressors

- Compressed air is received from three large compressors at the Sheraton Center, and is backed up by one unit in the Capitol building
  - Atlas Copco SF-15 air compressor serving the building
    - Two (x2) 100SCFM capacity Airtek compressed air dryers serve this compressor

Emergency Generators

- [redacted] back-up generators located at the Sheraton provide backup power to the building

Other systems

- One CHW-HX Serves Electric Data Processing Room
- Fire protection system
  - Main pump with 125HP motor
  - Jockey pump with 2HP motor

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- System appears to be in good condition

Potential energy efficiency measures (EEMs)

No cost/low cost measures

- Retro-commission of HVAC systems and controls
  - Scheduling of HVAC equipment and space temperature setbacks
  - Optimize HW supply temperature reset control
  - Optimize CHW supply temperature reset control
  - Optimize supply air temperature reset controls
- If not already implemented, implement pump differential pressure reset controls on the CHW and secondary loop pumps
- If not already implemented, implement differential pressure reset for HW system

Capital measures

- Replace single-glazed windows with high performance windows
- Replace interior fluorescent light fixtures with LED fixtures
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces, especially in corridors, conference rooms, and break rooms
- Replace pneumatic actuators with electric actuator
- Convert pneumatic zone controls to DDC
  - Install occupancy-based HVAC controls to allow for automatic setback of space temperature setpoints in unoccupied zones during normal occupied mode periods
  - As an alternative to converting zone controls to DDC, wireless pneumatic thermostats could be installed and used to schedule space temperature setbacks during unoccupied hours
- Consider replacing direct steam heating coils and perimeter steam units with hot water
- Replace constant volume dual duct AHU systems with VAV systems at the end of their useful life
- Replace existing constant volume single-zone (CVSZ) air handling unit systems with new single-zone variable air volume (VAV) systems at systems' end of useful life

O&M measures

- Change any remaining v-belt fan drives to cogged belt fan drives
- Repair or replace missing and damaged piping, duct, and equipment insulation
- Repair piping and equipment leaks
- Participate in a steam trap survey and repair program

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EMPIRE STATE PLAZA | STATE EDUCATION BUILDING | BUILDING ASSESSMENT

Building Description

Building Name: Education Building (EB), and Education Building Annex (EBA)

Year Constructed: EB: 1908-1912
EBA: Late 1950s

No. of Floors: EB: 6 + Subbasement + Attic
EBA: 10 + Basement + Penthouse

Est. GSF: 750,000

EB, from Washington Ave

EBA, from N Hawk St

Recent Building Upgrades

- EB second floor north and fifth floor north wing renovations (ongoing)
  - Controller and valve upgrades
- EBA district chilled water pumps P-1/P-2 variable frequency drive installation (ongoing)

Functional Description

The State Education Building and Annex are an administrative office building for the New York State Education Department. They are located to the north of the Empire State Plaza (ESP). The EB housed the State Museum and State Library prior to the construction of the Cultural Education Center (CEC) in the 1970s.

Occupancy Patterns

The building is primarily occupied from 7 a.m. to 6 p.m. on weekdays only.

Building Envelope

Roof

- Primarily flat roofs with black EPDM membranes
- EBA has a mechanical penthouse above the roofline
- Roof insulation types and levels were not accessible during the walk-through

Exterior Walls

- Marble façades on the sides of the building facing Swan St, Washington Ave, and Hawk St, and on the side of EBA facing Elk St; brick façades on the sides of the building facing driveways and parking lots, and on the side of EB facing Elk St
- Exterior wall insulation types and levels were not accessible during the walk-through

Floors/Foundation

- Basements

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Windows

- EB has a mix of:
  - Double-pane, wooden frame, fixed windows with and without interior shades or blinds
    - Operable, but have been locked to prevent opening
  - Original, single-pane, wooden frame, single-hung windows with interior shades or blinds
  - Stained-glass windows
  - Curb mount, fixed, pyramid skylights
  - Deck mount, fixed, flat skylights on the pitched portion of the roof
- EBA has a mix of:
  - Double-pane, metal frame, fixed and hopper windows with and without interior shades or blinds
  - Triple-pane, metal frame, fixed and hopper windows with interior blinds

Doors

- EB main entryway doors are revolving, glass, metal frame doors
- EBA main entryway doors are swinging and revolving, glass, metal frame doors

Air Infiltration/Leakage

- No excessive air infiltration/leakage through the building envelope was observed during the walk-through

Utilities

Electricity

- Electricity is delivered to the building by National Grid
  - Service is separate from other buildings at and associated with ESP

Natural Gas

- A natural gas line entering the EBA basement mechanical room previously served a commercial kitchen located on the EBA tenth floor. The kitchen and cafeteria closed during the COVID-19 pandemic and the line has since been capped, and the cooking equipment removed.

District Steam

- The building receives high-pressure district steam from the Sheridan Ave Steam Plant (SASP)
  - District steam enters the building in the EB subbasement. It is reduced to approximately 20 psig medium-pressure steam for building use at a pressure reducing valve (PRV) station and then supplied to six sets of steam-to-hot-water heat exchangers and to two snow melt pits. Low-pressure steam is supplied to domestic hot water (DHW) heaters.

District Chilled Water

- The building receives district chilled water (CHW) from both loops originating at the Central Air Conditioning Plant (CACP): the main loop and the Electronic Data Processing (EDP) loop
  - The main loop provides CHW at approximately 35°F for space cooling in EB and EBA
  - The EDP loop serves mission critical systems in EBA

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District Compressed Air

- The building receives district compressed air from the SASP for pneumatic HVAC controls and a workshop air hose

Metering

Utility Feeds and Meters

- The utility-owned electric meter is located in the EB subbasement
- The out-of-service gas utility meter is located in the EBA basement

Submeters

- District steam and district CHW are metered at the building level

Lighting

Interior Fixture Types

Table 1. Interior Lighting Fixtures

Fixture Type	High Bay	Lamp Type	Space Type	Estimated % Area
Compact Fluorescent	No	Spiral	Mechanical	5
Fluorescent T8	No	Linear	Office, Mechanical	30
LED	No	Dual Basket Troffer	Office	30
LED	No	Standard Bulb, Corn Bulb	Mechanical	5
Low-Pressure Sodium	Yes	Standard Bulb	Corridor, Office	15
Metal Halide	Yes	Standard Bulb	Corridor, Office	15

Interior Lighting Controls

- Interior lighting is controlled primarily via manual switches
- Occupancy sensors were observed in some mechanical rooms
- EB second floor lighting is scheduled through the building automation system (BAS)
  - At the time of the walk-through, EB second floor lights (all ten zones) were scheduled on from 6 a.m. to 10 p.m. on weekdays only

Exterior Fixture Types

- Exterior lighting consists of a mix of high-pressure sodium, incandescent, LED, and metal halide fixtures

Exterior Lighting Controls

- Exterior lighting is controlled via photocells

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HVAC

Central Heating System

- Three pairs of shell & tube steam-to-hot-water heat exchangers generate heating hot water (HW) for air handling unit (AHU) heating coils, reheat coils, and zone equipment in EB
  - 1/3 & 2/3 direct digital control (DDC) steam valves modulate the HW supply temperature from each heat exchanger
    - The HW supply temperature setpoints were 120°F at the time of the July walk-through. HW supply temperature setpoints are manually adjusted through the BAS on a seasonal basis; automatic reset controls are not implemented.
  - [redacted] HW pumps, [redacted] circulate HW throughout EB
    - [redacted]
    - Each pair of EB HW pumps operates as lead/lag
    - [redacted] EB HW pumps have variable frequency drive (VFD) control of pump motor speed based on differential pressure. Differential pressure setpoints are fixed.
    - The EB HW pumping system operates year round
- A packaged heat transfer system consisting of three sets of shell & coil steam-to-hot-water heat exchangers on a shared steam manifold generates HW for AHU heating coils and zone equipment in EBA
  - ELGE Type MD heat exchangers, manufactured in 2006
  - The main HW loop in EBA operates year-round. HW is provided to the two dual-temperature fan coil unit (FCU) loops when the building is operating in winter mode, typically October or November through April or May.
  - Steam valves modulate the HW supply temperature from each heat exchanger
    - The main HW loop supply temperature setpoint was 118°F at the time of the July walk-through. HW supply temperature setpoints are manually adjusted through the BAS on a seasonal basis; automatic reset controls are not implemented.
  - [redacted] HW pumps, [redacted] circulate HW throughout EBA
    - [redacted] operate as lead/lag
    - [redacted] EBA HW pumps have VFD control of pump motor speed based on differential pressure. Differential pressure setpoints are fixed.
    - FCU loop dual-temperature pumps are detailed in the central cooling section below
- Piping insulation observations
  - Damaged insulation was observed on some steam piping in the EB subbasement and on some HW piping in the EBA basement
  - Missing insulation was observed on some HW piping in the EB subbasement
- Equipment insulation observations
  - Missing insulation was observed on some HW pumps in the EB subbasement and in the EBA basement
- Piping leak observations
  - A steam leak was observed near the PRV station in the EB subbasement. A defective flange is reportedly the cause of the leak and is scheduled to be replaced in October.
  - A steam leak was also observed near HX-1 in the EBA basement

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Table 2. Heating System Heat Exchangers

Tag	Type	Service	Size	Units
C-1	Steam-to-HW	AHU Coils, Reheat Coils, Zone Equipment – EB East	--	--
C-2	Steam-to-HW		--	--
C-1	Steam-to-HW	AHU Coils, Reheat Coils, Zone Equipment – EB Center	--	--
C-2	Steam-to-HW		--	--
C-1	Steam-to-HW	AHU Coils, Reheat Coils, Zone Equipment – EB West	--	--
C-2	Steam-to-HW		--	--
HX-1	Steam-to-HW	AHU Coils, Zone Equipment - EBA	--	--
HX-2	Steam-to-HW		--	--
HX-3	Steam-to-HW		--	--

Table 3. Heating System Pumps

Tag	Service	Motor HP	Control	GPM	Head (ft)
P-1	HW – EB East	15	VFD	340	85
P-2	HW – EB East	15	VFD	340	85
P-3	HW – EB Center	15	VFD	340	85
P-4	HW – EB Center	15	VFD	340	85
P-5	HW – EB West	15	VFD	340	85
P-6	HW – EB West	15	VFD	340	85
P-11	HW - EBA	20	VFD	552	75
P-12	HW - EBA	20	VFD	552	75

Central Cooling System

- District CHW enters the building in the EB subbasement
  - [redacted] CHW pumps, [redacted] circulate district CHW throughout EB
    - [redacted] operate as lead/lag. Selection of the lead pump is done manually.
    - [redacted] motors operate at a constant speed
  - [redacted] CHW pumps, [redacted] circulate district CHW to a plate & frame water-to-water heat exchanger [redacted]
    - [redacted] operate as lead/lag. Selection of the lead pump is done manually.
    - [redacted] motors currently operate at a constant speed. A shared VFD is scheduled to be installed in the coming year.
    - Alfa-Laval type A15-BFG heat exchanger, manufactured in 1987
    - [redacted] CHW pumps, [redacted] circulate building-side CHW throughout EBA
      - [redacted] operate as lead/lag
      - Both EBA building side CHW pumps have VFD control of pump motor speed based on differential pressure. Differential pressure setpoints are fixed.

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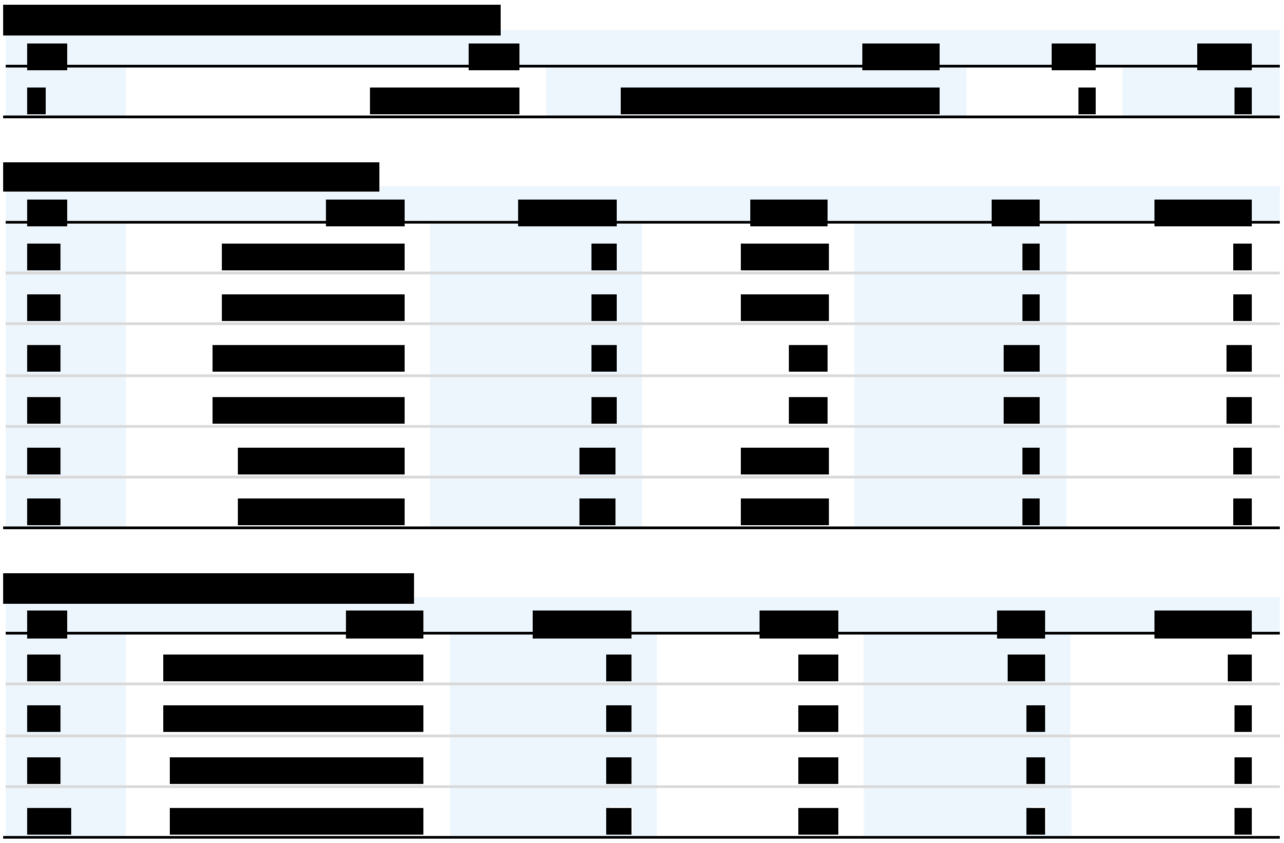
    - [redacted] dual-temperature pumps, [redacted] circulate HW in the winter and CHW in the summer to FCUs throughout EBA
        - [redacted]
        - [redacted] dual-temperature pumps operate as lead/lag
        - [redacted] EBA dual-temperature pumps have VFD control of pump motor speed based on differential pressure. Differential pressure setpoints are fixed.
        - HW/CHW changeover typically occurs in October or November and April or May
- Piping insulation observations
    - Damaged insulation was observed on some CHW piping in the EBA penthouse
- Equipment insulation observations
    - No missing or damaged cooling system equipment insulation was observed during the walk-through
- Piping leak observations
    - No cooling system piping leaks were observed during the walk-through



Condensate System

- The building's primary condensate receiver, located in the EB subbasement, collects and stores medium-pressure condensate return
    - Two primary condensate pumps with 5 horsepower (HP) motors, #1 and #2, return condensate to the SASP
    - Four smaller, secondary condensate return units are also located in the EB subbasement
        - Each unit has two pumps with 1.5HP motors

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    - One smaller, secondary condensate return unit is located in the EBA basement
        - Two pumps with 1 HP motors
- Piping insulation observations
    - Missing and damaged insulation was observed on some condensate piping in the EB subbasement and in the EBA basement
- Equipment insulation observations
    - Missing insulation was observed on the primary condensate pumps in the EB subbasement

Piping leak observations

- No condensate system piping leaks were observed during the walk-through

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Air Handling Units

- Control strategy
  - Most AHUs have VFD control of fan motor speed, but no variable air volume (VAV) boxes or static pressure sensors. VFDs maintain fixed frequencies.
  - Supply air temperature setpoints are fixed
  - Most EB AHUs have:
    - Pneumatic damper actuators
    - Enthalpy-based airside economizers
    - Pneumatically actuated coil control valves
    - Face & bypass dampers
    - Belt-driven fan motors
    - Direct steam injection humidifiers that have been abandoned in place; the building no longer has any spaces with sensitive humidity requirements
  - Most EBA AHUs have:
    - Enthalpy-based airside economizers
    - Electrically actuated coil control valves
  - The Chancellors Hall, an 800-seat auditorium, reportedly does not have to be heated due to its proximity to the district steam distribution tunnels
- Duct insulation observations
  - No missing or damaged duct insulation was observed during the walk-through
- Equipment insulation observations
  - No missing or damaged AHU equipment insulation was observed during the walk-through
- Duct leak observations
  - No duct leaks were observed during the walk-through

[redacted]

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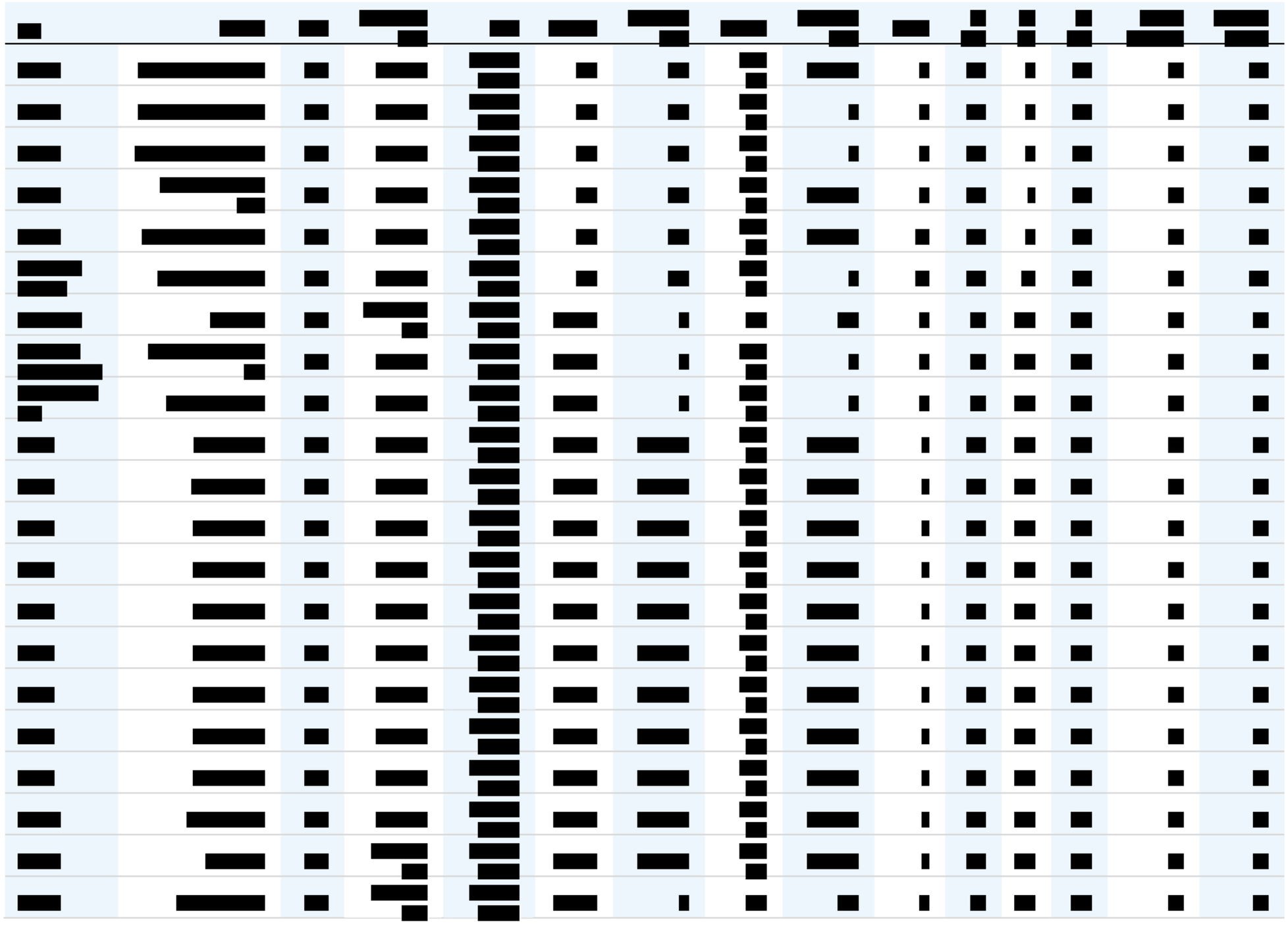

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Exhaust Systems

- Small exhaust fans serve bathrooms and mechanical rooms

Zone Heating/Cooling

- Ceiling diffusers provide airflow to select rooms in EB, interior spaces on the second, third, and fifth floors in EB, and interior spaces on all floors in EBA
  - HW reheat coils provide heating in EB
    - [redacted]
- Four-pipe FCUs provide airflow to the basement, first floor, fourth floor, and additional perimeter spaces in EB
  - EB 2nd floor north wing FCU setpoints are controlled through the BAS
  - Simultaneous heating and cooling appears to be possible in zones served by both AHUs and FCUs with no communication between the system controls
- Two-pipe FCUs provide airflow to all perimeter spaces in EBA
- [redacted]
- HW finned tube radiators provide perimeter heating on the fifth floor
- HW unit heaters and cabinet unit heaters provide heating to mechanical rooms
- One two-pipe FCU serves the EB elevator machine room
  - 100% recirculated air
  - Direct expansion (DX) cooling
  - Space temperature setpoint is controlled through the BAS
- One Mitsubishi Electric split-system heat pump serves the EBA elevator machine room
  - Model PKA indoor unit manufactured in 2015
  - Model PUZ outdoor unit manufactured in 2016
  - R-410A refrigerant
  - Space temperature is controlled through a programmable wall thermostat

HVAC Controls

Building Automation System

- There are generally no local controls in office spaces; ABB BAS is used for monitoring, DDC, and energy management of HVAC systems

Operating Schedules

- The following operating schedules were observed in the BAS. Schedules are manually adjusted on a seasonal basis. At the time of the walk-through, schedules had reportedly been extended for the summer to compensate for extreme heat.
  - [redacted]

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Domestic/Service Water Heating

Domestic Water Heaters

- Electric point-of-use water heaters provide DHW to EBA, and the third through fifth floors in EB
  - One of those observed during the walk-through was a State Industries Model SB6 water heater with a rated capacity of 12,000 W and 20 gallons
- Semi-instantaneous water heaters operating on low-pressure district steam provide DHW to the basement, first, and second floors in EB
  - One of those observed during the walk-through was a AERCO Model B+ 03 water heater manufactured in 1998

DHW Load

- Bathroom hand sinks
- Break room kitchenette sinks
- Utility sinks
- Several showers in the EB basement

Miscellaneous Loads

Plug Loads

- Break rooms: coffee makers, dishwashers, ice makers, microwaves, ranges, refrigerators/freezers, toasters, and toaster ovens
- Conference rooms: computers/laptops, monitors, projectors, etc.
- Convenience store: refrigerators/freezers and registers
- Corridors: monitors and vending machines
- Data centers: server racks
- Offices: computers/laptops, desk phones, printers, etc.
- Training rooms: computers, monitors, printers, and projectors
- Workshop: power tools and portable fans

Elevators

- One freight elevator, car 10, serves all floors in EB
  - Winding drum cable elevator
  - Controller dated 1965
- Four passenger elevators, cars 5 through 8, serve the basement through fifth floors in EB
  - Traction machines
  - 25 HP motors

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- Office floors in EB each have three to five passenger elevators serving the different elevations (mezzanines, exhibit levels) on the floor
  - Hydraulic machines
- One service elevator serves all floors in EBA
  - Haughton Elevator Company Model 33A2621
  - Motor-generator set
  - 25 HP motor
- Four passenger elevators, cars 1 through 4, serve the first through tenth floors in EBA
  - Hollister-Whitney
  - Traction machines
- Wheelchair lifts serve some small staircases in EB

Specialty Systems

Air Compressors

- One air compressor located in the EB subbasement generates compressed air for pneumatic controls in the event compressed air from the district system is unavailable
  - Quincy Model M0C25024D duplex compressor
  - 25 HP motors
  - Hankison Model 80100 air dryer
- A compressed air system located in the EBA penthouse has been abandoned in place

Automatic Fire Pump System

- One main fire pump with a 150 HP motor and one jockey pump serve the building's fire protection system

Snow Melt System

- Snow is pushed from the ground-level loading dock area on the north side of the building into two snow melt pits, which are level with the EB subbasement, and melted using steam
  - Steam valves are turned off and on manually

Potential Energy Efficiency Measures (EEMs)

No Cost/Low-Cost Measures

- Retro-commissioning of HVAC systems and controls
  - Optimize operation of airside economizers
  - Scheduling of HVAC equipment and space temperature setbacks
- Implement HW supply temperature reset control in EB and EBA
- Implement CHW supply temperature reset control in EBA
- Implement pump differential pressure reset controls on the HW pumps in EB and EBA
- Implement pump differential pressure reset controls on the EBA primary CHW pumps when the VFD is installed
- Implement pump differential pressure reset controls on the secondary CHW pumps in EBA
- Implement pump differential pressure reset controls on the dual-temperature pumps in EBA
- Implement supply air temperature reset controls

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- Convert larger constant volume single zone systems EB AHU-10 and Chancellors Hall AHU to single zone VAV systems by installing duct static pressure sensors and implementing temperature-based control schemes to modulate airflow using existing VFDs
- Install low-flow or ultra-low-flow showerheads

Capital Measures

- Replace single pane windows with high performance windows
- Replace interior fluorescent, low-pressure sodium, and metal halide light fixtures with LED fixtures
  - *As outlined in the results of the 2024 lighting audit completed by CDM Smith*
  - Consider onboard occupancy sensor control for individual fixture dimming/staging, or on/off control based on occupancy for public spaces, especially in corridors, conference rooms, and break rooms
  - Consider onboard daylight sensor control for individual fixture dimming/staging based on sensed daylight for public spaces that have adequate daylight harvesting opportunity, such as office spaces on the fifth floor beneath skylights
- Replace exterior incandescent, high-pressure sodium, and metal halide light fixtures with LED fixtures
- Install VFDs on EB district CHW pumps P-7 and P-8
- Replace pump and fan motors with beyond premium efficiency motors at end of useful life
- Consider converting EB constant volume AHUs with existing VFDs to VAV systems by retrofitting HW reheat coils with VAV boxes, installing duct static pressure sensors, and implementing temperature-based control schemes to modulate airflow
- Install occupancy-based HVAC controls to allow for automatic setback of space temperature setpoints in unoccupied zones during normal occupied mode periods
- Replace older fan coil units and include electronically commutated motors
- Consider installing destratification fans on the first through fifth floors in EB
- Replace pneumatic actuators with electric actuators
  - Convert pneumatic zone controls to DDC or use wireless pneumatic thermostats to schedule space temperature setbacks
  - Optimize zone heating and cooling availability to eliminate any simultaneous heating and cooling in EB
- Consider implementing demand control ventilation in the EB Fifth Floor Conference Room, the Chancellors Hall, EB Conference Room 146, and the Regents Room
- Consider integrating the ABB BAS and controls for this building into a single front end with the Honeywell BAS used by all other buildings at ESP

O&M Measures

- Change any v-belt fan drives to cogged belt fan drives
- Repair or replace missing and damaged piping and equipment insulation
- Repair steam piping leaks
- Participate in a steam trap survey and repair program

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Appendix C – EEM Supporting Documents

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Annual Savings			EEM-1 Replace Single Pane Windows	EEM-2 Replace Double Pane Windows	EEM-3 AHU Modernization 1	EEM-4 Lab Exhaust Energy Recovery	EEM-5 Laboratory VAV Exhaust/Supply	EEM-6 Install Occupancy-Based HVAC Controls	EEM-7 Additional Zone Controls on FTR	EEM-8 Laboratory DCV	EEM Package
Building	**Utility**	**Units**									
Agency 1	Electricity	kWh	**0**	2,101	**-5,068**	0	0	**6,118**	0	0	**-11,982**
	Electric Demand	kW	**0**	0	**-24**	0	0	**-1**	0	0	**-14**
	Steam	MMBtu	**0**	1,090	**1,560**	0	0	**430**	0	0	**2,110**
	CHW	MMBtu	**0**	99	**2,517**	0	0	**190**	0	0	**2,729**
	Total	MMBtu	**0**	1,196	**4,060**	0	0	**641**	0	0	**4,798**
	Utility Cost	$	**$0**	$7,968	**$28,755**	$0	$0	**$4,574**	$0	$0	**$33,731**
	Social Cost of Carbo	$	**$0**	$9,599	**$27,885**	$0	$0	**$4,769**	$0	$0	**$33,587**
	Total Cost	$	**$0**	$17,567	**$56,640**	$0	$0	**$9,343**	$0	$0	**$67,318**
Agency 2	Electricity	kWh	**0**	-2,957	**104,177**	0	0	**4,009**	0	0	**102,845**
	Electric Demand	kW	**0**	0	**-6**	0	0	**-1**	0	0	**-6**
	Steam	MMBtu	**0**	1,290	**1,960**	0	0	**250**	0	0	**2,200**
	CHW	MMBtu	**0**	79	**568**	0	0	**180**	0	0	**723**
	Total	MMBtu	**0**	1,359	**2,883**	0	0	**444**	0	0	**3,274**
	Utility Cost	$	**$0**	$8,820	**$23,338**	$0	$0	**$3,198**	$0	$0	**$26,018**
	Social Cost of Carbo	$	**$0**	$11,054	**$21,038**	$0	$0	**$3,197**	$0	$0	**$23,926**
	Total Cost	$	**$0**	$19,874	**$44,376**	$0	$0	**$6,395**	$0	$0	**$49,944**
Agency 3	Electricity	kWh	**0**	5,474	**127,922**	0	0	**6,222**	0	0	**125,556**
	Electric Demand	kW	**0**	0	**-13**	0	0	**-2**	0	0	**-12**
	Steam	MMBtu	**0**	1,240	**5,230**	0	0	**480**	0	0	**5,725**
	CHW	MMBtu	**0**	139	**2,894**	0	0	**259**	0	0	**3,090**
	Total	MMBtu	**0**	1,398	**8,560**	0	0	**760**	0	0	**9,243**
	Utility Cost	$	**$0**	$9,386	**$63,298**	$0	$0	**$5,398**	$0	$0	**$67,865**
	Social Cost of Carbo	$	**$0**	$11,123	**$62,268**	$0	$0	**$5,596**	$0	$0	**$67,487**
	Total Cost	$	**$0**	$20,509	**$125,566**	$0	$0	**$10,994**	$0	$0	**$135,352**
Agency 4	Electricity	kWh	**0**	3,041	**132,640**	0	0	**11,449**	0	0	**130,144**
	Electric Demand	kW	**0**	0	**-5**	0	0	**-1**	0	0	**-7**
	Steam	MMBtu	**0**	1,540	**6,190**	0	0	**740**	0	0	**6,755**
	CHW	MMBtu	**0**	123	**3,742**	0	0	**241**	0	0	**3,897**
	Total	MMBtu	**0**	1,673	**10,385**	0	0	**1,020**	0	0	**11,096**
	Utility Cost	$	**$0**	$11,088	**$76,388**	$0	$0	**$7,252**	$0	$0	**$80,991**
	Social Cost of Carbo	$	**$0**	$13,462	**$75,332**	$0	$0	**$7,704**	$0	$0	**$80,879**
	Total Cost	$	**$0**	$24,550	**$151,720**	$0	$0	**$14,956**	$0	$0	**$161,870**
CEC	Electricity	kWh	**3,933**	17,583	**1,211,475**	0	0	**-336**	483,860	0	**1,271,898**
	Electric Demand	kW	**0**	0	**-79**	0	0	**-1**	0	0	**-60**
	Steam	MMBtu	**1,200**	1,800	**125,740**	0	0	**3,300**	38,300	0	**130,640**
	CHW	MMBtu	**90**	280	**50,900**	0	0	**-1,410**	9,140	0	**51,170**
	Total	MMBtu	**1,303**	2,140	**180,774**	0	0	**1,889**	49,091	0	**186,150**
	Utility Cost	$	**$8,553**	$14,588	**$1,265,518**	$0	$0	**$10,923**	$344,242	$0	**$1,303,148**
	Social Cost of Carbo	$	**$10,477**	$16,754	**$1,358,261**	$0	$0	**$18,701**	$377,155	$0	**$1,401,092**
	Total Cost	$	**$19,030**	$31,342	**$2,623,779**	$0	$0	**$29,624**	$721,397	$0	**$2,704,240**
Corning Tower	Electricity	kWh	**0**	12,719	**368,012**	0	0	**33,178**	0	0	**471,620**
	Electric Demand	kW	**0**	6	**145**	0	0	**22**	0	0	**160**
	Steam	MMBtu	**0**	4,870	**27,600**	0	0	**1,230**	0	0	**31,860**
	CHW	MMBtu	**0**	790	**3,170**	0	0	**140**	0	0	**4,301**
	Total	MMBtu	**0**	5,703	**32,026**	0	0	**1,483**	0	0	**37,770**
	Utility Cost	$	**$0**	$38,346	**$226,959**	$0	$0	**$10,966**	$0	$0	**$268,682**
	Social Cost of Carbo	$	**$0**	$45,024	**$251,551**	$0	$0	**$11,443**	$0	$0	**$294,900**
	Total Cost	$	**$0**	$83,370	**$478,510**	$0	$0	**$22,409**	$0	$0	**$563,582**
Health Lab	Electricity	kWh	**0**	2,319	**0**	-1,771,690	3,111,277	**-7,061**	0	2,801,471	**0**
	Electric Demand	kW	**0**	0	**0**	-233	24	**0**	0	-1	**0**
	Steam	MMBtu	**0**	500	**0**	106,300	8,600	**14,600**	0	8,600	**0**
	CHW	MMBtu	**0**	100	**0**	33,300	7,900	**-2,200**	0	8,000	**0**
	Total	MMBtu	**0**	608	**0**	133,555	27,116	**12,376**	0	26,159	**0**
	Utility Cost	$	**$0**	$4,290	**$0**	$834,030	$287,622	**$77,799**	$0	$270,665	**$0**
	Social Cost of Carbo	$	**$0**	$4,751	**$0**	$1,049,868	$162,730	**$106,905**	$0	$158,901	**$0**
	Total Cost	$	**$0**	$9,041	**$0**	$1,883,898	$450,352	**$184,704**	$0	$429,566	**$0**
Repurposed Health Lab	Electricity	kWh	**0**	**59,998**	**12,728,196**	**0**	**0**	**17,982**	**0**	**0**	**12,746,178**
	Electric Demand	kW	**0**	**11**	**1,269**	**0**	**0**	**9**	**0**	**0**	**1,278**
	Steam	MMBtu	**0**	**567**	**284,517**	**0**	**0**	**555**	**0**	**0**	**285,072**
	CHW	MMBtu	**0**	**260**	**147,561**	**0**	**0**	**120**	**0**	**0**	**147,681**
	Total	MMBtu	**0**	**1,032**	**475,507**	**0**	**0**	**736**	**0**	**0**	**476,243**
	Utility Cost	$	**$0**	**$9,292**	**$3,710,174**	**$0**	**$0**	**$5,796**	**$0**	**$0**	**$3,715,970**
	Social Cost of Carbo	$	**$0**	$7,088	**$3,410,646**	$0	$0	**$5,547**	$0	$0	**$3,416,193**
	Total Cost	$	**$0**	$16,380	**$7,120,820**	$0	$0	**$11,343**	$0	$0	**$7,132,163**
JOB	Electricity	kWh	**0**	46,016	**115,759**	0	0	**53,187**	55,629	0	**109,341**
	Electric Demand	kW	**0**	1	**23**	0	0	**-25**	-34	0	**19**
	Steam	MMBtu	**0**	651	**3,903**	0	0	**892**	180	0	**4,476**
	CHW	MMBtu	**0**	360	**1,176**	0	0	**-49**	-4	0	**1,181**
	Total	MMBtu	**0**	1,168	**5,474**	0	0	**1,024**	366	0	**6,030**
	Utility Cost	$	**$0**	$9,452	**$39,095**	$0	$0	**$4,871**	$630	$0	**$42,472**
	Social Cost of Carbo	$	**$0**	$8,180	**$40,853**	$0	$0	**$7,811**	$2,254	$0	**$45,509**
	Total Cost	$	**$0**	$17,632	**$79,948**	$0	$0	**$12,682**	$2,884	$0	**$87,981**
LOB	Electricity	kWh	**0**	57,042	**689,026**	0	0	**7,879**	62,530	0	**667,402**
	Electric Demand	kW	**0**	-20	**87**	0	0	**-94**	12	0	**91**
	Steam	MMBtu	**0**	2,390	**12,096**	0	0	**1,380**	1,890	0	**13,434**
	CHW	MMBtu	**0**	80	**6,565**	0	0	**30**	90	0	**7,024**
	Total	MMBtu	**0**	2,665	**21,012**	0	0	**1,437**	2,193	0	**22,735**
	Utility Cost	$	**$0**	$18,939	**$170,438**	$0	$0	**$8,561**	$15,204	$0	**$181,226**
	Social Cost of Carbo	$	**$0**	$20,975	**$148,866**	$0	$0	**$11,656**	$16,997	$0	**$162,330**
	Total Cost	$	**$0**	$39,914	**$319,304**	$0	$0	**$20,217**	$32,201	$0	**$343,556**
Swan St	Electricity	kWh	**30,634**	232,471	**1,790,031**	0	0	**22,869**	126,469	0	**1,804,653**
	Electric Demand	kW	**0**	0	**309**	0	0	**-3**	1	0	**311**
	Steam	MMBtu	**500**	4,430	**15,350**	0	0	**2,630**	1,910	0	**16,800**
	CHW	MMBtu	**0**	280	**2,560**	0	0	**490**	70	0	**2,945**
	Total	MMBtu	**605**	5,503	**24,018**	0	0	**3,198**	2,412	0	**25,902**
	Utility Cost	$	**$4,980**	$43,714	**$231,459**	$0	$0	**$22,016**	$19,867	$0	**$243,924**
	Social Cost of Carbo	$	**$4,555**	$41,481	**$167,356**	$0	$0	**$24,924**	$17,955	$0	**$181,816**
	Total Cost	$	**$9,535**	$85,195	**$398,815**	$0	$0	**$46,940**	$37,822	$0	**$425,740**

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Annual Savings			EEM-1 Replace Single Pane Windows	EEM-2 Replace Double Pane Windows	EEM-3 AHU Modernization 1	EEM-4 Lab Exhaust Energy Recovery	EEM-5 Laboratory VAV Exhaust/Supply	EEM-6 Install Occupancy-Based HVAC Controls	EEM-7 Additional Zone Controls on FTR	EEM-8 Laboratory DCV	EEM Package
Building	**Utility**	**Units**									
The Egg	Electricity	kWh	**65,656**	65,656	**1,424,577**	0	0	**37,860**	0	0	**1,441,762**
	Electric Demand	kW	**23**	23	**384**	0	0	**1**	0	0	**386**
	Steam	MMBtu	**10**	10	**9,988**	0	0	**0**	0	0	**10,262**
	CHW	MMBtu	**53**	53	**5,756**	0	0	**4**	0	0	**5,800**
	Total	MMBtu	**287**	287	**20,605**	0	0	**133**	0	0	**20,981**
	Utility Cost	$	**$4,471**	$4,471	**$197,126**	$0	$0	**$2,257**	$0	$0	**$200,246**
	Social Cost of Carbo	$	**$1,339**	$1,339	**$137,169**	$0	$0	**$565**	$0	$0	**$139,935**
	Total Cost	$	**$5,810**	$5,810	**$334,295**	$0	$0	**$2,822**	$0	$0	**$340,181**
Main Platform	Electricity	kWh	**0**	0	**11,273,029**	0	0	**300,868**	0	0	**11,120,835**
	Electric Demand	kW	**0**	0	**2,021**	0	0	**0**	0	0	**1,995**
	Steam	MMBtu	**0**	0	**11,650**	0	0	**3,800**	0	0	**48,450**
	CHW	MMBtu	**0**	0	**25,940**	0	0	**1,030**	0	0	**26,030**
	Total	MMBtu	**0**	0	**76,054**	0	0	**5,857**	0	0	**112,424**
	Utility Cost	$	**$0**	$0	**$957,105**	$0	$0	**$49,267**	$0	$0	**$1,188,306**
	Social Cost of Carbo	$	**$0**	$0	**$412,857**	$0	$0	**$41,775**	$0	$0	**$714,230**
	Total Cost	$	**$0**	$0	**$1,369,962**	$0	$0	**$91,042**	$0	$0	**$1,902,536**
Total	Electricity	kWh	**100,223**	499,144	**29,959,776**	-1,771,690	3,111,277	**501,285**	728,488	2,801,471	**29,980,252**
	Electric Demand	kW	**23**	20	**4,111**	-233	24	**-97**	-21	-1	**4,141**
	Steam	MMBtu	**1,710**	19,878	**505,784**	106,300	8,600	**15,687**	42,280	8,600	**557,784**
	CHW	MMBtu	**143**	2,543	**253,349**	33,300	7,900	**1,225**	9,296	8,000	**256,571**
	Total	MMBtu	**2,195**	24,124	**861,356**	133,555	27,116	**18,622**	54,062	26,159	**916,648**
	Utility Cost	$	**$18,004**	$176,064	**$6,989,653**	$834,030	$287,622	**$135,079**	$379,943	$270,665	**$7,352,579**
	Social Cost of Carbo	$	**$16,372**	$186,079	**$6,114,082**	$1,049,868	$162,730	**$143,688**	$414,360	$158,901	**$6,561,883**
	Total Cost	$	**$34,376**	$362,143	**$13,103,735**	$1,883,898	$450,352	**$278,767**	$794,303	$429,566	**$13,914,462**

Notes:

1. AHU Modernization is a complete replacement of existing air handling units, ductwork, and terminal devices, and includes:
   - Demand controlled ventilation (DCV) where required by code
   - Energy recovery where required by code
   - Direct digital controls (DDC)

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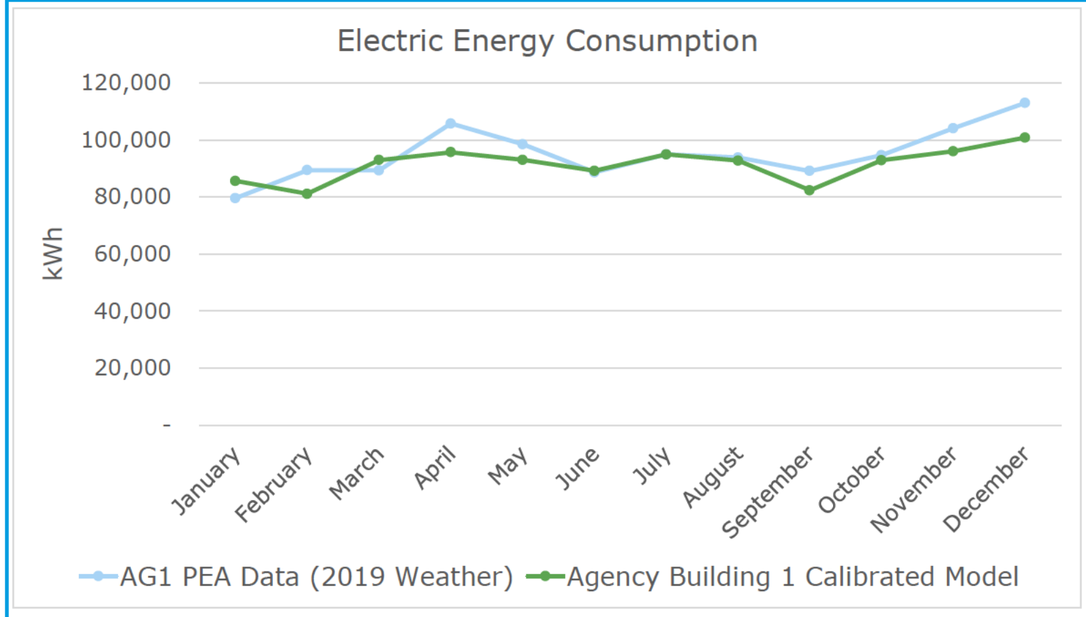
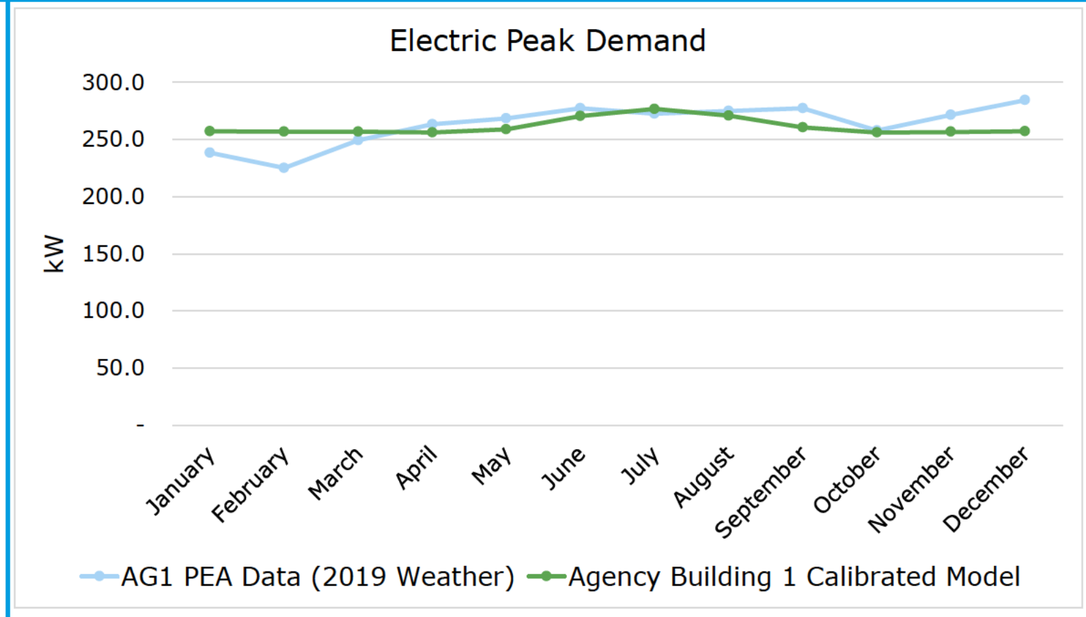
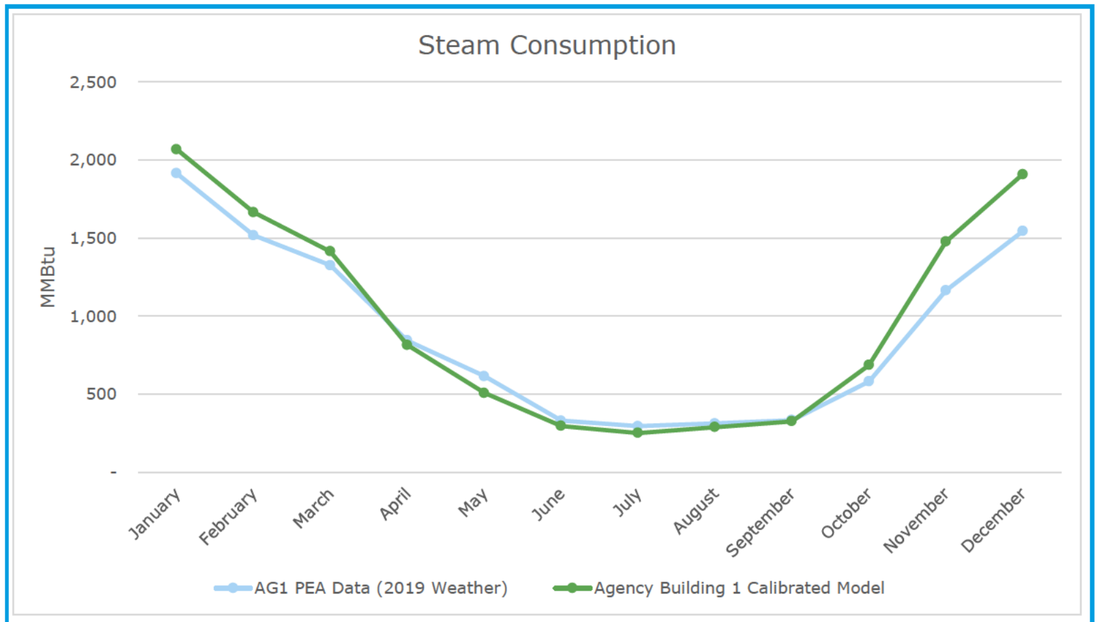
Agency Building 1
Calibration



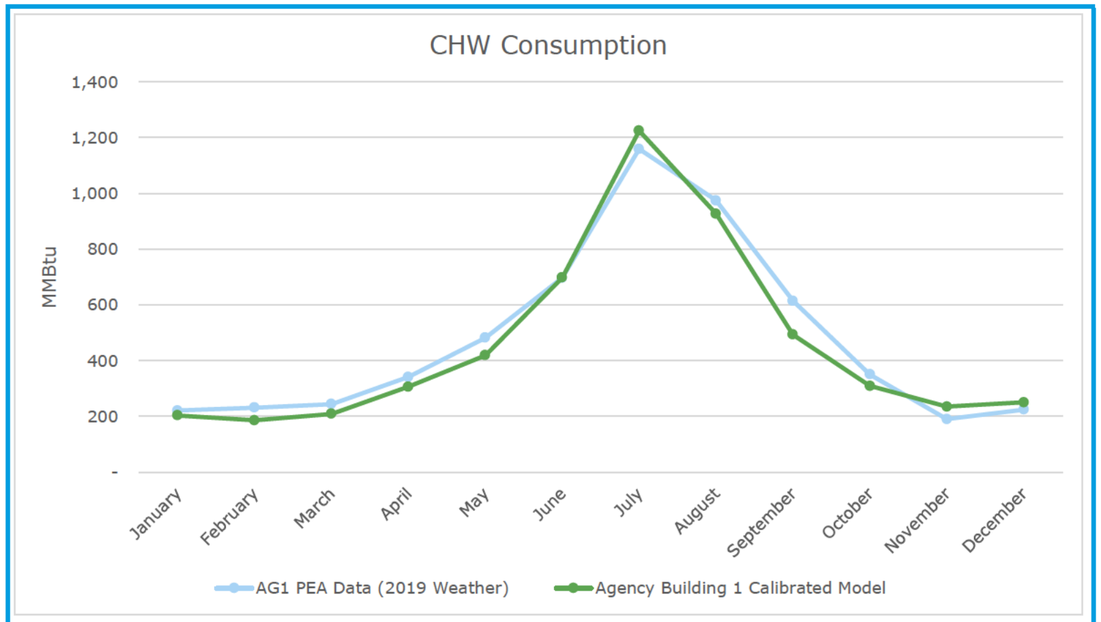
	Limit	Actual
NMBE	5%	4%
CV(RMSE)	15%	7%



	Limit	Actual
NMBE	5%	1%
CV(RMSE)	15%	6%



	Limit	Actual
NMBE	5%	-9%
CV(RMSE)	15%	19%



	Limit	Actual
NMBE	5%	5%
CV(RMSE)	15%	12%

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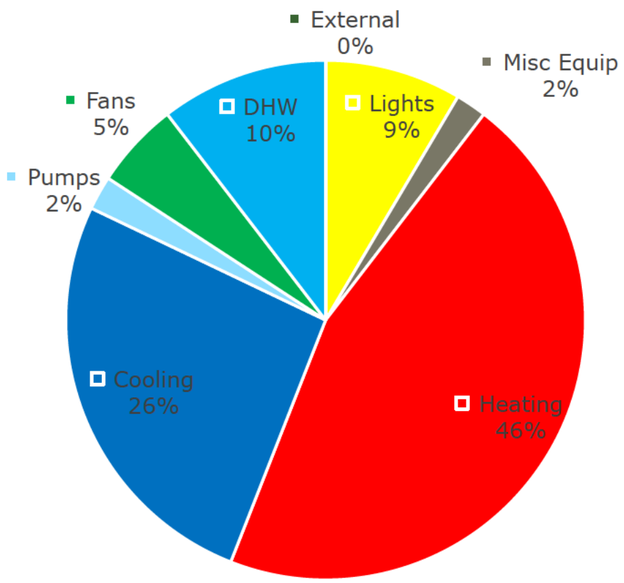
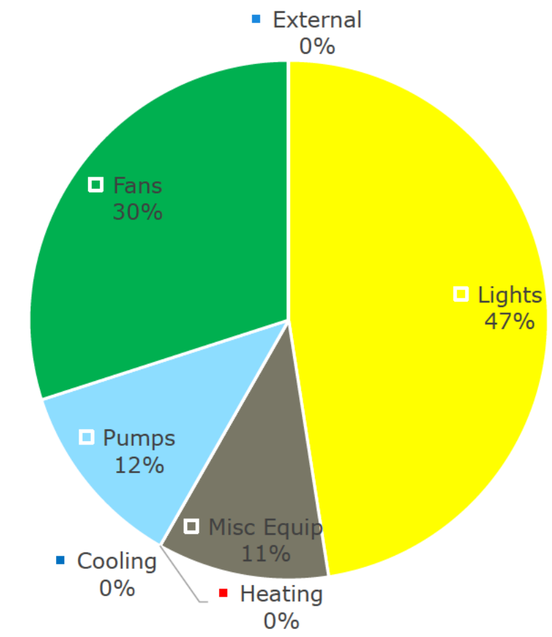
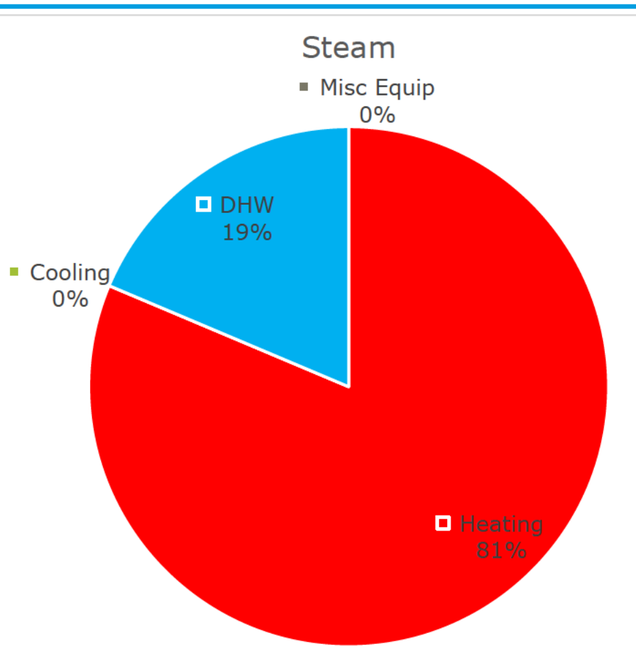
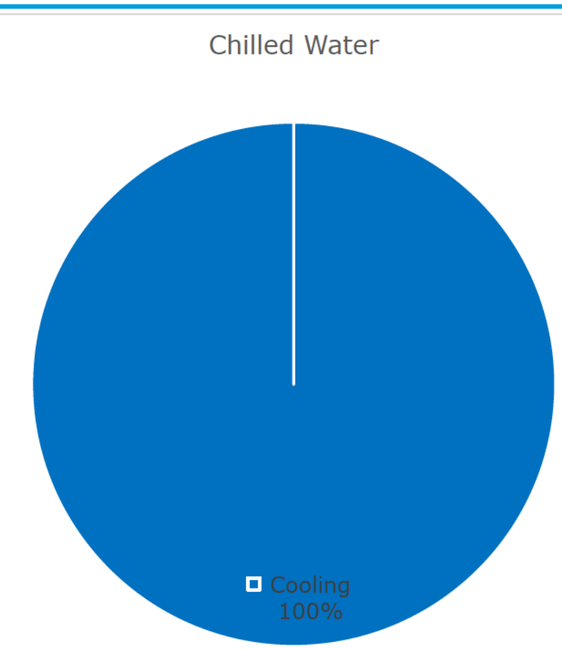
Agency Building 1 Calibrated Model
End Use Summary





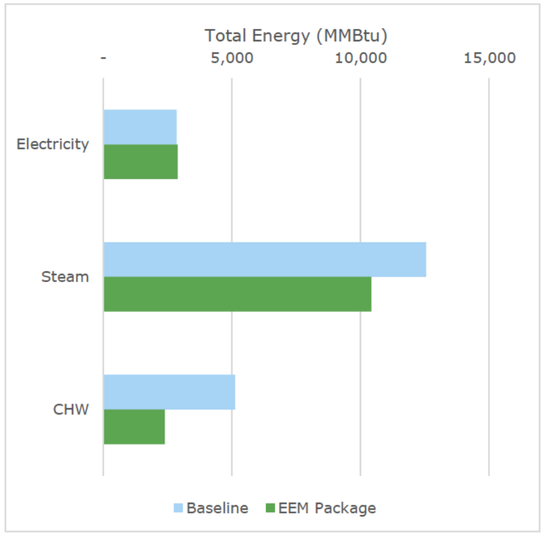


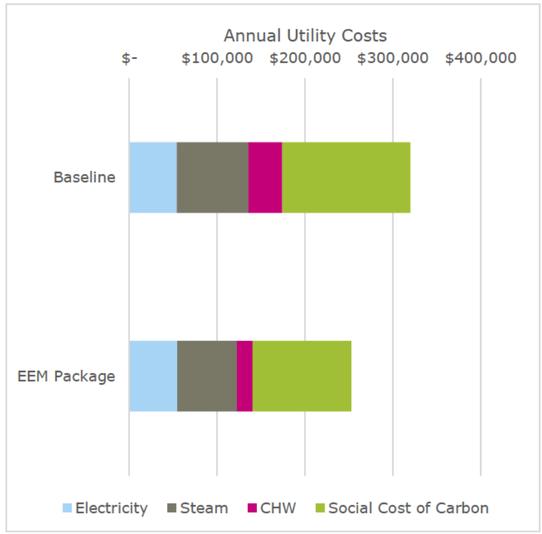


CONFIDENTIAL AND PROPRIETARY

Agency 1 EEM Package Summary

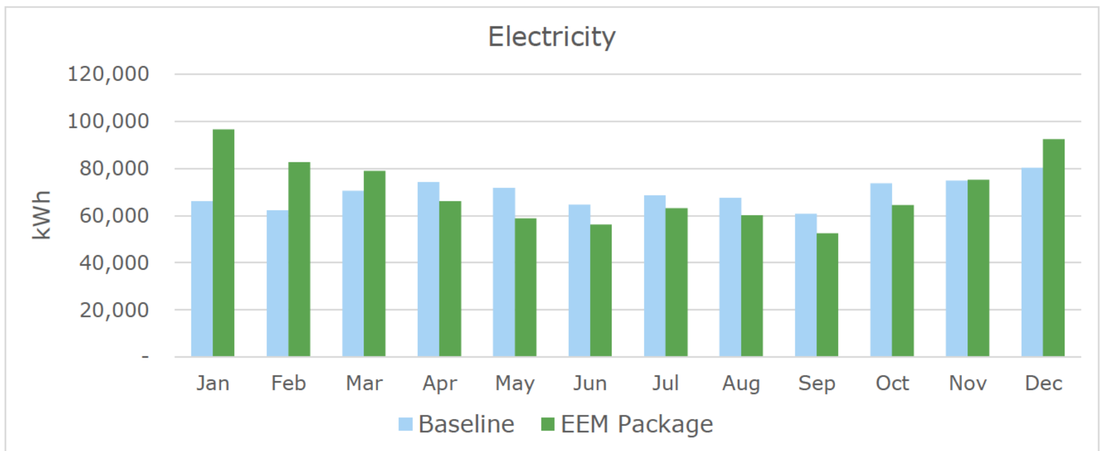
	Units	Baseline	EEM Package	Savings	% Savings
Annual Electric Use	kWh	834,712	846,694	(11,982)	-1.4%
Annual Steam Use	MMBtu	12,530	10,420	2,110	16.8%
Annual CHW Use	MMBtu	5,117	2,388	2,729	53.3%
Annual Total Energy Use	MMBtu	20,495	15,697	4,798	23.4%
EUI	**kBtu/GSF**	**102.9**	**78.8**	**24.1**	**23.4%**
Total Emissions	**MTCO2e**	**1,176**	**905**	**271**	**23.0%**
Annual Electric Cost	$	$ 54,216	$ 54,678	$ (462)	-0.9%
Annual Natural Gas Cost	$	$ -	$ -	$ -	N/A
Annual Steam Cost	$	$ 81,476	$ 67,749	$ 13,727	16.8%
Annual CHW Cost	$	$ 38,375	$ 17,909	$ 20,466	53.3%
Annual Utility Cost	$	$ 174,067	$ 140,336	$ 33,731	19.4%
Social Cost of Carbon	$	$ 145,829	$ 112,242	$ 33,587	23.0%
Annual Combined Cost	**$**	**$ 319,896**	**$ 252,578**	**$ 67,318**	**21.0%**





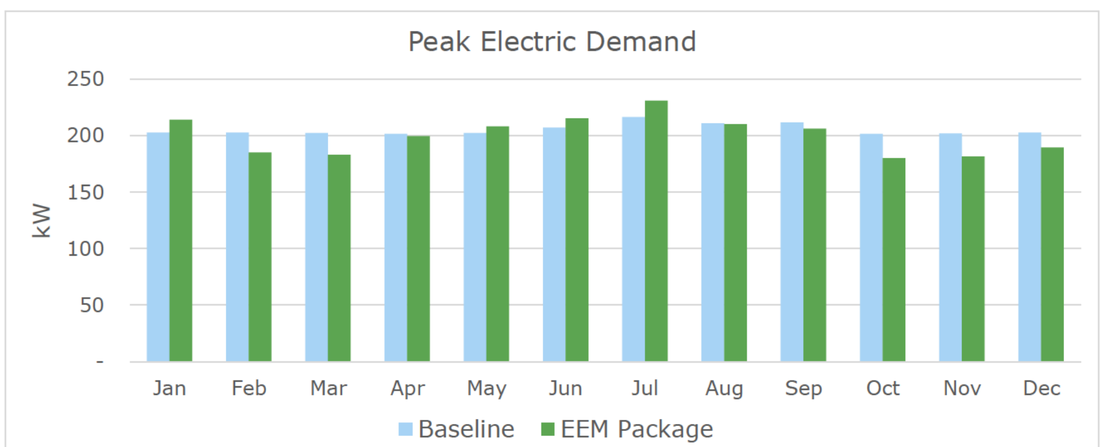
Electric Energy

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kWh	266,110	266,110	-	0.0%
Misc Equip	kWh	117,458	117,458	-	0.0%
Heating	kWh	-	-	-	N/A
Cooling	kWh	-	-	-	N/A
Pumps	kWh	126,961	36,741	90,220	71.1%
Fans	kWh	324,184	426,386	(102,202)	-31.5%
Refrigeration	kWh	-	-	-	N/A
DHW	kWh	-	-	-	N/A
External	kWh	-	-	-	N/A
Total Electric	**kWh**	**834,712**	**846,694**	**(11,982)**	**-1.4%**



Electric Peak Demand

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kW	57.2	57.2	-	0.0%
Misc Equip	kW	28.3	28.3	-	0.0%
Heating	kW	-	-	-	N/A
Cooling	kW	-	-	-	N/A
Pumps	kW	41.5	10.9	30.6	73.7%
Fans	kW	90.4	141.3	(50.9)	-56.3%
Refrigeration	kW	-	-	-	N/A
DHW	kW	-	-	-	N/A
External	kW	-	-	-	N/A
Total kW	**kW**	**216.5**	**230.7**	**(14.3)**	**-6.6%**

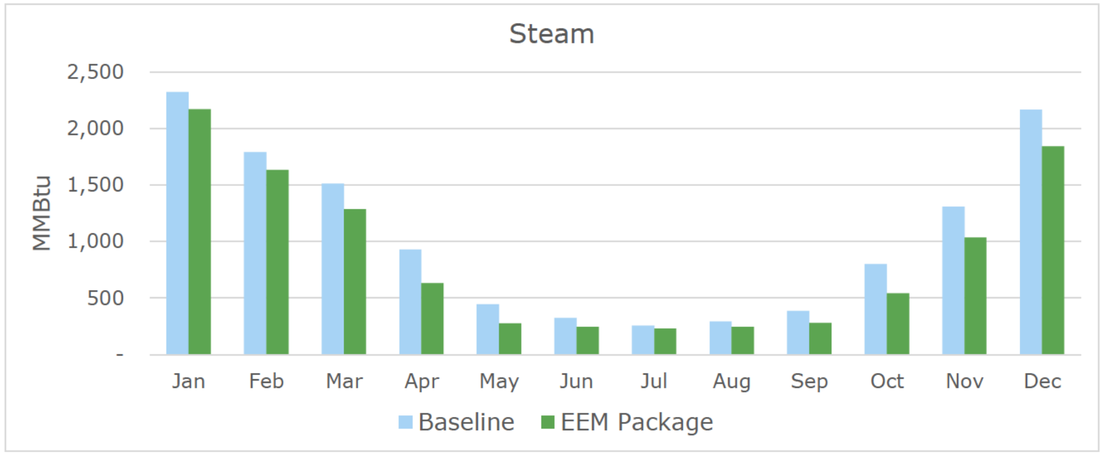


CONFIDENTIAL AND PROPRIETARY

Agency 1 EEM Package Summary (cont.)

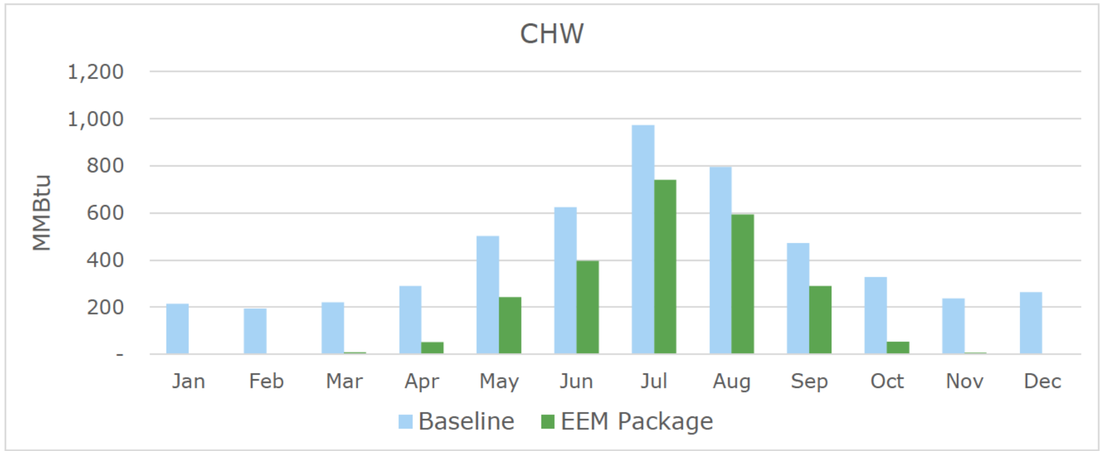
Steam

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	10,300	8,220	2,080	20.2%
Cooling	MMBtu	-	-	-	N/A
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	2,190	2,200	(10)	-0.5%
External	MMBtu	-	-	-	N/A
Total Steam	**MMBtu**	**12,530**	**10,420**	**2,110**	**16.8%**



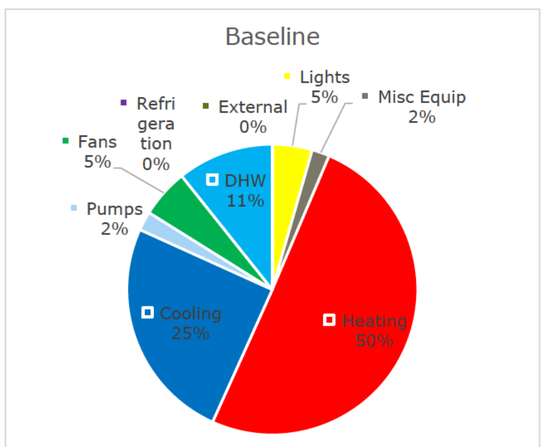
CHW

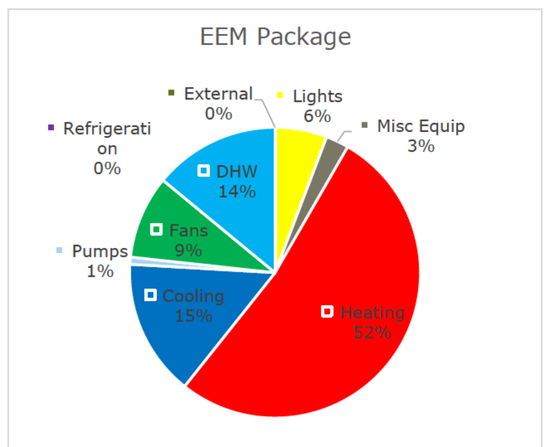
End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	-	-	-	N/A
Cooling	MMBtu	5,120	2,390	2,730	53.3%
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	-	-	-	N/A
External	MMBtu	-	-	-	N/A
Total CHW	**MMBtu**	**5,117**	**2,388**	**2,729**	**53.3%**



All Utilities

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	908	908	-	0.0%
Misc Equip	MMBtu	401	401	-	0.0%
Heating	MMBtu	10,300	8,220	2,080	20.2%
Cooling	MMBtu	5,120	2,390	2,730	53.3%
Pumps	MMBtu	433	125	308	71.1%
Fans	MMBtu	1,106	1,455	(349)	-31.5%
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	2,190	2,200	(10)	-0.5%
External	MMBtu	-	-	-	N/A
Total	**MMBtu**	**20,495**	**15,697**	**4,798**	**23.4%**





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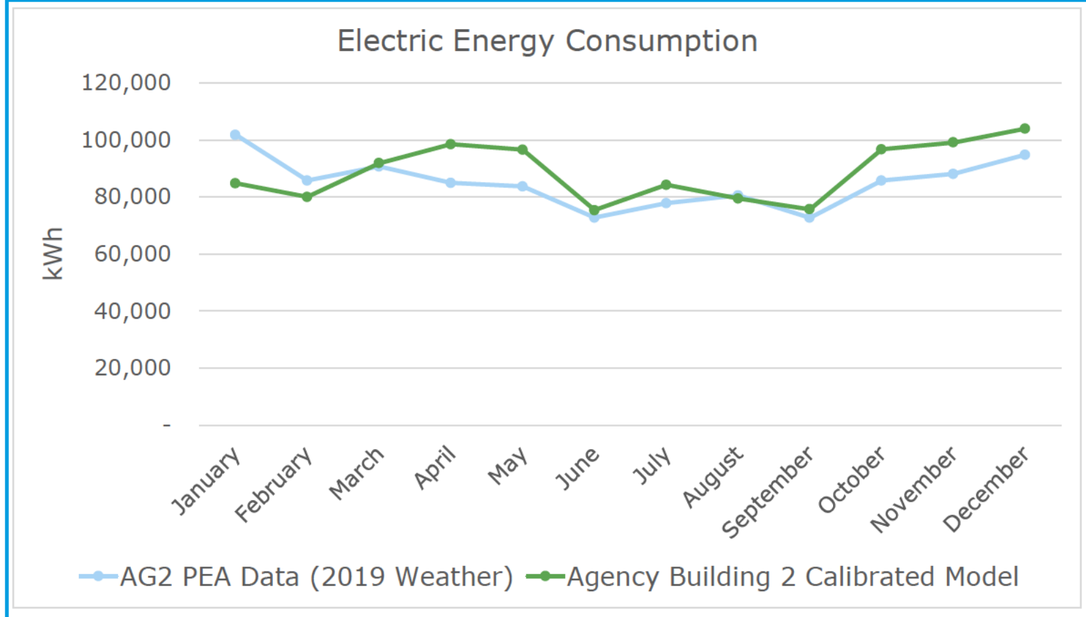
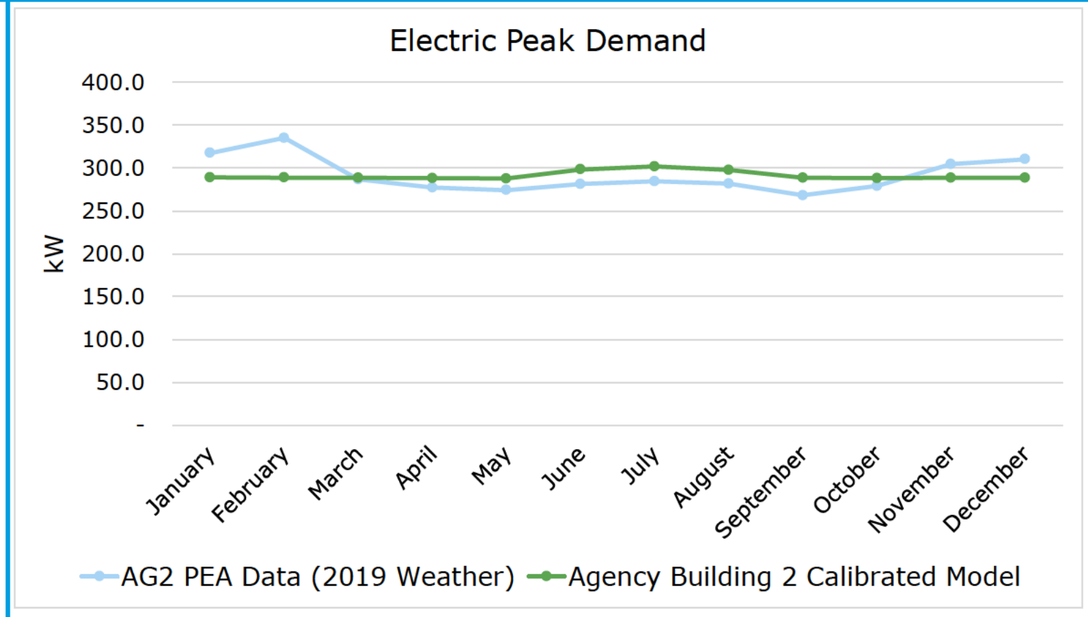
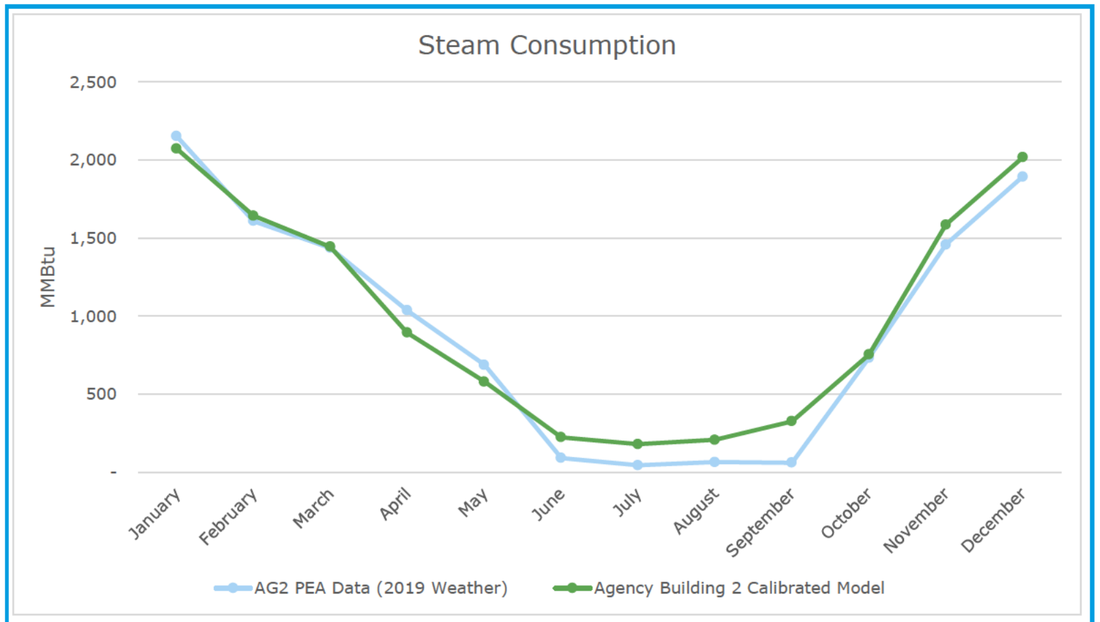
Agency Building 2 Calibration



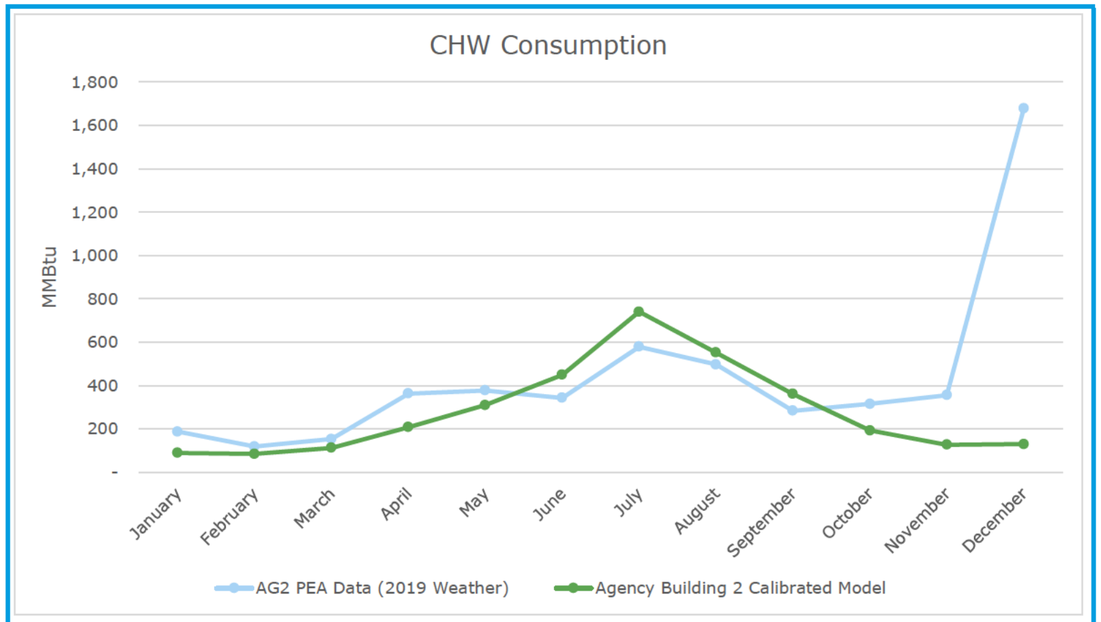
	Limit	Actual
NMBE	5%	-5%
CV(RMSE)	15%	12%



	Limit	Actual
NMBE	5%	0%
CV(RMSE)	15%	8%



	Limit	Actual
NMBE	5%	-6%
CV(RMSE)	15%	14%



	Limit	Actual
NMBE	5%	39%
CV(RMSE)	15%	110%

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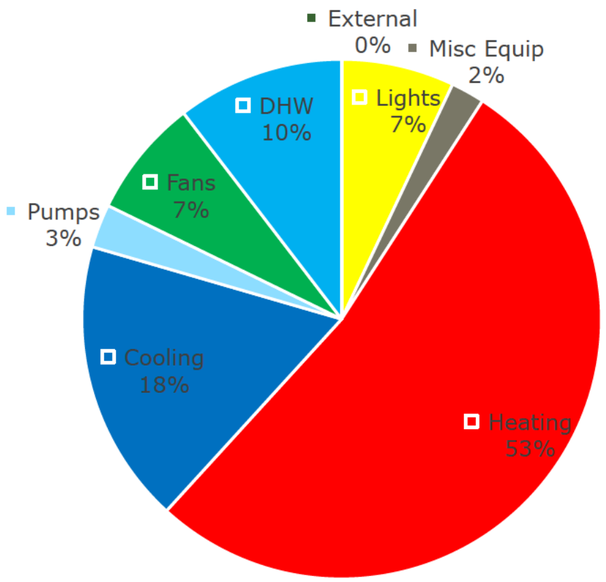
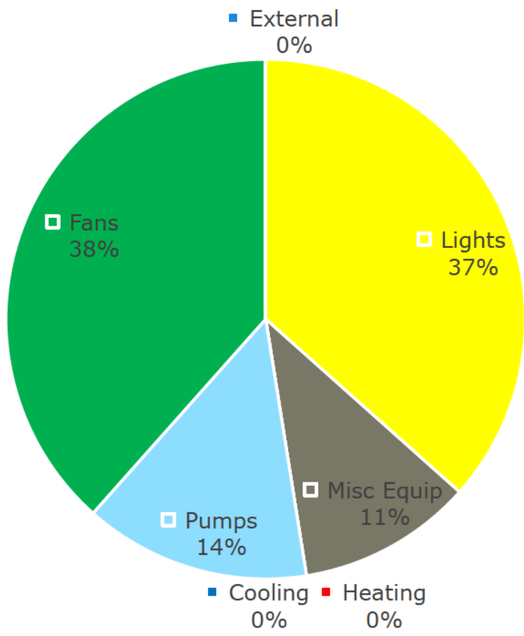
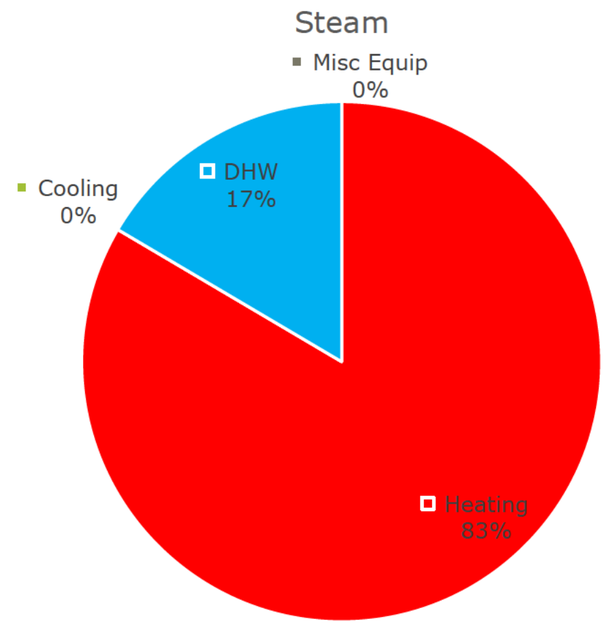
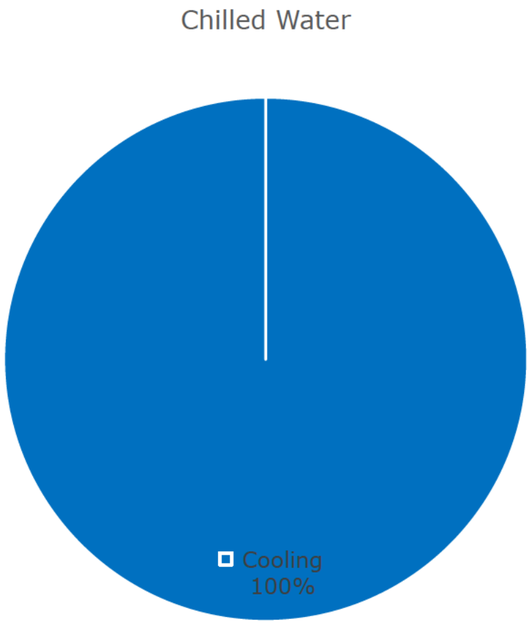
Agency Building 2 Calibrated Model
End Use Summary









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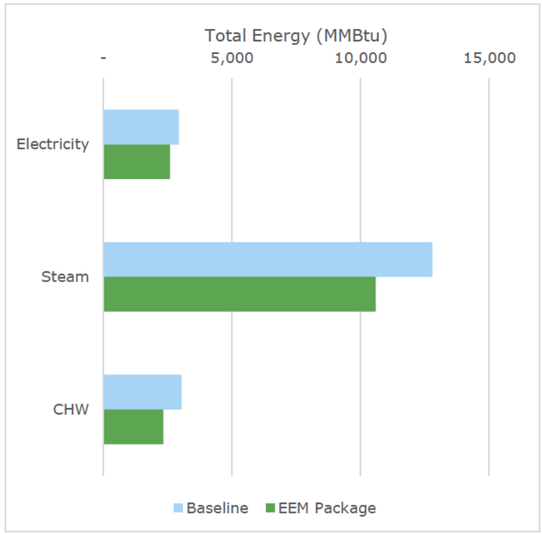
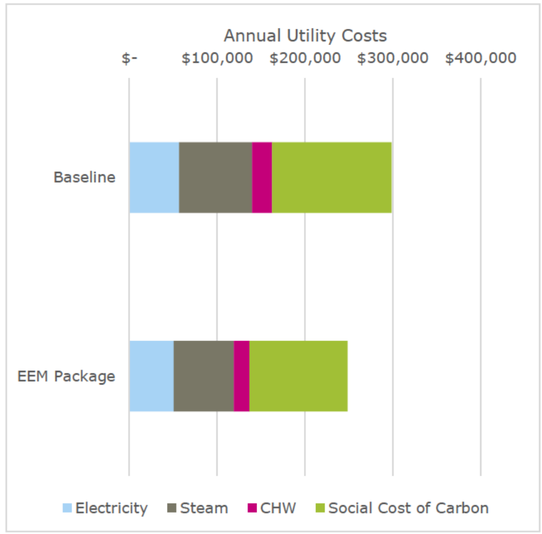
Agency 2 EEM Package Summary

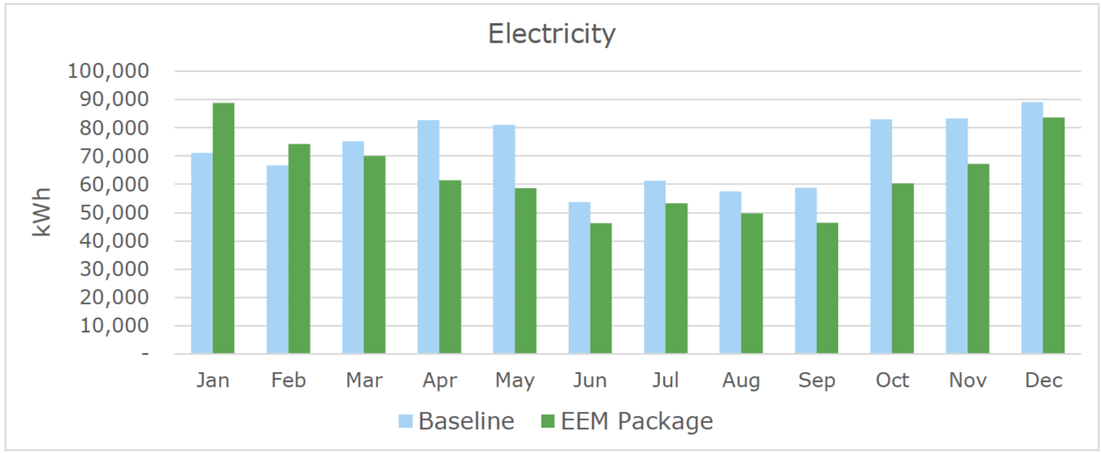
	Units	Baseline	EEM Package	Savings	% Savings
Annual Electric Use	kWh	862,721	759,876	102,845	11.9%
Annual Steam Use	MMBtu	12,780	10,580	2,200	17.2%
Annual CHW Use	MMBtu	3,046	2,323	723	23.7%
Annual Total Energy Use	MMBtu	18,770	15,496	3,274	17.4%
EUI	**kBtu/GSF**	**94.3**	**77.8**	**16.4**	**17.4%**
Total Emissions	**MTCO2e**	**1,096**	**903**	**193**	**17.6%**
Annual Electric Cost	$	$ 56,673	$ 50,393	$ 6,280	11.1%
Annual Natural Gas Cost	$	$ -	$ -	$ -	N/A
Annual Steam Cost	$	$ 83,072	$ 68,760	$ 14,312	17.2%
Annual CHW Cost	$	$ 22,845	$ 17,419	$ 5,426	23.8%
Annual Utility Cost	$	$ 162,590	$ 136,572	$ 26,018	16.0%
Social Cost of Carbon	$	$ 135,853	$ 111,927	$ 23,926	17.6%
Annual Combined Cost	**$**	**$ 298,443**	**$ 248,499**	**$ 49,944**	**16.7%**





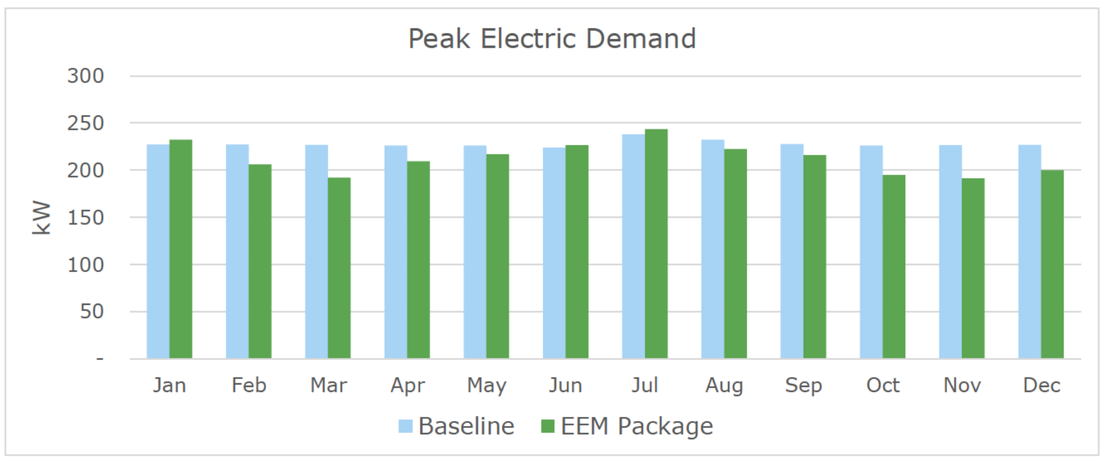
Electric Energy

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kWh	199,001	199,001	-	0.0%
Misc Equip	kWh	116,156	116,156	-	0.0%
Heating	kWh	-	-	-	N/A
Cooling	kWh	-	-	-	N/A
Pumps	kWh	148,468	33,950	114,518	77.1%
Fans	kWh	399,097	410,768	(11,671)	-2.9%
Refrigeration	kWh	-	-	-	N/A
DHW	kWh	-	-	-	N/A
External	kWh	-	-	-	N/A
Total Electric	**kWh**	**862,721**	**759,876**	**102,845**	**11.9%**



Electric Peak Demand

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kW	64.3	64.3	-	0.0%
Misc Equip	kW	39.6	39.6	-	0.0%
Heating	kW	-	-	-	N/A
Cooling	kW	-	-	-	N/A
Pumps	kW	33.5	10.9	22.6	67.5%
Fans	kW	102.8	138.8	(36.0)	-35.0%
Refrigeration	kW	-	-	-	N/A
DHW	kW	-	-	-	N/A
External	kW	-	-	-	N/A
Total kW	**kW**	**238.1**	**243.6**	**(5.5)**	**-2.3%**



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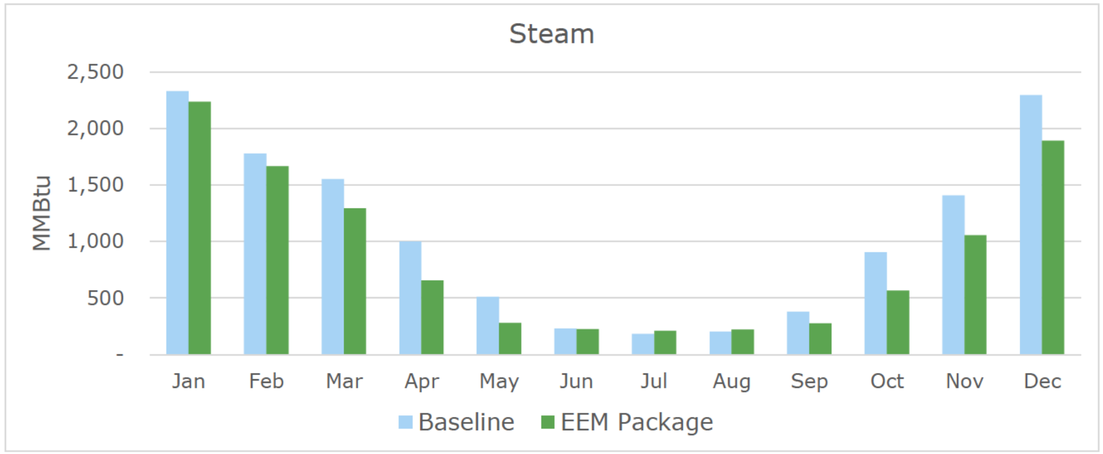
Agency 2 EEM Package Summary (cont.)

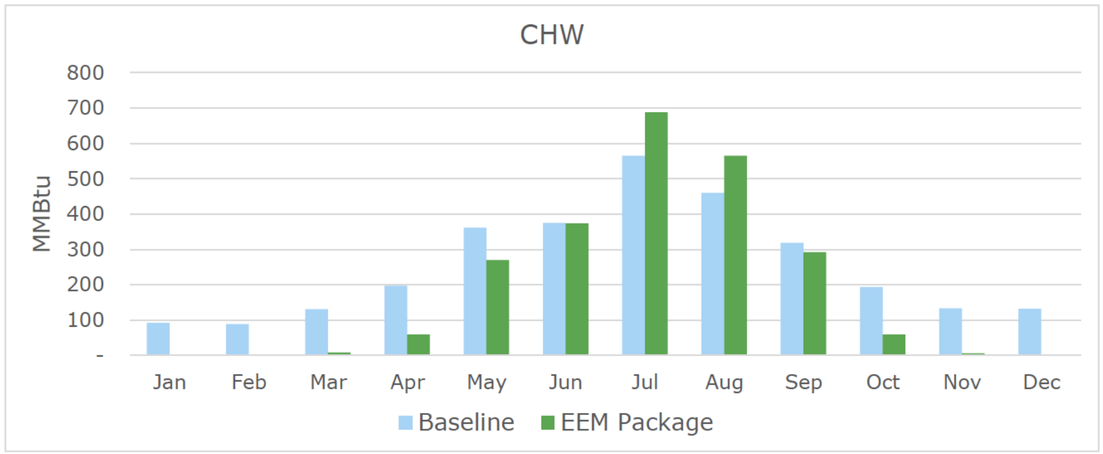
Steam

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	10,800	8,600	2,200	20.4%
Cooling	MMBtu	-	-	-	N/A
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	1,970	1,980	(10)	-0.5%
External	MMBtu	-	-	-	N/A
Total Steam	**MMBtu**	**12,780**	**10,580**	**2,200**	**17.2%**



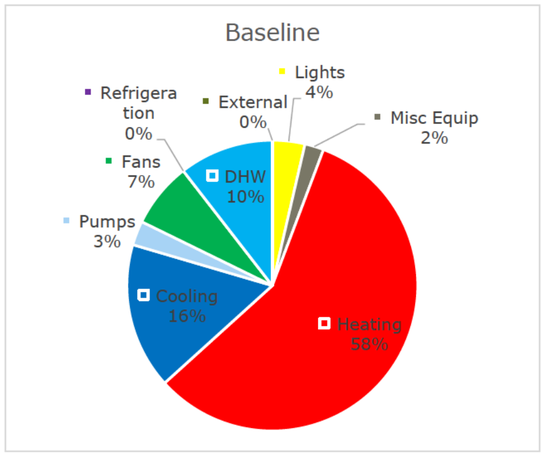
CHW

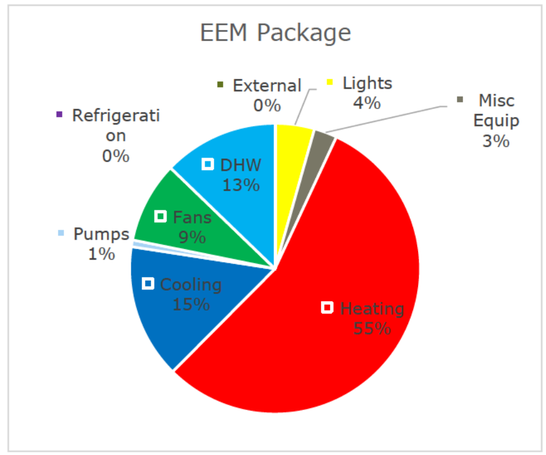
End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	-	-	-	N/A
Cooling	MMBtu	3,050	2,320	730	23.9%
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	-	-	-	N/A
External	MMBtu	-	-	-	N/A
Total CHW	**MMBtu**	**3,046**	**2,323**	**723**	**23.7%**



All Utilities

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	679	679	-	0.0%
Misc Equip	MMBtu	396	396	-	0.0%
Heating	MMBtu	10,800	8,600	2,200	20.4%
Cooling	MMBtu	3,050	2,320	730	23.9%
Pumps	MMBtu	507	116	391	77.1%
Fans	MMBtu	1,362	1,402	(40)	-2.9%
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	1,970	1,980	(10)	-0.5%
External	MMBtu	-	-	-	N/A
Total	**MMBtu**	**18,770**	**15,496**	**3,274**	**17.4%**





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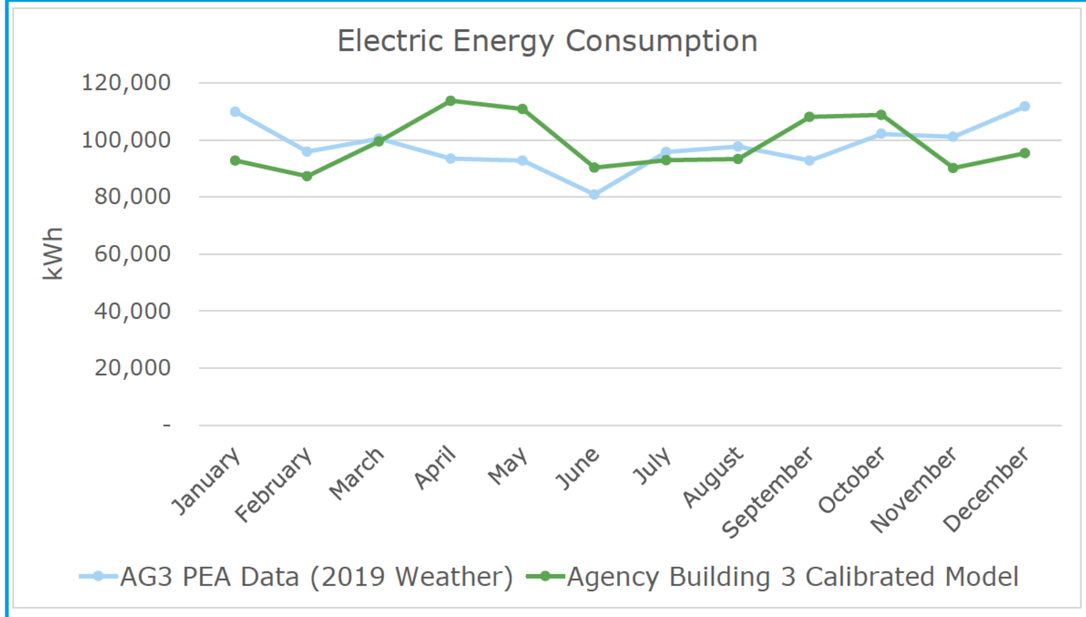
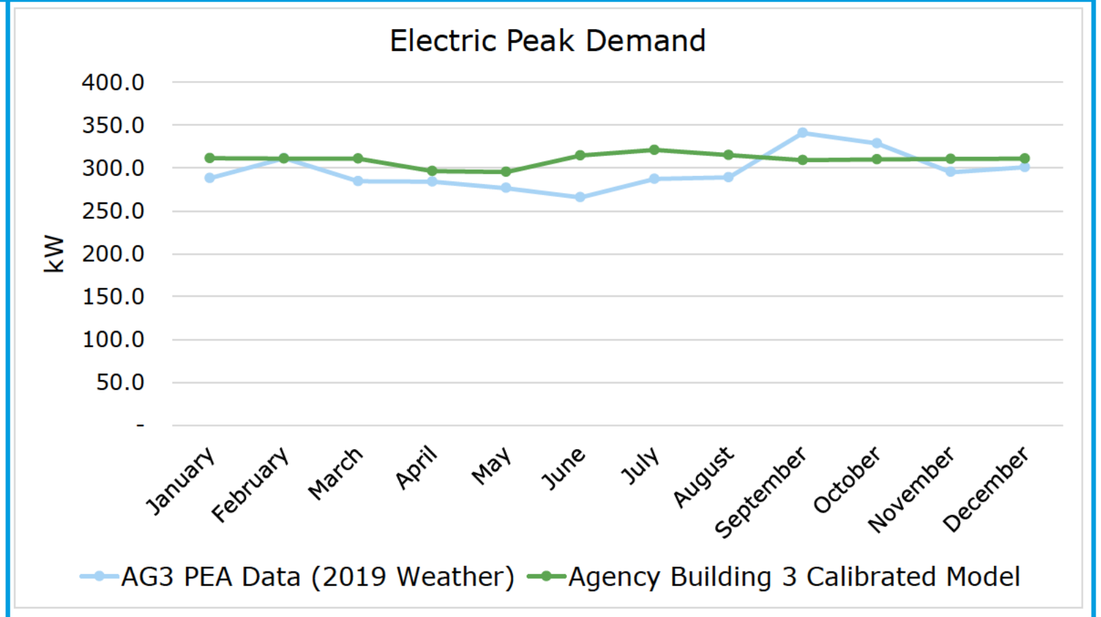
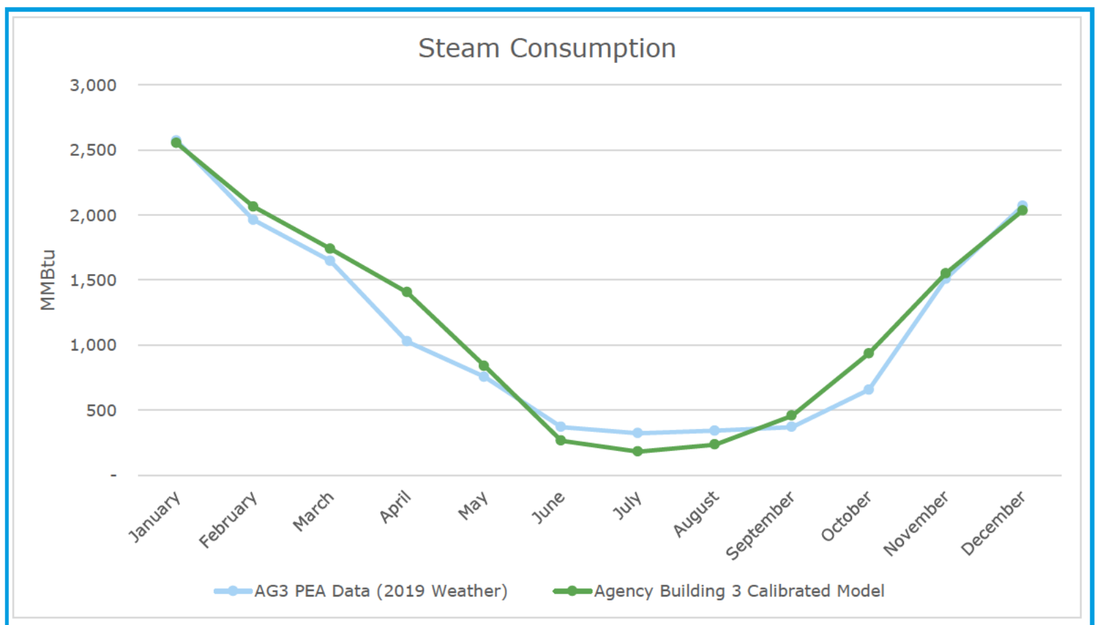
Agency Building 3 Calibration



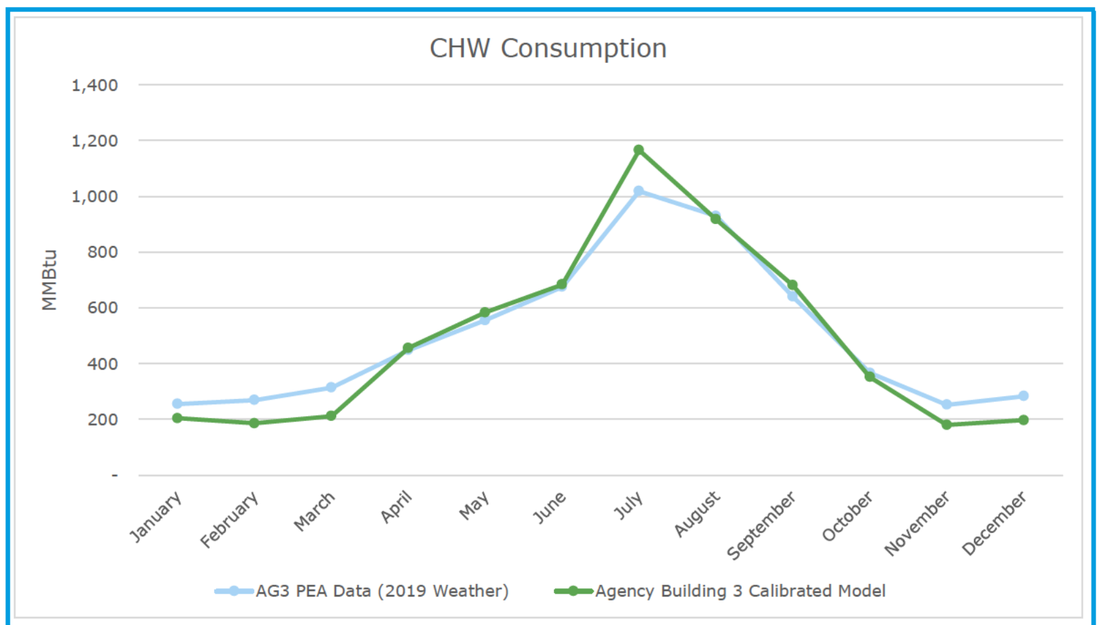
	Limit	Actual
NMBE	5%	-1%
CV(RMSE)	15%	13%



	Limit	Actual
NMBE	5%	-5%
CV(RMSE)	15%	9%



	Limit	Actual
NMBE	5%	-5%
CV(RMSE)	15%	15%



	Limit	Actual
NMBE	5%	3%
CV(RMSE)	15%	14%

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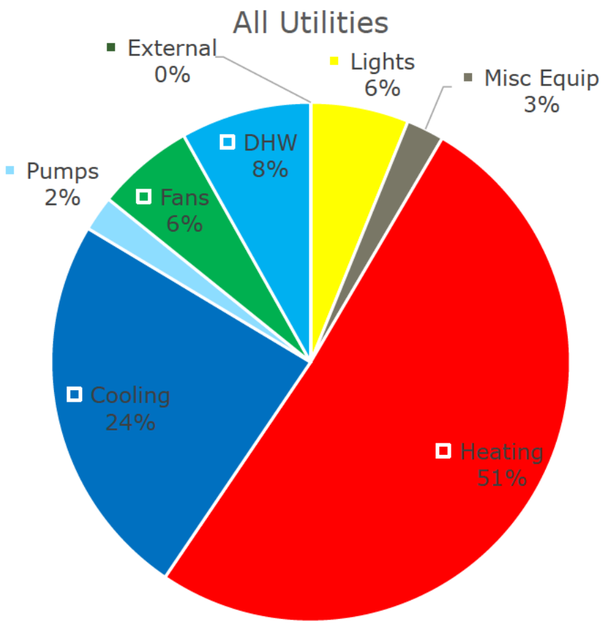
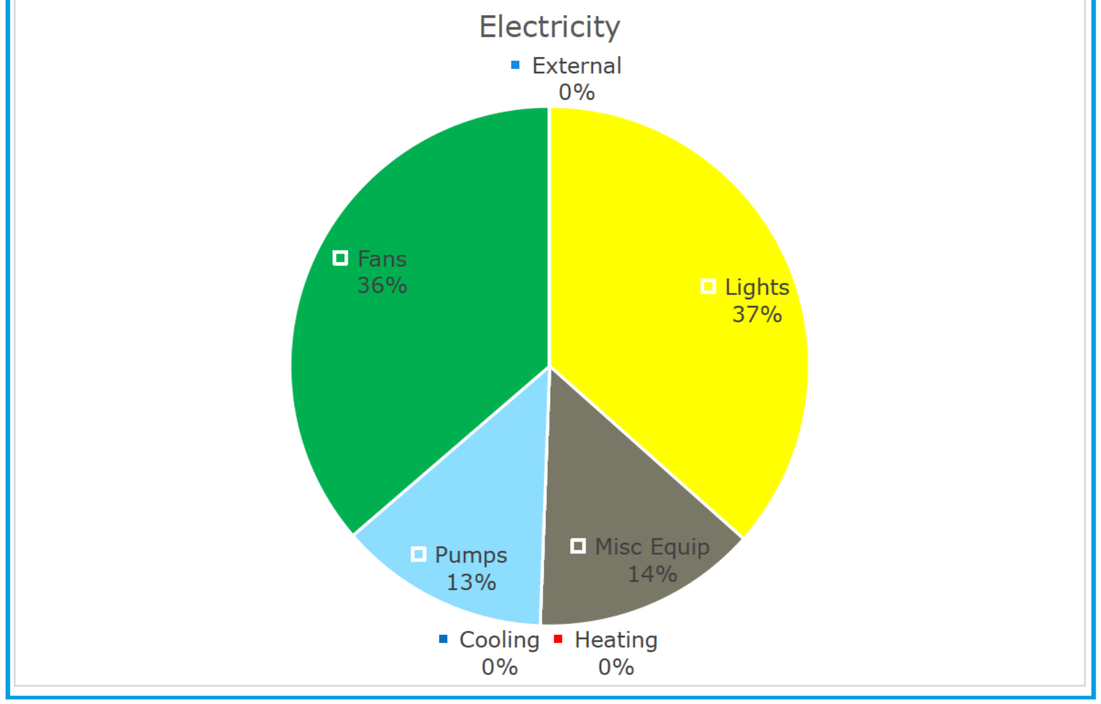
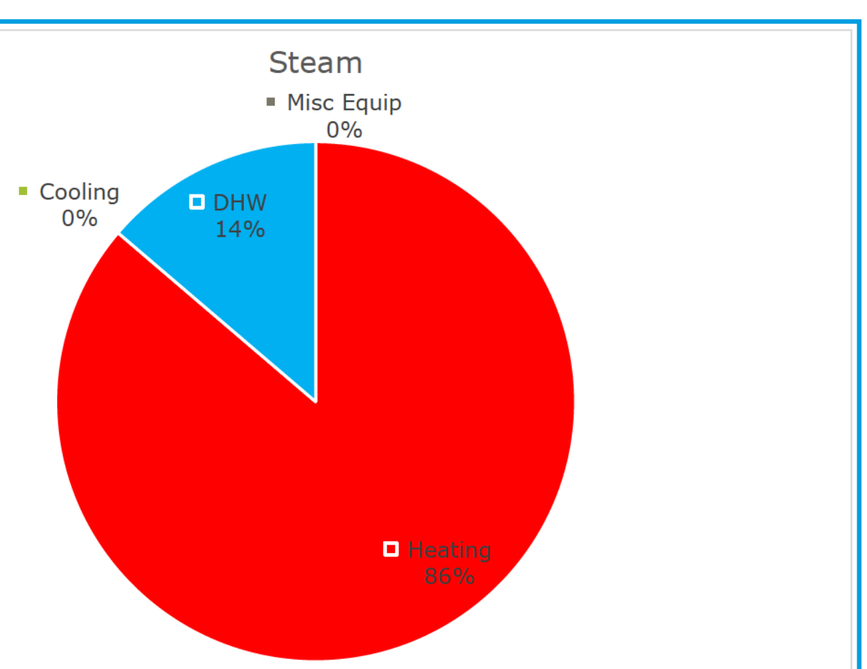
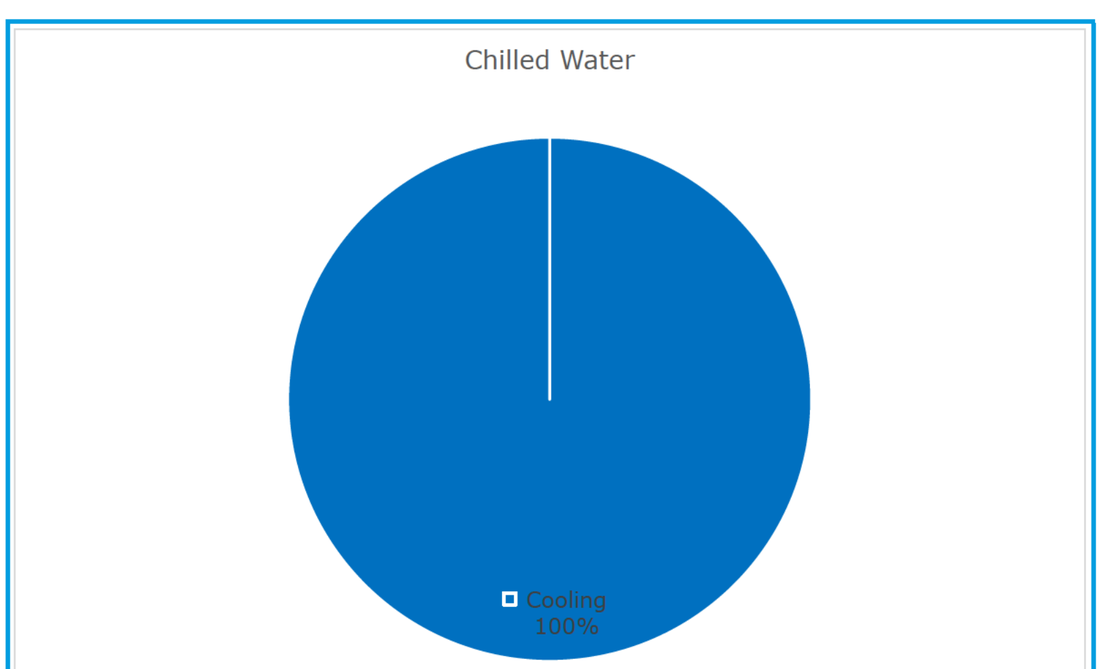
Agency Building 3 Calibrated Model
End Use Summary





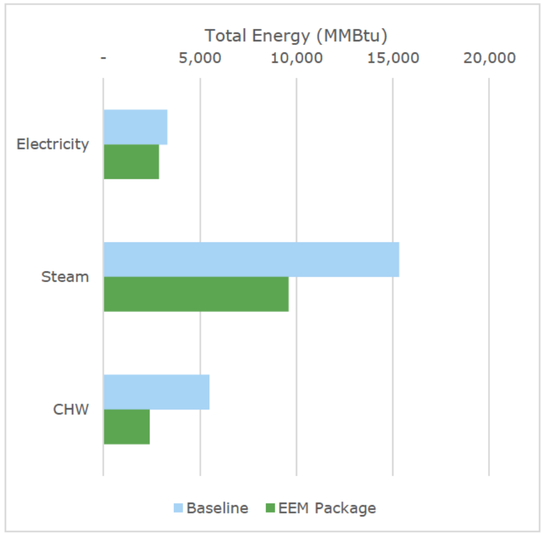


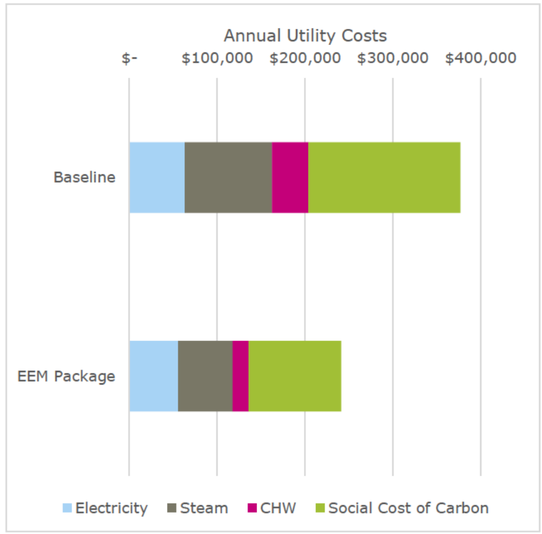


CONFIDENTIAL AND PROPRIETARY

Agency 3 EEM Package Summary

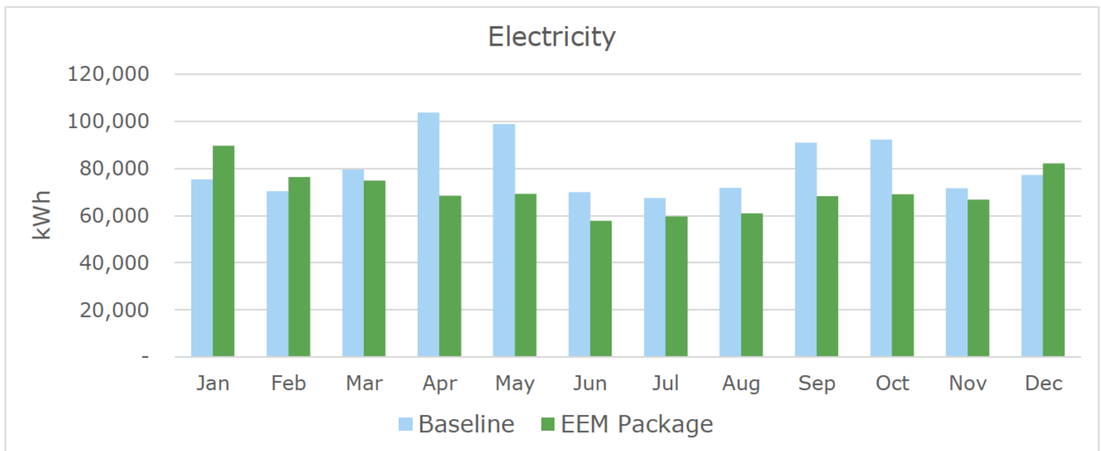
	Units	Baseline	EEM Package	Savings	% Savings
Annual Electric Use	kWh	968,456	842,900	125,556	13.0%
Annual Steam Use	MMBtu	15,320	9,595	5,725	37.4%
Annual CHW Use	MMBtu	5,494	2,404	3,090	56.2%
Annual Total Energy Use	MMBtu	24,118	14,875	9,243	38.3%
EUI	**kBtu/GSF**	**121.1**	**74.7**	**46.4**	**38.3%**
Total Emissions	**MTCO2e**	**1,395**	**851**	**544**	**39.0%**
Annual Electric Cost	$	$ 62,930	$ 55,430	$ 7,500	11.9%
Annual Natural Gas Cost	$	$ -	$ -	$ -	N/A
Annual Steam Cost	$	$ 99,567	$ 62,370	$ 37,197	37.4%
Annual CHW Cost	$	$ 41,201	$ 18,033	$ 23,168	56.2%
Annual Utility Cost	$	$ 203,698	$ 135,833	$ 67,865	33.3%
Social Cost of Carbon	$	$ 172,977	$ 105,490	$ 67,487	39.0%
Annual Combined Cost	**$**	**$ 376,675**	**$ 241,323**	**$ 135,352**	**35.9%**





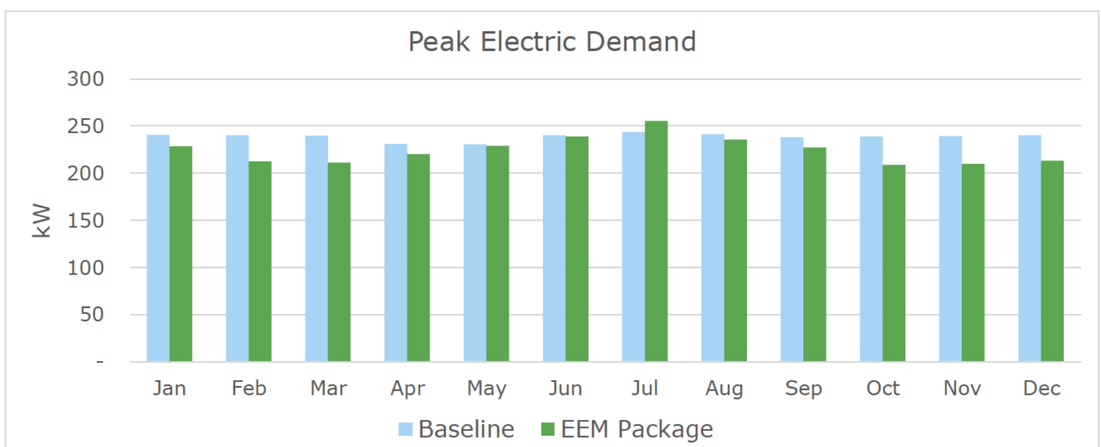
Electric Energy

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kWh	220,728	220,728	-	0.0%
Misc Equip	kWh	165,570	165,570	-	0.0%
Heating	kWh	-	-	-	N/A
Cooling	kWh	-	-	-	N/A
Pumps	kWh	155,539	40,229	115,310	74.1%
Fans	kWh	426,620	416,374	10,246	2.4%
Refrigeration	kWh	-	-	-	N/A
DHW	kWh	-	-	-	N/A
External	kWh	-	-	-	N/A
Total Electric	**kWh**	**968,456**	**842,900**	**125,556**	**13.0%**



Electric Peak Demand

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kW	74.3	74.3	-	0.0%
Misc Equip	kW	47.3	47.3	-	0.0%
Heating	kW	-	-	-	N/A
Cooling	kW	-	-	-	N/A
Pumps	kW	42.4	9.7	32.7	77.1%
Fans	kW	86.6	155.2	(68.6)	-79.3%
Refrigeration	kW	-	-	-	N/A
DHW	kW	-	-	-	N/A
External	kW	-	-	-	N/A
Total kW	**kW**	**243.5**	**255.6**	**(12.1)**	**-5.0%**



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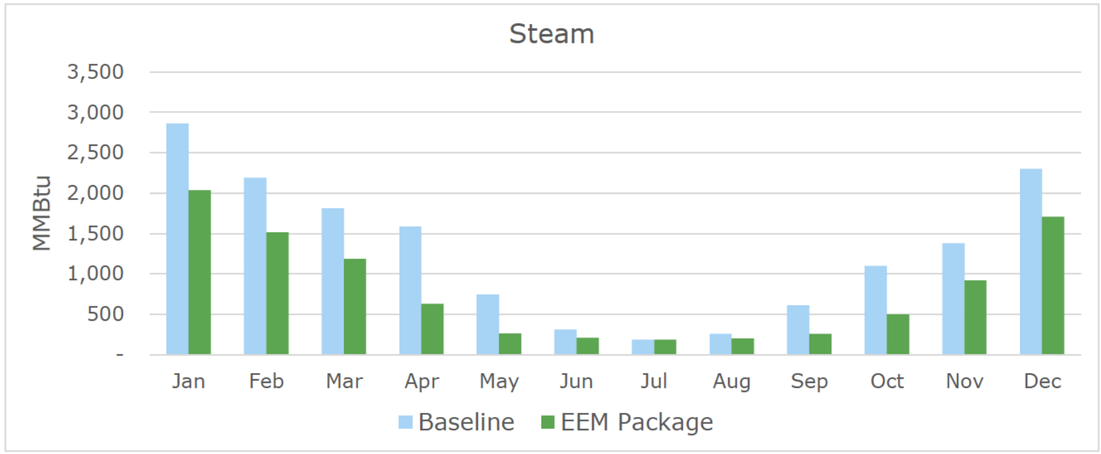
Agency 3 EEM Package Summary (cont.)

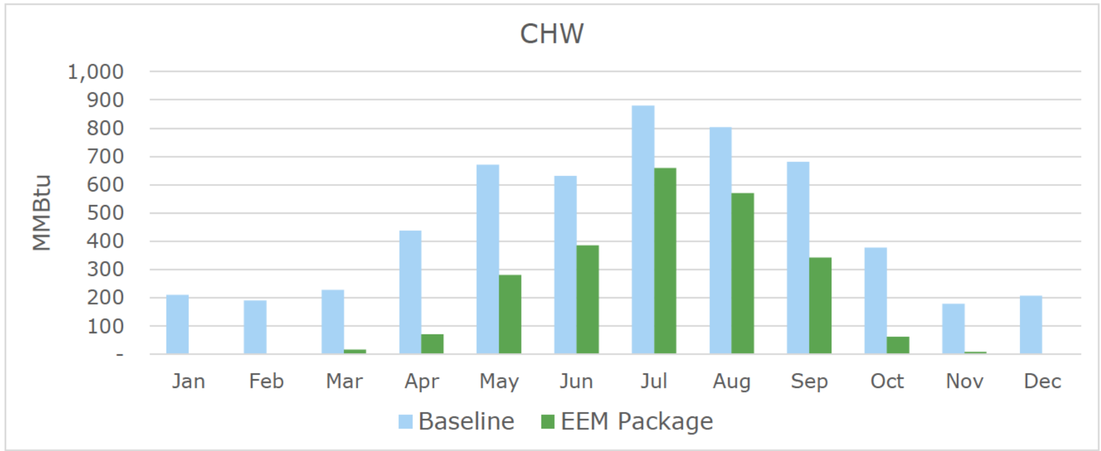
Steam

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	13,400	7,610	5,790	43.2%
Cooling	MMBtu	-	-	-	N/A
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	1,960	1,980	(20)	-1.0%
External	MMBtu	-	-	-	N/A
Total Steam	**MMBtu**	**15,320**	**9,595**	**5,725**	**37.4%**



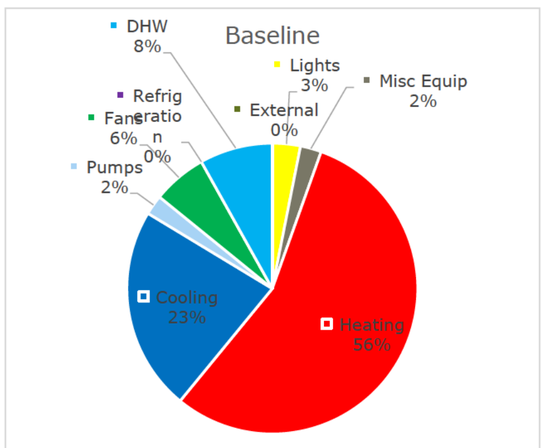
CHW

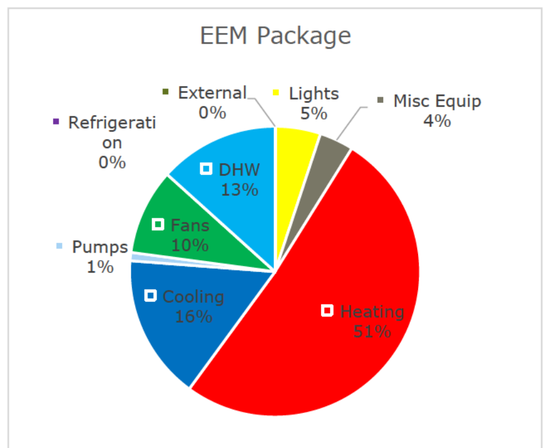
End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	-	-	-	N/A
Cooling	MMBtu	5,490	2,400	3,090	56.3%
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	-	-	-	N/A
External	MMBtu	-	-	-	N/A
Total CHW	**MMBtu**	**5,494**	**2,404**	**3,090**	**56.2%**



All Utilities

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	753	753	-	0.0%
Misc Equip	MMBtu	565	565	-	0.0%
Heating	MMBtu	13,400	7,610	5,790	43.2%
Cooling	MMBtu	5,490	2,400	3,090	56.3%
Pumps	MMBtu	531	137	393	74.1%
Fans	MMBtu	1,456	1,421	35	2.4%
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	1,960	1,980	(20)	-1.0%
External	MMBtu	-	-	-	N/A
Total	**MMBtu**	**24,118**	**14,875**	**9,243**	**38.3%**





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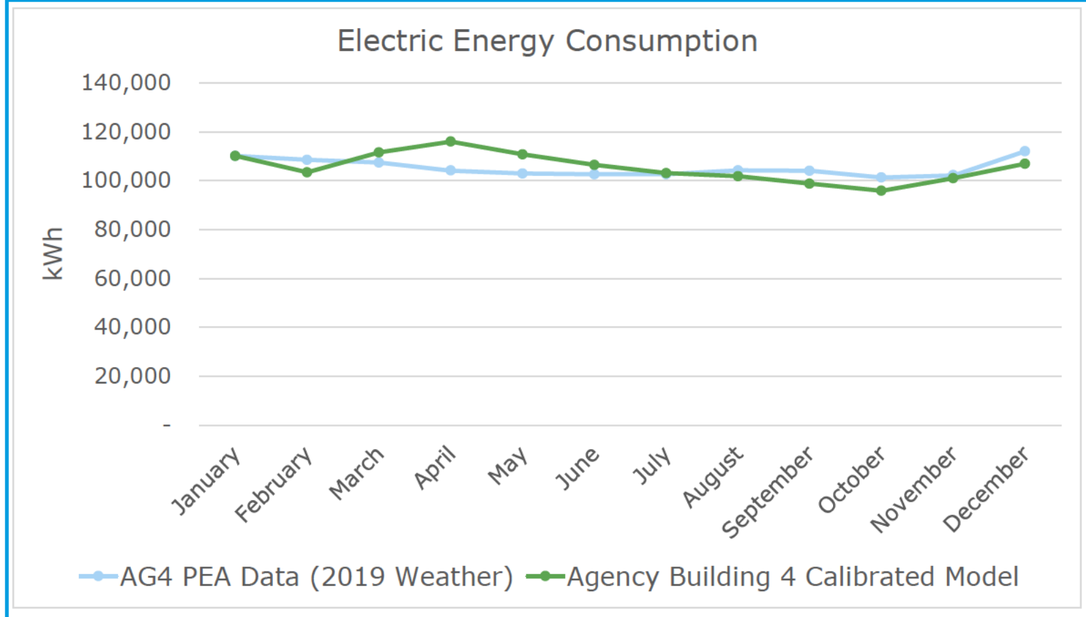
Agency Building 4 Calibration



	Limit	Actual
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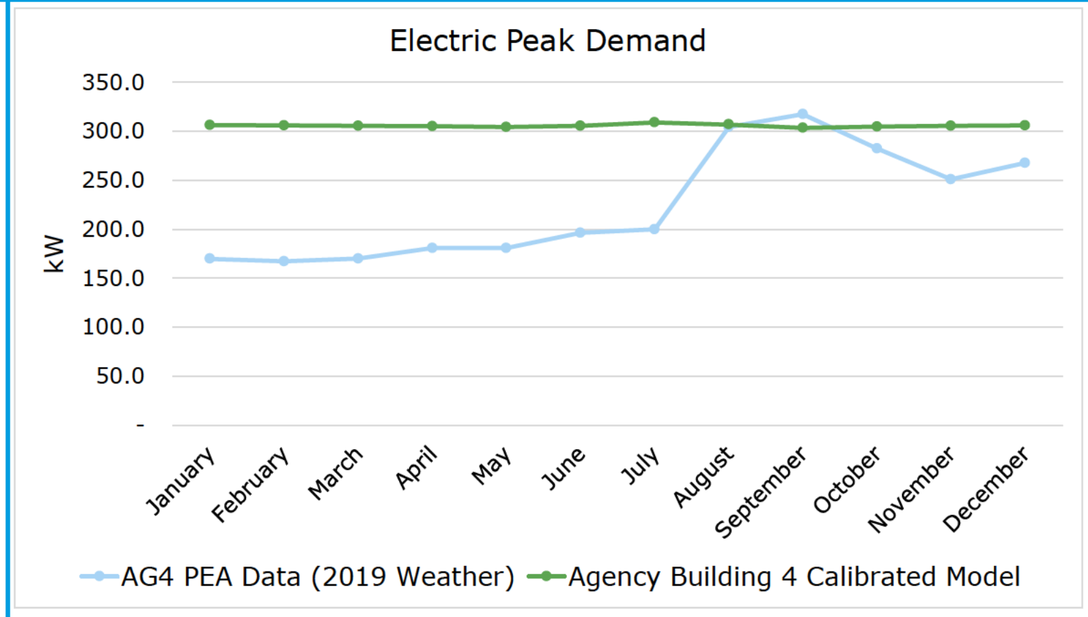
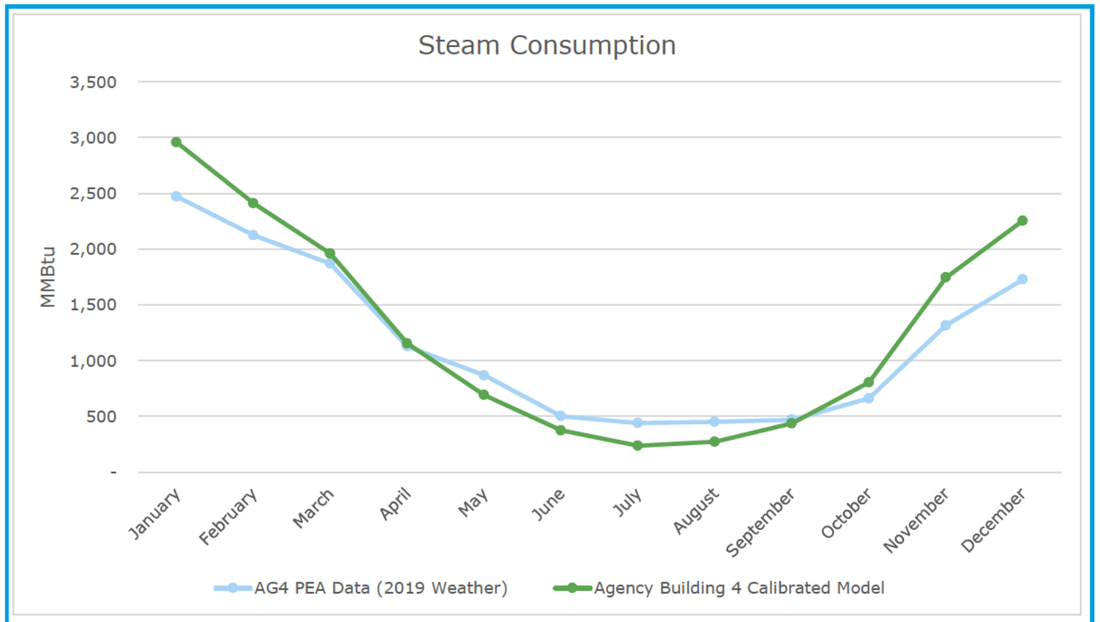
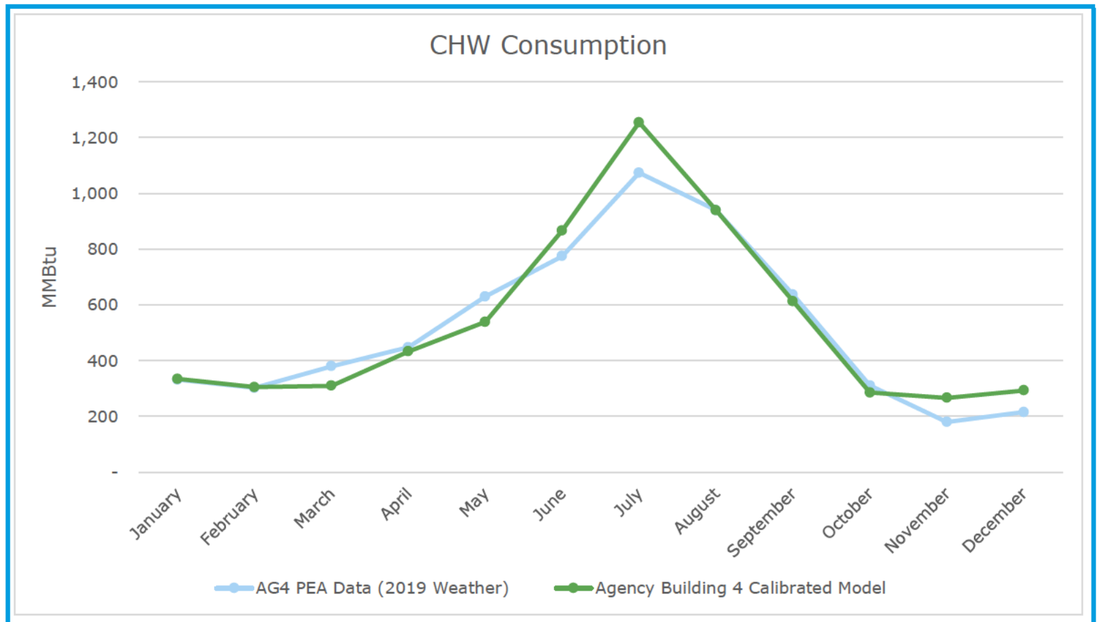
CV(RMSE)	15%	5%



	Limit	Actual
NMBE	5%	-40%
CV(RMSE)	15%	46%



	Limit	Actual
NMBE	5%	-10%
CV(RMSE)	15%	25%



	Limit	Actual
NMBE	5%	-4%
CV(RMSE)	15%	15%

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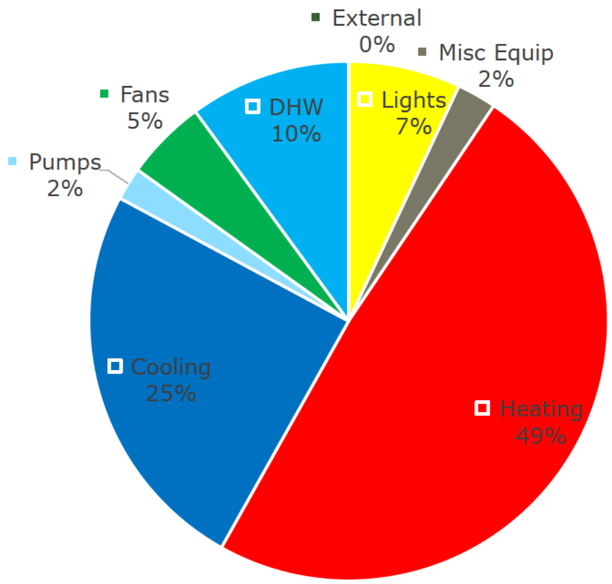
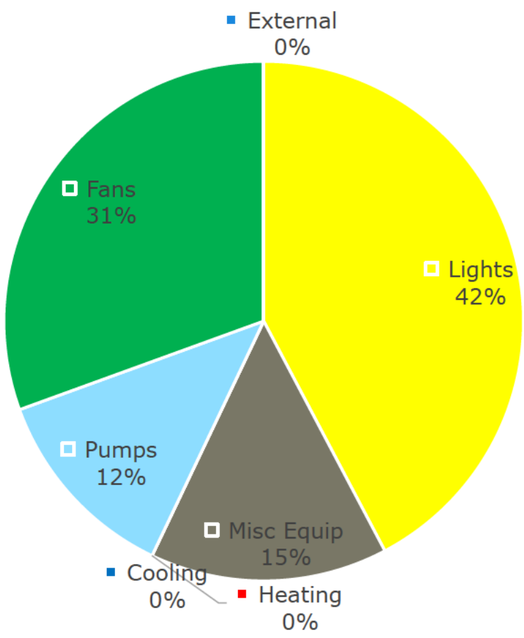
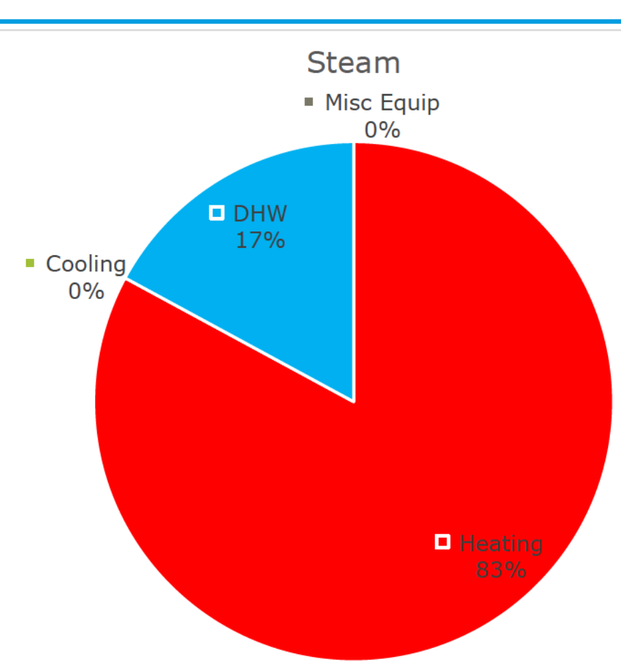
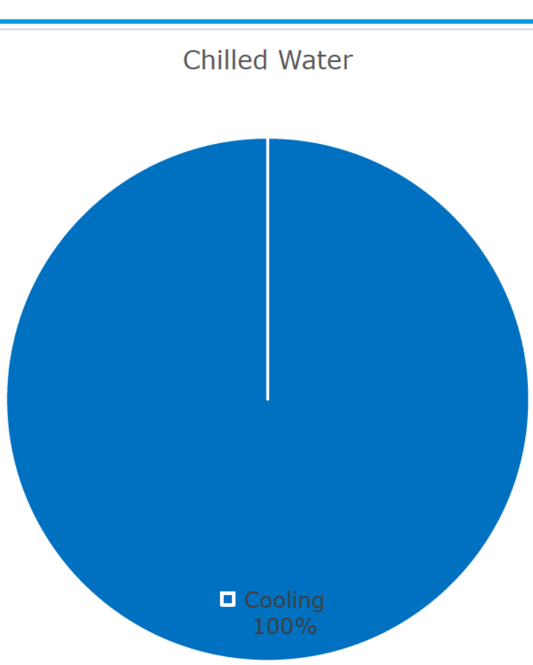
Agency Building 4 Calibrated Model
End Use Summary









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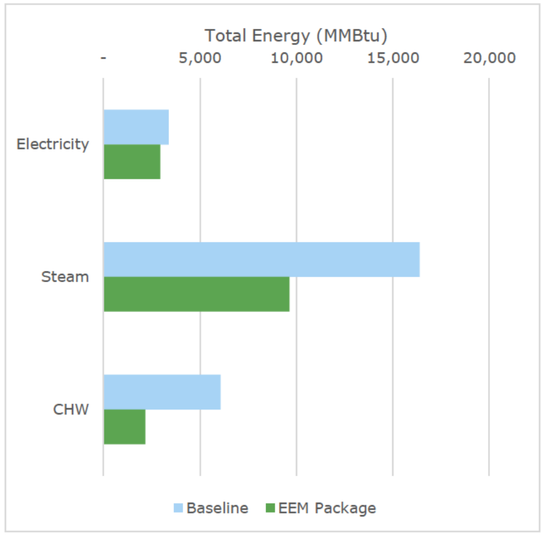
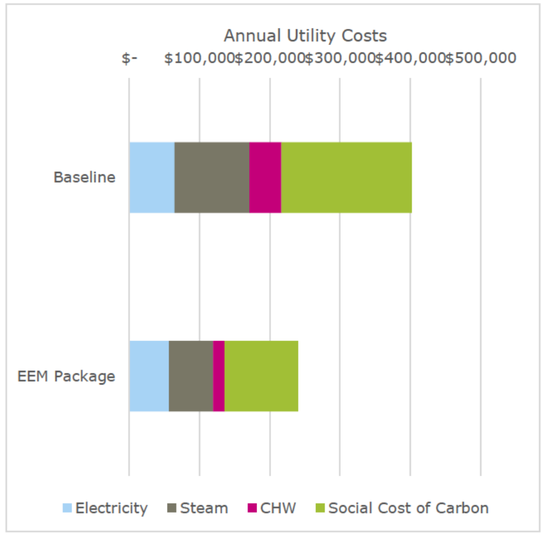
Agency 4 EEM Package Summary

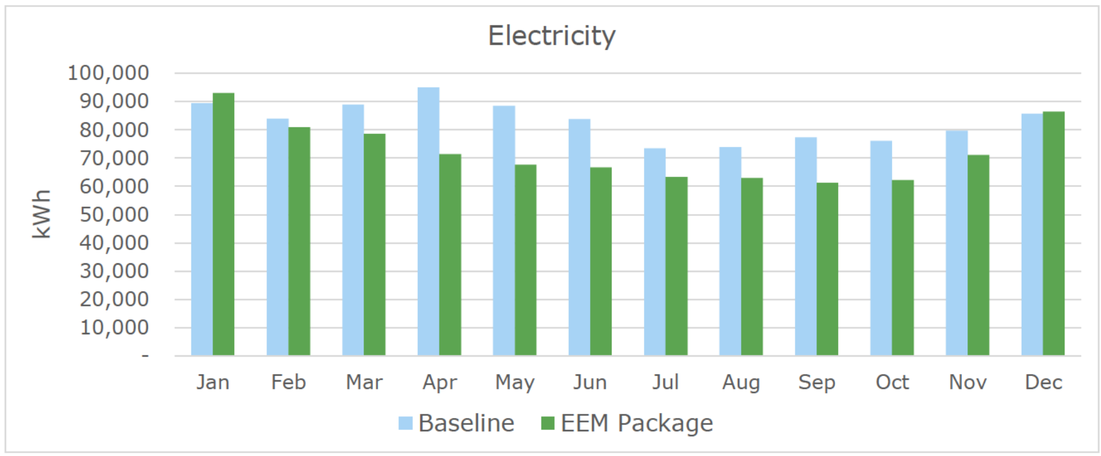
	Units	Baseline	EEM Package	Savings	% Savings
Annual Electric Use	kWh	995,384	865,240	130,144	13.1%
Annual Steam Use	MMBtu	16,400	9,645	6,755	41.2%
Annual CHW Use	MMBtu	6,070	2,173	3,897	64.2%
Annual Total Energy Use	MMBtu	25,866	14,770	11,096	42.9%
EUI	**kBtu/GSF**	**129.9**	**74.2**	**55.7**	**42.9%**
Total Emissions	**MTCO2e**	**1,498**	**845**	**652**	**43.6%**
Annual Electric Cost	$	$ 64,347	$ 56,487	$ 7,860	12.2%
Annual Natural Gas Cost	$	$ -	$ -	$ -	N/A
Annual Steam Cost	$	$ 106,595	$ 62,694	$ 43,901	41.2%
Annual CHW Cost	$	$ 45,526	$ 16,296	$ 29,230	64.2%
Annual Utility Cost	$	$ 216,468	$ 135,477	$ 80,991	37.4%
Social Cost of Carbon	$	$ 185,713	$ 104,835	$ 80,879	43.6%
Annual Combined Cost	**$**	**$ 402,181**	**$ 240,312**	**$ 161,870**	**40.2%**





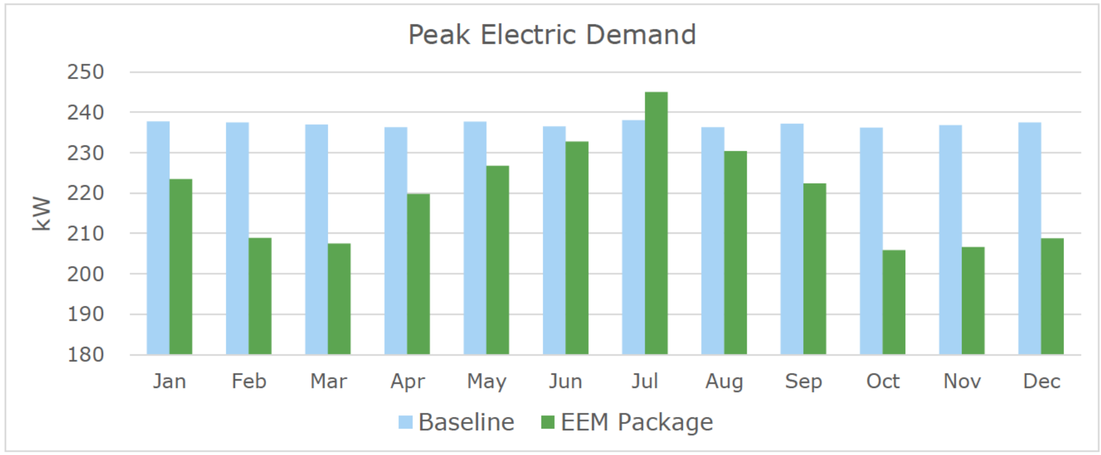
Electric Energy

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kWh	272,916	272,916	-	0.0%
Misc Equip	kWh	187,204	187,204	-	0.0%
Heating	kWh	-	-	-	N/A
Cooling	kWh	-	-	-	N/A
Pumps	kWh	152,393	37,526	114,867	75.4%
Fans	kWh	382,869	367,593	15,276	4.0%
Refrigeration	kWh	-	-	-	N/A
DHW	kWh	-	-	-	N/A
External	kWh	-	-	-	N/A
Total Electric	**kWh**	**995,384**	**865,240**	**130,144**	**13.1%**



Electric Peak Demand

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kW	71.7	71.7	-	0.0%
Misc Equip	kW	47.3	47.3	-	0.0%
Heating	kW	-	-	-	N/A
Cooling	kW	-	-	-	N/A
Pumps	kW	42.6	9.8	32.8	77.0%
Fans	kW	86.5	137.5	(51.0)	-59.0%
Refrigeration	kW	-	-	-	N/A
DHW	kW	-	-	-	N/A
External	kW	-	-	-	N/A
Total kW	**kW**	**238.0**	**245.0**	**(7.0)**	**-2.9%**



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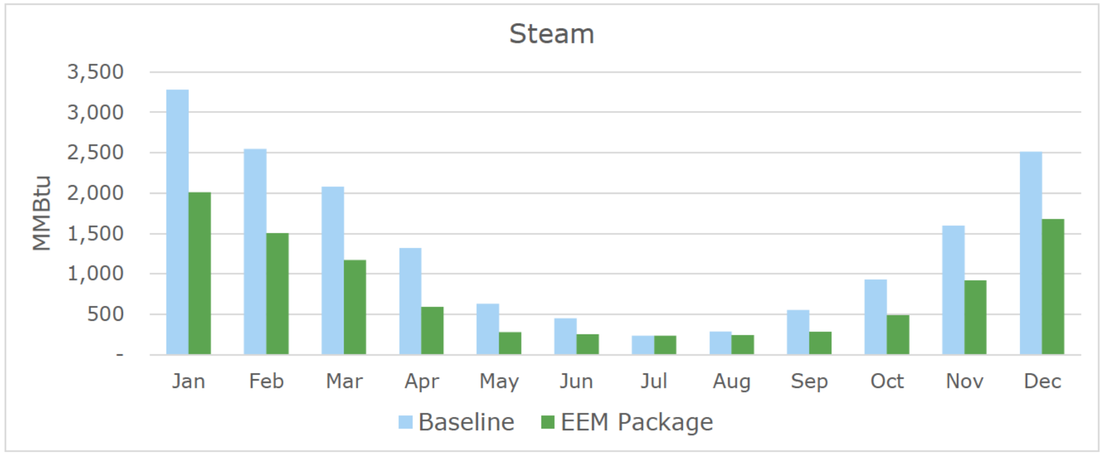
Agency 4 EEM Package Summary (cont.)

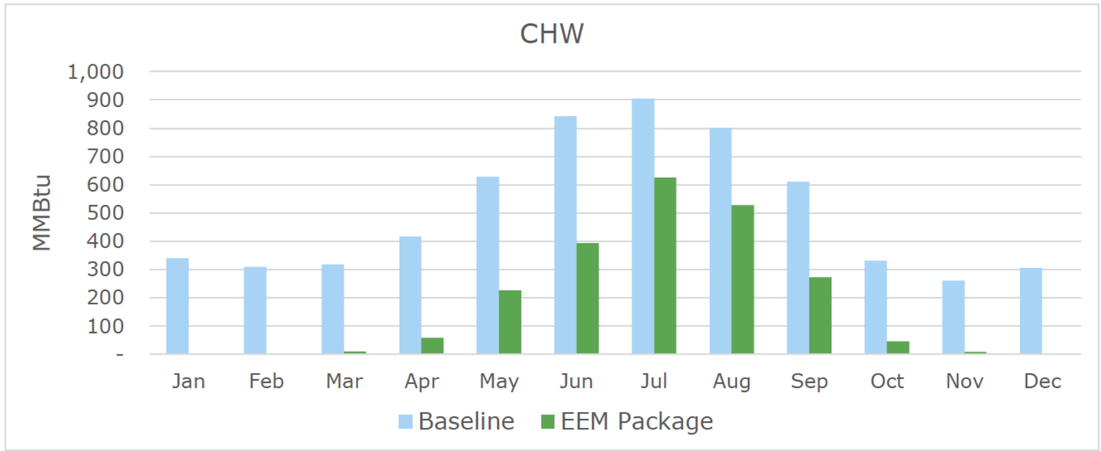
Steam

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	13,800	7,010	6,790	49.2%
Cooling	MMBtu	-	-	-	N/A
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	2,630	2,640	(10)	-0.4%
External	MMBtu	-	-	-	N/A
Total Steam	**MMBtu**	**16,400**	**9,645**	**6,755**	**41.2%**



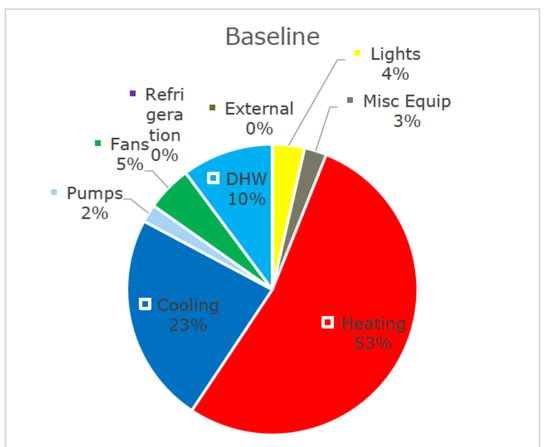
CHW

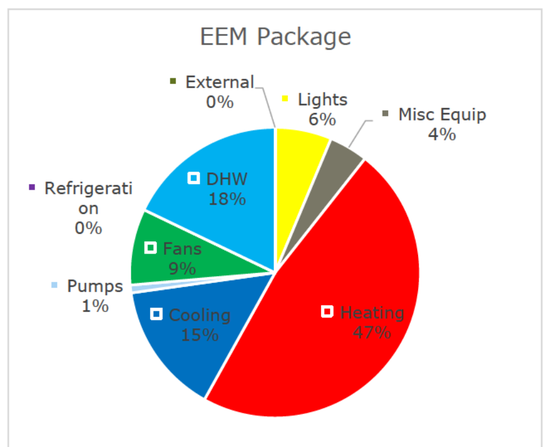
End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	-	-	-	N/A
Cooling	MMBtu	6,070	2,170	3,900	64.3%
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	-	-	-	N/A
External	MMBtu	-	-	-	N/A
Total CHW	**MMBtu**	**6,070**	**2,173**	**3,897**	**64.2%**



All Utilities

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	931	931	-	0.0%
Misc Equip	MMBtu	639	639	-	0.0%
Heating	MMBtu	13,800	7,010	6,790	49.2%
Cooling	MMBtu	6,070	2,170	3,900	64.3%
Pumps	MMBtu	520	128	392	75.4%
Fans	MMBtu	1,306	1,254	52	4.0%
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	2,630	2,640	(10)	-0.4%
External	MMBtu	-	-	-	N/A
Total	**MMBtu**	**25,866**	**14,770**	**11,096**	**42.9%**





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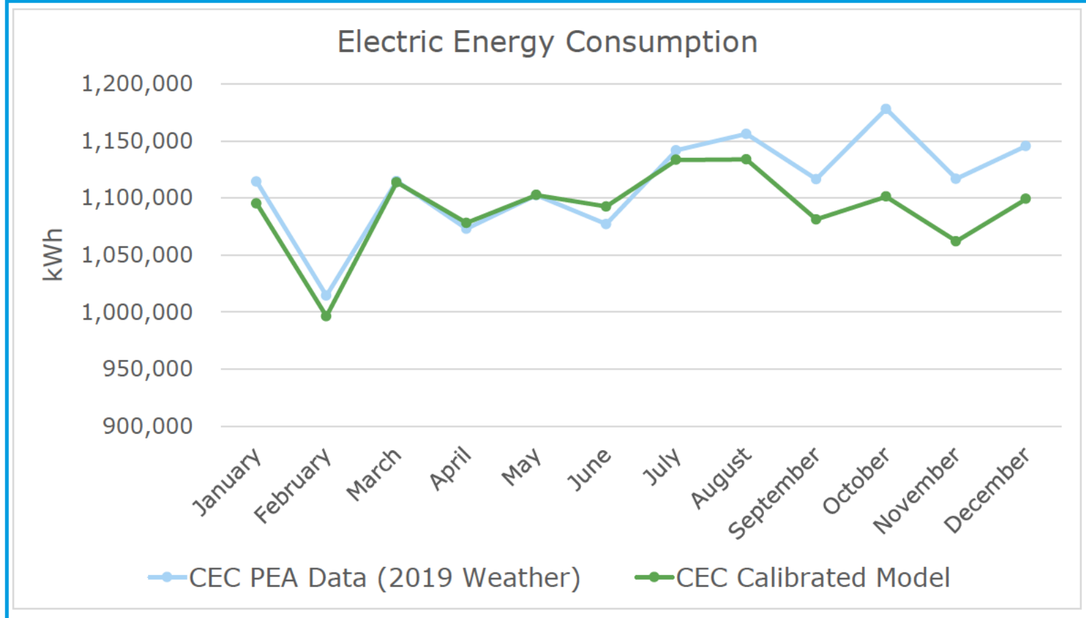
CEC Calibration



	Limit	Actual
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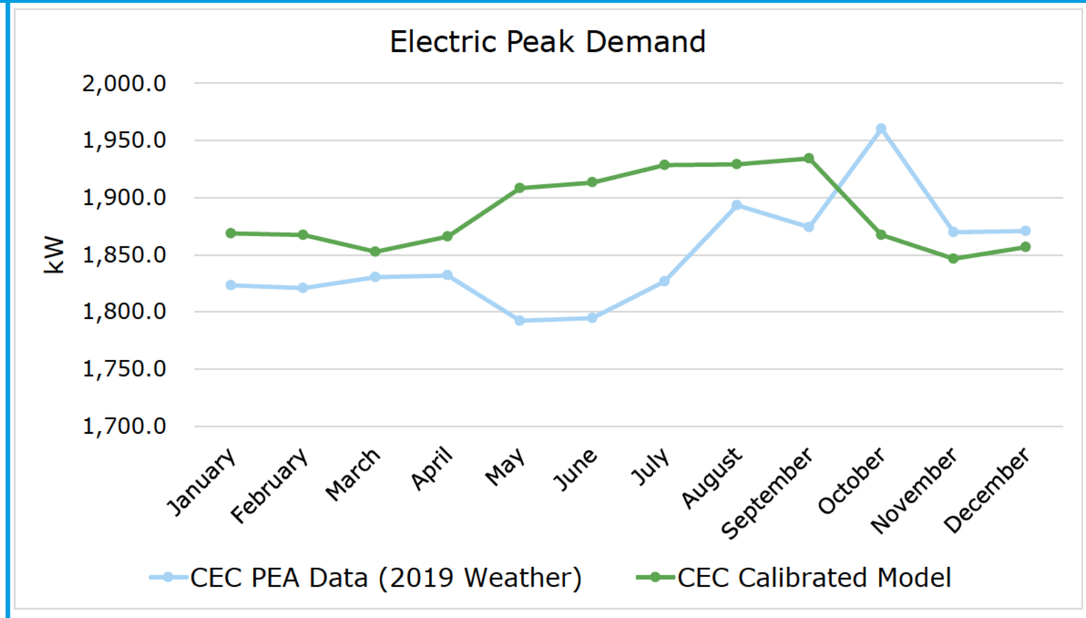
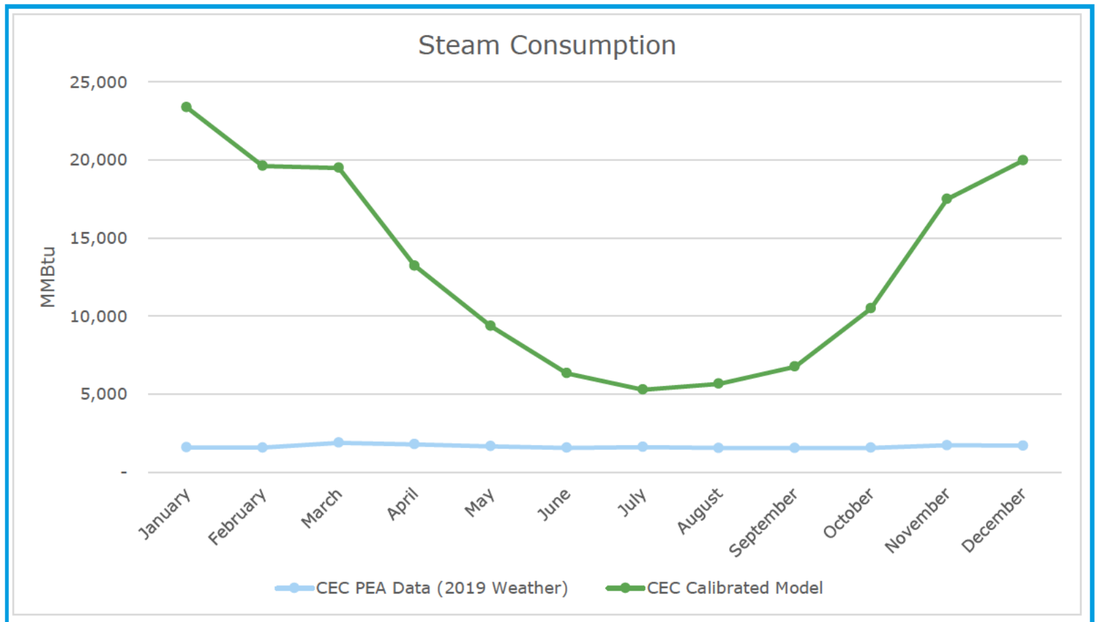
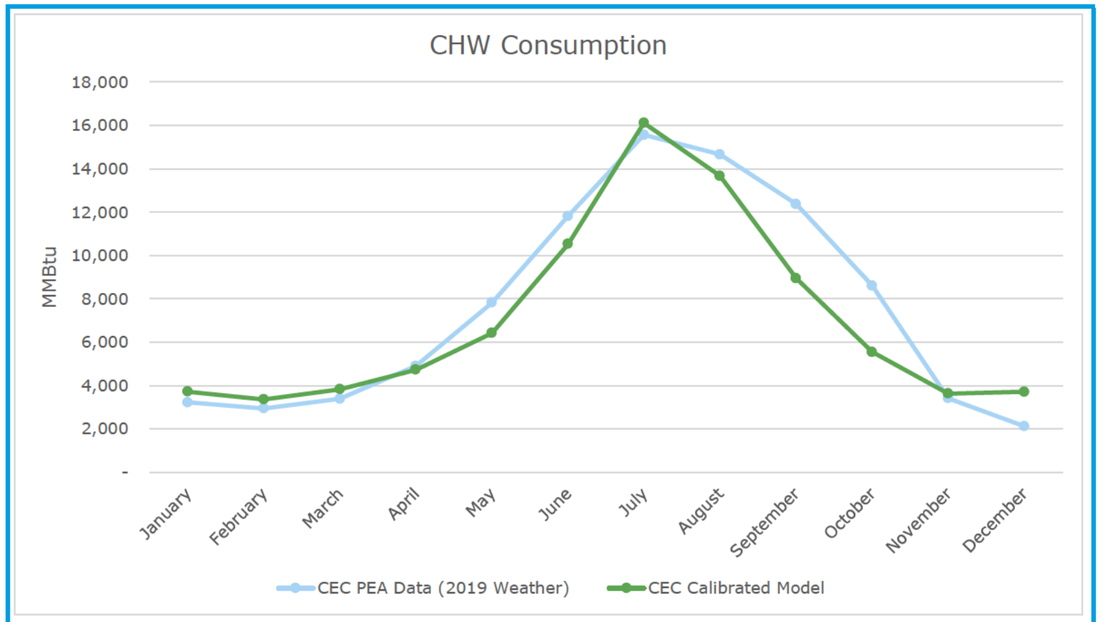
CV(RMSE)	15%	3%



	Limit	Actual
NMBE	5%	-2%
CV(RMSE)	15%	4%



	Limit	Actual
NMBE	5%	-764%
CV(RMSE)	15%	834%



	Limit	Actual
NMBE	5%	8%
CV(RMSE)	15%	22%

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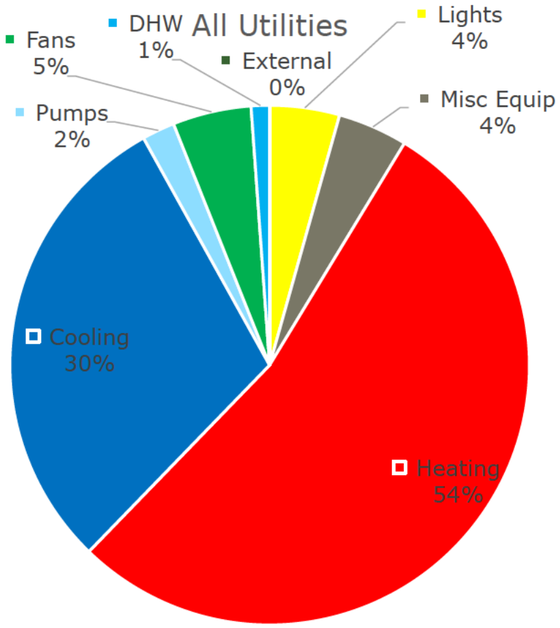
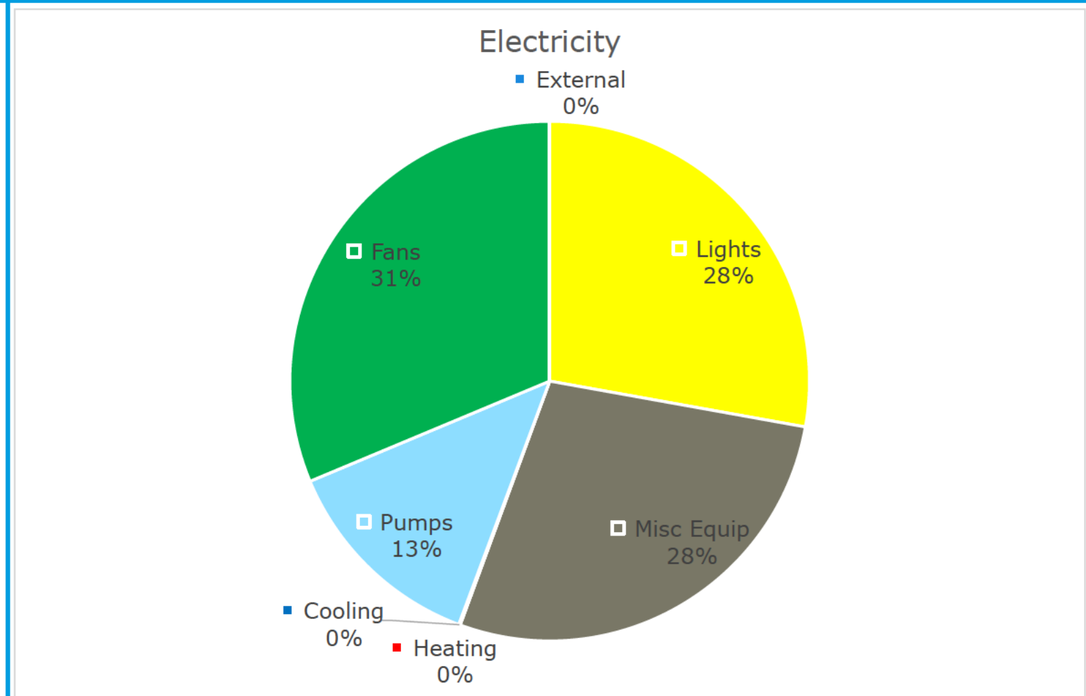
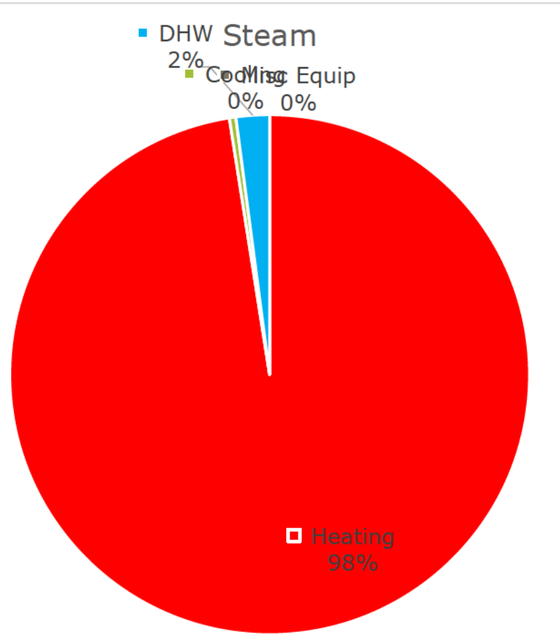
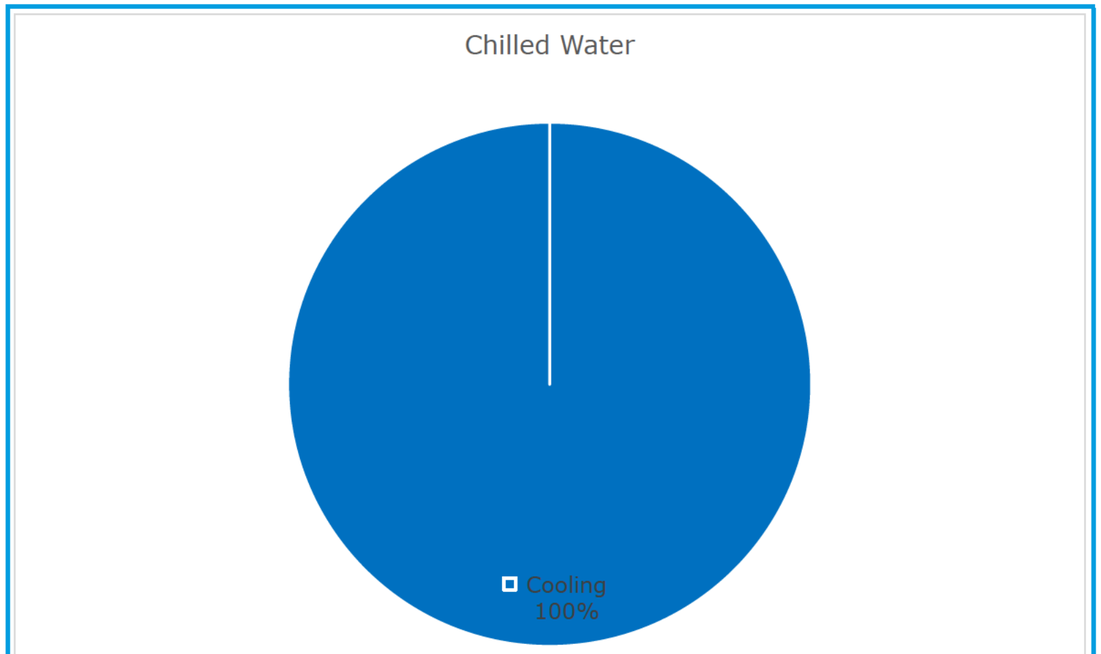
CEC Calibrated Model
End Use Summary





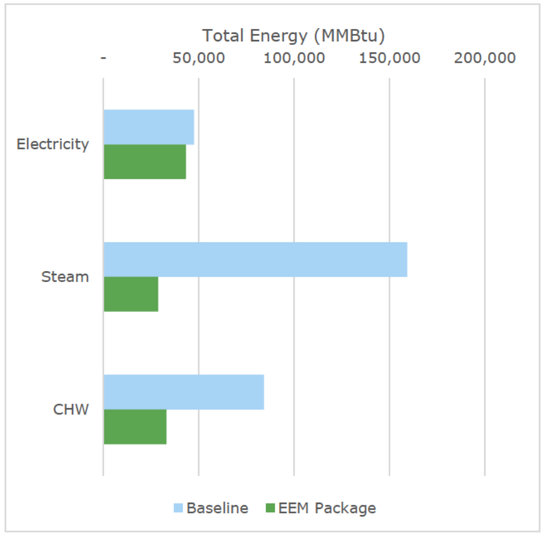


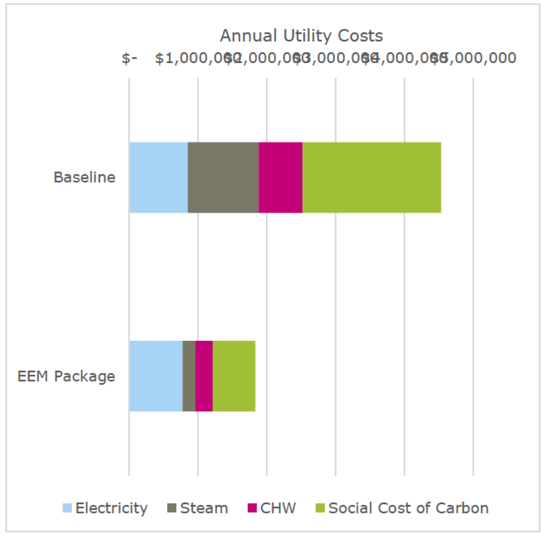


CONFIDENTIAL AND PROPRIETARY

CEC EEM Package Summary

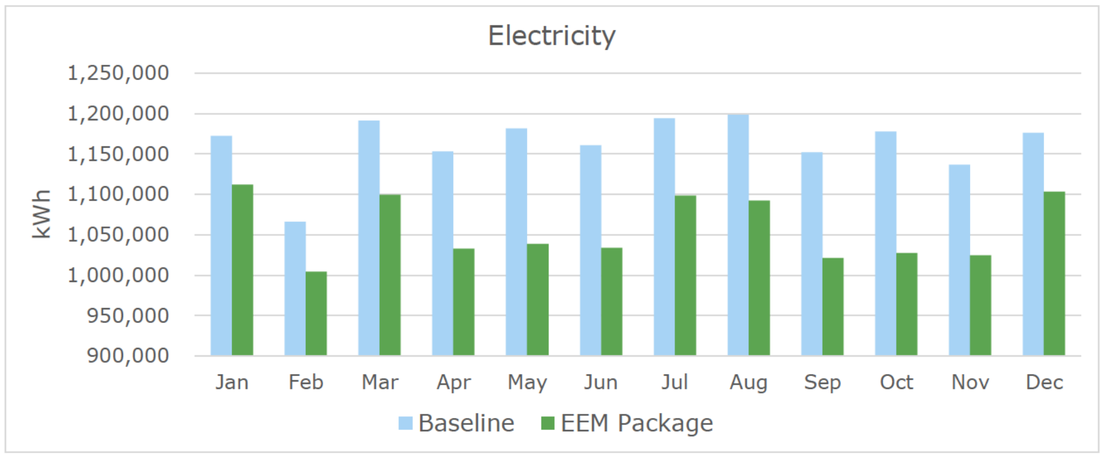
	Units	Baseline	EEM Package	Savings	% Savings
Annual Electric Use	kWh	13,960,266	12,688,368	1,271,898	9.1%
Annual Steam Use	MMBtu	159,500	28,860	130,640	81.9%
Annual CHW Use	MMBtu	84,340	33,170	51,170	60.7%
Annual Total Energy Use	MMBtu	291,472	105,323	186,150	63.9%
EUI	**kBtu/GSF**	**246.2**	**89.0**	**157.2**	**63.9%**
Total Emissions	**MTCO2e**	**16,283**	**4,985**	**11,298**	**69.4%**
Annual Electric Cost	$	$ 848,013	$ 777,488	$ 70,525	8.3%
Annual Natural Gas Cost	$	$ -	$ -	$ -	N/A
Annual Steam Cost	$	$ 1,036,436	$ 187,612	$ 848,824	81.9%
Annual CHW Cost	$	$ 632,583	$ 248,784	$ 383,799	60.7%
Annual Utility Cost	$	$ 2,517,032	$ 1,213,884	$ 1,303,148	51.8%
Social Cost of Carbon	$	$ 2,019,302	$ 618,210	$ 1,401,092	69.4%
Annual Combined Cost	**$**	**$ 4,536,334**	**$ 1,832,094**	**$ 2,704,240**	**59.6%**





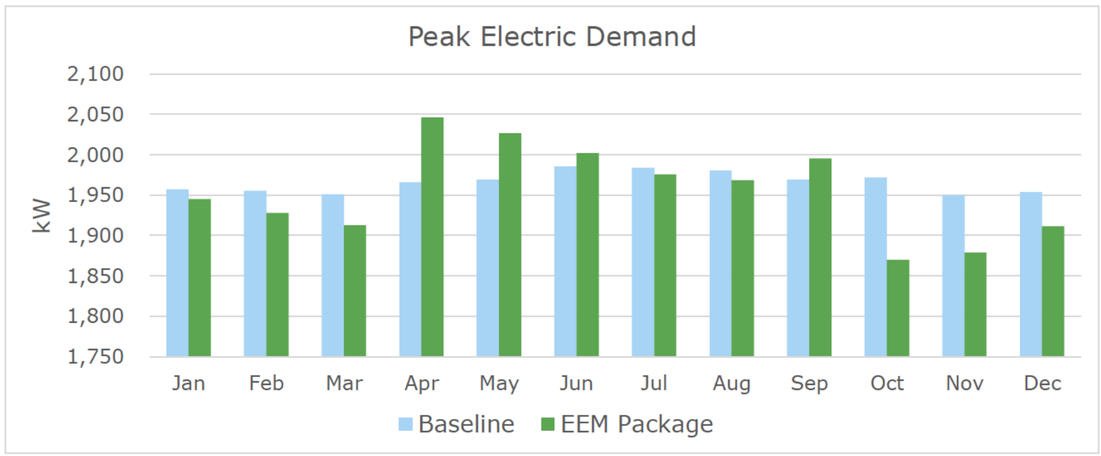
Electric Energy

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kWh	3,641,476	3,641,476	-	0.0%
Misc Equip	kWh	3,635,965	3,635,965	-	0.0%
Heating	kWh	-	419,010	(419,010)	N/A
Cooling	kWh	12,560	210,750	(198,190)	-1577.9%
Pumps	kWh	2,576,772	952,170	1,624,602	63.0%
Fans	kWh	4,093,507	3,829,002	264,505	6.5%
Refrigeration	kWh	-	-	-	N/A
DHW	kWh	-	-	-	N/A
External	kWh	-	-	-	N/A
Total Electric	**kWh**	**13,960,266**	**12,688,368**	**1,271,898**	**9.1%**



Electric Peak Demand

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kW	653.3	653.3	-	0.0%
Misc Equip	kW	448.0	448.0	-	0.0%
Heating	kW	-	126.8	(126.8)	N/A
Cooling	kW	8.3	124.9	(116.6)	-1412.7%
Pumps	kW	327.9	133.0	194.9	59.4%
Fans	kW	566.7	630.6	(63.9)	-11.3%
Refrigeration	kW	-	-	-	N/A
DHW	kW	-	-	-	N/A
External	kW	-	-	-	N/A
Total kW	**kW**	**1,985.8**	**2,046.0**	**(60.2)**	**-3.0%**

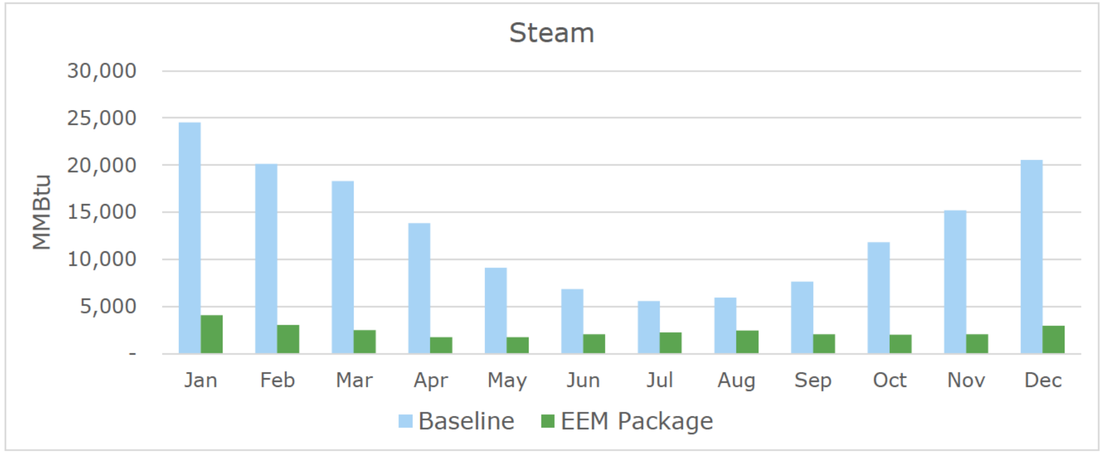


CONFIDENTIAL AND PROPRIETARY

CEC EEM Package Summary (cont.)

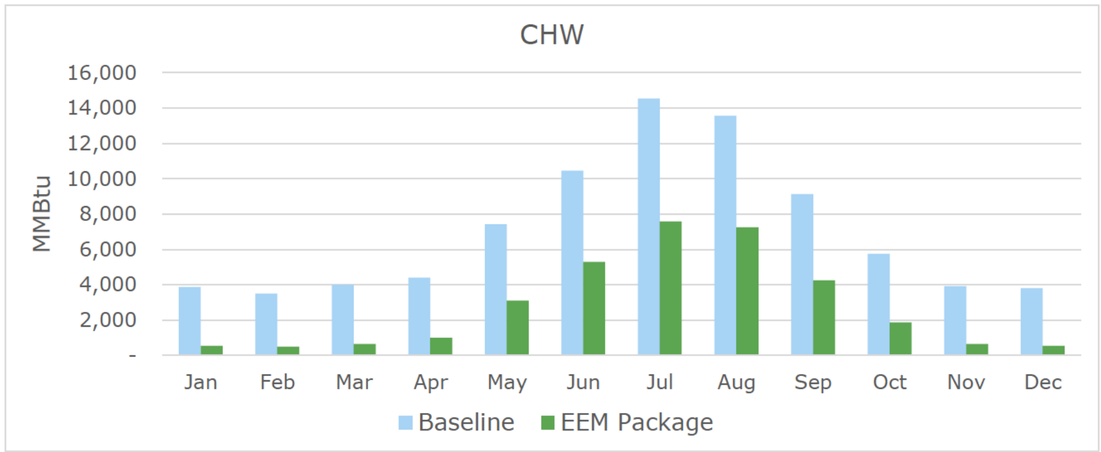
Steam

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	156,000	25,600	130,400	83.6%
Cooling	MMBtu	629	-	629	100.0%
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	3,260	3,260	-	0.0%
External	MMBtu	-	-	-	N/A
Total Steam	**MMBtu**	**159,500**	**28,860**	**130,640**	**81.9%**



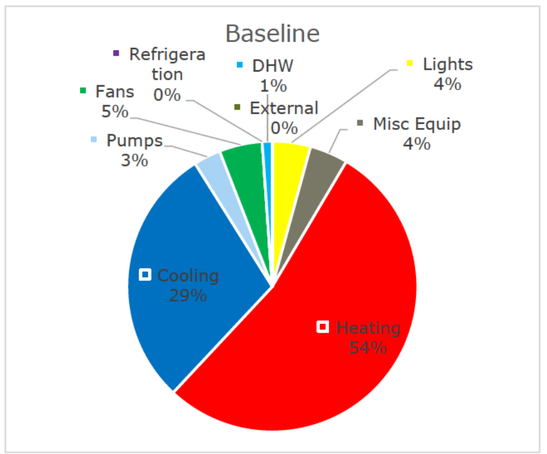
CHW

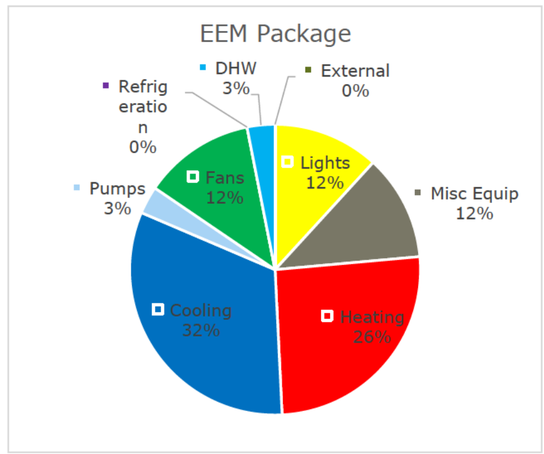
End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	-	-	-	N/A
Cooling	MMBtu	84,300	33,200	51,100	60.6%
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	-	-	-	N/A
External	MMBtu	-	-	-	N/A
Total CHW	**MMBtu**	**84,340**	**33,170**	**51,170**	**60.7%**



All Utilities

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	12,425	12,425	-	0.0%
Misc Equip	MMBtu	12,406	12,406	-	0.0%
Heating	MMBtu	156,000	27,030	128,970	82.7%
Cooling	MMBtu	84,972	33,919	51,053	60.1%
Pumps	MMBtu	8,792	3,249	5,543	63.0%
Fans	MMBtu	13,967	13,065	902	6.5%
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	3,260	3,260	-	0.0%
External	MMBtu	-	-	-	N/A
Total	**MMBtu**	**291,472**	**105,323**	**186,150**	**63.9%**





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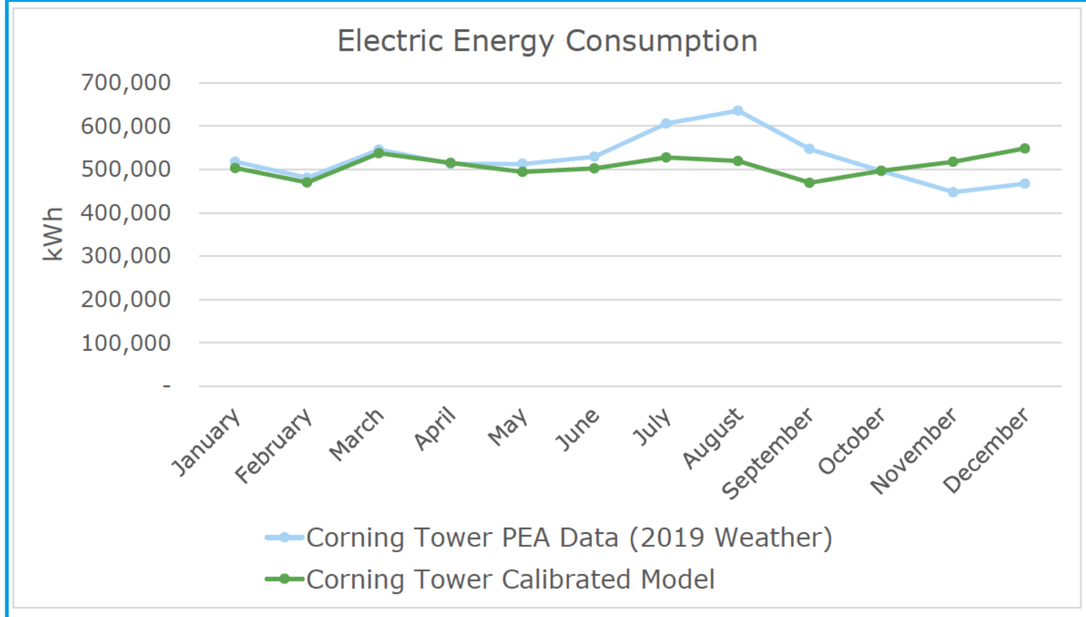
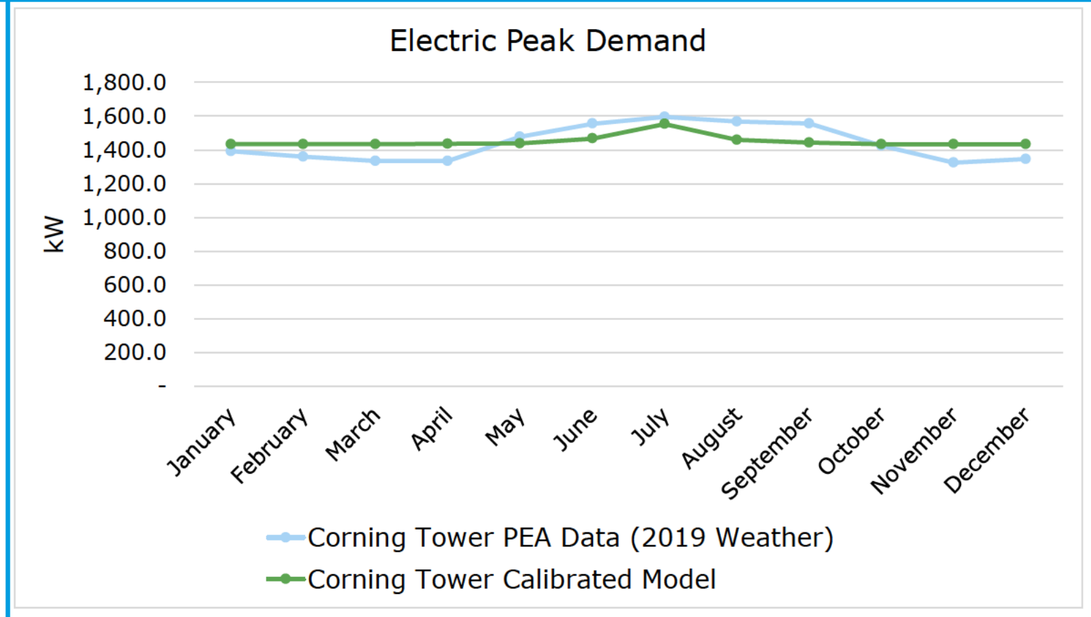
Corning Tower Calibration



	Limit	Actual
NMBE	5%	3%
CV(RMSE)	15%	11%



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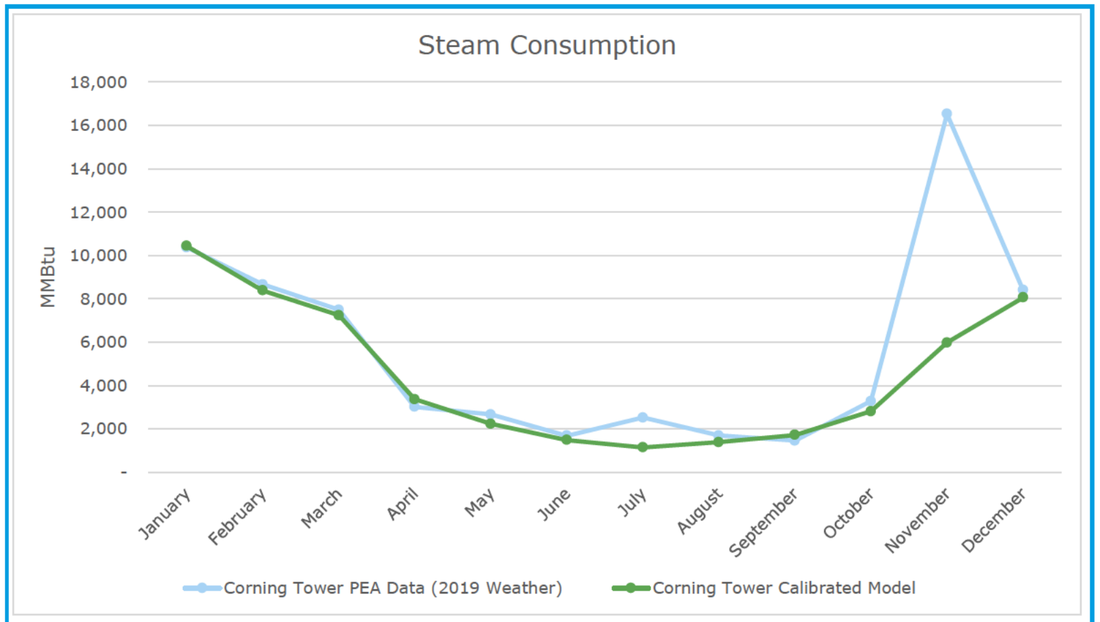
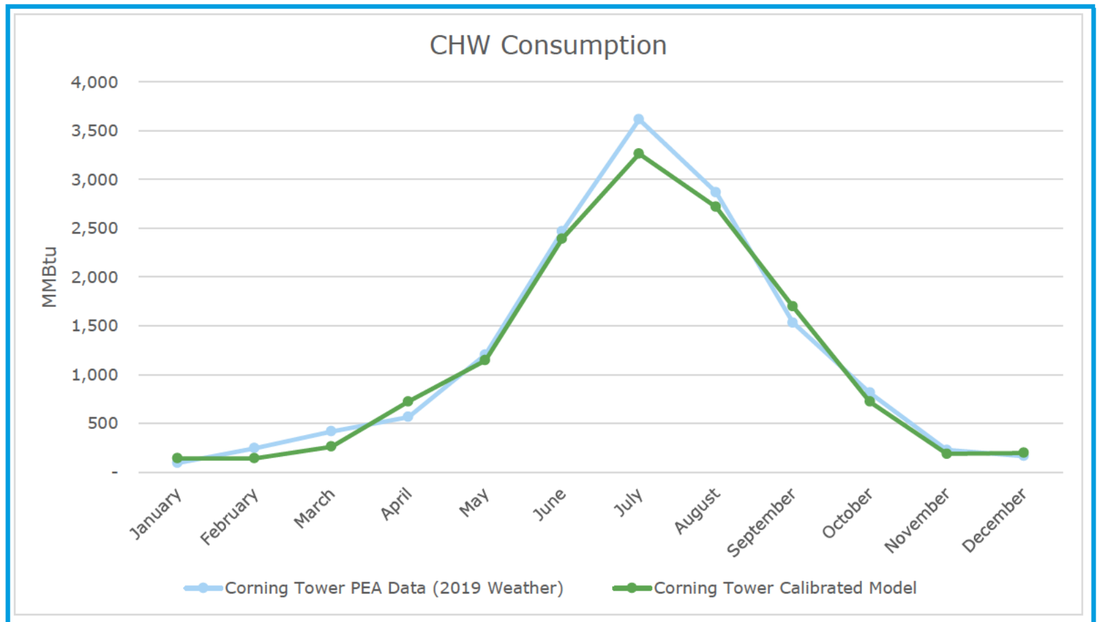
NMBE	5%	-1%
CV(RMSE)	15%	6%



	Limit	Actual
NMBE	5%	22%
CV(RMSE)	15%	57%



	Limit	Actual
NMBE	5%	5%
CV(RMSE)	15%	13%

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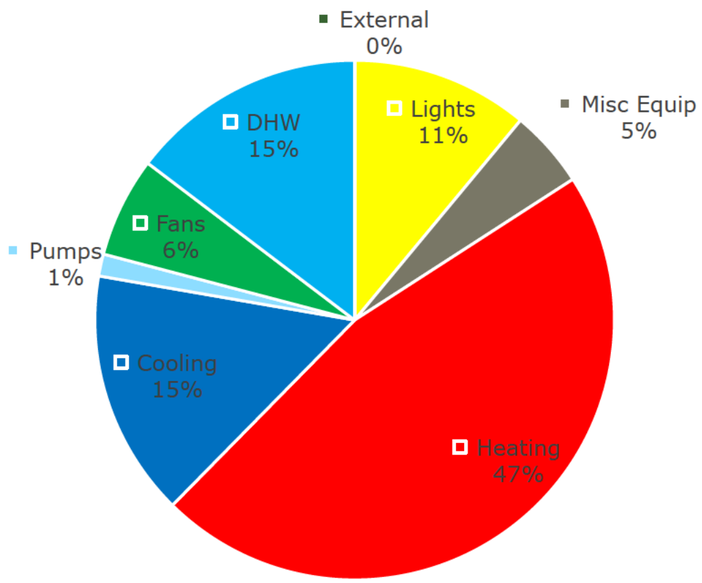
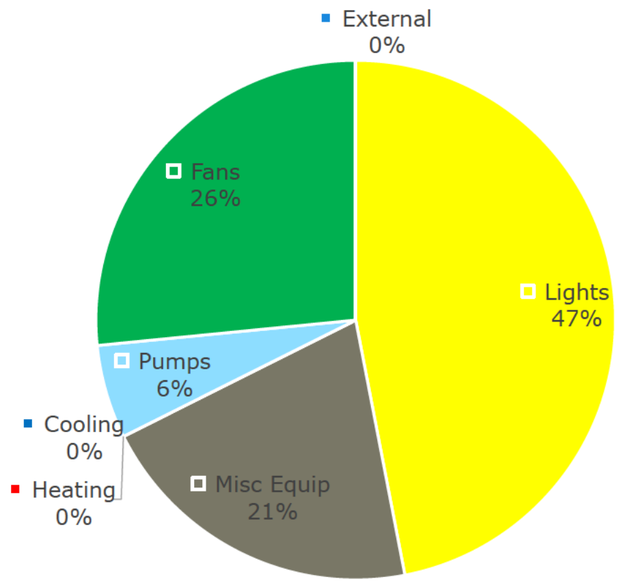
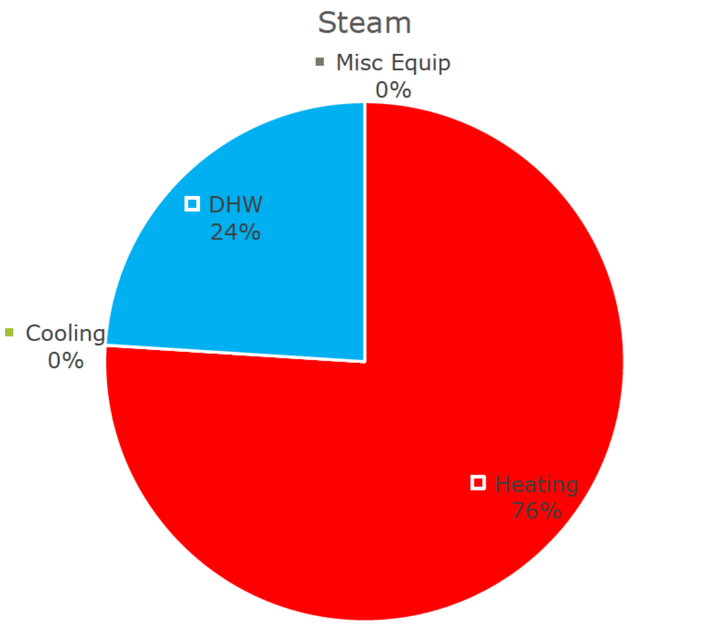
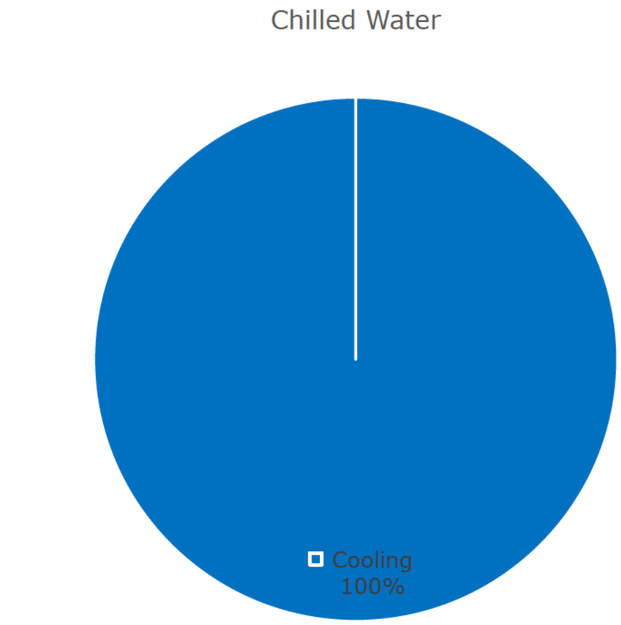
Corning Tower Calibrated Model
End Use Summary









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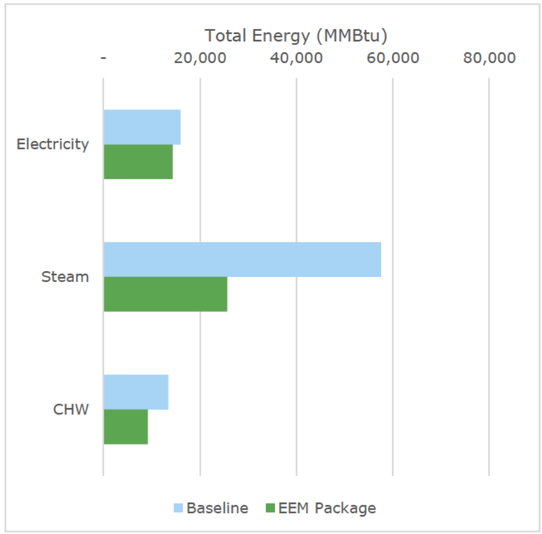
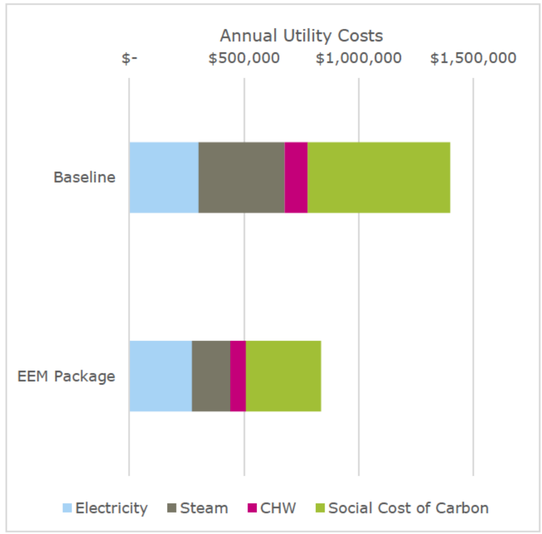
Corning Tower EEM Package Summary

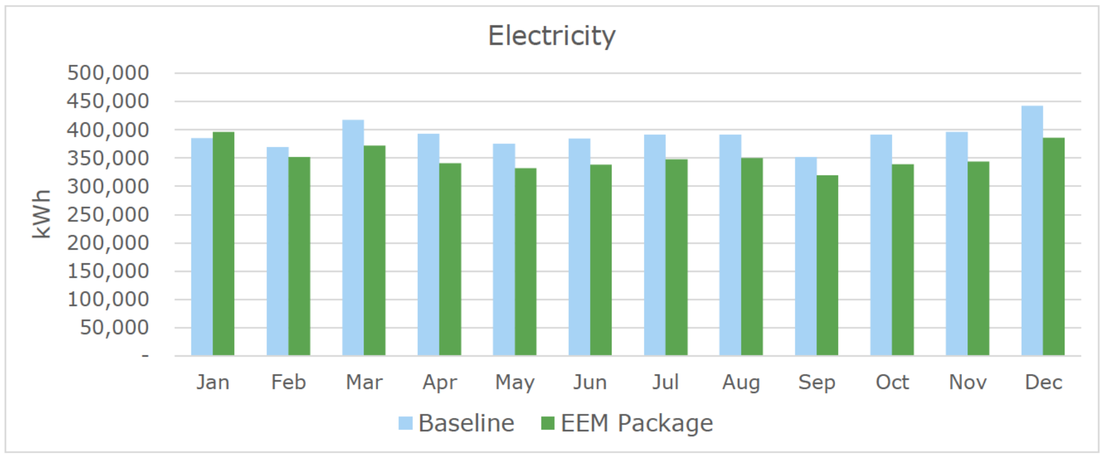
	Units	Baseline	EEM Package	Savings	% Savings
Annual Electric Use	kWh	4,688,566	4,216,946	471,620	10.1%
Annual Steam Use	MMBtu	57,530	25,670	31,860	55.4%
Annual CHW Use	MMBtu	13,460	9,159	4,301	32.0%
Annual Total Energy Use	MMBtu	86,987	49,217	37,770	43.4%
EUI	**kBtu/GSF**	**95.0**	**53.7**	**41.2**	**43.4%**
Total Emissions	**MTCO2e**	**5,012**	**2,634**	**2,378**	**47.4%**
Annual Electric Cost	$	$ 303,276	$ 273,947	$ 29,329	9.7%
Annual Natural Gas Cost	$	$ -	$ -	$ -	N/A
Annual Steam Cost	$	$ 373,971	$ 166,845	$ 207,126	55.4%
Annual CHW Cost	$	$ 100,922	$ 68,695	$ 32,227	31.9%
Annual Utility Cost	$	$ 778,169	$ 509,487	$ 268,682	34.5%
Social Cost of Carbon	$	$ 621,551	$ 326,652	$ 294,900	47.4%
Annual Combined Cost	**$**	**$ 1,399,720**	**$ 836,139**	**$ 563,582**	**40.3%**





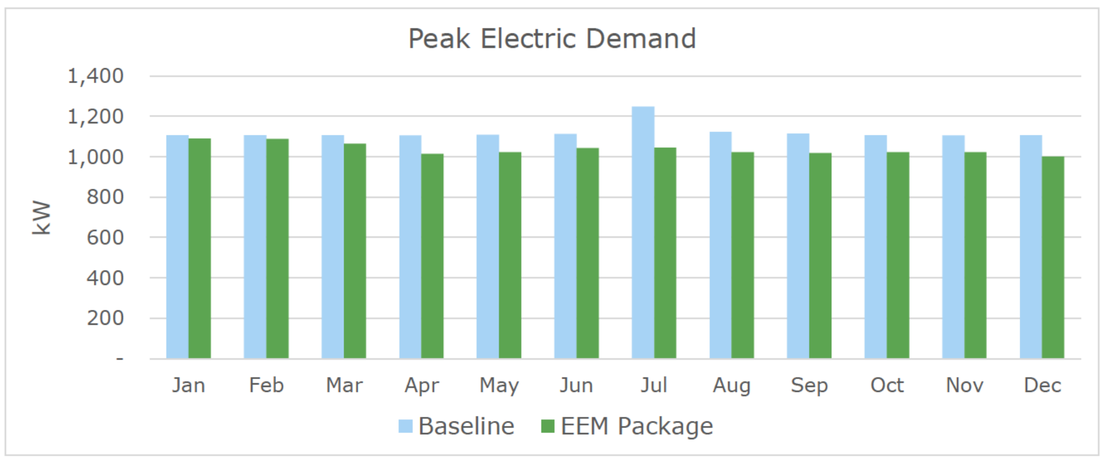
Electric Energy

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kWh	1,461,688	1,461,688	-	0.0%
Misc Equip	kWh	1,259,623	1,259,623	-	0.0%
Heating	kWh	-	-	-	N/A
Cooling	kWh	-	-	-	N/A
Pumps	kWh	362,367	212,534	149,833	41.3%
Fans	kWh	1,604,888	1,283,105	321,783	20.1%
Refrigeration	kWh	-	-	-	N/A
DHW	kWh	-	-	-	N/A
External	kWh	-	-	-	N/A
Total Electric	**kWh**	**4,688,566**	**4,216,946**	**471,620**	**10.1%**



Electric Peak Demand

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kW	340.7	340.7	-	0.0%
Misc Equip	kW	335.4	335.4	-	0.0%
Heating	kW	-	-	-	N/A
Cooling	kW	-	-	-	N/A
Pumps	kW	95.1	45.0	50.1	52.7%
Fans	kW	504.9	606.0	(101.1)	-20.0%
Refrigeration	kW	-	-	-	N/A
DHW	kW	-	-	-	N/A
External	kW	-	-	-	N/A
Total kW	**kW**	**1,249.1**	**1,089.4**	**159.7**	**12.8%**



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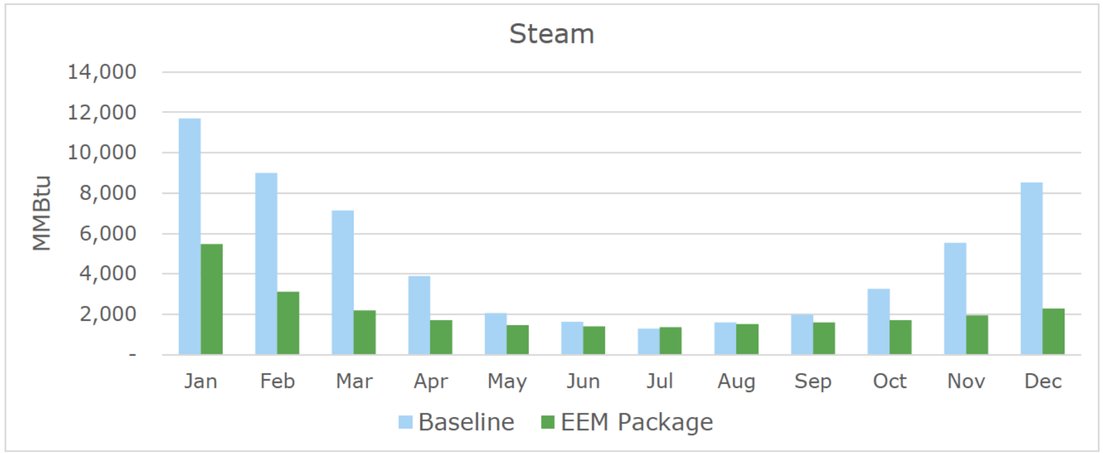
Corning Tower EEM Package Summary (cont.)

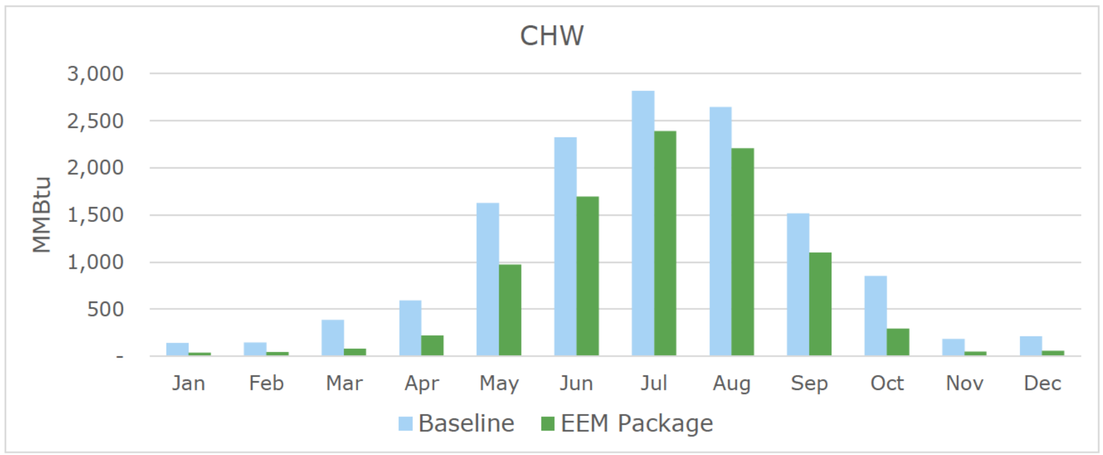
Steam

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	44,600	12,600	32,000	71.7%
Cooling	MMBtu	-	-	-	N/A
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	13,000	13,000	-	0.0%
External	MMBtu	-	-	-	N/A
Total Steam	**MMBtu**	**57,530**	**25,670**	**31,860**	**55.4%**



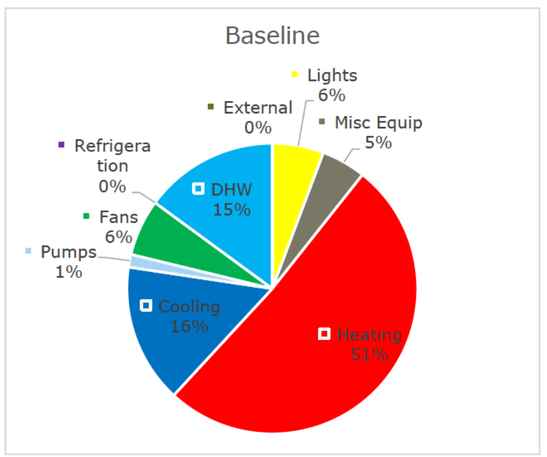
CHW

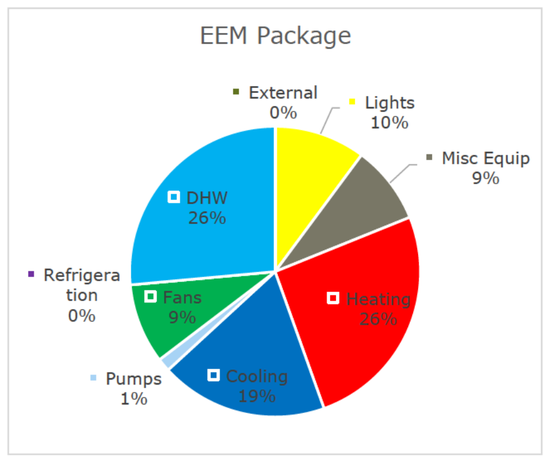
End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	-	-	-	N/A
Cooling	MMBtu	13,500	9,160	4,340	32.1%
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	-	-	-	N/A
External	MMBtu	-	-	-	N/A
Total CHW	**MMBtu**	**13,460**	**9,159**	**4,301**	**32.0%**



All Utilities

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	4,987	4,987	-	0.0%
Misc Equip	MMBtu	4,298	4,298	-	0.0%
Heating	MMBtu	44,600	12,600	32,000	71.7%
Cooling	MMBtu	13,500	9,160	4,340	32.1%
Pumps	MMBtu	1,236	725	511	41.3%
Fans	MMBtu	5,476	4,378	1,098	20.1%
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	13,000	13,000	-	0.0%
External	MMBtu	-	-	-	N/A
Total	**MMBtu**	**86,987**	**49,217**	**37,770**	**43.4%**





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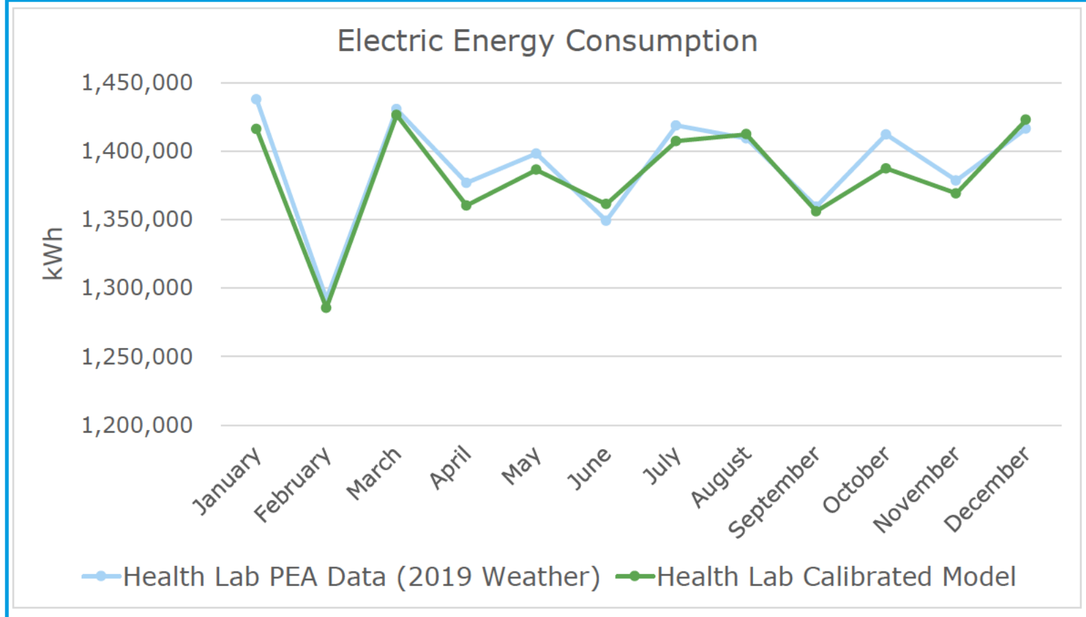
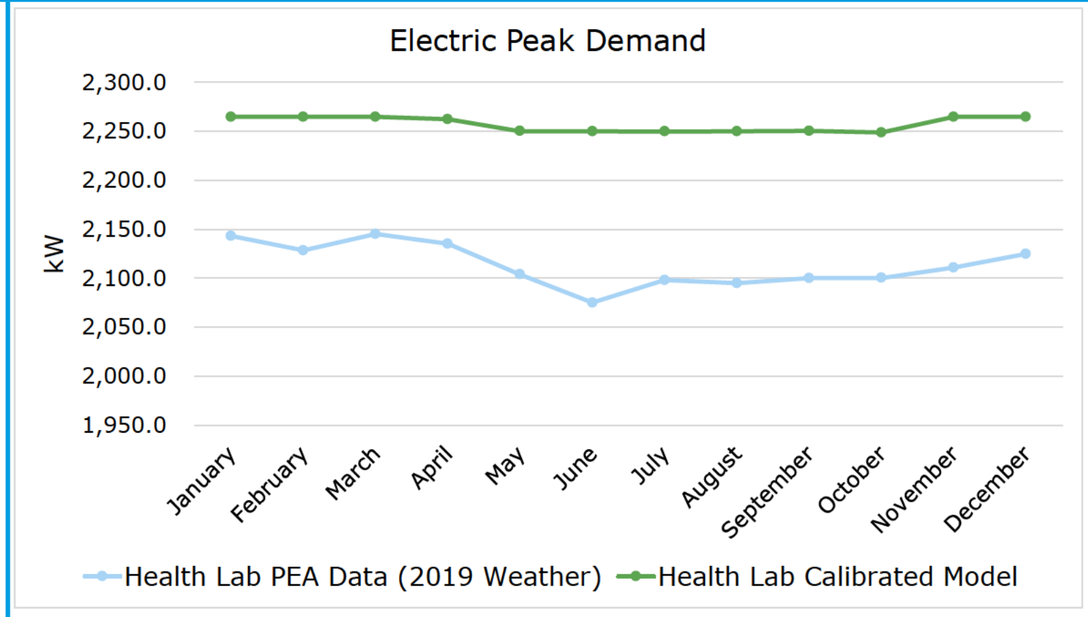
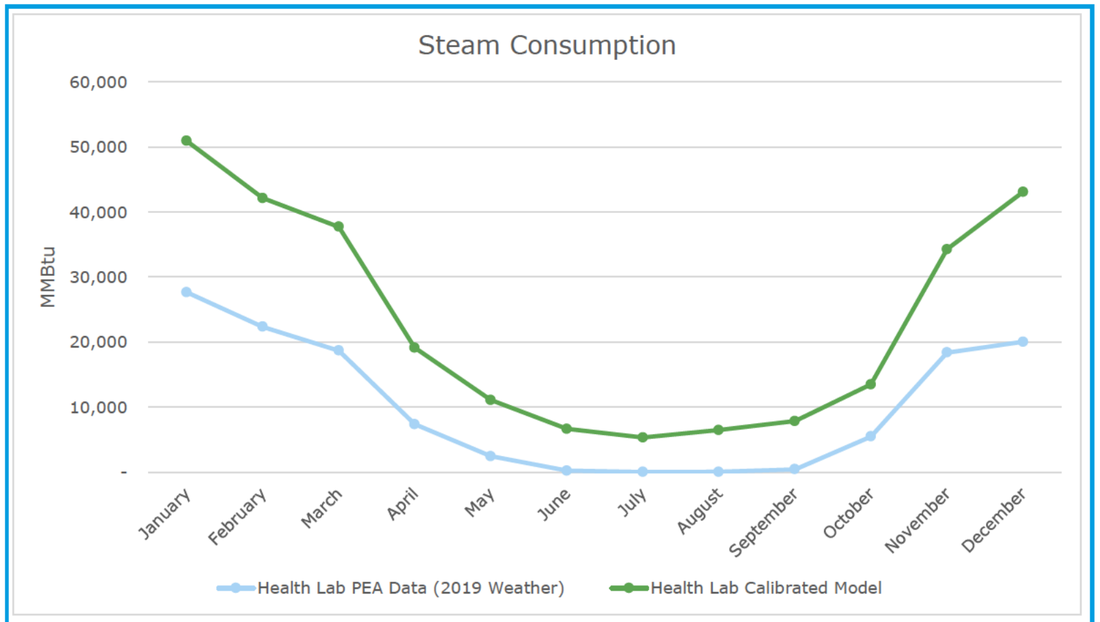
Health Lab Calibration



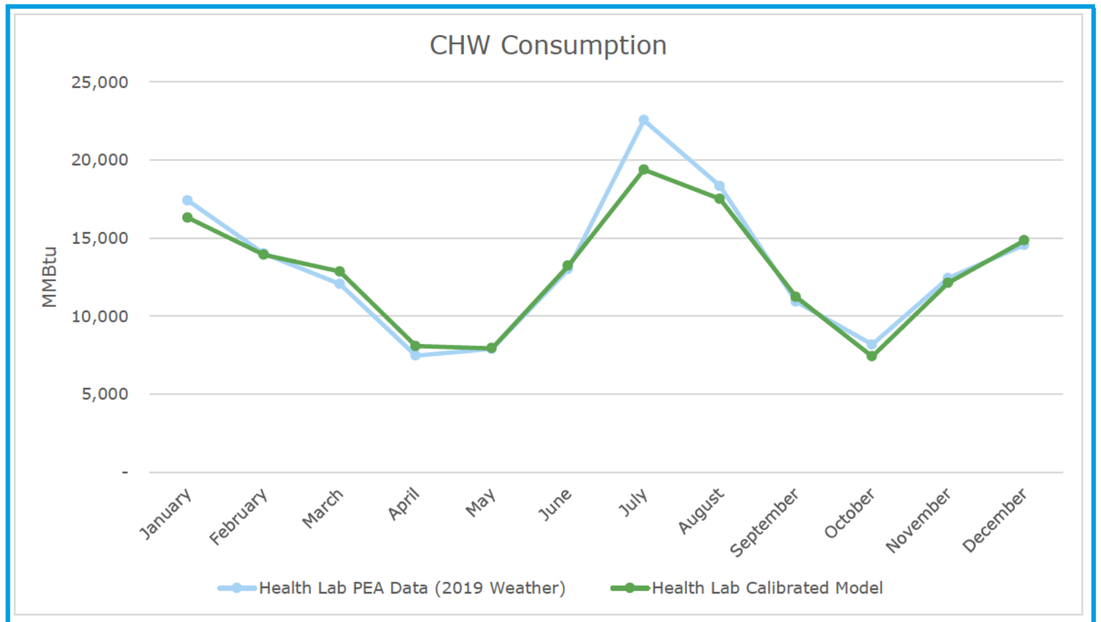
	Limit	Actual
NMBE	5%	1%
CV(RMSE)	15%	1%



	Limit	Actual
NMBE	5%	-7%
CV(RMSE)	15%	7%



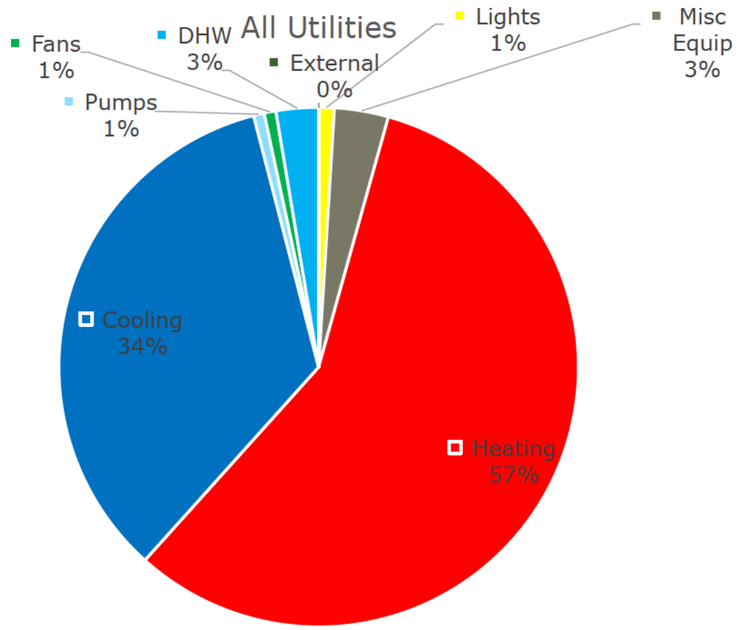
	Limit	Actual
NMBE	5%	-138%
CV(RMSE)	15%	148%

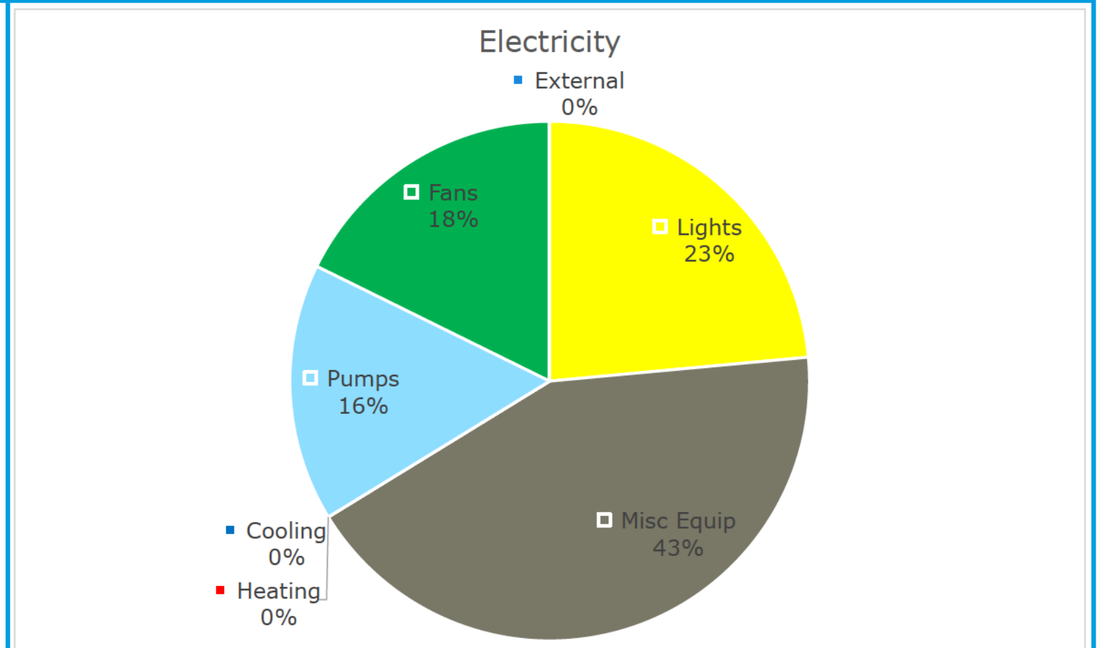


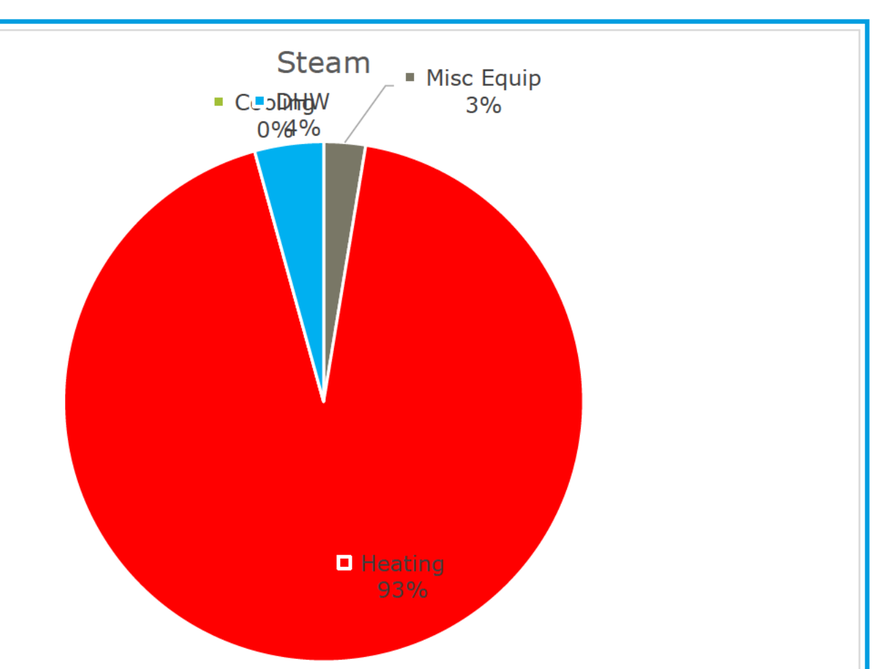
	Limit	Actual
NMBE	5%	3%
CV(RMSE)	15%	8%

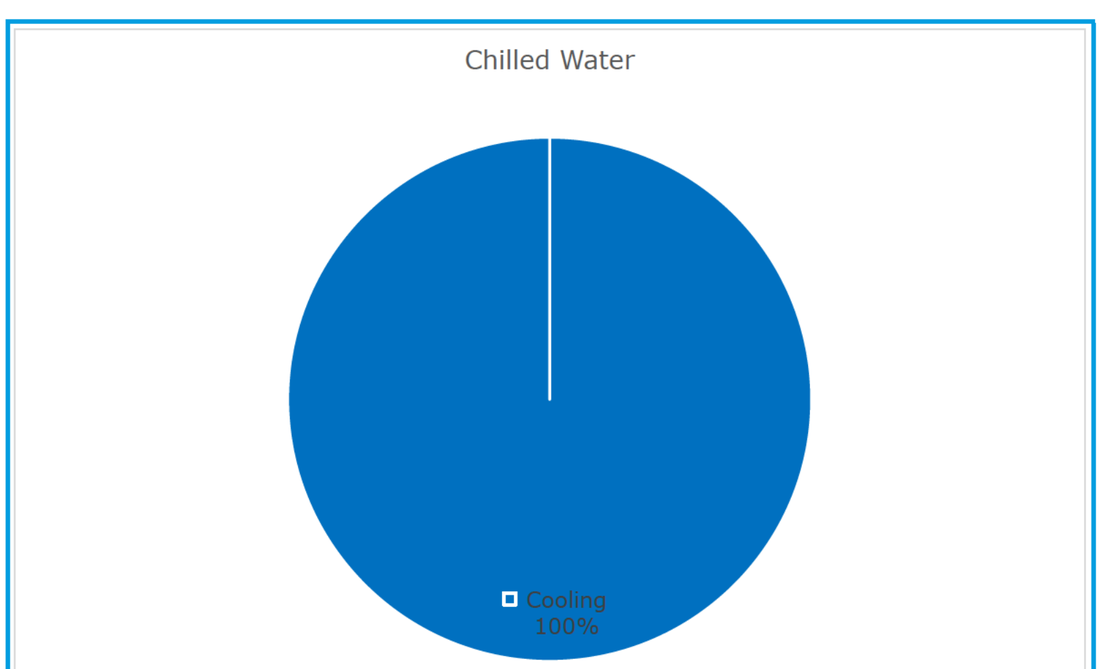
CONFIDENTIAL AND PROPRIETARY

Health Lab Calibrated Model
End Use Summary









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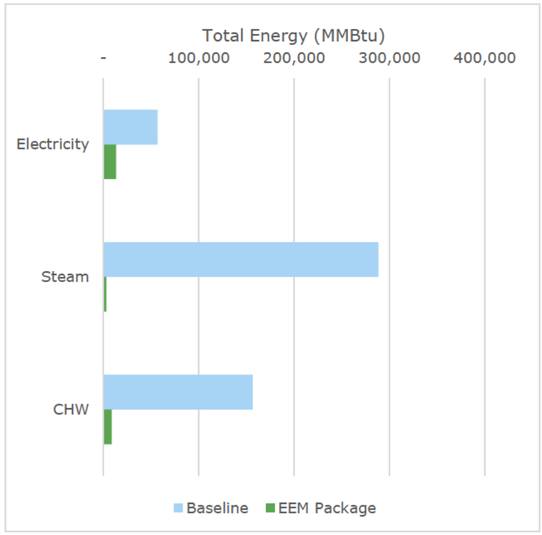
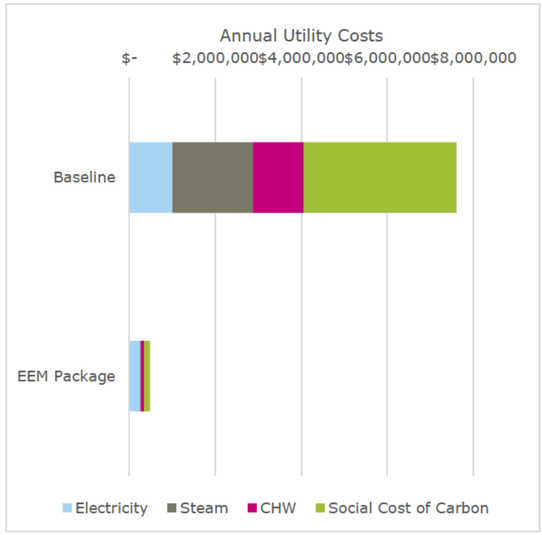
Health Lab EEM Package Summary

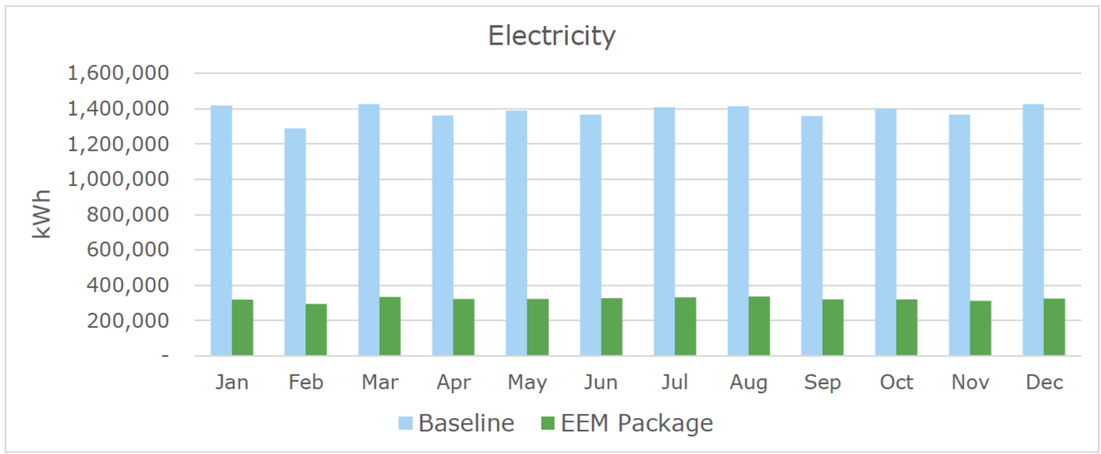
	Units	Baseline	EEM Package	Savings	% Savings
Annual Electric Use	kWh	16,606,150	3,859,972	12,746,178	76.8%
Annual Steam Use	MMBtu	288,400	3,328	285,072	98.8%
Annual CHW Use	MMBtu	156,700	9,019	147,681	94.2%
Annual Total Energy Use	MMBtu	501,760	25,517	476,243	94.9%
EUI	**kBtu/GSF**	**1,053.9**	**53.6**	**1,000.3**	**94.9%**
Total Emissions	**MTCO2e**	**28,651**	**1,103**	**27,548**	**96.2%**
Annual Electric Cost	$	$ 1,005,468	$ 250,240	$ 755,228	75.1%
Annual Natural Gas Cost	$	$ -	$ -	$ -	N/A
Annual Steam Cost	$	$ 1,874,857	$ 21,633	$ 1,853,224	98.8%
Annual CHW Cost	$	$ 1,175,161	$ 67,643	$ 1,107,518	94.2%
Annual Utility Cost	$	$ 4,055,486	$ 339,516	$ 3,715,970	91.6%
Social Cost of Carbon	$	$ 3,552,938	$ 136,745	$ 3,416,193	96.2%
Annual Combined Cost	**$**	**$ 7,608,424**	**$ 476,261**	**$ 7,132,163**	**93.7%**





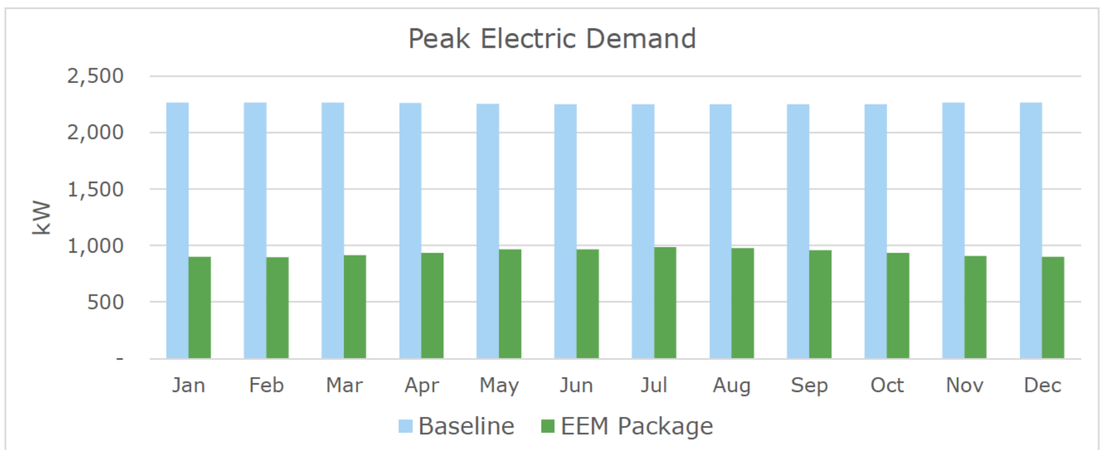
Electric Energy

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kWh	1,286,307	986,855	299,452	23.3%
Misc Equip	kWh	2,334,717	1,375,329	959,388	41.1%
Heating	kWh	-	-	-	N/A
Cooling	kWh	-	-	-	N/A
Pumps	kWh	892,635	31,879	860,756	96.4%
Fans	kWh	10,968,097	1,465,904	9,502,193	86.6%
Refrigeration	kWh	1,124,342	-	1,124,342	100.0%
DHW	kWh	-	-	-	N/A
External	kWh	-	-	-	N/A
Total Electric	**kWh**	**16,606,150**	**3,859,972**	**12,746,178**	**76.8%**



Electric Peak Demand

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kW	338.9	406.3	(67.4)	-19.9%
Misc Equip	kW	419.2	305.2	114.0	27.2%
Heating	kW	-	-	-	N/A
Cooling	kW	-	-	-	N/A
Pumps	kW	126.9	4.8	122.0	96.2%
Fans	kW	1,252.1	279.1	973.0	77.7%
Refrigeration	kW	128.4	-	128.4	100.0%
DHW	kW	-	-	-	N/A
External	kW	-	-	-	N/A
Total kW	**kW**	**2,264.7**	**986.7**	**1,278.0**	**56.4%**



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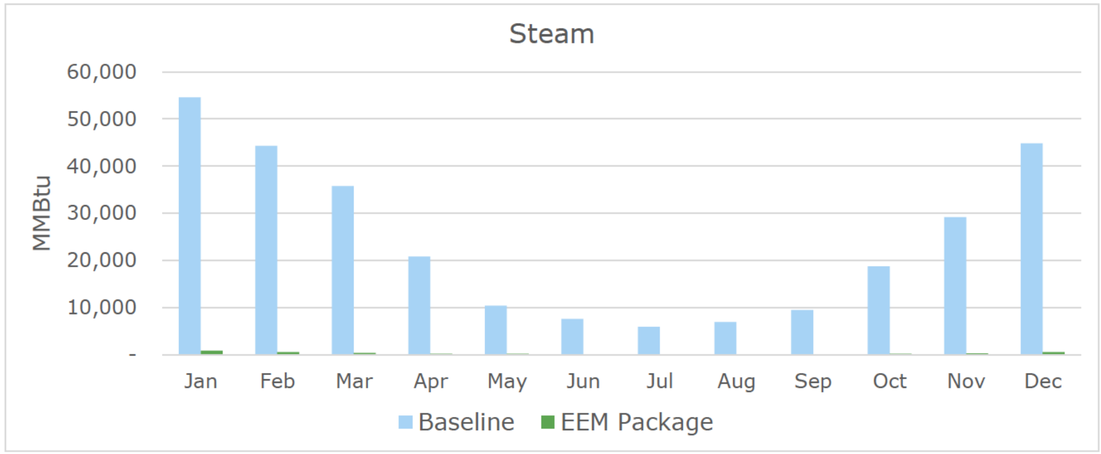
Health Lab EEM Package Summary (cont.)

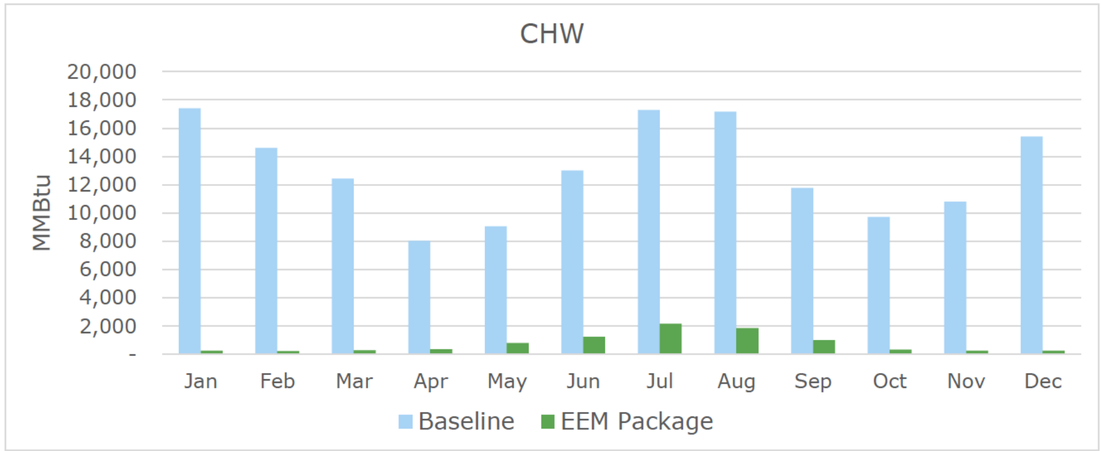
Steam

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	7,220	-	7,220	100.0%
Heating	MMBtu	269,000	2,600	266,400	99.0%
Cooling	MMBtu	-	-	-	N/A
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	11,900	725	11,175	93.9%
External	MMBtu	-	-	-	N/A
Total Steam	**MMBtu**	**288,400**	**3,328**	**285,072**	**98.8%**



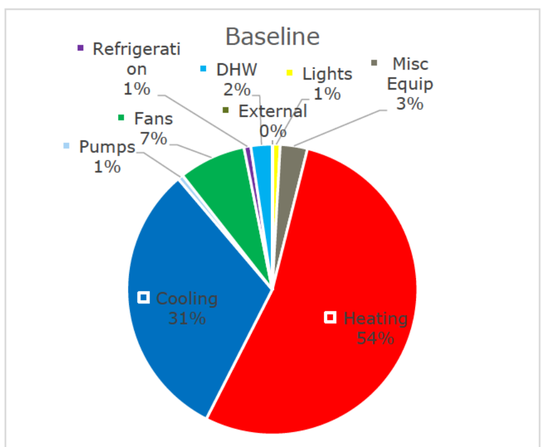
CHW

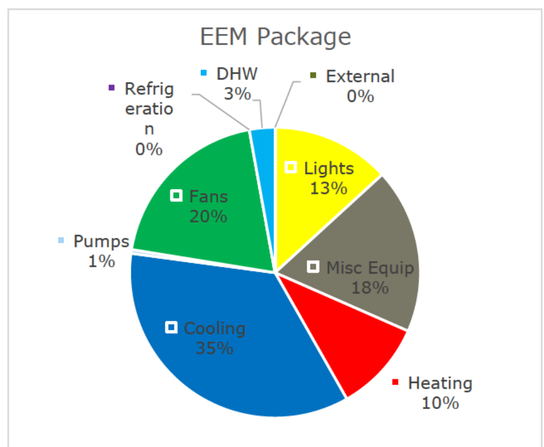
End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	-	-	-	N/A
Cooling	MMBtu	157,000	9,020	147,980	94.3%
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	-	-	-	N/A
External	MMBtu	-	-	-	N/A
Total CHW	**MMBtu**	**156,700**	**9,019**	**147,681**	**94.2%**



All Utilities

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	4,389	3,367	1,022	23.3%
Misc Equip	MMBtu	15,186	4,693	10,493	69.1%
Heating	MMBtu	269,000	2,600	266,400	99.0%
Cooling	MMBtu	157,000	9,020	147,980	94.3%
Pumps	MMBtu	3,046	109	2,937	96.4%
Fans	MMBtu	37,423	5,002	32,421	86.6%
Refrigeration	MMBtu	3,836	-	3,836	100.0%
DHW	MMBtu	11,900	725	11,175	93.9%
External	MMBtu	-	-	-	N/A
Total	**MMBtu**	**501,760**	**25,517**	**476,243**	**94.9%**





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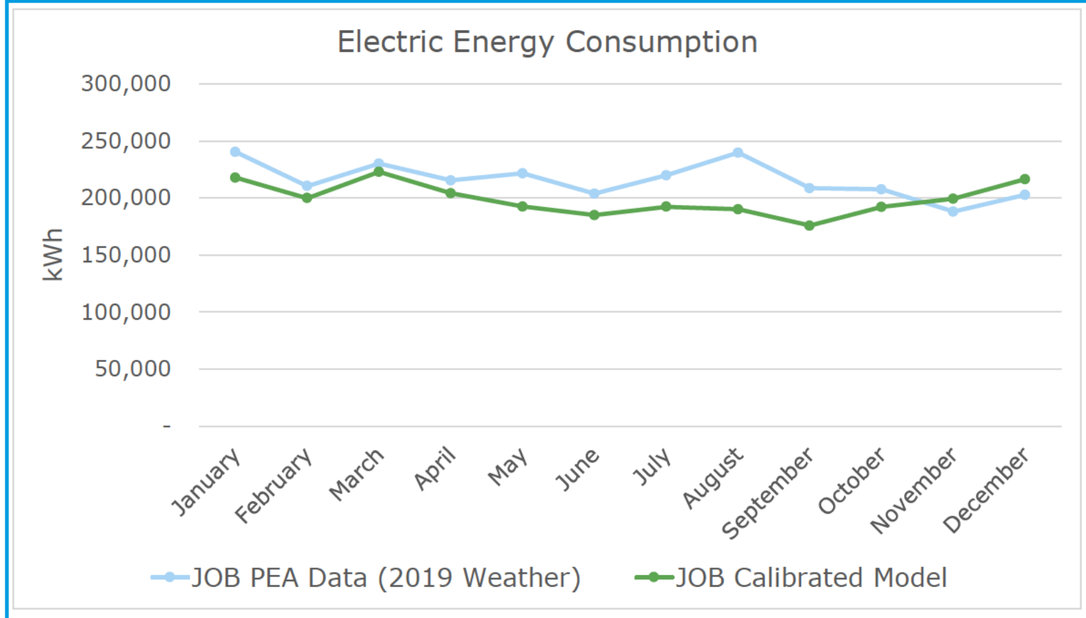
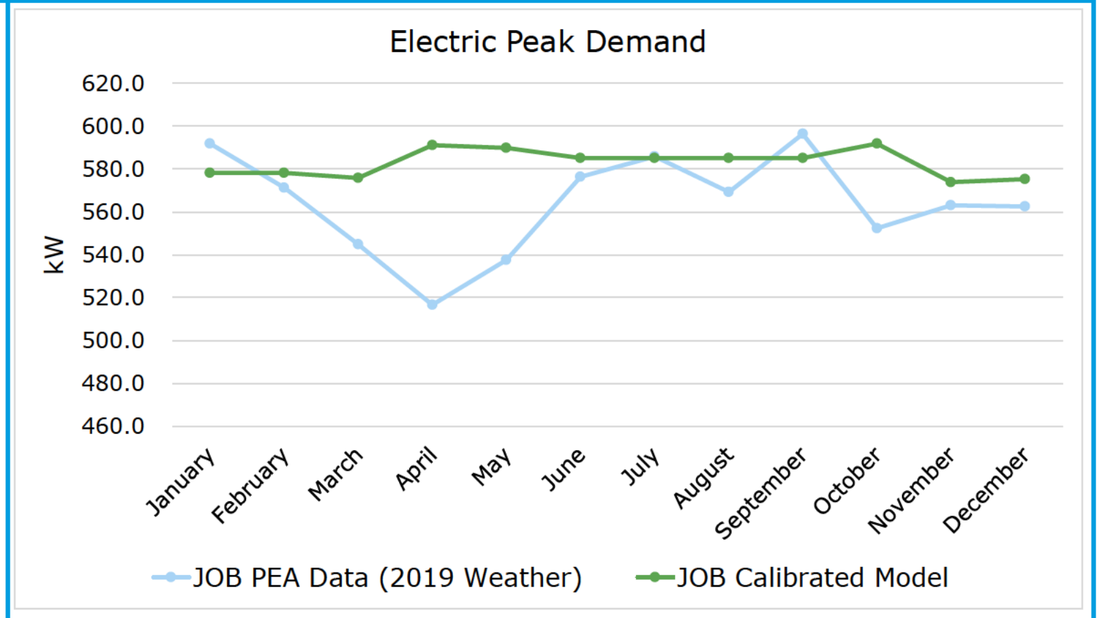
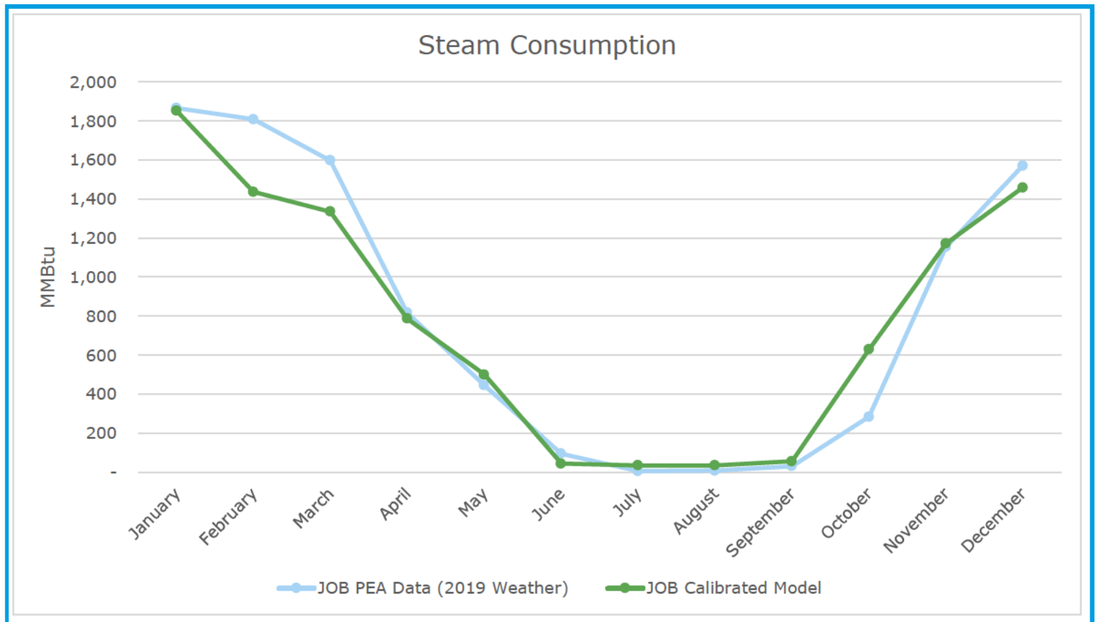
JOB Calibration



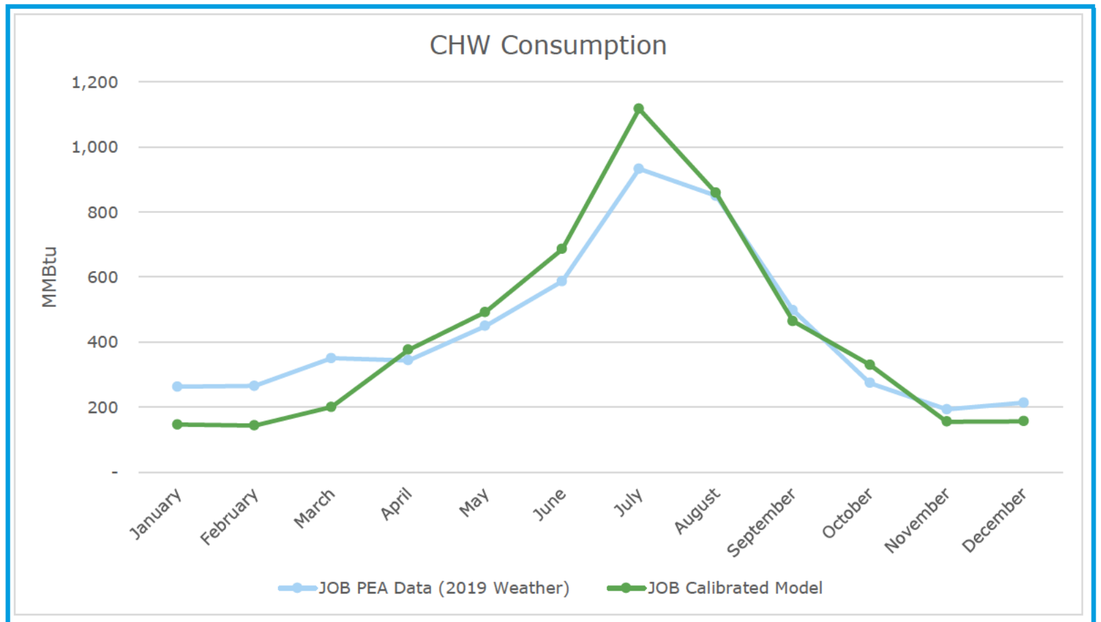
	Limit	Actual
NMBE	5%	8%
CV(RMSE)	15%	12%



	Limit	Actual
NMBE	5%	-4%
CV(RMSE)	15%	6%



	Limit	Actual
NMBE	5%	4%
CV(RMSE)	15%	22%



	Limit	Actual
NMBE	5%	2%
CV(RMSE)	15%	23%

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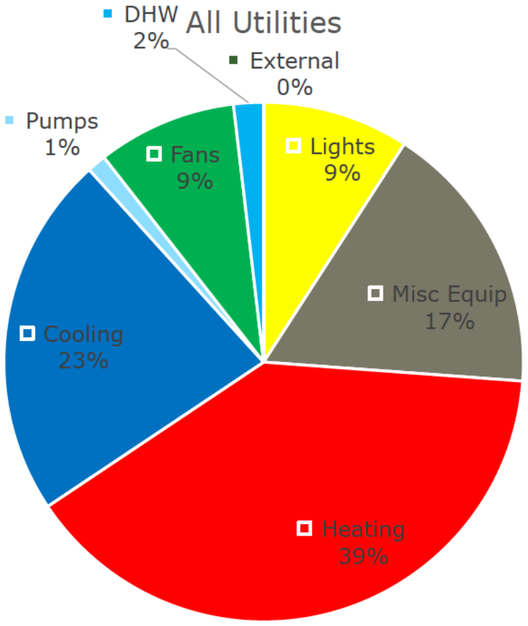
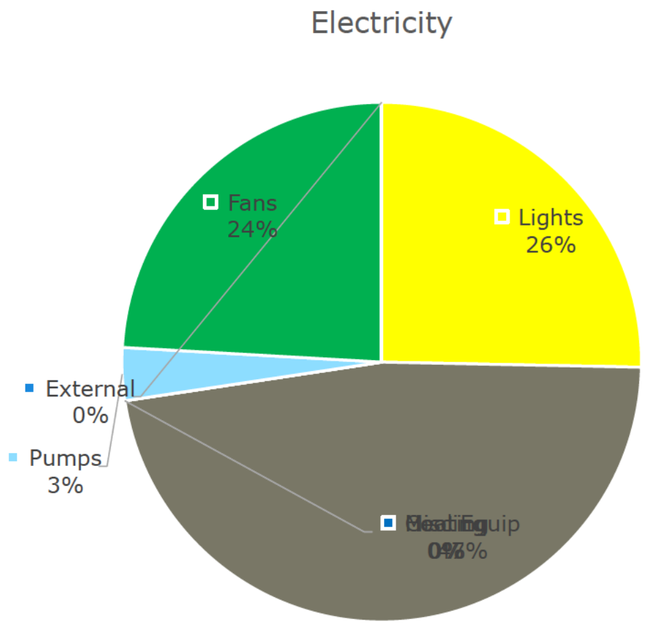
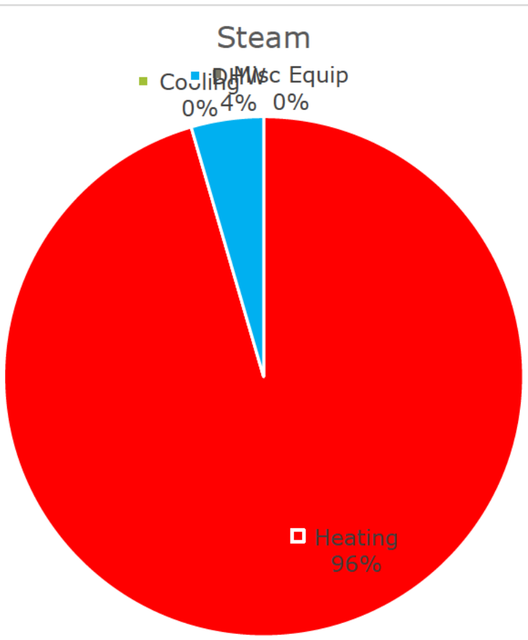
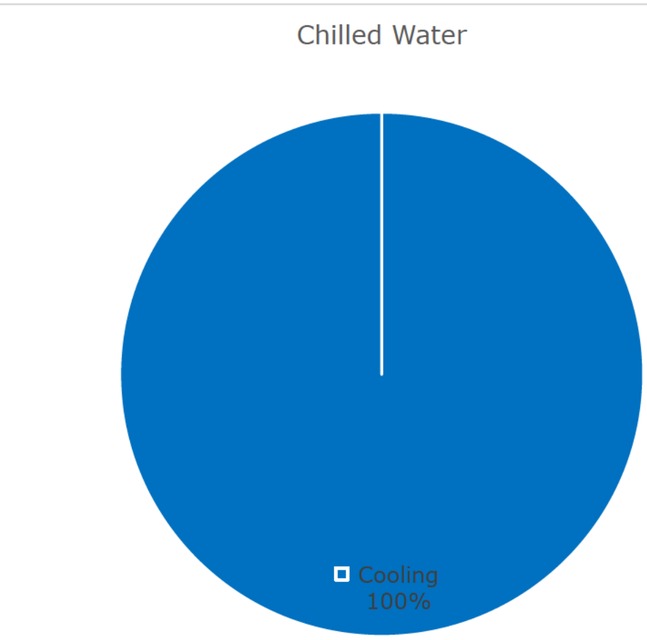
JOB Calibrated Model
End Use Summary









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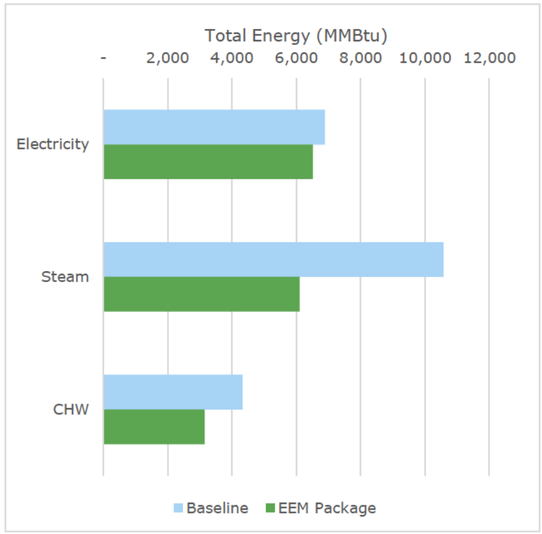
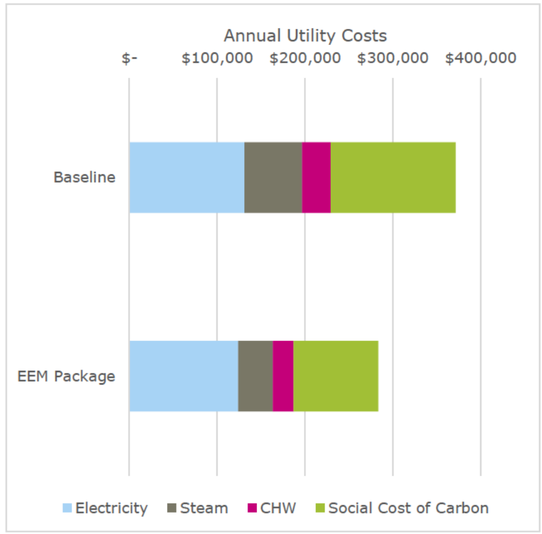
JOB EEM Package Summary

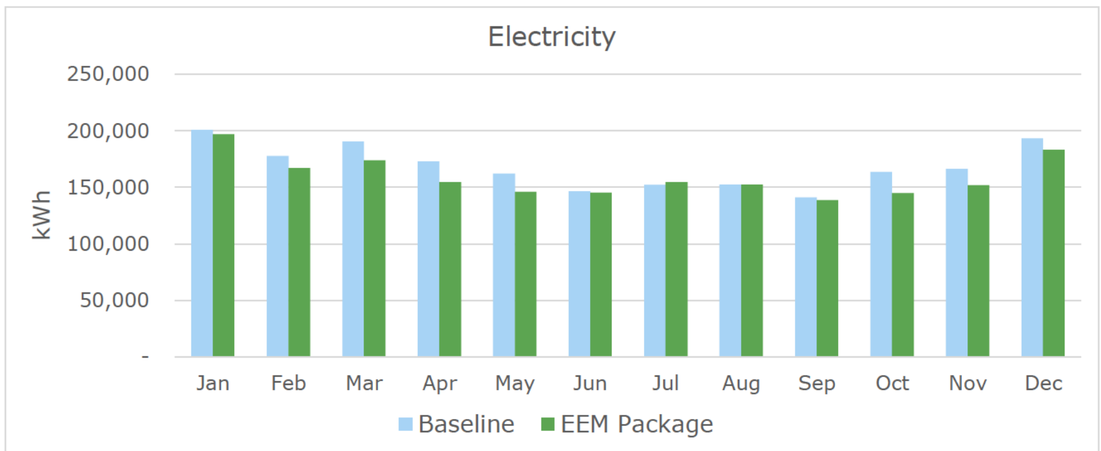
	Units	Baseline	EEM Package	Savings	% Savings
Annual Electric Use	kWh	2,018,585	1,909,244	109,341	5.4%
Annual Steam Use	MMBtu	10,570	6,094	4,476	42.3%
Annual CHW Use	MMBtu	4,329	3,148	1,181	27.3%
Annual Total Energy Use	MMBtu	21,786	15,756	6,030	27.7%
EUI	**kBtu/GSF**	**84.4**	**61.1**	**23.4**	**27.7%**
Total Emissions	**MTCO2e**	**1,144**	**777**	**367**	**32.1%**
Annual Electric Cost	$	$ 130,940	$ 123,673	$ 7,267	5.5%
Annual Natural Gas Cost	$	$ -	$ -	$ -	N/A
Annual Steam Cost	$	$ 65,963	$ 39,613	$ 26,350	39.9%
Annual CHW Cost	$	$ 32,466	$ 23,611	$ 8,855	27.3%
Annual Utility Cost	$	$ 229,369	$ 186,897	$ 42,472	18.5%
Social Cost of Carbon	$	$ 141,887	$ 96,378	$ 45,509	32.1%
Annual Combined Cost	**$**	**$ 371,256**	**$ 283,275**	**$ 87,981**	**23.7%**





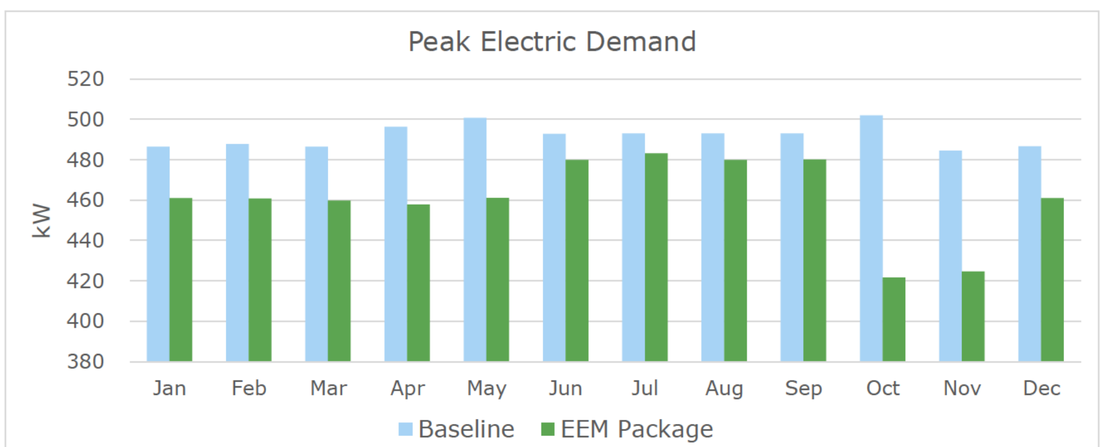
Electric Energy

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kWh	239,844	239,844	-	0.0%
Misc Equip	kWh	1,131,710	1,131,710	-	0.0%
Heating	kWh	-	-	-	N/A
Cooling	kWh	-	-	-	N/A
Pumps	kWh	76,027	66,666	9,361	12.3%
Fans	kWh	571,003	471,024	99,979	17.5%
Refrigeration	kWh	-	-	-	N/A
DHW	kWh	-	-	-	N/A
External	kWh	-	-	-	N/A
Total Electric	**kWh**	**2,018,585**	**1,909,244**	**109,341**	**5.4%**



Electric Peak Demand

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kW	70.0	70.0	-	0.0%
Misc Equip	kW	227.6	227.6	-	0.0%
Heating	kW	-	-	-	N/A
Cooling	kW	-	-	-	N/A
Pumps	kW	31.6	30.5	1.1	3.3%
Fans	kW	217.3	198.5	18.8	8.7%
Refrigeration	kW	-	-	-	N/A
DHW	kW	-	-	-	N/A
External	kW	-	-	-	N/A
Total kW	**kW**	**502.0**	**483.1**	**18.8**	**3.8%**



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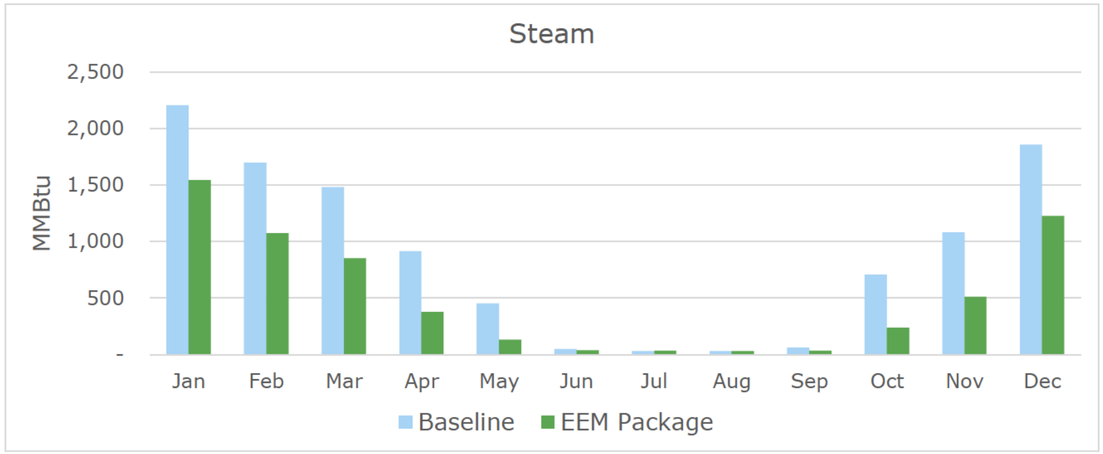
JOB EEM Package Summary (cont.)

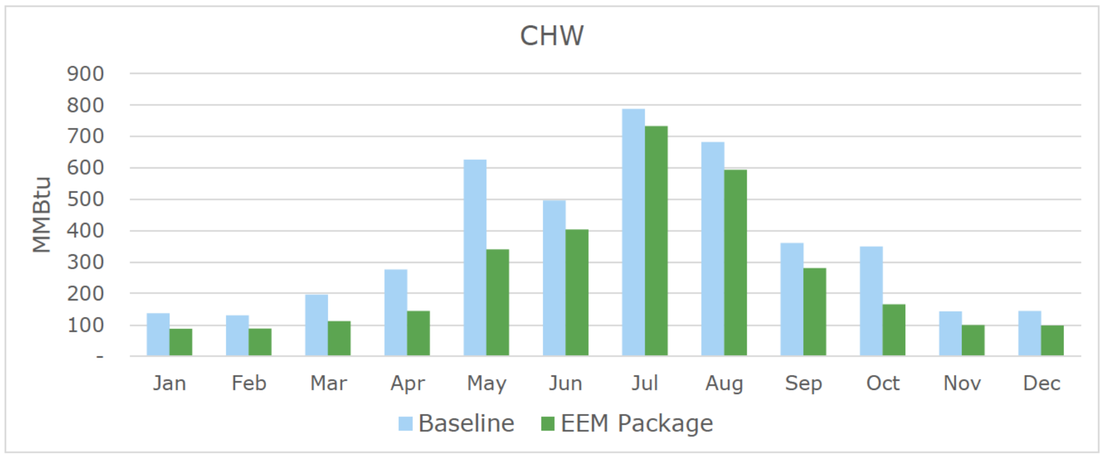
Steam

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	10,100	5,670	4,430	43.9%
Cooling	MMBtu	-	-	-	N/A
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	420	420	-	0.0%
External	MMBtu	-	-	-	N/A
Total Steam	**MMBtu**	**10,570**	**6,094**	**4,476**	**42.3%**



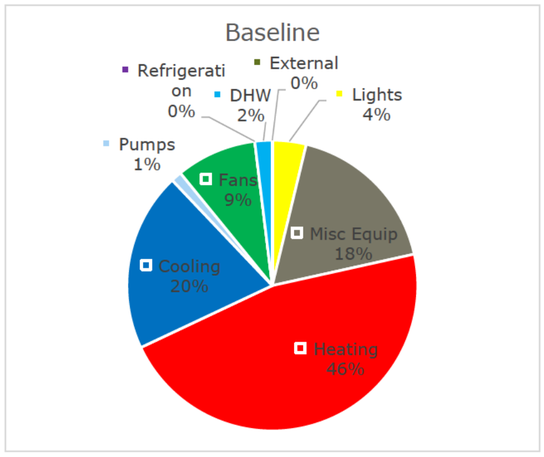
CHW

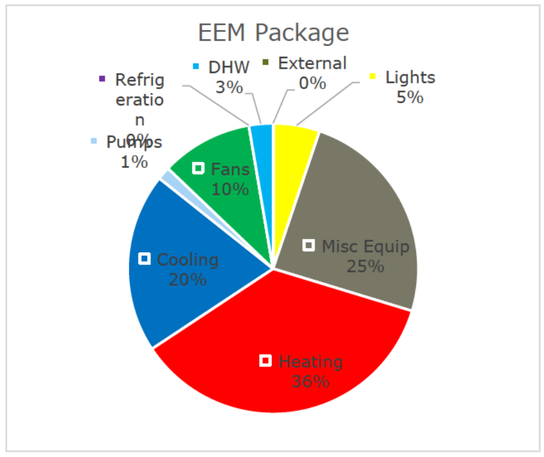
End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	-	-	-	N/A
Cooling	MMBtu	4,330	3,150	1,180	27.3%
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	-	-	-	N/A
External	MMBtu	-	-	-	N/A
Total CHW	**MMBtu**	**4,329**	**3,148**	**1,181**	**27.3%**



All Utilities

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	818	818	-	0.0%
Misc Equip	MMBtu	3,861	3,861	-	0.0%
Heating	MMBtu	10,100	5,670	4,430	43.9%
Cooling	MMBtu	4,330	3,150	1,180	27.3%
Pumps	MMBtu	259	227	32	12.3%
Fans	MMBtu	1,948	1,607	341	17.5%
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	420	420	-	0.0%
External	MMBtu	-	-	-	N/A
Total	**MMBtu**	**21,786**	**15,756**	**6,030**	**27.7%**





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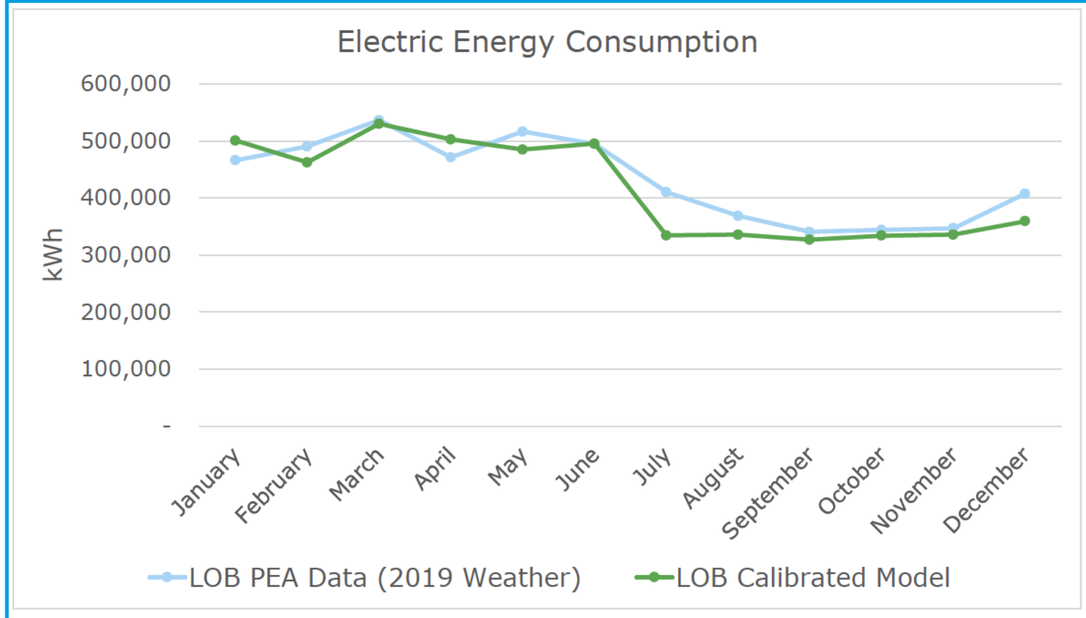
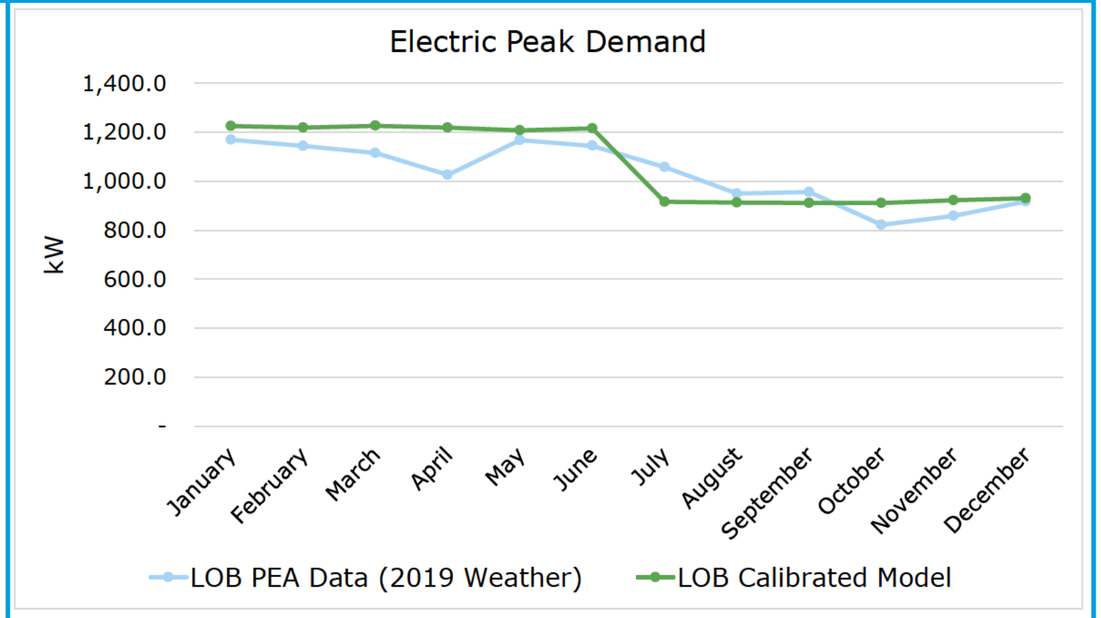
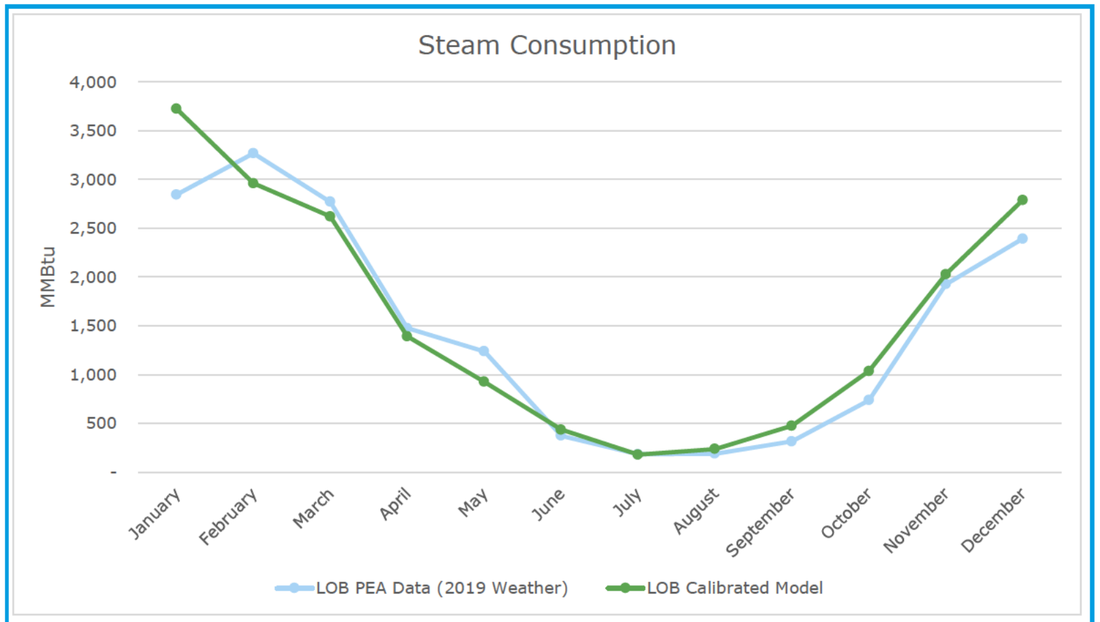
LOB Calibration



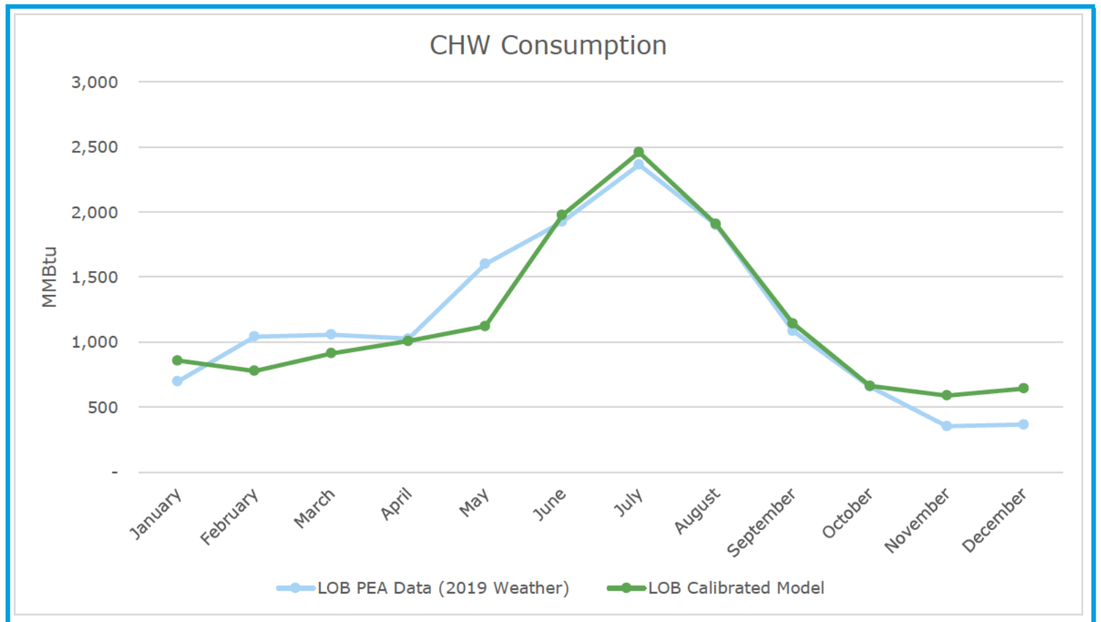
	Limit	Actual
NMBE	5%	4%
CV(RMSE)	15%	8%



	Limit	Actual
NMBE	5%	-4%
CV(RMSE)	15%	9%



	Limit	Actual
NMBE	5%	-7%
CV(RMSE)	15%	23%



	Limit	Actual
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CV(RMSE)	15%	18%

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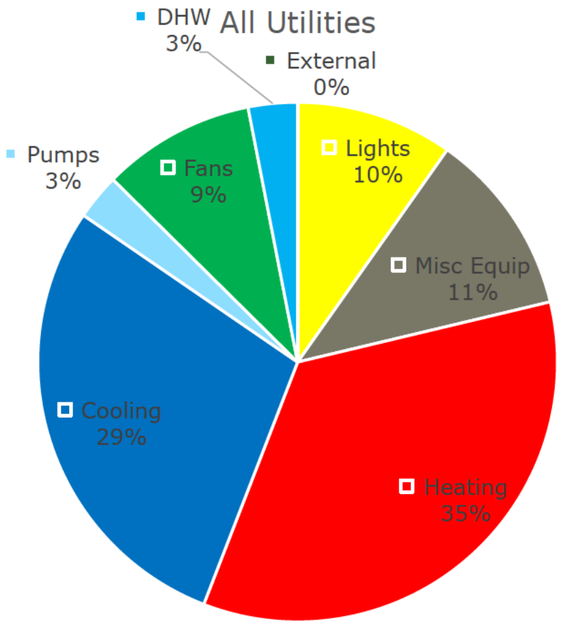
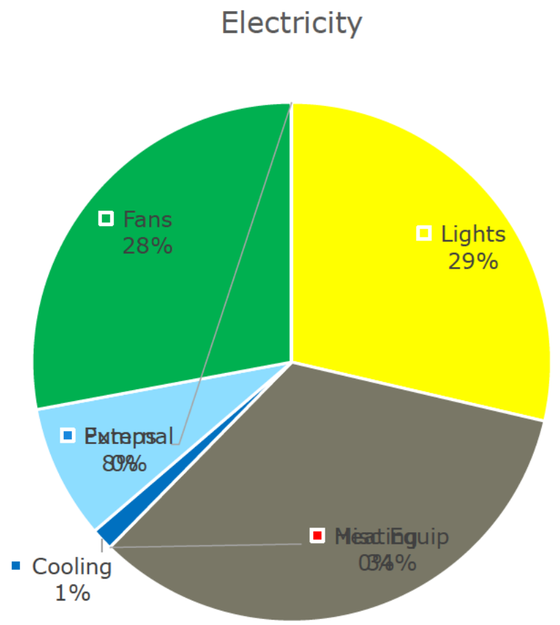
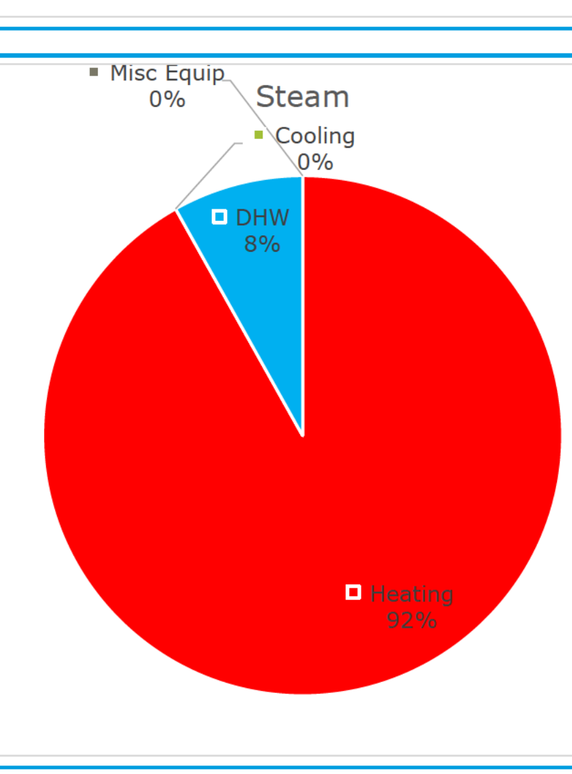
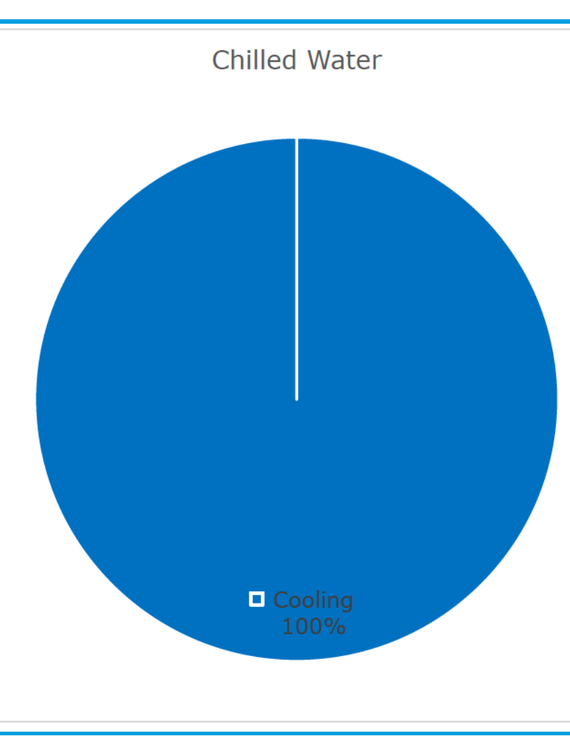
LOB Calibrated Model
End Use Summary









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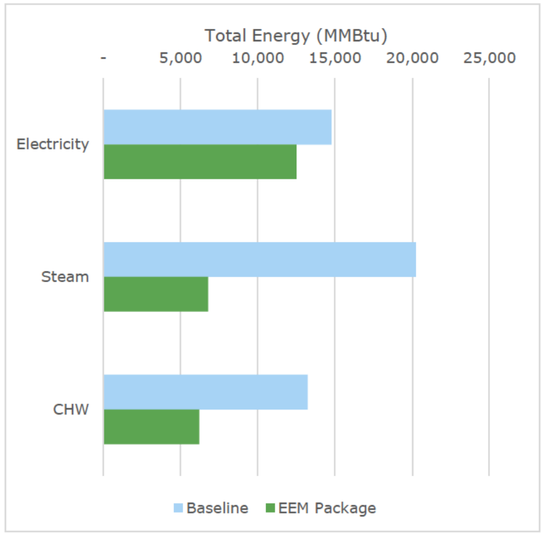
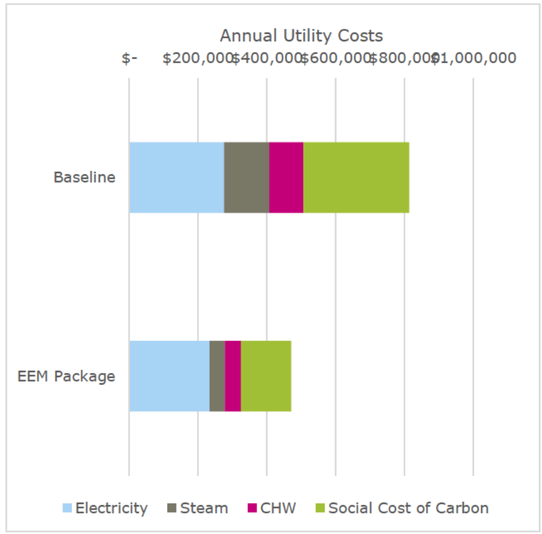
LOB EEM Package Summary

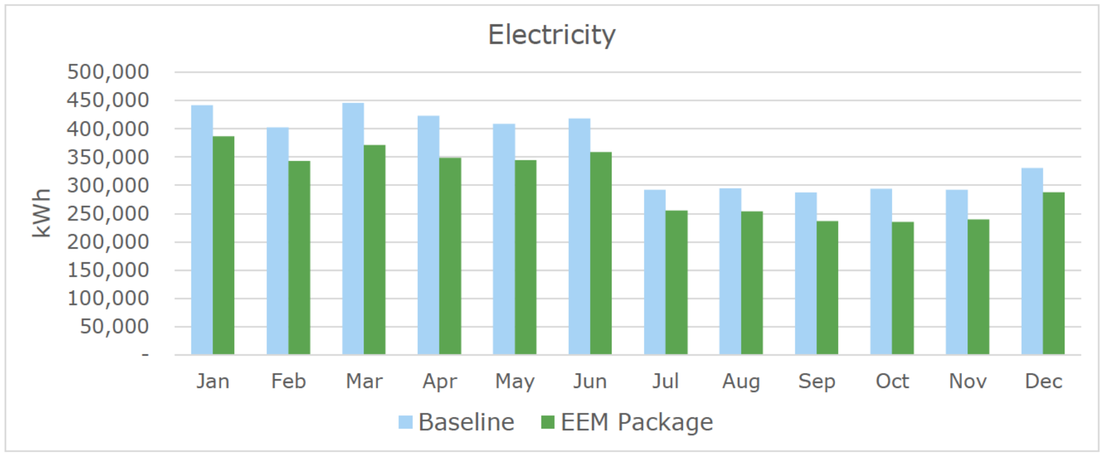
	Units	Baseline	EEM Package	Savings	% Savings
Annual Electric Use	kWh	4,328,270	3,660,868	667,402	15.4%
Annual Steam Use	MMBtu	20,230	6,796	13,434	66.4%
Annual CHW Use	MMBtu	13,230	6,206	7,024	53.1%
Annual Total Energy Use	MMBtu	48,228	25,493	22,735	47.1%
EUI	**kBtu/GSF**	**73.1**	**38.7**	**34.5**	**47.1%**
Total Emissions	**MTCO2e**	**2,483**	**1,174**	**1,309**	**52.7%**
Annual Electric Cost	$	$ 275,299	$ 234,080	$ 41,219	15.0%
Annual Natural Gas Cost	$	$ -	$ -	$ -	N/A
Annual Steam Cost	$	$ 131,501	$ 44,174	$ 87,327	66.4%
Annual CHW Cost	$	$ 99,222	$ 46,542	$ 52,680	53.1%
Annual Utility Cost	$	$ 506,022	$ 324,796	$ 181,226	35.8%
Social Cost of Carbon	$	$ 307,893	$ 145,564	$ 162,330	52.7%
Annual Combined Cost	**$**	**$ 813,915**	**$ 470,360**	**$ 343,556**	**42.2%**





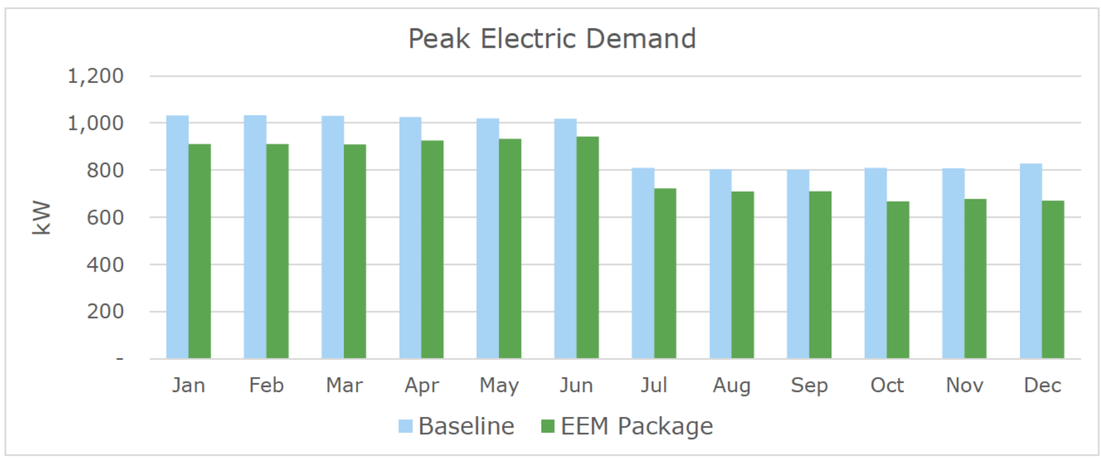
Electric Energy

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kWh	725,144	725,144	-	0.0%
Misc Equip	kWh	1,684,586	1,684,586	-	0.0%
Heating	kWh	-	-	-	N/A
Cooling	kWh	68,179	68,184	(5)	0.0%
Pumps	kWh	435,233	238,656	196,577	45.2%
Fans	kWh	1,415,131	944,297	470,834	33.3%
Refrigeration	kWh	-	-	-	N/A
DHW	kWh	-	-	-	N/A
External	kWh	-	-	-	N/A
Total Electric	**kWh**	**4,328,270**	**3,660,868**	**667,402**	**15.4%**



Electric Peak Demand

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kW	191.4	191.4	-	0.0%
Misc Equip	kW	377.5	377.5	-	0.0%
Heating	kW	-	-	-	N/A
Cooling	kW	21.1	21.1	(0.0)	0.0%
Pumps	kW	70.1	50.4	19.7	28.1%
Fans	kW	401.4	316.7	84.7	21.1%
Refrigeration	kW	-	-	-	N/A
DHW	kW	-	-	-	N/A
External	kW	-	-	-	N/A
Total kW	**kW**	**1,034.0**	**943.1**	**90.9**	**8.8%**



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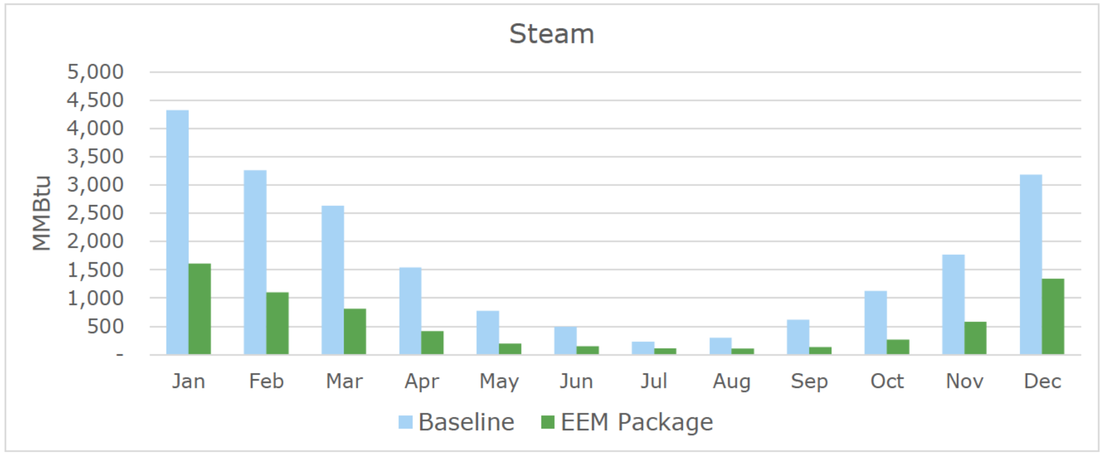
LOB EEM Package Summary (cont.)

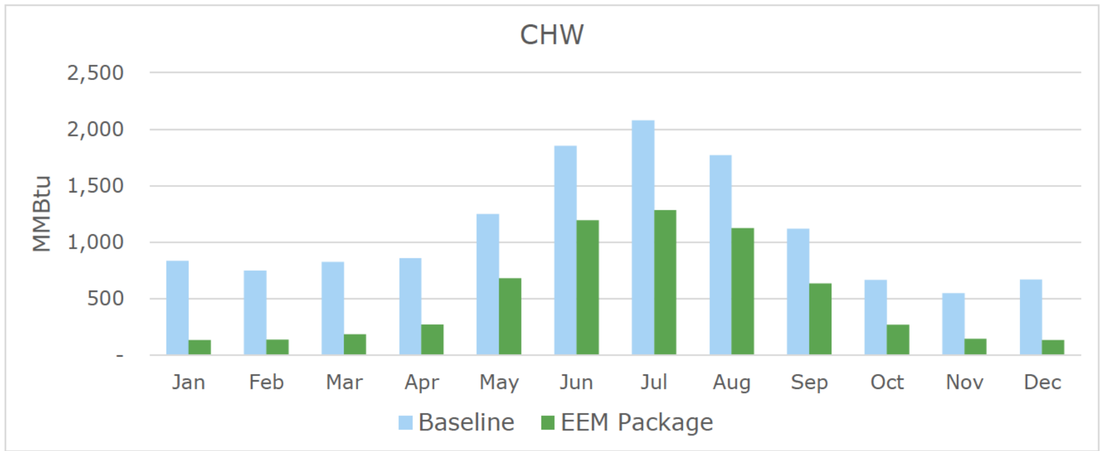
Steam

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	18,700	5,270	13,430	71.8%
Cooling	MMBtu	-	-	-	N/A
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	1,530	1,530	-	0.0%
External	MMBtu	-	-	-	N/A
Total Steam	**MMBtu**	**20,230**	**6,796**	**13,434**	**66.4%**



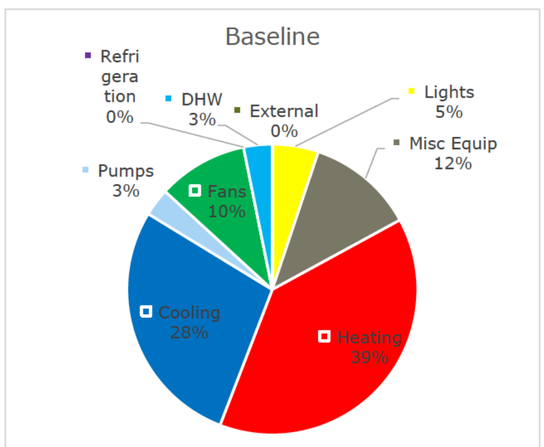
CHW

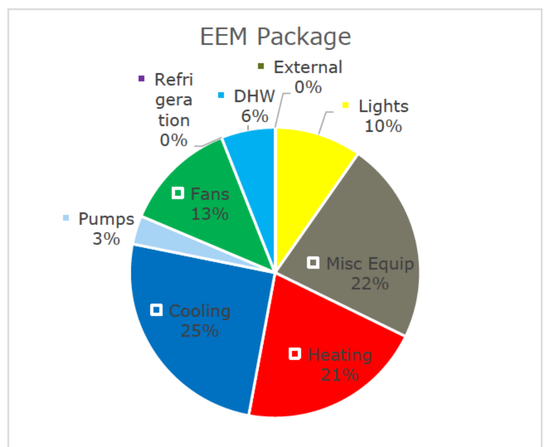
End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	-	-	-	N/A
Cooling	MMBtu	13,200	6,210	6,990	53.0%
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	-	-	-	N/A
External	MMBtu	-	-	-	N/A
Total CHW	**MMBtu**	**13,230**	**6,206**	**7,024**	**53.1%**



All Utilities

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	2,474	2,474	-	0.0%
Misc Equip	MMBtu	5,748	5,748	-	0.0%
Heating	MMBtu	18,700	5,270	13,430	71.8%
Cooling	MMBtu	13,433	6,443	6,990	52.0%
Pumps	MMBtu	1,485	814	671	45.2%
Fans	MMBtu	4,828	3,222	1,606	33.3%
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	1,530	1,530	-	0.0%
External	MMBtu	-	-	-	N/A
Total	**MMBtu**	**48,228**	**25,493**	**22,735**	**47.1%**





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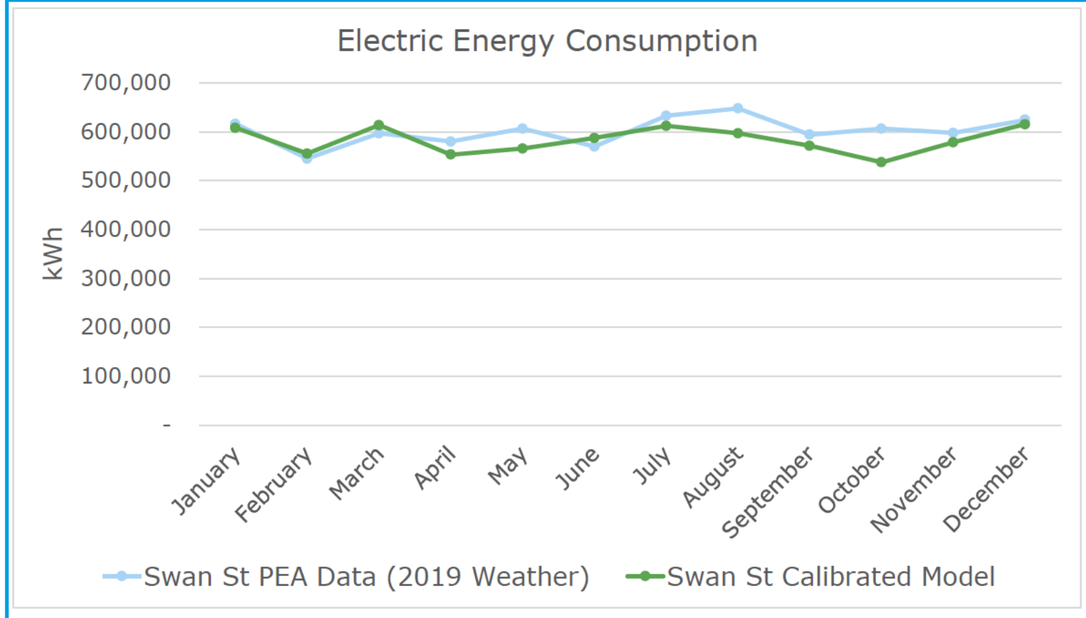
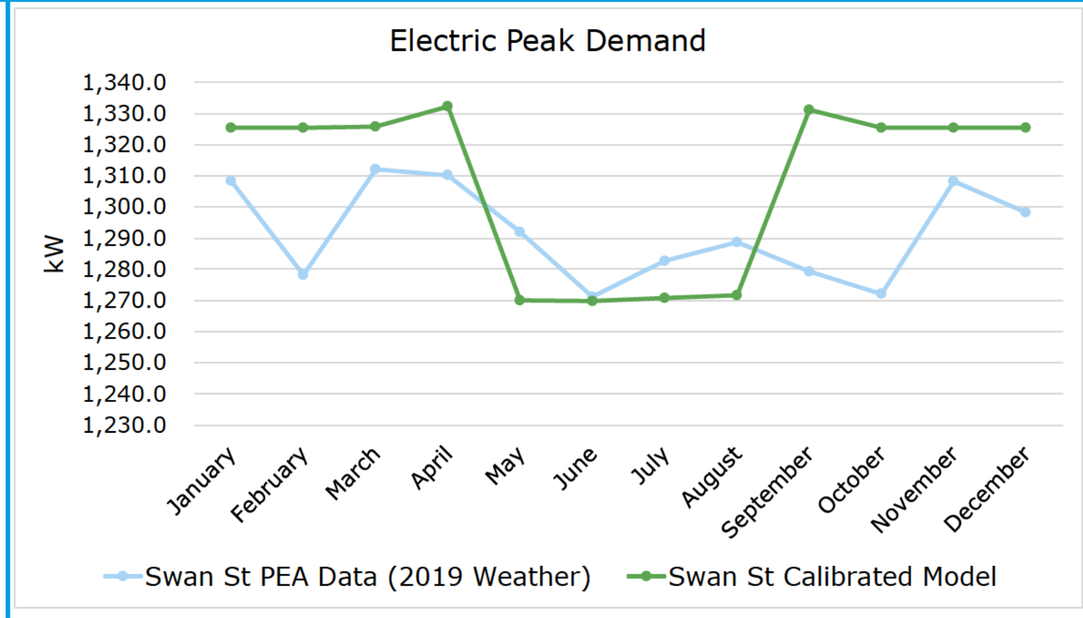
Swan St Calibration



	Limit	Actual
NMBE	5%	3%
CV(RMSE)	15%	5%



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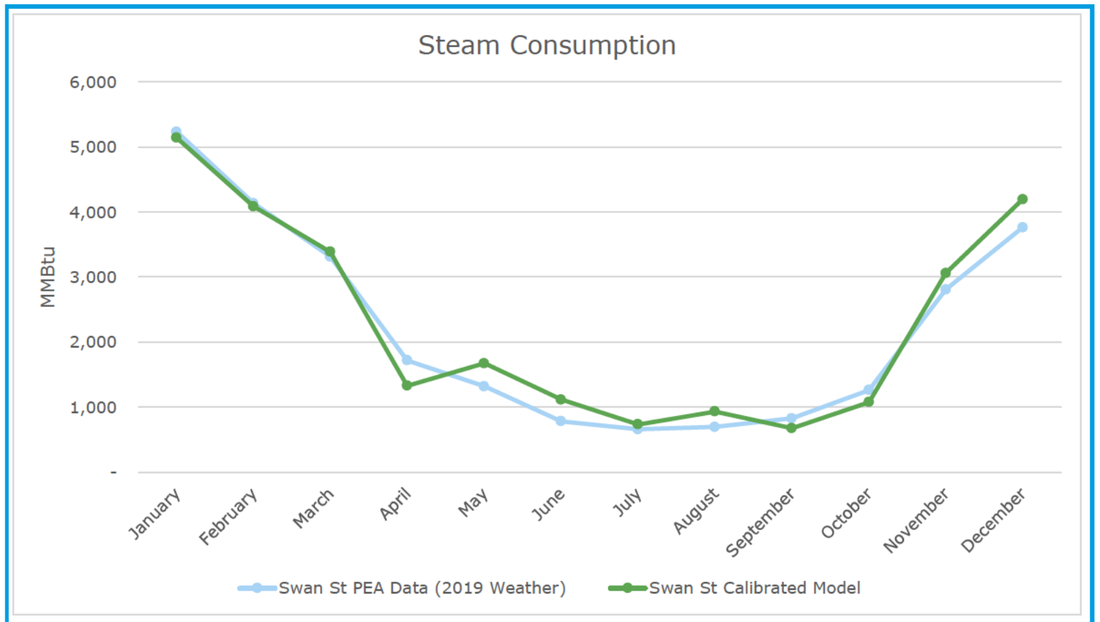
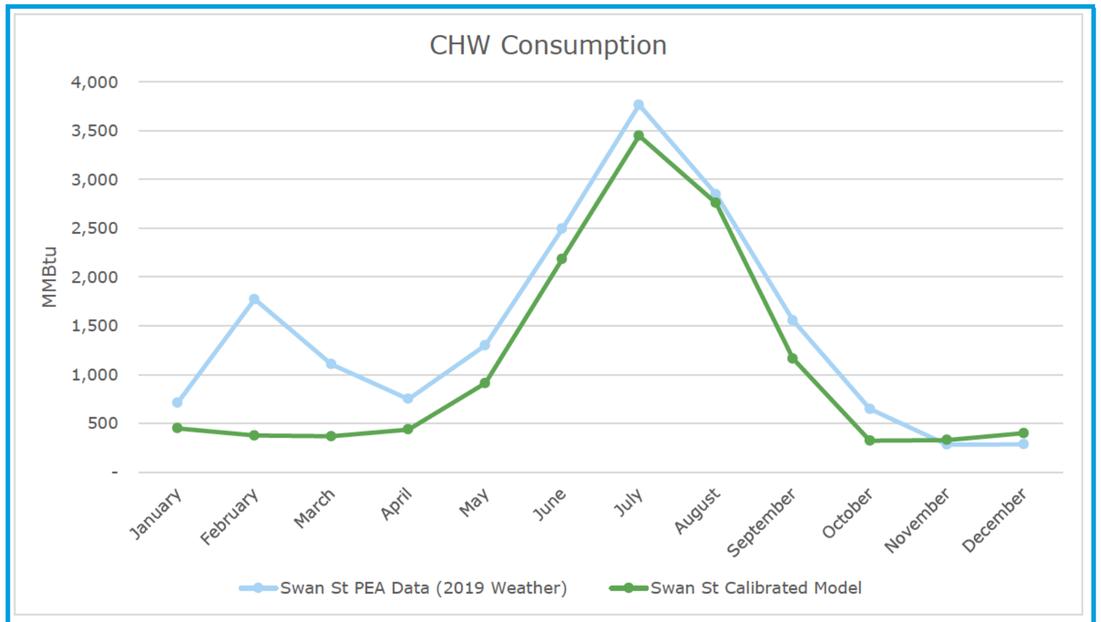
NMBE	5%	-1%
CV(RMSE)	15%	2%



	Limit	Actual
NMBE	5%	-4%
CV(RMSE)	15%	12%



	Limit	Actual
NMBE	5%	27%
CV(RMSE)	15%	38%

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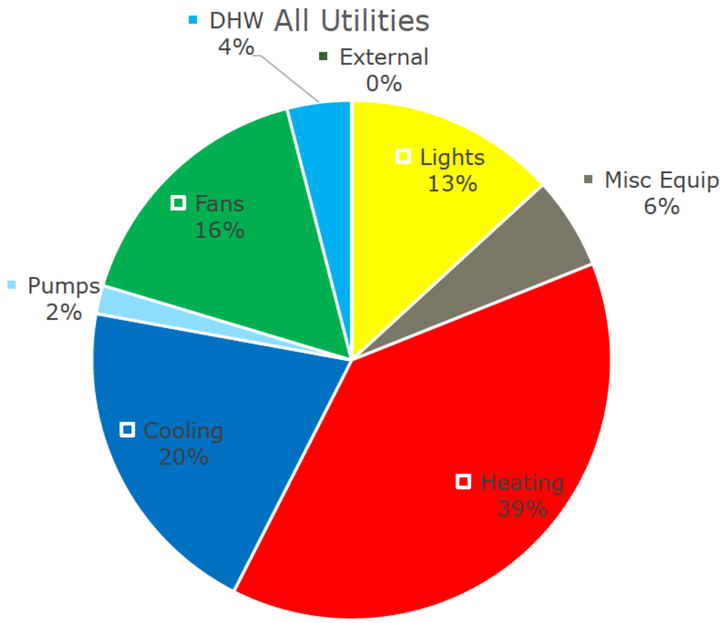
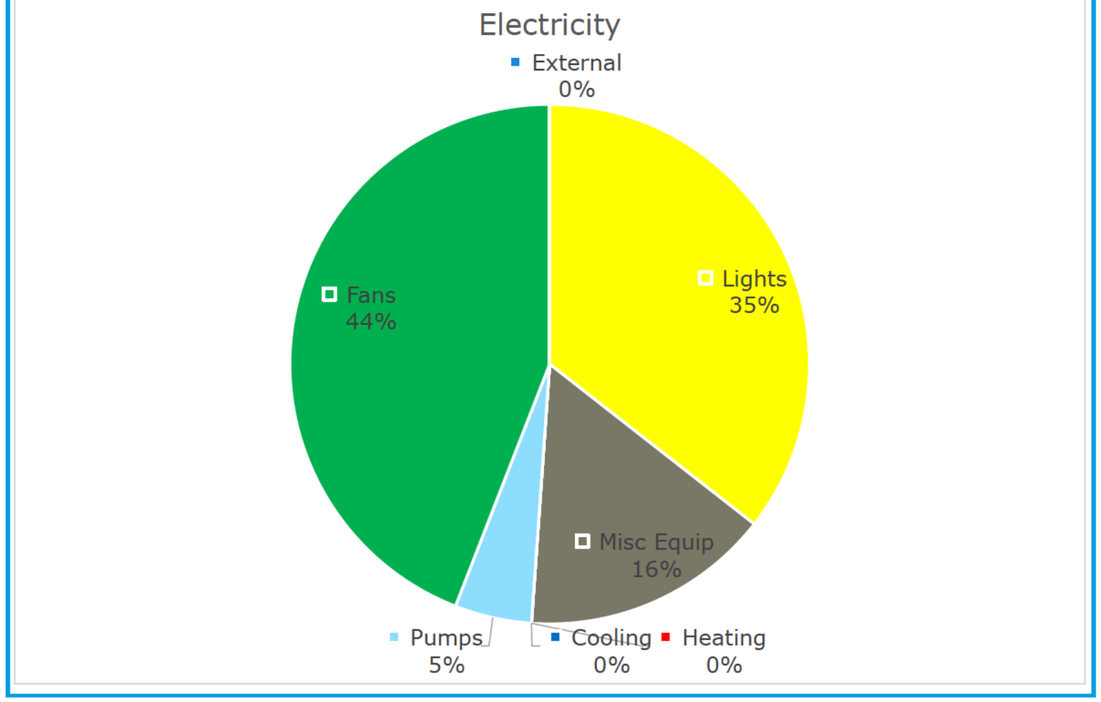
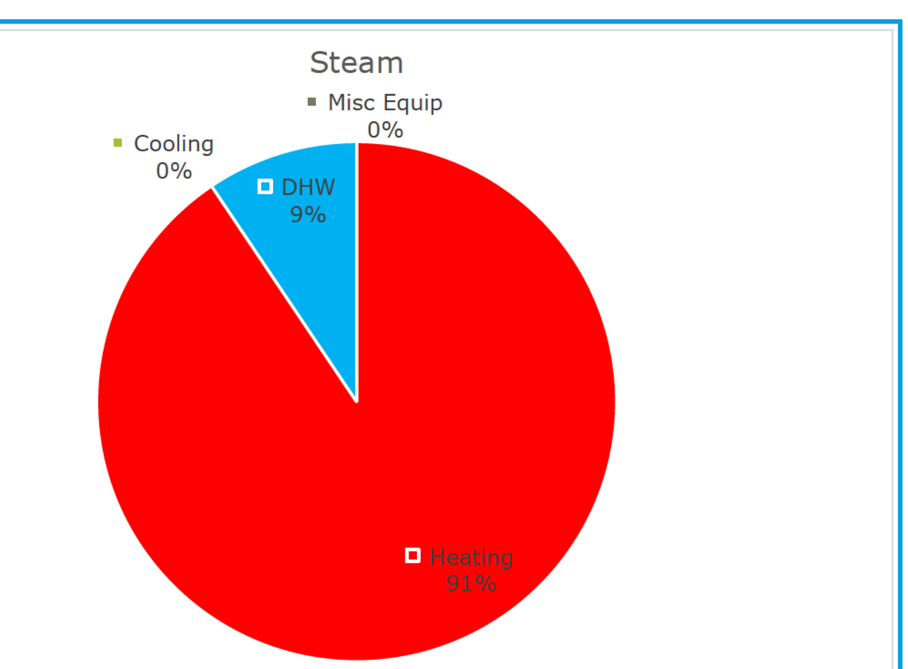
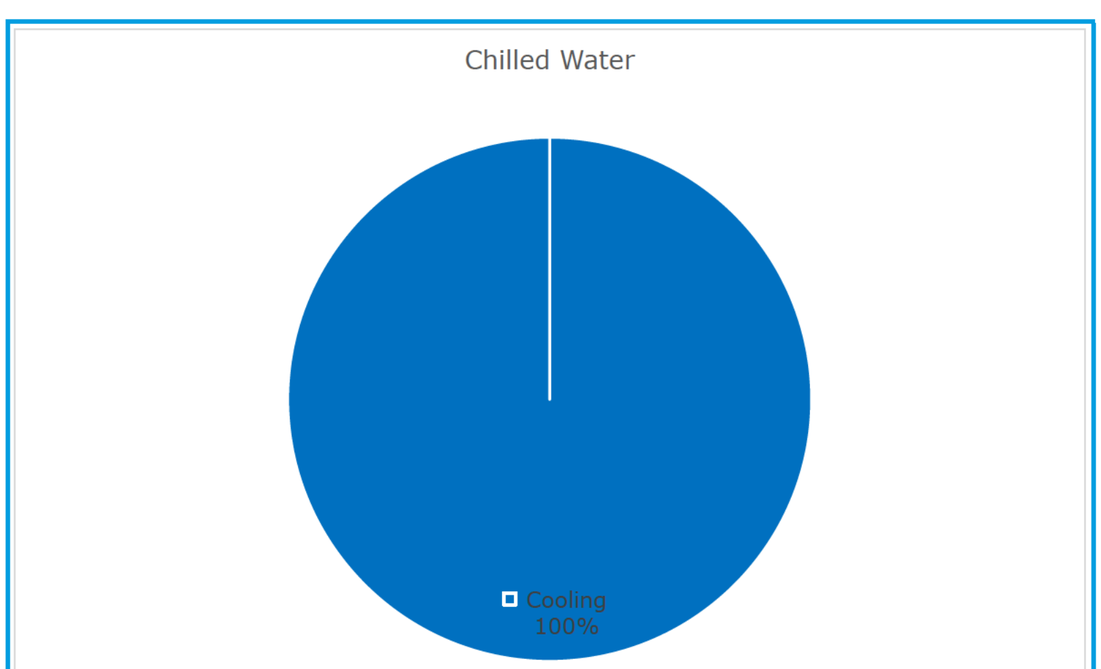
Swan St Calibrated Model
End Use Summary









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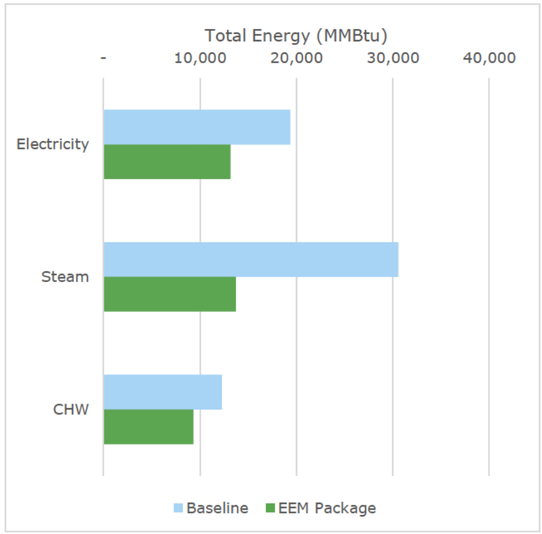
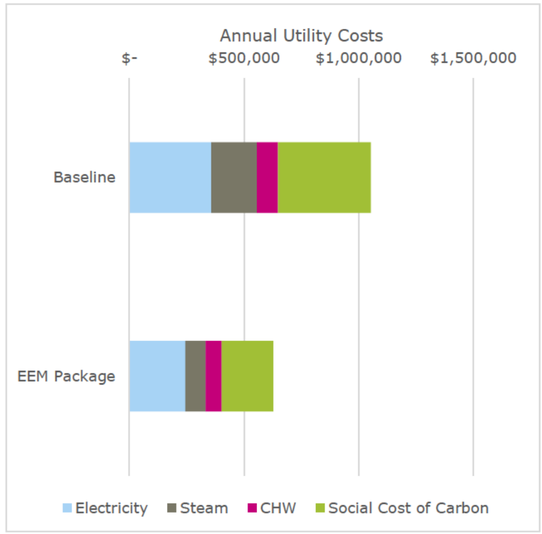
Swan St EEM Package Summary

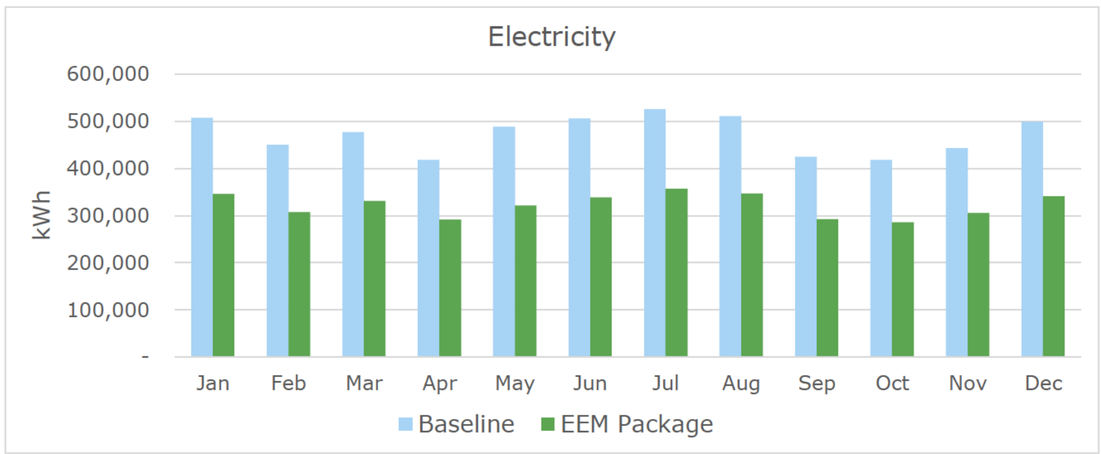
	Units	Baseline	EEM Package	Savings	% Savings
Annual Electric Use	kWh	5,667,877	3,863,224	1,804,653	31.8%
Annual Steam Use	MMBtu	30,540	13,740	16,800	55.0%
Annual CHW Use	MMBtu	12,260	9,315	2,945	24.0%
Annual Total Energy Use	MMBtu	62,139	36,236	25,902	41.7%
EUI	**kBtu/GSF**	**74.0**	**43.1**	**30.8**	**41.7%**
Total Emissions	**MTCO2e**	**3,275**	**1,809**	**1,466**	**44.8%**
Annual Electric Cost	$	$ 357,138	$ 244,497	$ 112,641	31.5%
Annual Natural Gas Cost	$	$ -	$ -	$ -	N/A
Annual Steam Cost	$	$ 198,504	$ 89,296	$ 109,208	55.0%
Annual CHW Cost	$	$ 91,936	$ 69,861	$ 22,075	24.0%
Annual Utility Cost	$	$ 647,578	$ 403,654	$ 243,924	37.7%
Social Cost of Carbon	$	$ 406,116	$ 224,300	$ 181,816	44.8%
Annual Combined Cost	**$**	**$ 1,053,694**	**$ 627,954**	**$ 425,740**	**40.4%**





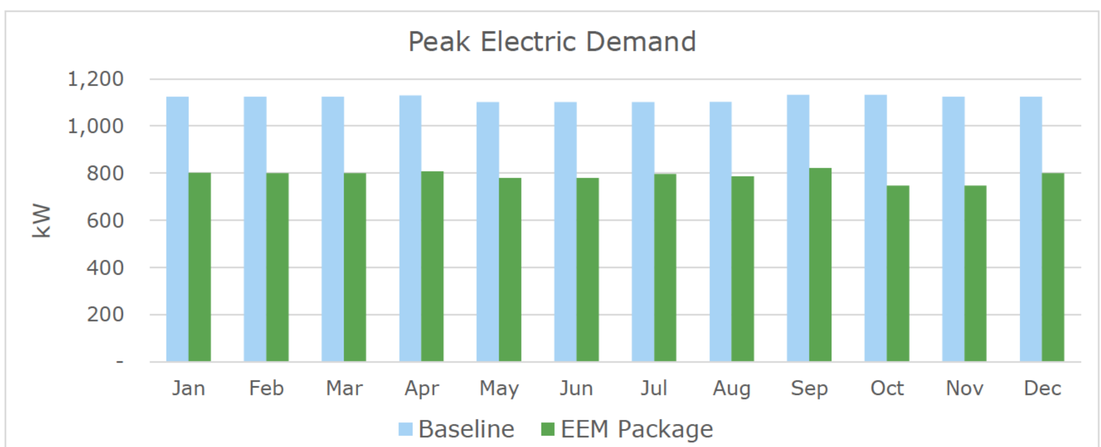
Electric Energy

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kWh	1,268,017	1,268,017	-	0.0%
Misc Equip	kWh	1,087,938	1,087,938	-	0.0%
Heating	kWh	-	-	-	N/A
Cooling	kWh	-	-	-	N/A
Pumps	kWh	316,335	236,417	79,918	25.3%
Fans	kWh	2,995,584	1,270,847	1,724,737	57.6%
Refrigeration	kWh	-	-	-	N/A
DHW	kWh	-	-	-	N/A
External	kWh	-	-	-	N/A
Total Electric	**kWh**	**5,667,877**	**3,863,224**	**1,804,653**	**31.8%**



Electric Peak Demand

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kW	210.5	210.5	-	0.0%
Misc Equip	kW	172.1	172.1	-	0.0%
Heating	kW	-	-	-	N/A
Cooling	kW	-	-	-	N/A
Pumps	kW	63.6	55.8	7.8	12.3%
Fans	kW	700.1	395.1	305.1	43.6%
Refrigeration	kW	-	-	-	N/A
DHW	kW	-	-	-	N/A
External	kW	-	-	-	N/A
Total kW	**kW**	**1,133.2**	**821.8**	**311.4**	**27.5%**



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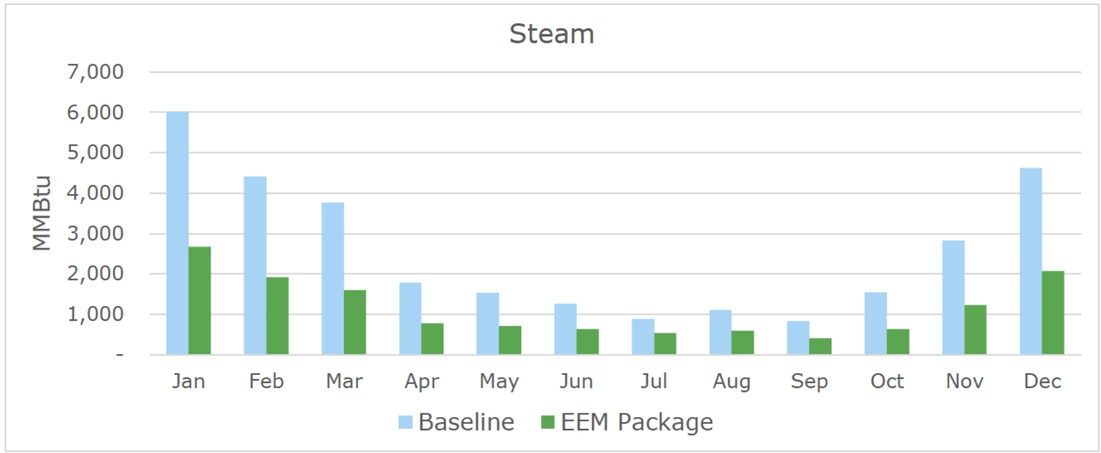
Swan St EEM Package Summary (cont.)

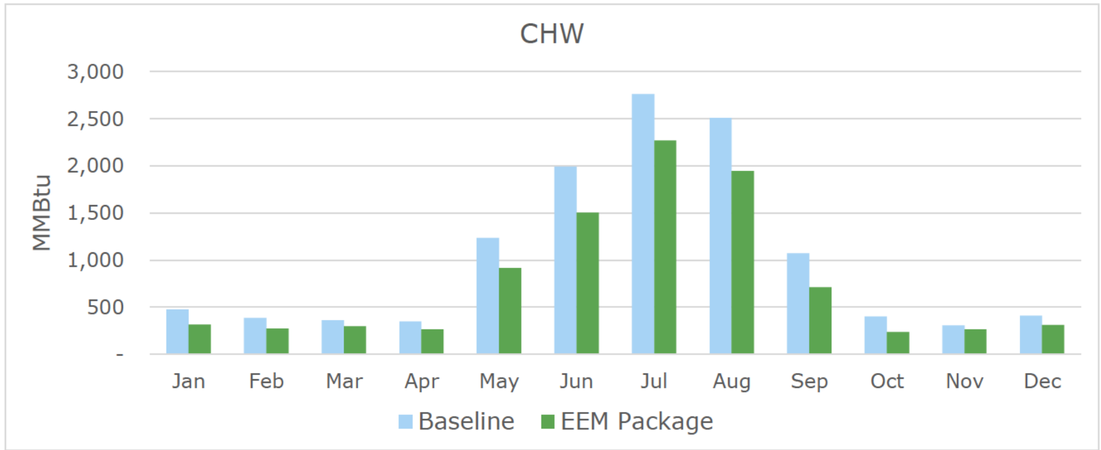
Steam

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	27,900	11,100	16,800	60.2%
Cooling	MMBtu	-	-	-	N/A
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	2,600	2,680	(80)	-3.1%
External	MMBtu	-	-	-	N/A
Total Steam	**MMBtu**	**30,540**	**13,740**	**16,800**	**55.0%**



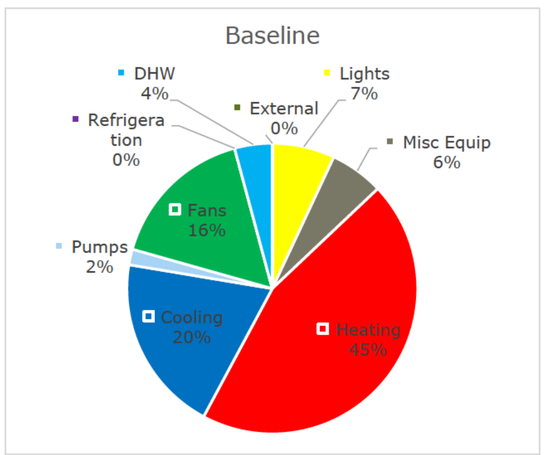
CHW

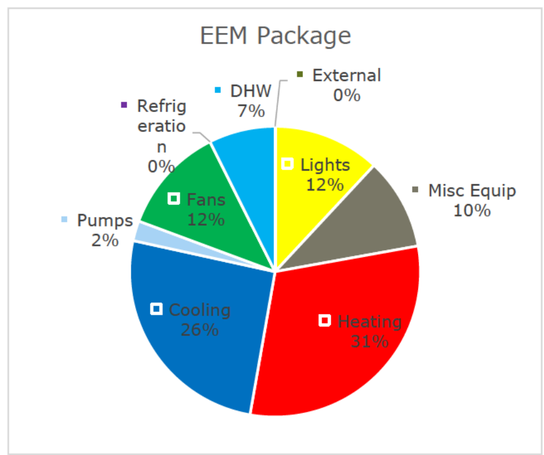
End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	-	-	-	N/A
Cooling	MMBtu	12,300	9,310	2,990	24.3%
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	-	-	-	N/A
External	MMBtu	-	-	-	N/A
Total CHW	**MMBtu**	**12,260**	**9,315**	**2,945**	**24.0%**



All Utilities

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	4,326	4,326	-	0.0%
Misc Equip	MMBtu	3,712	3,712	-	0.0%
Heating	MMBtu	27,900	11,100	16,800	60.2%
Cooling	MMBtu	12,300	9,310	2,990	24.3%
Pumps	MMBtu	1,079	807	273	25.3%
Fans	MMBtu	10,221	4,336	5,885	57.6%
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	2,600	2,680	(80)	-3.1%
External	MMBtu	-	-	-	N/A
Total	**MMBtu**	**62,139**	**36,236**	**25,902**	**41.7%**





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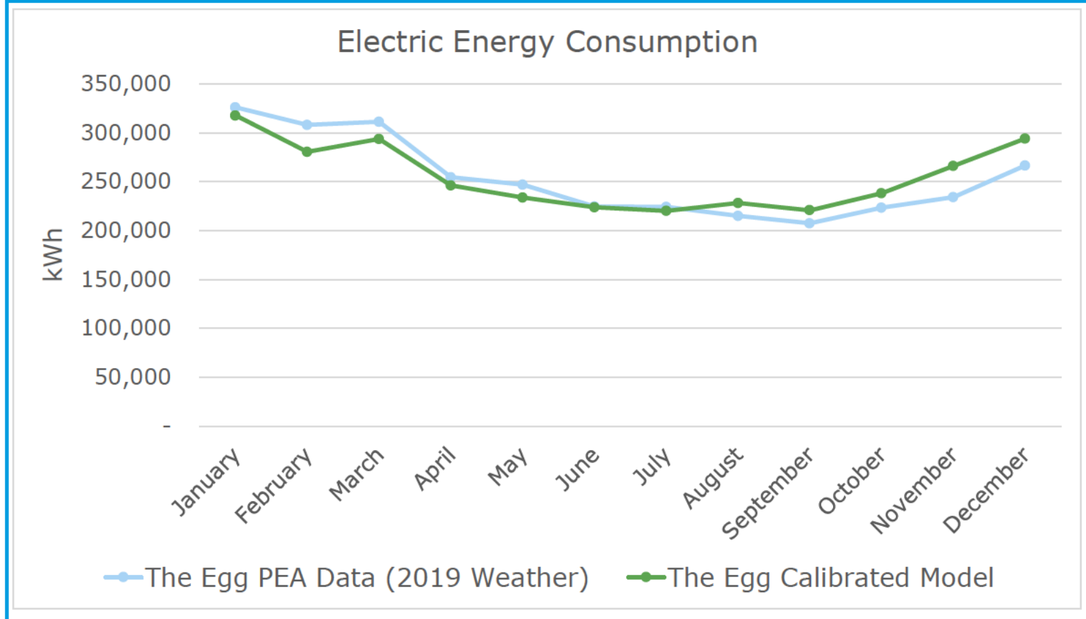
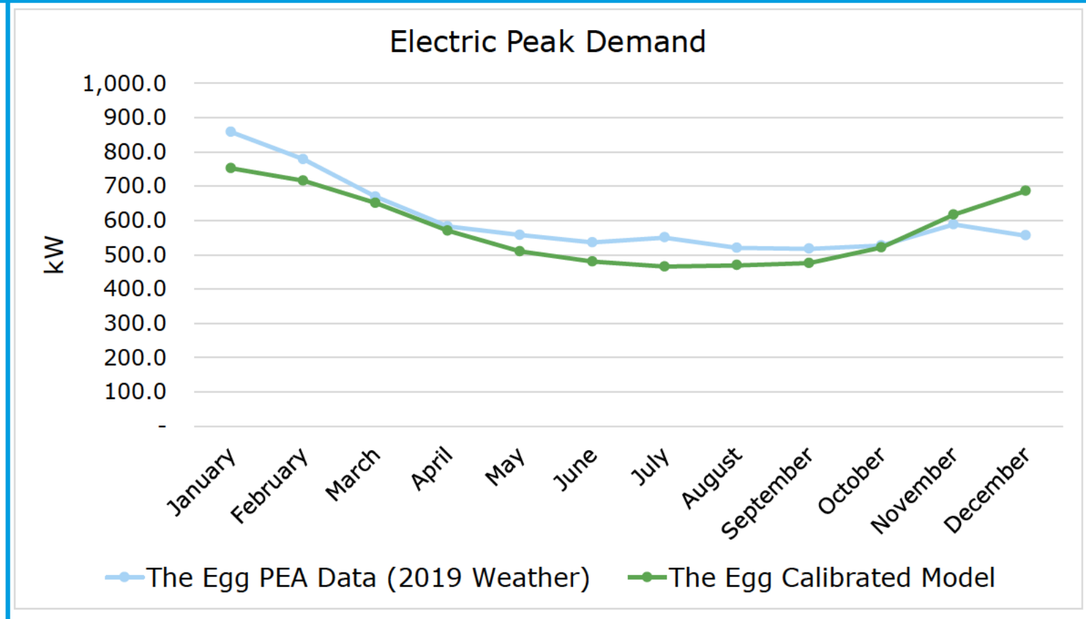
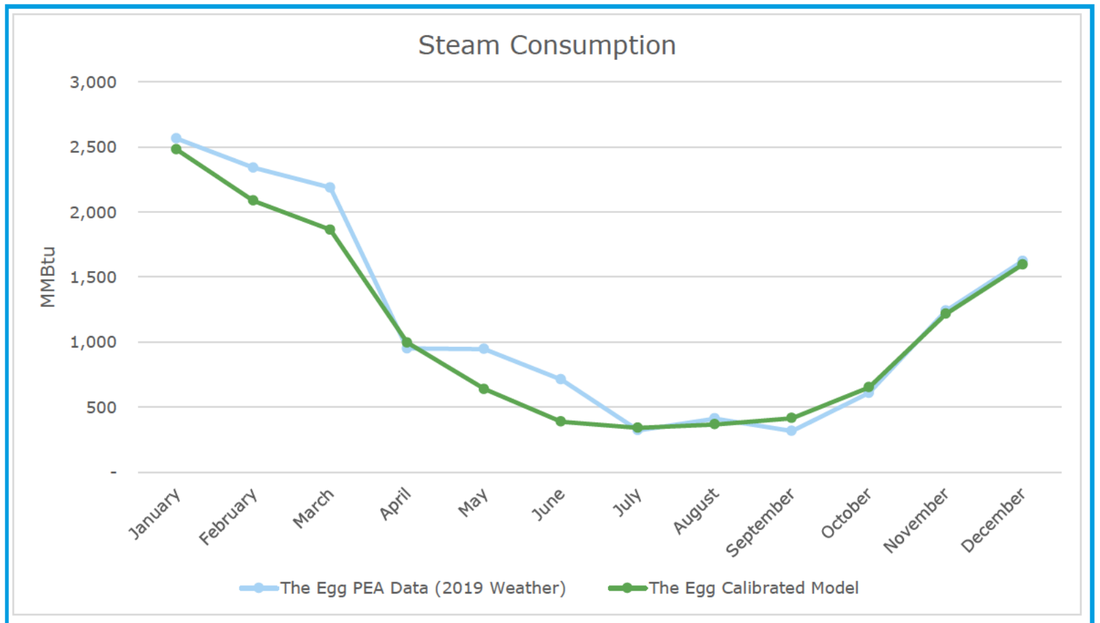
The Egg Calibration



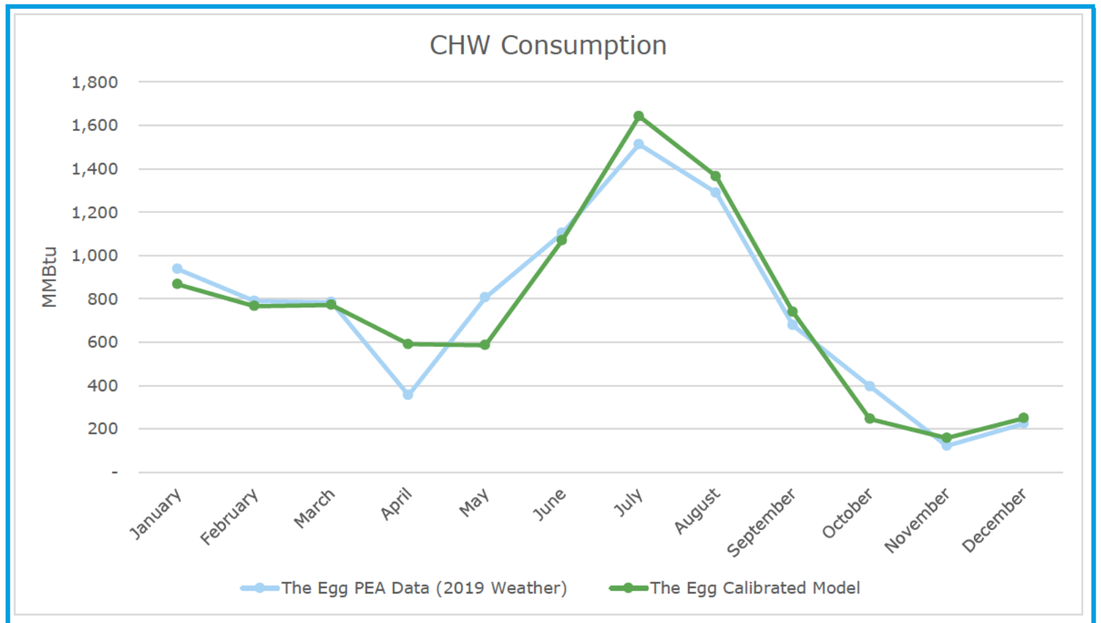
	Limit	Actual
NMBE	5%	-1%
CV(RMSE)	15%	7%



	Limit	Actual
NMBE	5%	5%
CV(RMSE)	15%	11%



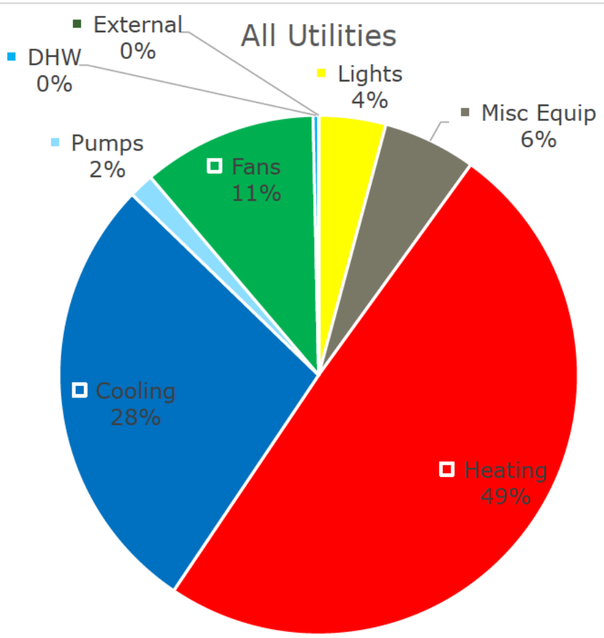
	Limit	Actual
NMBE	5%	9%
CV(RMSE)	15%	16%

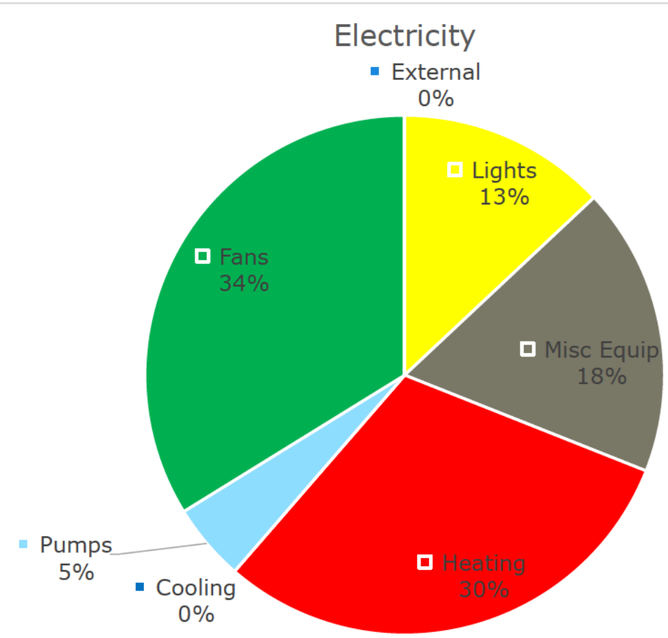


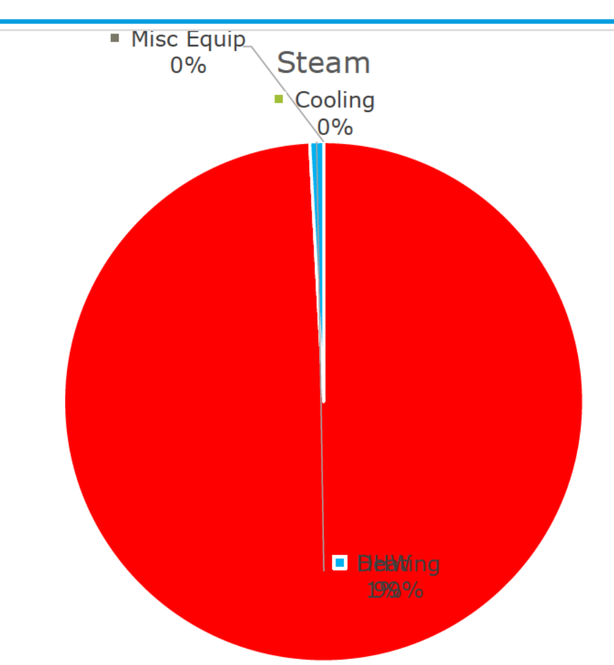
	Limit	Actual
NMBE	5%	-1%
CV(RMSE)	15%	16%

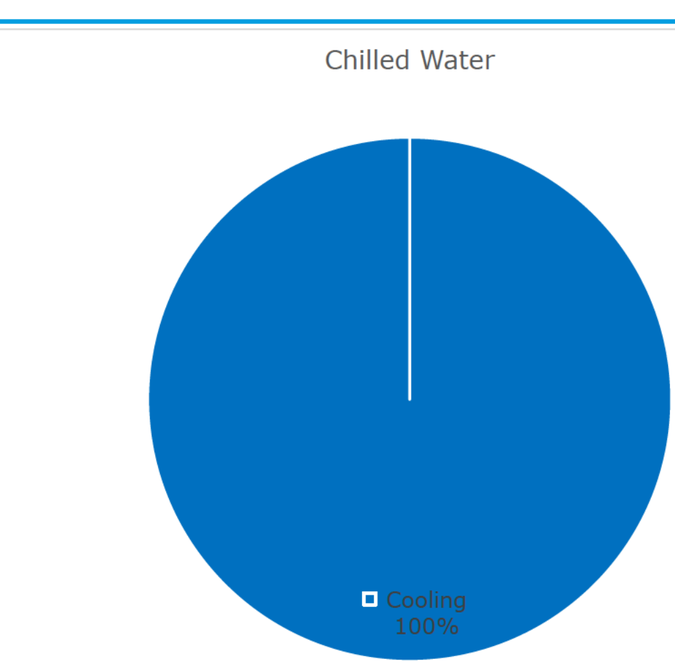
CONFIDENTIAL AND PROPRIETARY

The Egg Calibrated Model
End Use Summary









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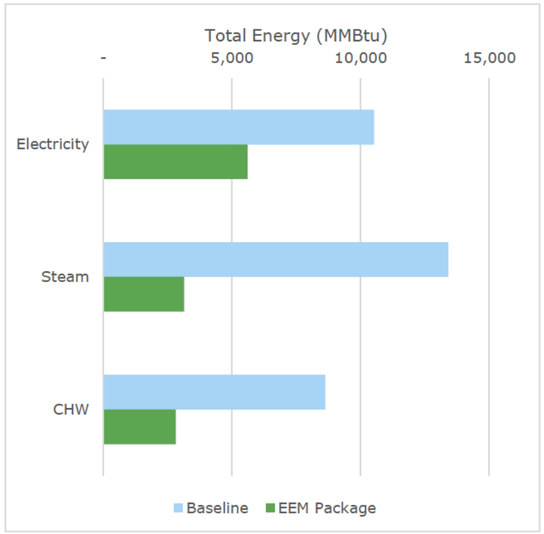
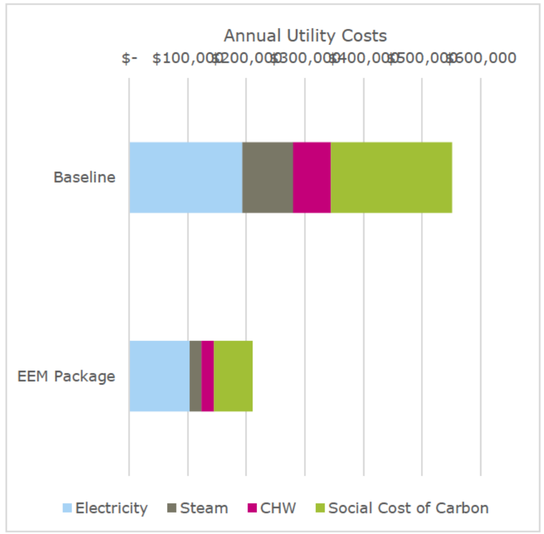
The Egg EEM Package Summary

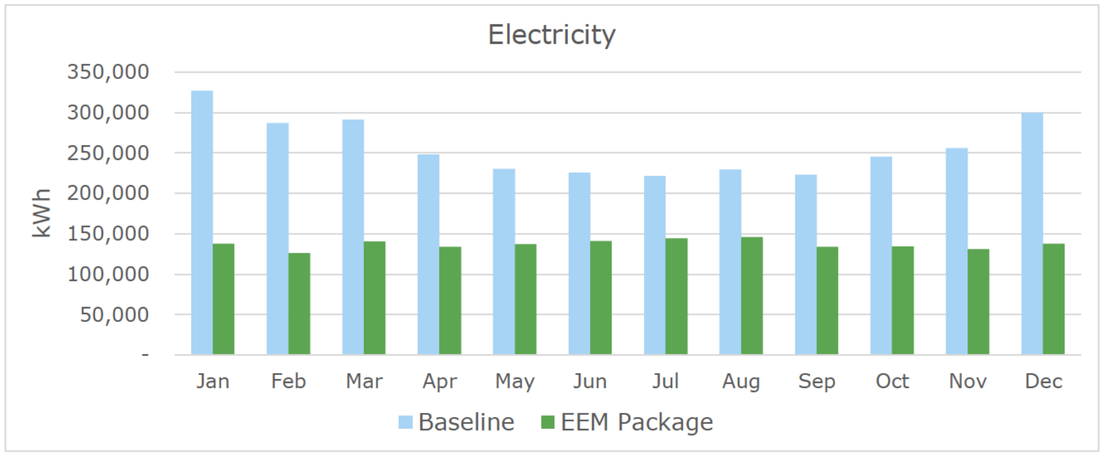
	Units	Baseline	EEM Package	Savings	% Savings
Annual Electric Use	kWh	3,084,378	1,642,616	1,441,762	46.7%
Annual Steam Use	MMBtu	13,400	3,138	10,262	76.6%
Annual CHW Use	MMBtu	8,617	2,817	5,800	67.3%
Annual Total Energy Use	MMBtu	32,541	11,560	20,981	64.5%
EUI	**kBtu/GSF**	**301.9**	**107.2**	**194.6**	**64.5%**
Total Emissions	**MTCO2e**	**1,663**	**534**	**1,128**	**67.9%**
Annual Electric Cost	$	$ 192,975	$ 102,914	$ 90,061	46.7%
Annual Natural Gas Cost	$	$ -	$ -	$ -	N/A
Annual Steam Cost	$	$ 87,079	$ 20,395	$ 66,684	76.6%
Annual CHW Cost	$	$ 64,628	$ 21,127	$ 43,501	67.3%
Annual Utility Cost	$	$ 344,682	$ 144,436	$ 200,246	58.1%
Social Cost of Carbon	$	$ 206,173	$ 66,238	$ 139,935	67.9%
Annual Combined Cost	**$**	**$ 550,855**	**$ 210,674**	**$ 340,181**	**61.8%**





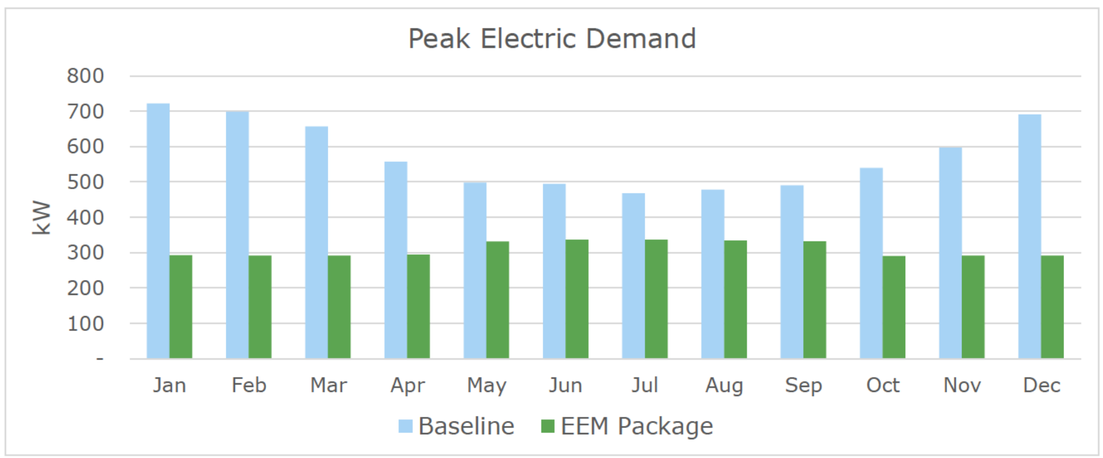
Electric Energy

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kWh	398,309	398,309	-	0.0%
Misc Equip	kWh	550,939	550,939	-	0.0%
Heating	kWh	949,393	-	949,393	100.0%
Cooling	kWh	-	-	-	N/A
Pumps	kWh	149,110	78,976	70,134	47.0%
Fans	kWh	1,036,623	614,393	422,230	40.7%
Refrigeration	kWh	-	-	-	N/A
DHW	kWh	-	-	-	N/A
External	kWh	-	-	-	N/A
Total Electric	**kWh**	**3,084,378**	**1,642,616**	**1,441,762**	**46.7%**



Electric Peak Demand

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kW	88.9	88.9	-	0.0%
Misc Equip	kW	123.8	123.8	-	0.0%
Heating	kW	399.8	-	399.8	100.0%
Cooling	kW	-	-	-	N/A
Pumps	kW	25.2	14.4	10.8	42.8%
Fans	kW	160.5	111.5	49.0	30.5%
Refrigeration	kW	-	-	-	N/A
DHW	kW	-	-	-	N/A
External	kW	-	-	-	N/A
Total kW	**kW**	**721.9**	**336.3**	**385.6**	**53.4%**



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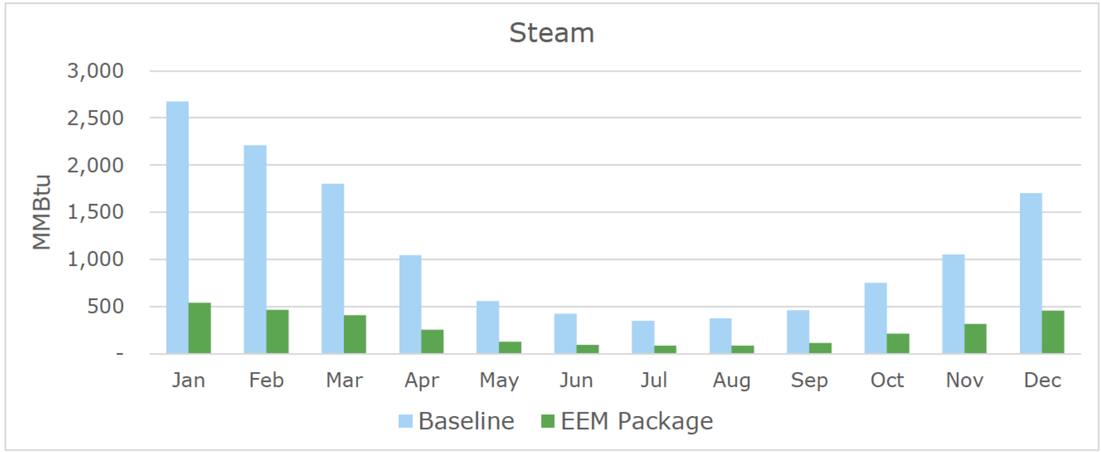
The Egg EEM Package Summary (cont.)

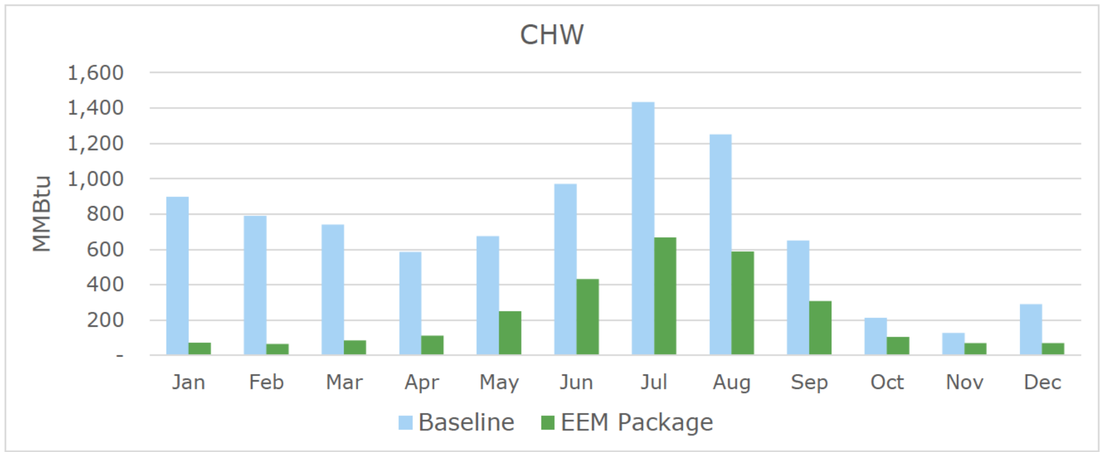
Steam

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	13,300	3,030	10,270	77.2%
Cooling	MMBtu	-	-	-	N/A
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	111	111	-	0.0%
External	MMBtu	-	-	-	N/A
Total Steam	**MMBtu**	**13,400**	**3,138**	**10,262**	**76.6%**



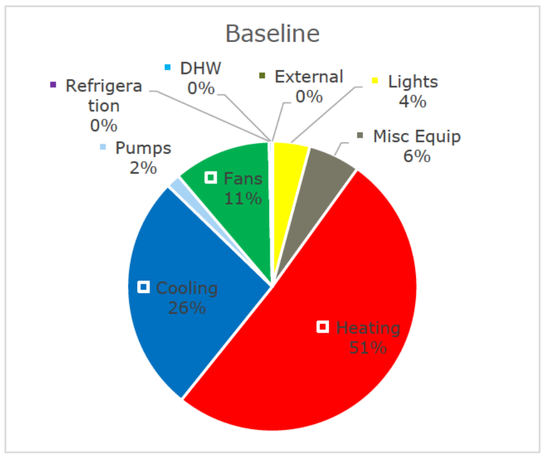
CHW

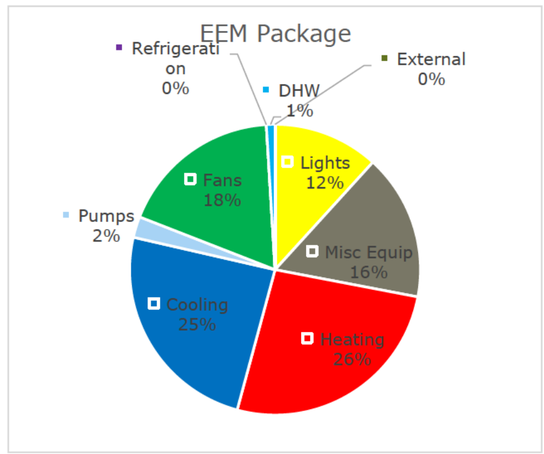
End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	-	-	-	N/A
Cooling	MMBtu	8,620	2,820	5,800	67.3%
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	-	-	-	N/A
External	MMBtu	-	-	-	N/A
Total CHW	**MMBtu**	**8,617**	**2,817**	**5,800**	**67.3%**



All Utilities

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	1,359	1,359	-	0.0%
Misc Equip	MMBtu	1,880	1,880	-	0.0%
Heating	MMBtu	16,539	3,030	13,509	81.7%
Cooling	MMBtu	8,620	2,820	5,800	67.3%
Pumps	MMBtu	509	269	239	47.0%
Fans	MMBtu	3,537	2,096	1,441	40.7%
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	111	111	-	0.0%
External	MMBtu	-	-	-	N/A
Total	**MMBtu**	**32,541**	**11,560**	**20,981**	**64.5%**





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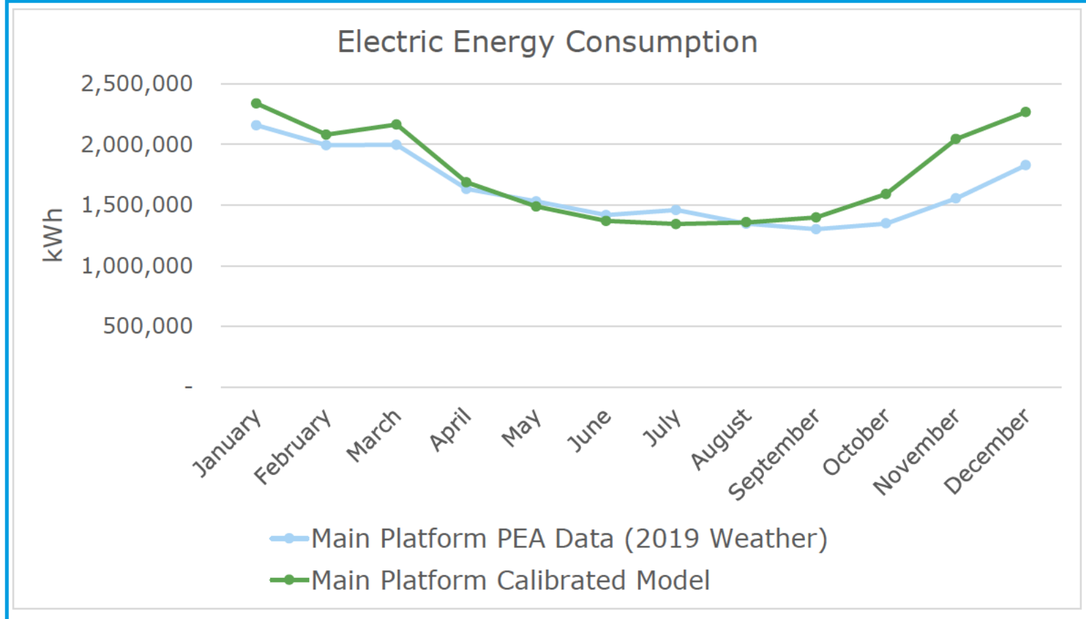
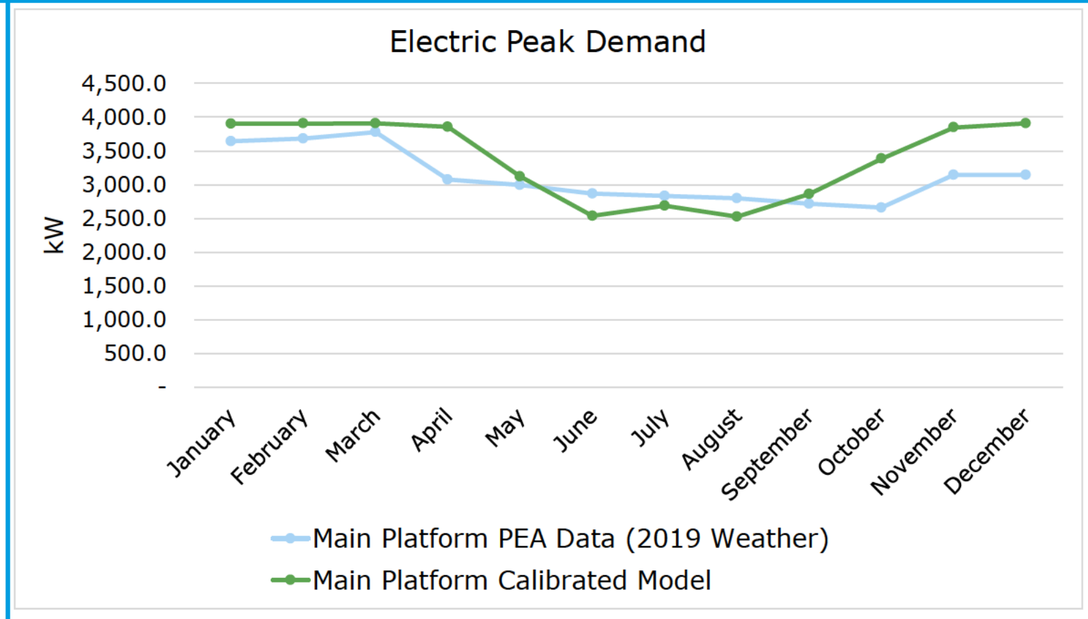
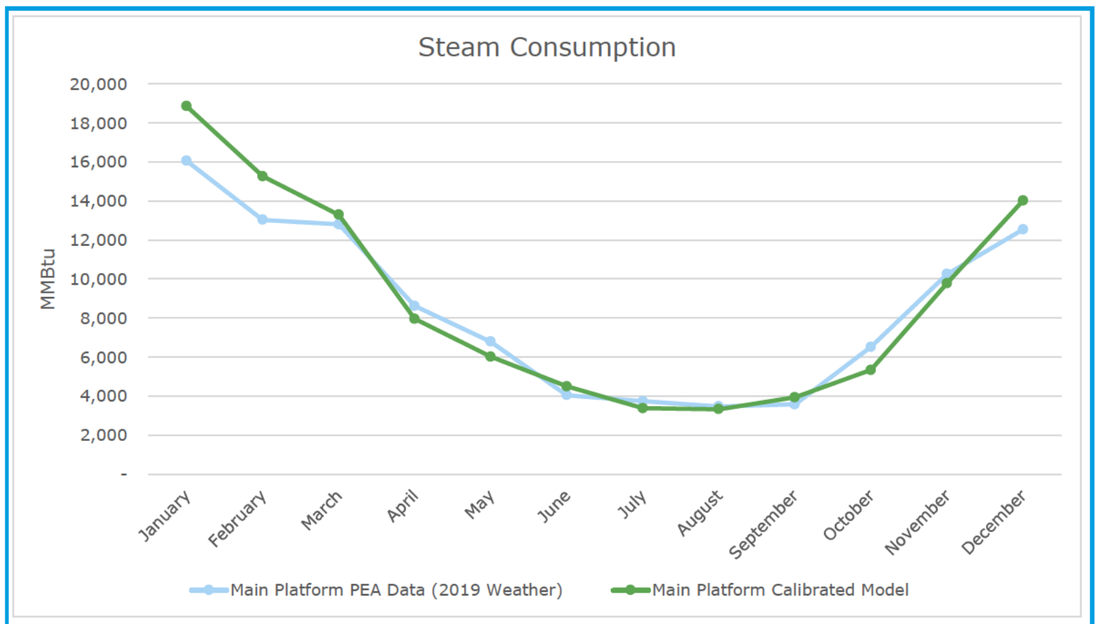
Main Platform Calibration



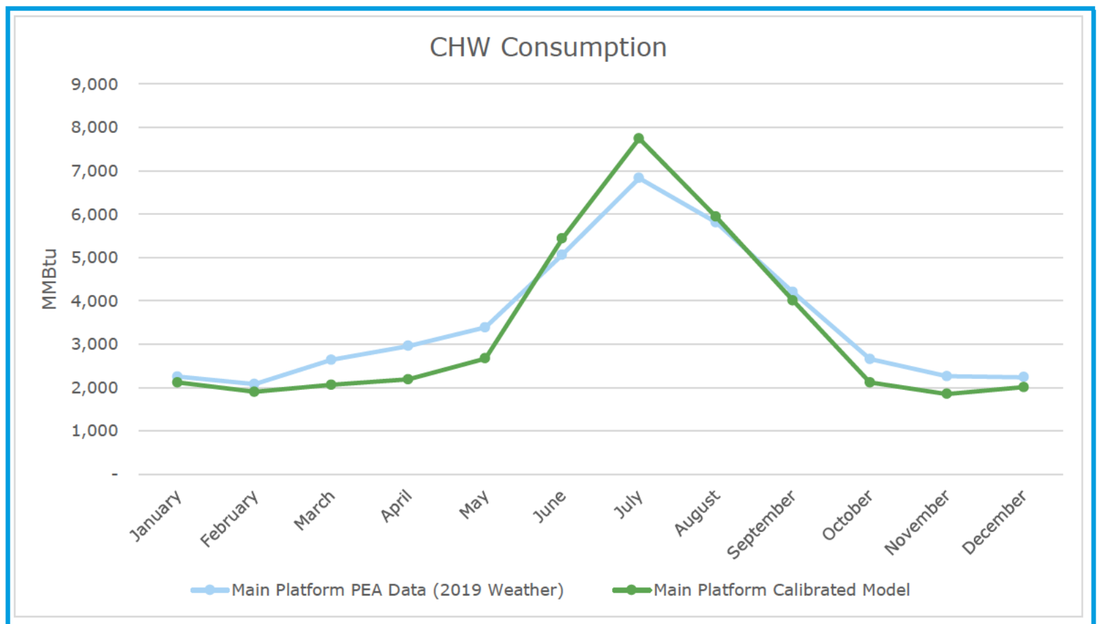
	Limit	Actual
NMBE	5%	-9%
CV(RMSE)	15%	14%



	Limit	Actual
NMBE	5%	-9%
CV(RMSE)	15%	16%



	Limit	Actual
NMBE	5%	-5%
CV(RMSE)	15%	15%



	Limit	Actual
NMBE	5%	6%
CV(RMSE)	15%	15%

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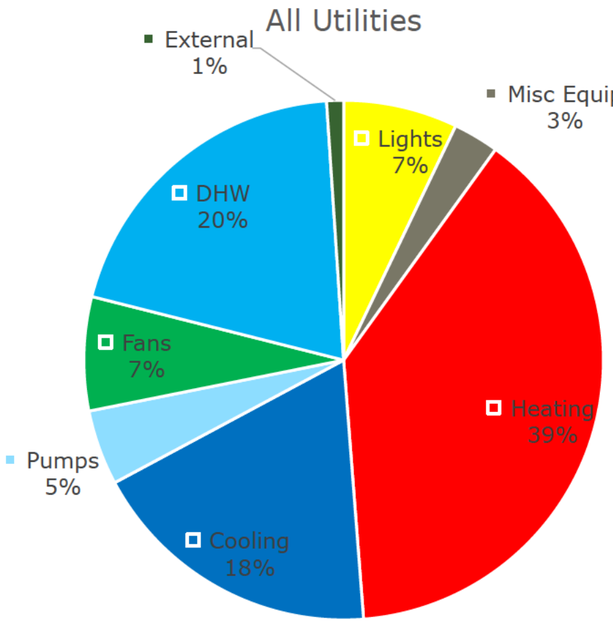
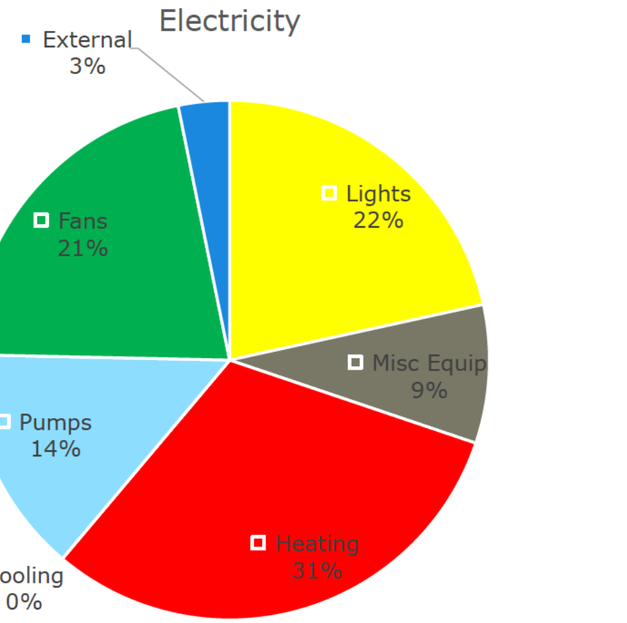
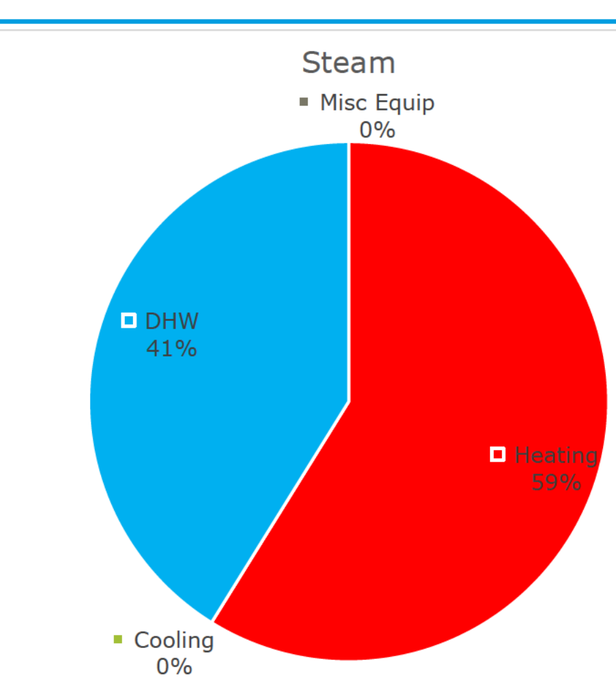
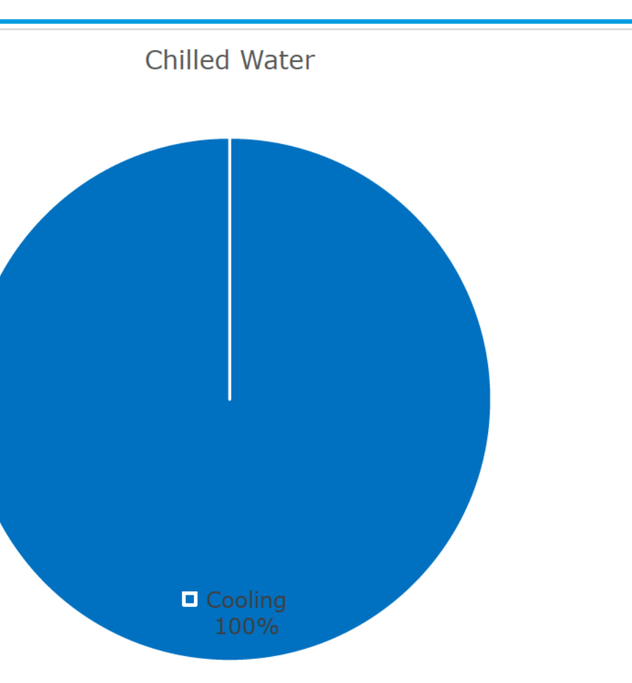
Main Platform Calibrated Model
End Use Summary









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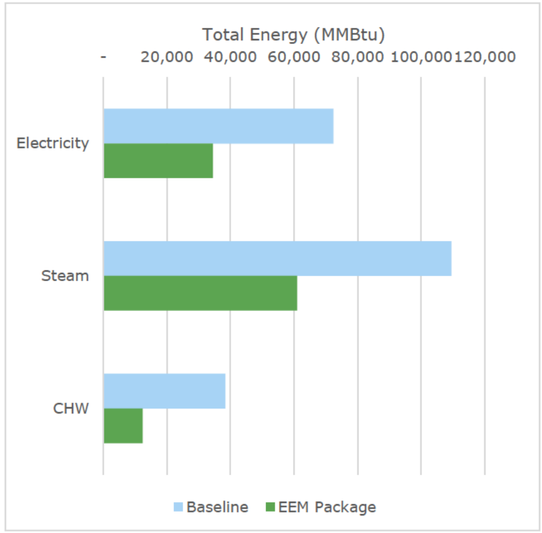
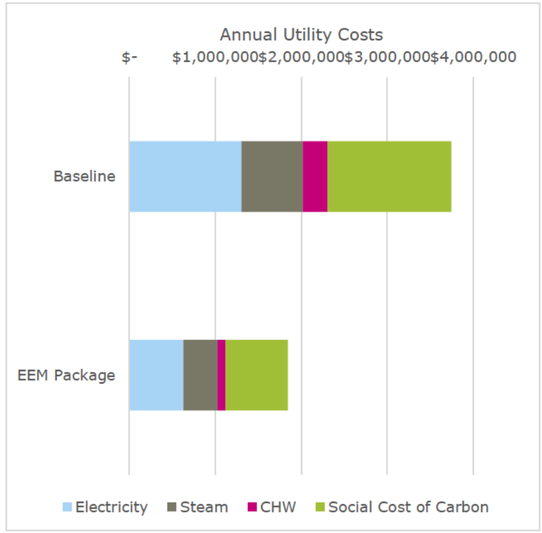
Main Platform EEM Package Summary

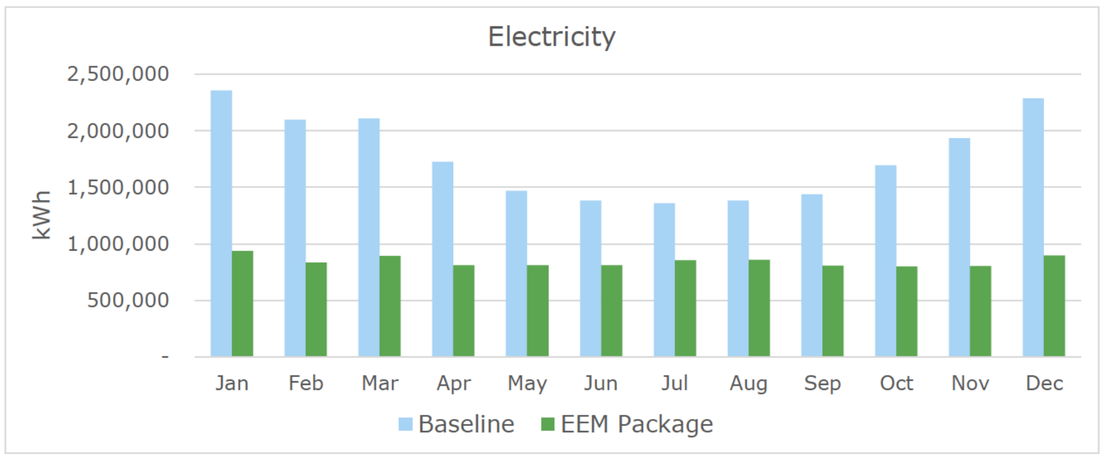
	Units	Baseline	EEM Package	Savings	% Savings
Annual Electric Use	kWh	21,238,406	10,117,571	11,120,835	52.4%
Annual Steam Use	MMBtu	109,500	61,050	48,450	44.2%
Annual CHW Use	MMBtu	38,410	12,380	26,030	67.8%
Annual Total Energy Use	MMBtu	220,375	107,951	112,424	51.0%
EUI	**kBtu/GSF**	**63.0**	**30.9**	**32.1**	**51.0%**
Total Emissions	**MTCO2e**	**11,579**	**5,819**	**5,759**	**49.7%**
Annual Electric Cost	$	$ 1,307,164	$ 629,246	$ 677,918	51.9%
Annual Natural Gas Cost	$	$ -	$ -	$ -	N/A
Annual Steam Cost	$	$ 712,022	$ 396,811	$ 315,211	44.3%
Annual CHW Cost	$	$ 288,061	$ 92,884	$ 195,177	67.8%
Annual Utility Cost	$	$ 2,307,247	$ 1,118,941	$ 1,188,306	51.5%
Social Cost of Carbon	$	$ 1,435,907	$ 721,677	$ 714,230	49.7%
Annual Combined Cost	**$**	**$ 3,743,154**	**$ 1,840,618**	**$ 1,902,536**	**50.8%**





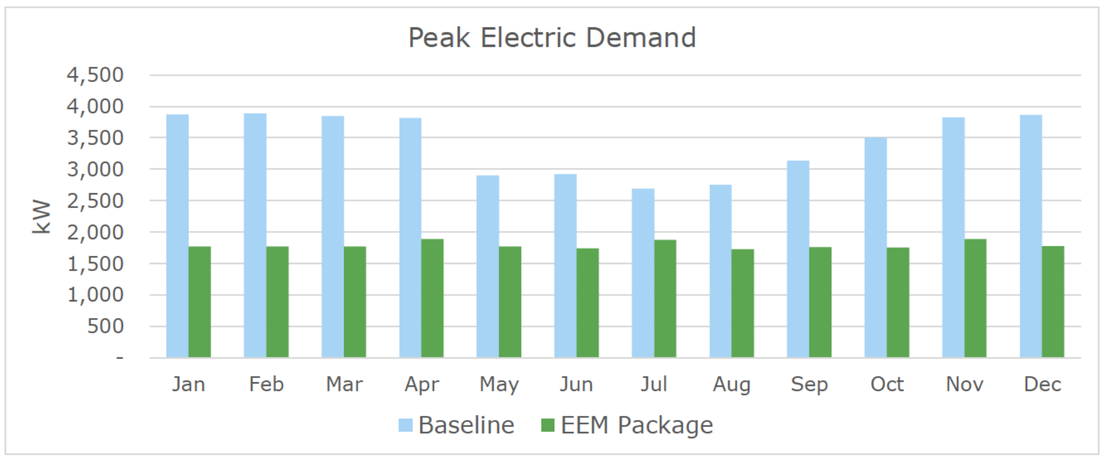
Electric Energy

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kWh	4,527,400	4,527,400	-	0.0%
Misc Equip	kWh	1,809,643	1,809,643	-	0.0%
Heating	kWh	6,533,906	-	6,533,906	100.0%
Cooling	kWh	-	-	-	N/A
Pumps	kWh	3,013,896	765,180	2,248,716	74.6%
Fans	kWh	4,557,282	2,219,069	2,338,213	51.3%
Refrigeration	kWh	127,765	127,765	-	0.0%
DHW	kWh	-	-	-	N/A
External	kWh	668,508	668,508	-	0.0%
Total Electric	**kWh**	**21,238,406**	**10,117,571**	**11,120,835**	**52.4%**



Electric Peak Demand

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kW	702.7	702.7	-	0.0%
Misc Equip	kW	308.3	308.3	-	0.0%
Heating	kW	1,435.4	-	1,435.4	100.0%
Cooling	kW	-	-	-	N/A
Pumps	kW	367.2	182.8	184.4	50.2%
Fans	kW	1,148.8	798.1	350.7	30.5%
Refrigeration	kW	14.6	14.6	-	0.0%
DHW	kW	-	-	-	N/A
External	kW	338.7	338.7	-	0.0%
Total kW	**kW**	**3,886.2**	**1,891.0**	**1,995.2**	**51.3%**



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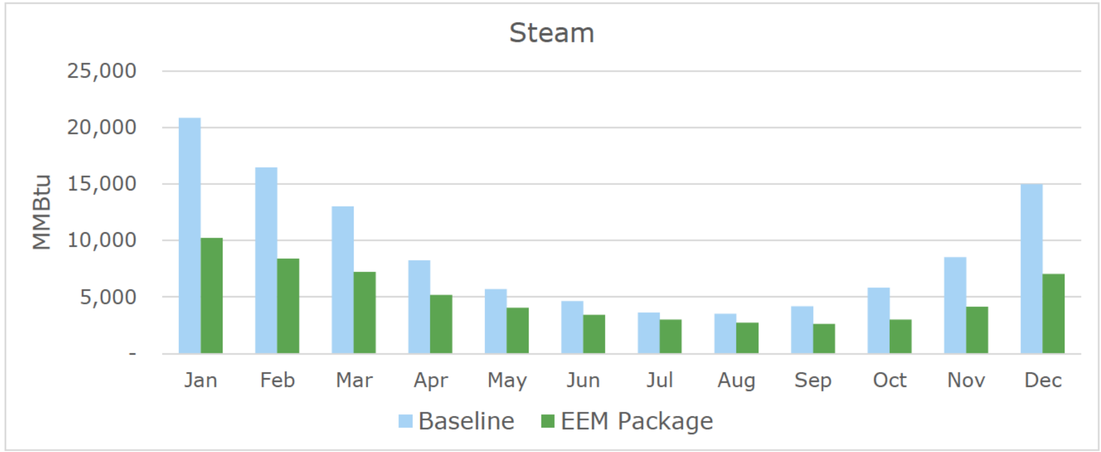
Main Platform EEM Package Summary (cont.)

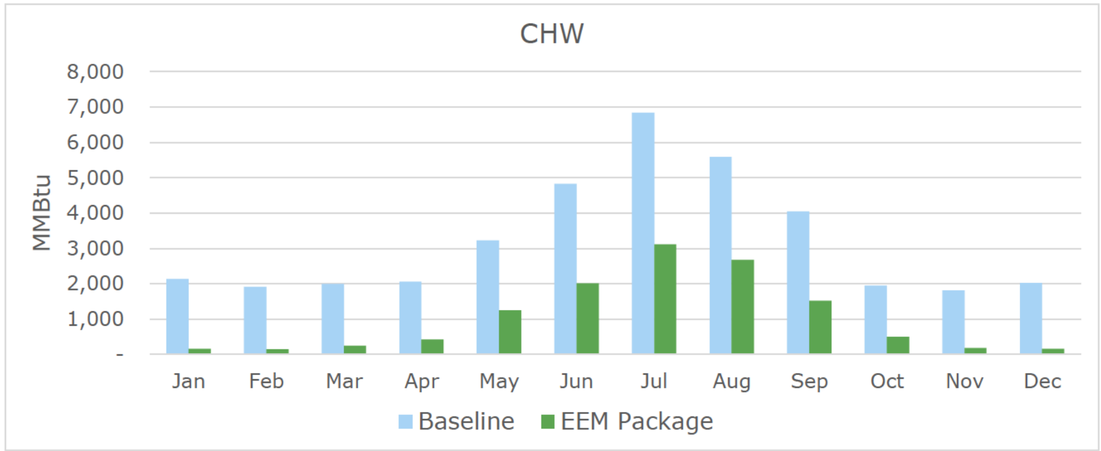
Steam

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	66,100	17,600	48,500	73.4%
Cooling	MMBtu	-	-	-	N/A
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	43,500	43,500	-	0.0%
External	MMBtu	-	-	-	N/A
Total Steam	**MMBtu**	**109,500**	**61,050**	**48,450**	**44.2%**



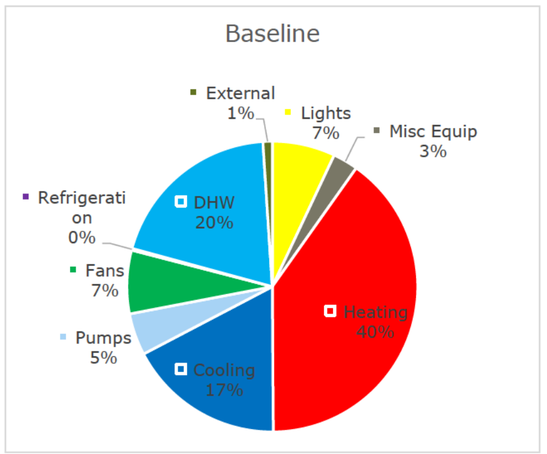
CHW

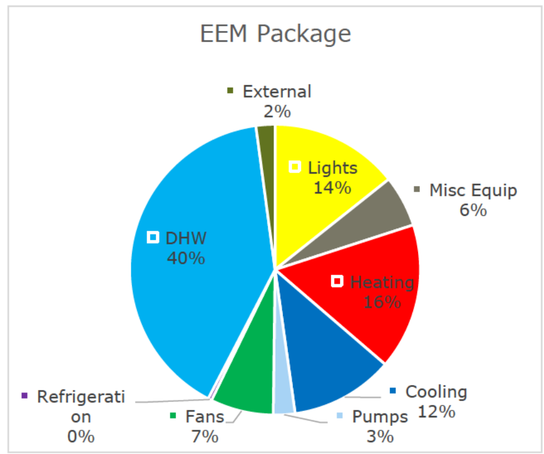
End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	-	-	-	N/A
Cooling	MMBtu	38,400	12,400	26,000	67.7%
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	-	-	-	N/A
External	MMBtu	-	-	-	N/A
Total CHW	**MMBtu**	**38,410**	**12,380**	**26,030**	**67.8%**



All Utilities

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	15,447	15,447	-	0.0%
Misc Equip	MMBtu	6,175	6,175	-	0.0%
Heating	MMBtu	88,394	17,600	70,794	80.1%
Cooling	MMBtu	38,400	12,400	26,000	67.7%
Pumps	MMBtu	10,283	2,611	7,673	74.6%
Fans	MMBtu	15,549	7,571	7,978	51.3%
Refrigeration	MMBtu	436	436	-	0.0%
DHW	MMBtu	43,500	43,500	-	0.0%
External	MMBtu	2,281	2,281	-	0.0%
Total	**MMBtu**	**220,375**	**107,951**	**112,424**	**51.0%**





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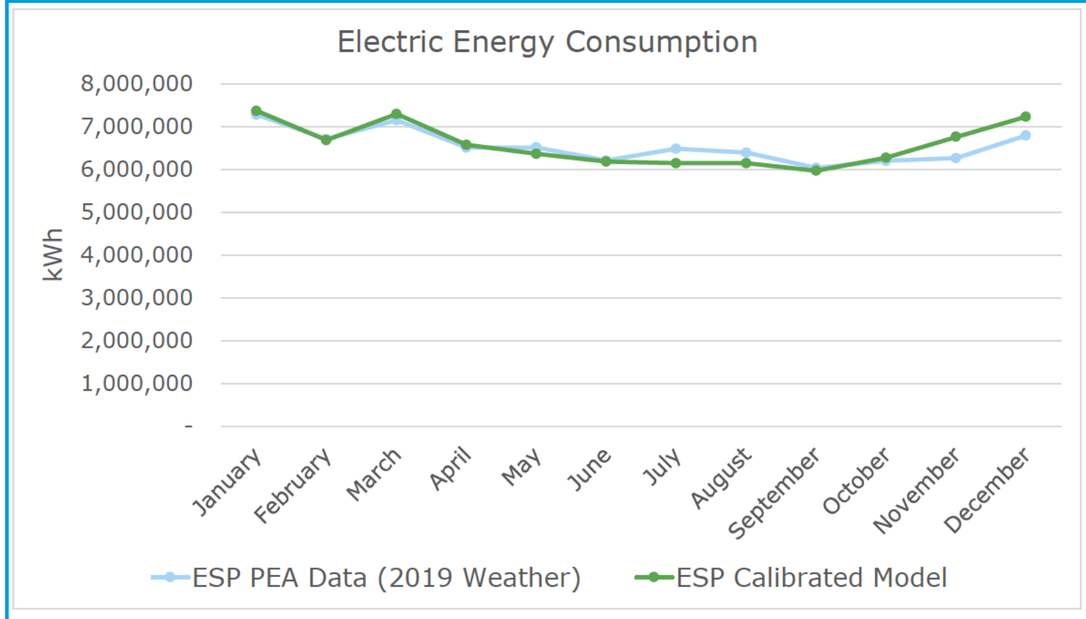
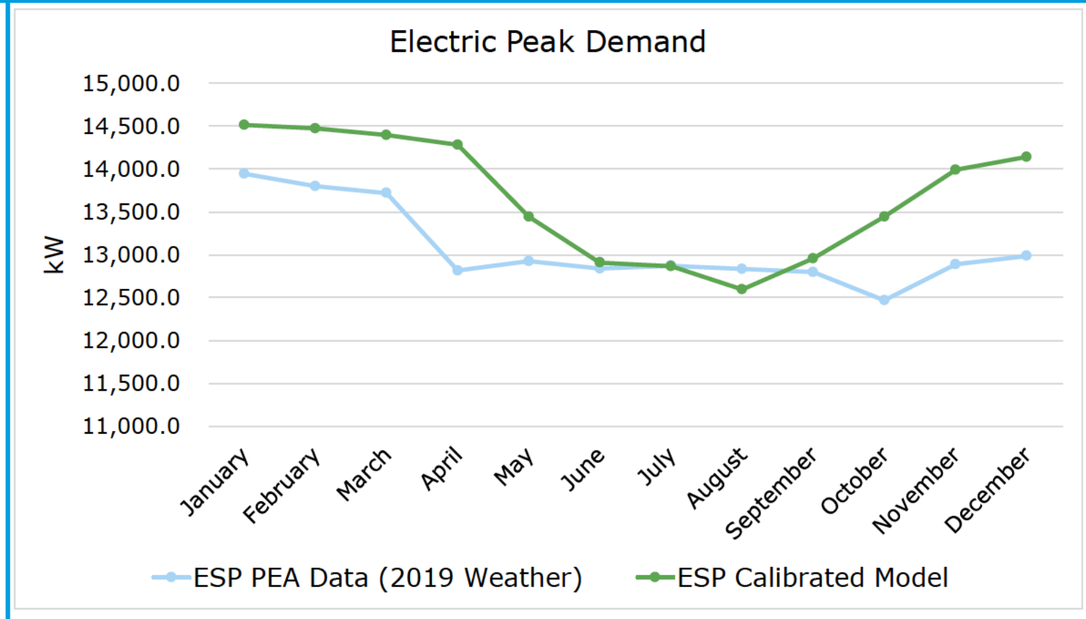
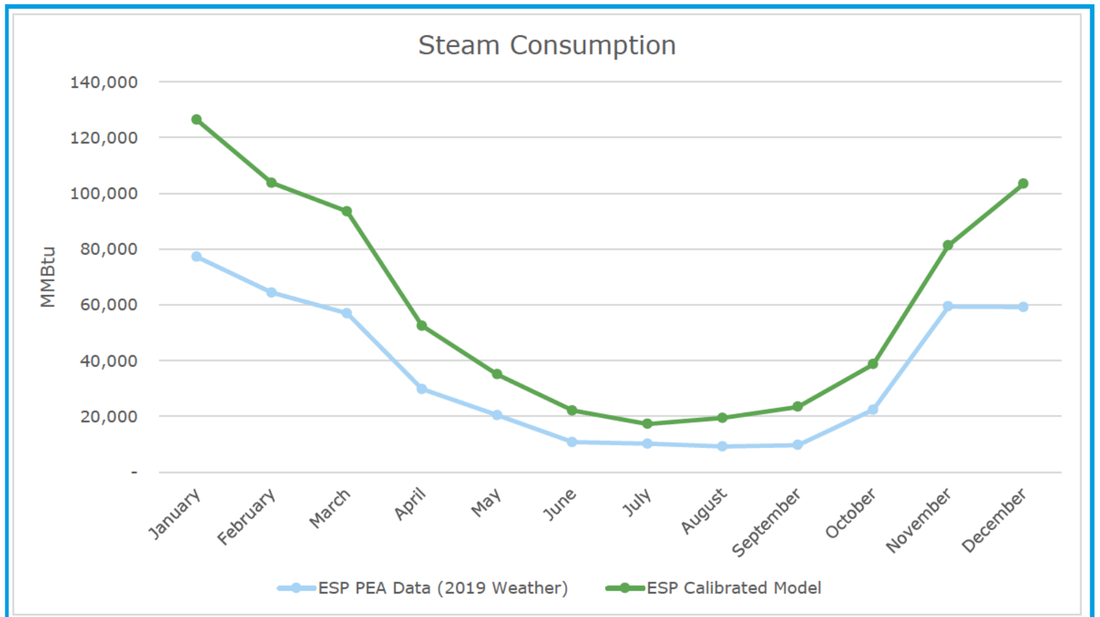
ESP Calibration



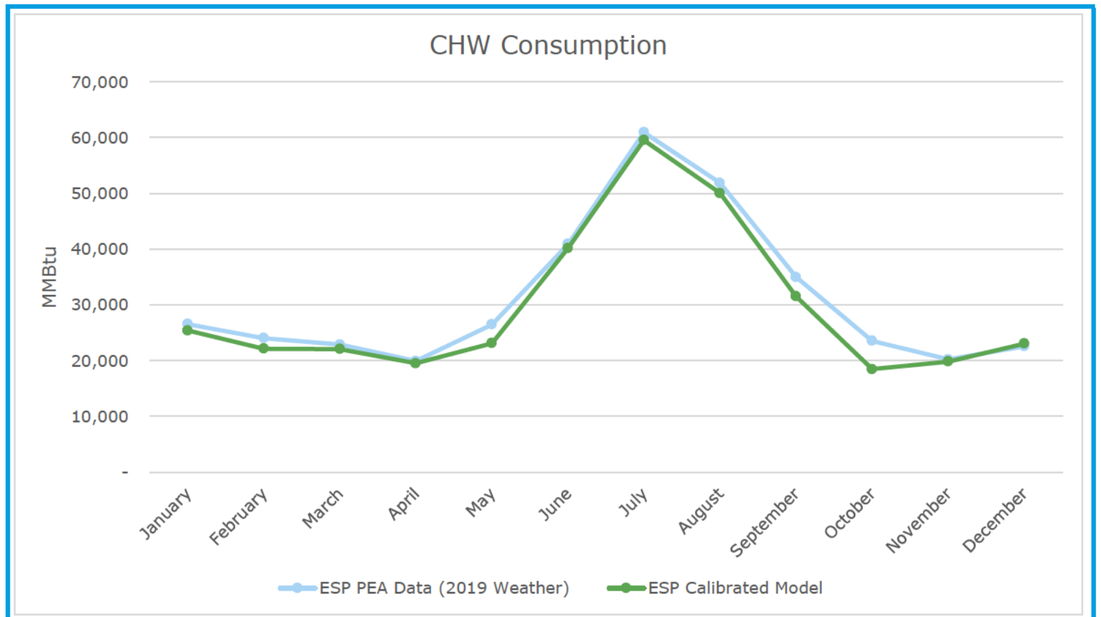
	Limit	Actual
NMBE	5%	-1%
CV(RMSE)	15%	4%



	Limit	Actual
NMBE	5%	-5%
CV(RMSE)	15%	6%



	Limit	Actual
NMBE	5%	-73%
CV(RMSE)	15%	81%



	Limit	Actual
NMBE	5%	6%
CV(RMSE)	15%	8%

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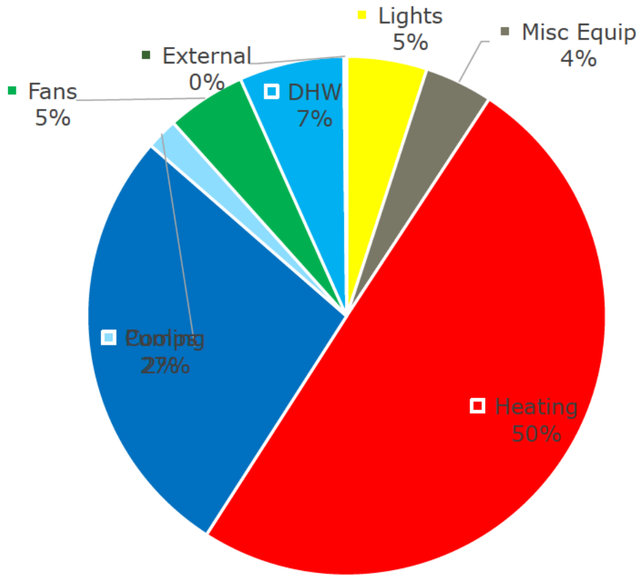
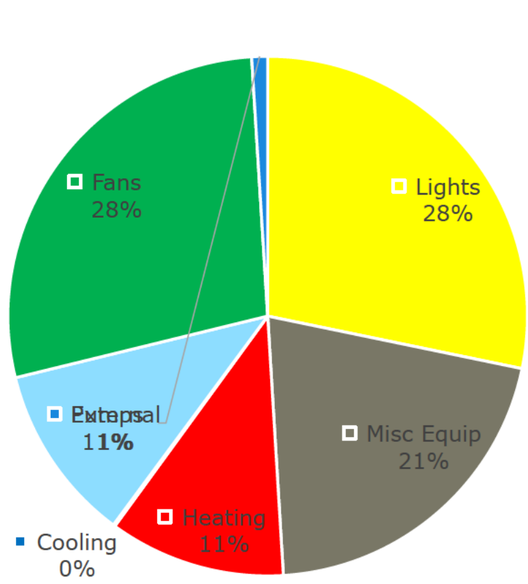
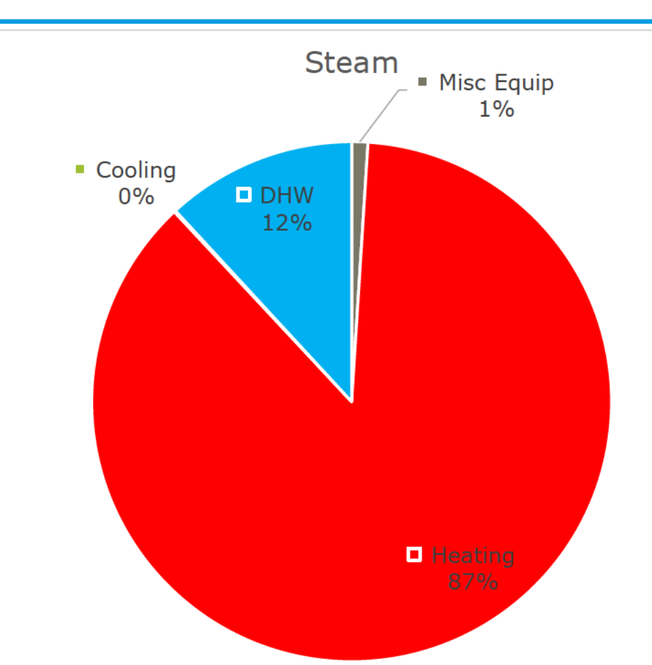
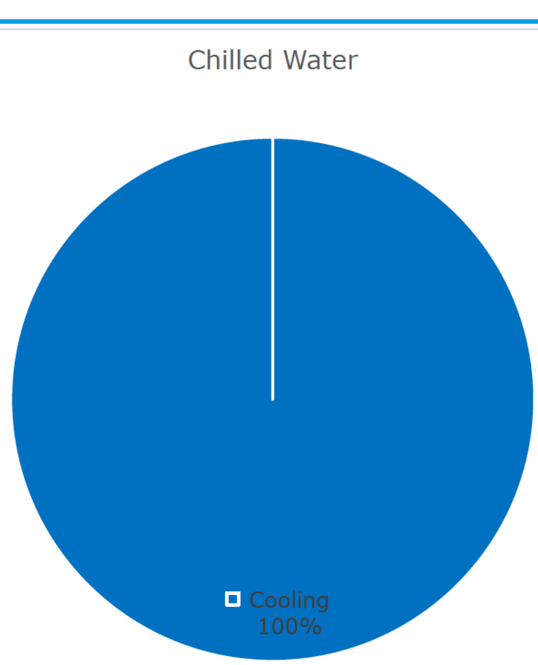
ESP Calibrated Model
End Use Summary









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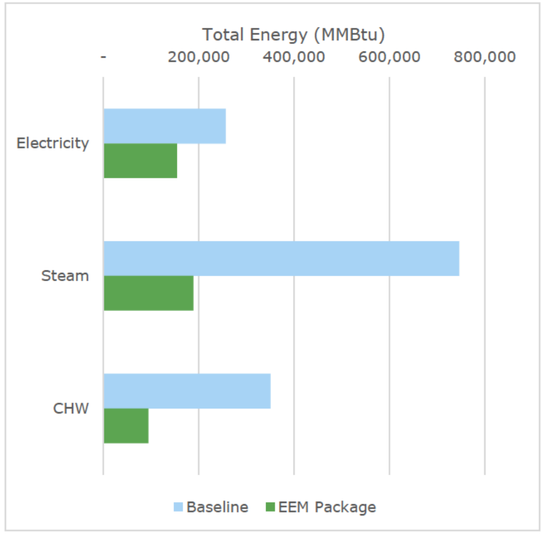
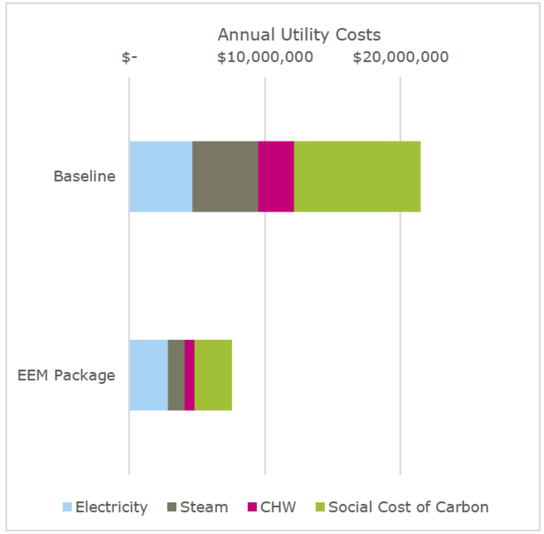
ESP EEM Package Summary

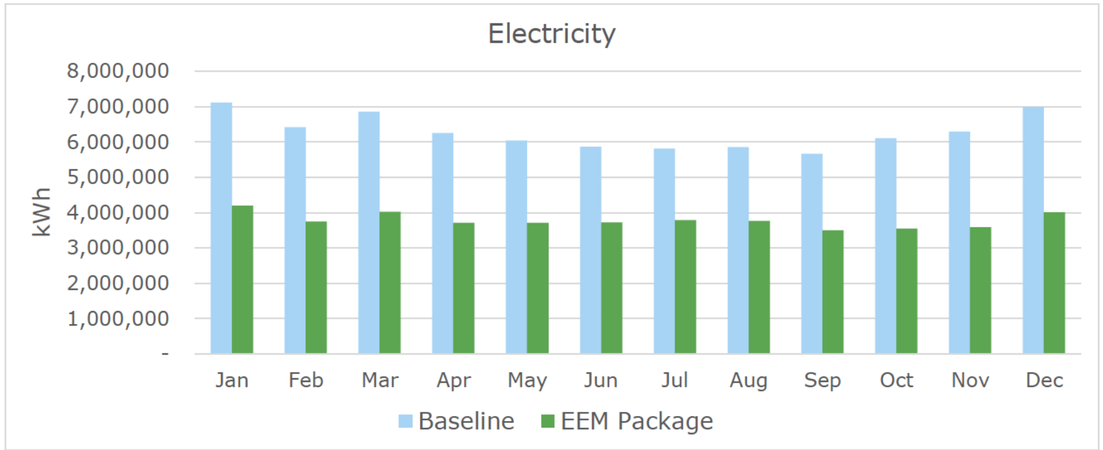
	Units	Baseline	EEM Package	Savings	% Savings
Annual Electric Use	kWh	75,253,771	45,273,519	29,980,252	39.8%
Annual Steam Use	MMBtu	746,700	188,916	557,784	74.7%
Annual CHW Use	MMBtu	351,073	94,502	256,571	73.1%
Annual Total Energy Use	MMBtu	1,354,539	437,891	916,648	67.7%
EUI	**kBtu/GSF**	**155.1**	**50.1**	**104.9**	**67.7%**
Total Emissions	**MTCO2e**	**75,253**	**22,338**	**52,914**	**70.3%**
Annual Electric Cost	$	$ 4,658,439	$ 2,853,073	$ 1,805,366	38.8%
Annual Natural Gas Cost	$	$ -	$ -	$ -	N/A
Annual Steam Cost	$	$ 4,851,043	$ 1,227,952	$ 3,623,091	74.7%
Annual CHW Cost	$	$ 2,632,926	$ 708,804	$ 1,924,122	73.1%
Annual Utility Cost	$	$ 12,142,408	$ 4,789,829	$ 7,352,579	60.6%
Social Cost of Carbon	$	$ 9,332,140	$ 2,770,257	$ 6,561,883	70.3%
Annual Combined Cost	**$**	**$ 21,474,548**	**$ 7,560,086**	**$ 13,914,462**	**64.8%**





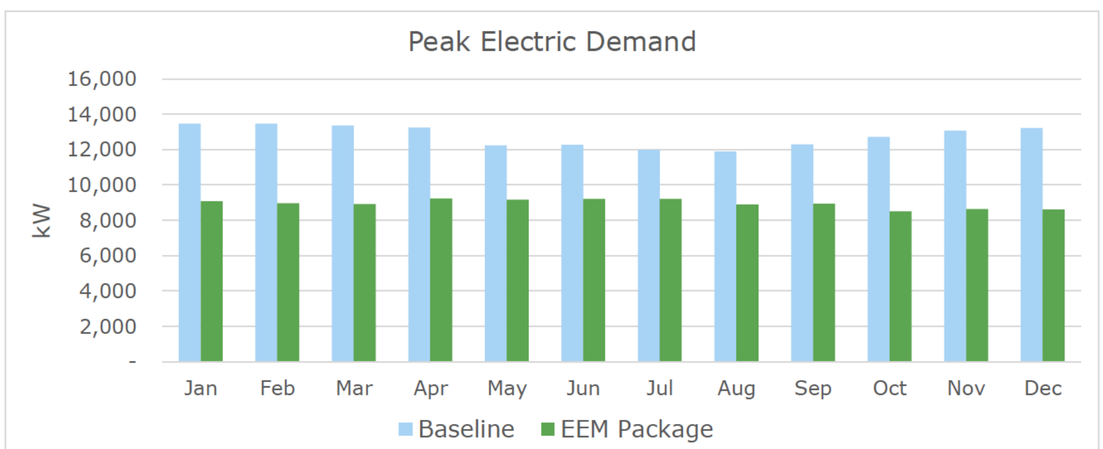
Electric Energy

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kWh	14,506,940	14,207,488	299,452	2.1%
Misc Equip	kWh	14,081,509	13,122,121	959,388	6.8%
Heating	kWh	7,483,299	419,010	7,064,289	94.4%
Cooling	kWh	80,739	278,934	(198,195)	-245.5%
Pumps	kWh	8,405,736	2,730,924	5,674,812	67.5%
Fans	kWh	28,774,885	13,718,762	15,056,123	52.3%
Refrigeration	kWh	1,252,107	127,765	1,124,342	89.8%
DHW	kWh	-	-	-	N/A
External	kWh	668,508	668,508	-	0.0%
Total Electric	**kWh**	**75,253,771**	**45,273,519**	**29,980,252**	**39.8%**



Electric Peak Demand

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	kW	2,863.9	2,931.3	(67.4)	-2.4%
Misc Equip	kW	2,574.4	2,460.4	114.0	4.4%
Heating	kW	1,835.2	126.8	1,708.4	93.1%
Cooling	kW	29.4	146.0	(116.6)	-397.1%
Pumps	kW	1,267.5	558.1	709.4	56.0%
Fans	kW	5,318.1	3,908.3	1,409.7	26.5%
Refrigeration	kW	142.9	14.6	128.4	89.8%
DHW	kW	-	-	-	N/A
External	kW	338.7	338.7	-	0.0%
Total kW	**kW**	**13,713.0**	**9,572.4**	**4,140.6**	**30.2%**



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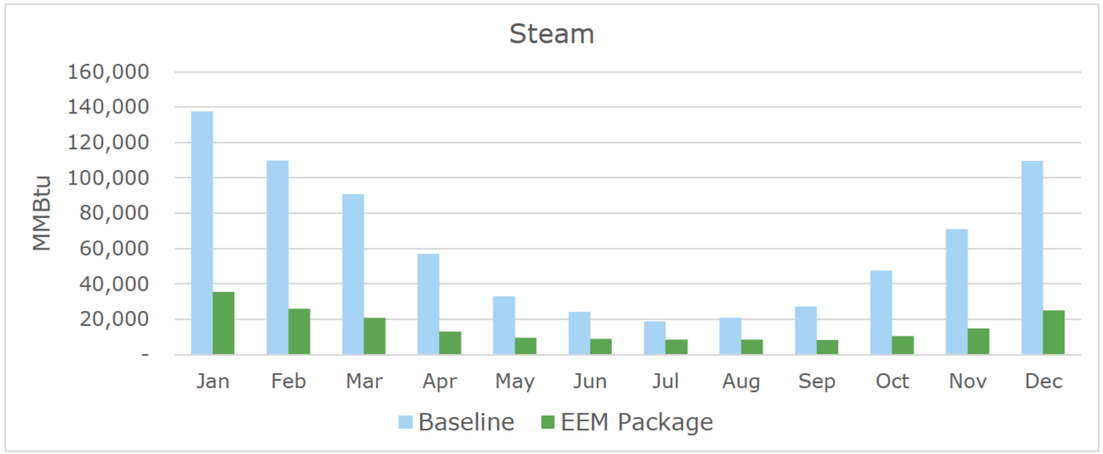
ESP EEM Package Summary (cont.)

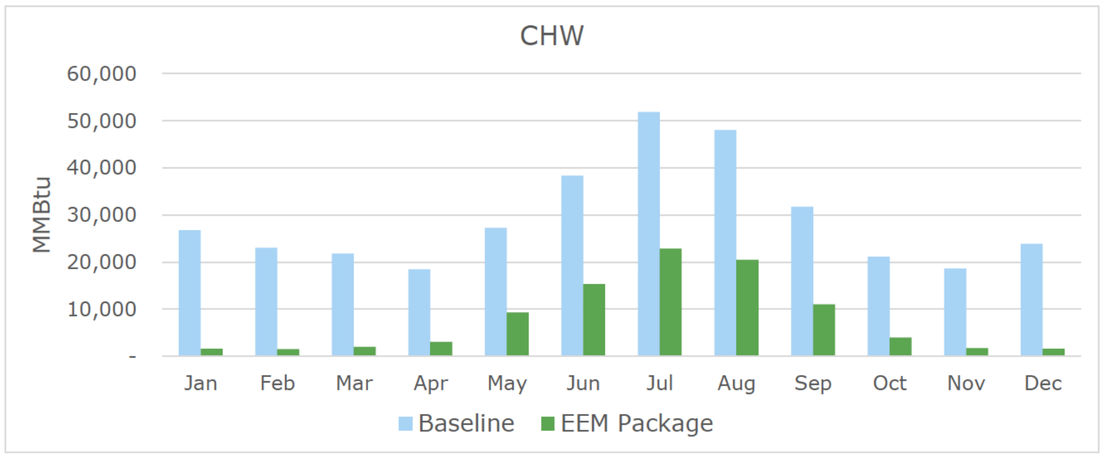
Steam

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	7,220	-	7,220	100.0%
Heating	MMBtu	654,000	114,910	539,090	82.4%
Cooling	MMBtu	629	-	629	100.0%
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	85,071	74,026	11,045	13.0%
External	MMBtu	-	-	-	N/A
Total Steam	**MMBtu**	**746,700**	**188,916**	**557,784**	**74.7%**



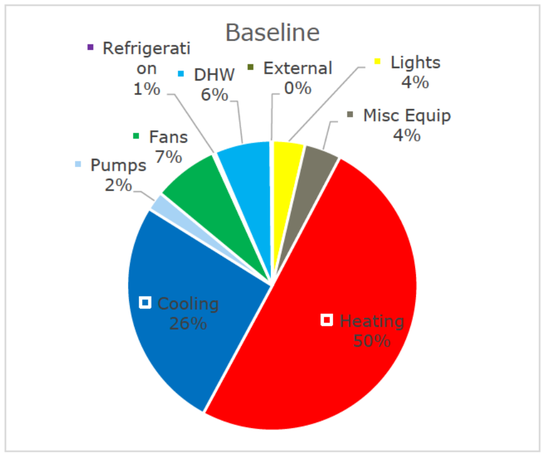
CHW

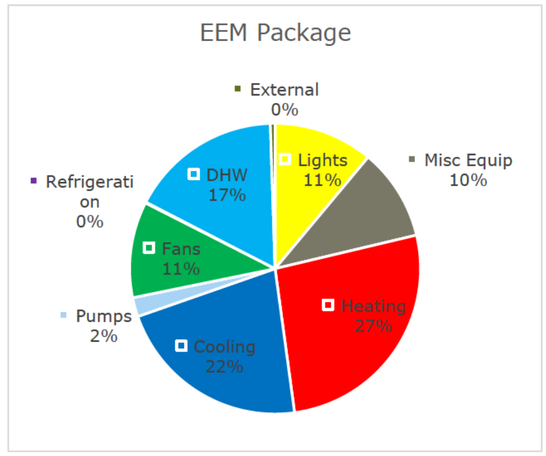
End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	-	-	-	N/A
Misc Equip	MMBtu	-	-	-	N/A
Heating	MMBtu	-	-	-	N/A
Cooling	MMBtu	351,380	94,550	256,830	73.1%
Pumps	MMBtu	-	-	-	N/A
Fans	MMBtu	-	-	-	N/A
Refrigeration	MMBtu	-	-	-	N/A
DHW	MMBtu	-	-	-	N/A
External	MMBtu	-	-	-	N/A
Total CHW	**MMBtu**	**351,073**	**94,502**	**256,571**	**73.1%**



All Utilities

End Use Components	Units	Baseline	EEM Package	Savings	% Savings
Lights	MMBtu	49,498	48,476	1,022	2.1%
Misc Equip	MMBtu	55,266	44,773	10,493	19.0%
Heating	MMBtu	679,533	116,340	563,193	82.9%
Cooling	MMBtu	352,284	95,502	256,783	72.9%
Pumps	MMBtu	28,680	9,318	19,362	67.5%
Fans	MMBtu	98,180	46,808	51,371	52.3%
Refrigeration	MMBtu	4,272	436	3,836	89.8%
DHW	MMBtu	85,071	74,026	11,045	13.0%
External	MMBtu	2,281	2,281	-	0.0%
Total	**MMBtu**	**1,354,539**	**437,891**	**916,648**	**67.7%**





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EMPIRE STATE PLAZA | EEM-1 RETRO-COMMISSIONING

Energy Opportunity Area: HVAC, Building Automation System (BAS), Lighting

Buildings Affected: Alfred E. Smith Office Building (AESOB)

Table 1. EEM-1 Summary Data

Description	Values	Units
Annual Electrical Energy Savings	0	kWh/year
Electrical Peak Demand Savings	0.0	kW
Annual Electrical Energy Cost Savings	$0	$/year
Annual Natural Gas Savings	56,435	Therms/year
Annual Natural Gas Cost Savings	$36,859	$/year
Total Annual Energy Cost Savings	**$36,859**	**$/year**
Estimated Implementation Cost	**$191,637**	**$**
Simple Payback Period	**5.2**	**years**

Recommended Action

This measure considers retro-commissioning (RCx) be conducted at Alfred E. Smith Office Building (AESOB). RCx is the application of the commissioning process to existing buildings to meet the Current Facility Requirements (CFR) and optimize the building's energy performance and occupant comfort characteristics. Newly constructed buildings are sometimes commissioned to a set of operating parameters that are not necessarily the most energy efficient. Energy efficiency and occupant comfort deteriorate as control schemes are modified, occupancy loads shift, existing equipment ages, key operating parameters drift away from their ideal operating states or setpoints. Frequently, routine maintenance issues are "solved" by compensating for them in ways that are not energy efficient. An example would be to operate a chiller to cool the building when an AHU's economizer feature is not operating properly. Additionally, if a building was not commissioned when constructed, it may be that it was never operating optimally.

It is not uncommon to find that the operating parameters of a building's sub-systems (*i.e.,* for an HVAC system, the temperature setpoints, air and water flows, valve and damper positions) are not well documented. When design operating conditions are misunderstood or unknown, facility staff may operate the equipment based on assumptions that are incorrect. RCx can include the development or revision of documentation, such as system manuals, that describe the building operating sequences and can serve as a basis for training the technicians who operate and service the building.

When performed correctly, RCx can provide significant benefits for the owner such as:

- Improved energy performance (6% median savings achieved per LBNL Study cited below)
- Improved equipment performance
- Increased asset value
- Improved thermal comfort and indoor air quality
- Training opportunities for building maintenance staff
- Improved building documentation (System Manuals)

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The RCx (also referred to as existing building commissioning or EBCx) process involves functionally testing and adjusting building sub-systems and ultimately demonstrating that they are being operated and maintained according to the CFR. According to the newest (2018) research from Lawrence Berkeley National Laboratory (LBNL) and the Building Commissioning Association (BCxA), building commissioning remains a cost-effective way to improve building operations and reduce energy use. The 2018 study (https://www.energy.gov/eere/buildings/articles/new-doe-research-strengthens-business-case-building-commissioning) is an update to the 2009 study entitled "Building Commissioning – A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions" and now includes nearly 1,500 new and existing building Cx projects. Of the 684 existing building Cx projects, 112 are higher education buildings.

The results revealed that the most common problems were associated with the HVAC systems and controls. RCx energy savings typically ranged from 3-10% with a median of 6%. Simple payback typically ranged from 1-4 years with a median of 2.2 years.

Larger buildings with HVAC systems that are less than 20 years old, and those that have DDC control systems, are generally good candidates for retro-commissioning. Small buildings and those with pneumatic controls often lack the type of sensors and controls necessary to implement the type of diagnostics and functional testing that can lead to significant performance improvements. Buildings with HVAC systems older than 20 years are approaching the end of their useful design life and would most likely benefit from a more extensive HVAC renovation or system replacement. Buildings with very simple HVAC infrastructure and control strategies also do not benefit as much. It would be more beneficial to upgrade the HVAC systems of such buildings to include energy saving features such as economizers and VFDs, and commission the systems as part of the upgrade project.

Retro-commissioning can provide many non-energy benefits. These may include improved thermal comfort, indoor environmental quality, and productivity; reduced occupant complaints, absenteeism, emergency repair calls, and liability; extended equipment life; and additional maintenance staff training. It is also an important component of LEED for Existing Buildings: Operations & Maintenance for buildings seeking certification.

To fully realize the benefits that RCx can provide, it is a good idea to address major outstanding repair and maintenance issues prior to implementing the project. Retro-commissioning should be performed every three to five years in order to maintain top levels of building performance and persistence of energy savings.

Estimated Energy Savings

Table 2 presents estimated energy savings that could be potentially achieved from retro-commissioning of AESOB, along with RCx costs and simple payback periods. The LBNL study referenced above was used as the basis for estimating potential energy savings and costs to perform the commissioning process.

As noted previously, the 2018 LBNL study shows that RCx savings typically range from 3-10% of total building energy use. The percent energy savings were scaled for AESOB based on the comparison of the actual energy use intensity (EUI) to the CBECS benchmark from the Preliminary Energy Use Analysis (PEA). Buildings that are at or below the CBECS benchmark are assumed to have 3% savings from RCx and buildings that are above the CBECS benchmark are scaled up towards the 10% savings referenced in the LBNL study.

Supporting documents include a detailed analysis spreadsheet showing assumed savings potential (percent savings) and estimated RCx cost for each building and the entire campus, along with simple

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payback period. Many campus buildings may not be good candidates for RCx, particularly those that are less energy intensive such as residence halls (although kitchen and dining hall HVAC systems and controls could benefit).

Table 2. EEM-1 Savings

Building	Annual Electrical Energy Savings (kWh/year)	Annual Natural Gas Savings (Therms/year)	Total Annual Energy Cost Savings ($/year)	Estimated Implementation Cost	Simple Payback Period
Alfred E Smith Office Building	0	56,435	36,859	$191,637	5.2
Total	**0**	**56,435**	**36,859**	**$191,637**	**5.2**

Estimated Project Cost

Costs presented in represent the scope of work described below. According to the 2018 LBNL study previously referenced, the typical cost of commissioning existing buildings ranged from $0.13/GSF to $0.48/GSF with a median cost of $0.25/GSF. For this project, these RCx costs were escalated to 2025 rates and subsequently scaled based on the building type.

The RCx implementation costs include development of a CFR and RCx Plan, functional testing, trend data analysis, estimating energy savings associated with correcting deficiencies, and developing a final report to document findings and present recommendations. The cost to correct deficiencies identified during the RCx process is not included in the estimate (*e.g.,* repairs that require capital expenses), although no cost/low cost measures that can often be done by in-house staff are commonly identified. These may include HVAC system and equipment schedule and setpoint adjustments through the BAS, repairing disconnected damper linkages or bound dampers, releasing manual overrides, revising sequence of operations to improve energy efficiency, etc.

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Table 3. EEM-1 Estimated Project Costs

Item Description	Qty	Unit	Unit Cost	Subtotal
Retro-Commissioning	1	Lump Sum	$191,637	$191,637
Labor and Materials Subtotal				**$191,637**
General Conditions	0%			$0
Labor and Materials Cost Total				**$191,637**
Architectural & Engineering Fees	0%			$0
Construction Management Fees	0%			$0
Contingency	0%			$0
Project Cost Subtotal				**$191,637**
Agency Administrative Fee	0%			$0
Total Project Cost				**$191,637**

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EEM-1 – RETRO-COMMISSIONING

SUPPORTING DOCUMENTS

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LIFE CYCLE COST ANALYSIS

EEM No.:	EEM-1		
EEM Title:	Retro-Commissioning		
General Parameters			
Base Date:	1/1/2027		
Service Date:	1/1/2027		
Study Period (Years):	5		
Discount Rate:	3%		
Cost Escalation:	0%		
FEMP UPV Discount Factor (Elect.):	4.93		
FEMP UPV Discount Factor (NG):	4.64		
Calculated UPV Discount Factor (CHW):	4.93		
Calculated UPV Discount Factor (Steam):	4.64		

Cost Data	**Baseline**	**Proposed**	**Savings**
Initial Capital Cost:		$191,637	($191,637)
Annual Electricity Costs:	$386,750	$386,750	$0
Annual Natural Gas Costs:	$264,829	$238,346	$26,483
Annual CHW Costs:	$0	$0	$0
Annual Steam Costs:	$0	$0	$0
Annual Water Costs:	$0	$0	$0
Annual OM&R Costs:	$5,749	$5,749	$0
Other Recurring Annual Costs:	$0	$0	$0

Life Cycle Cost Calculations	**Baseline**	**Proposed**	**Savings**
Present Value Investment Costs, I:	$0	$191,637	($191,637)
Present-Value Capital Replacement Cost, Repl:	$0	$0	$0
Present Value Residual Cost, Res:	$0	$0	$0
Present Value Energy Costs, E:	$3,135,666	$3,012,795	$122,871
Present Value Water Cost, W:	$0	$0	$0
Present Value O&M and Other Recurring Costs, OM&R:	$26,329	$26,329	$0
LCC:	**$3,161,996**	**$3,230,762**	**($68,766)**

Savings to Investment Ratio Calculations	
Present Value Energy Cost Savings, DE:	$122,871
Present Value Water Cost Savings, DW:	$0
Present Value OM&R Cost Savings, DOM&R:	$0
SIR:	**0.64**

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

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EMPIRE STATE PLAZA | EEM-2 PUMP DIFFERENTIAL PRESSURE RESET CONTROLS

Energy Opportunity Area: HVAC, Building Automation System (BAS)

Buildings Affected: NYS Capitol Building, Alfred E. Smith Office Building (AESOB), NYS Education Building

Table 1. EEM-2 Summary Data

Description	Values	Units
Annual Electrical Energy Savings	134,966	kWh/year
Electrical Peak Demand Savings	22.3	kW
Annual Electrical Energy Cost Savings	$9,483	$/year
Total Annual Energy Cost Savings	**$9,483**	**$/year**
Estimated Implementation Cost	**$46,020**	**$**
Simple Payback Period	**4.9**	**years**

Existing Conditions/Baseline

The variable flow chilled water (CHW) and hot water (HW) pumps listed in Table 2 are controlled by variable frequency drives (VFDs) that modulate pump speed (and flow) through the building automation system (BAS) to maintain a constant differential pressure across their associated water loops. These pumps deliver chilled or hot water (or glycol) to cooling and heating coils controlled by electronic two-way valves.

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Table 2. Chilled Water and Hot Water Pumps Controlled by VFDs

Building	Tag	System	Pump Quantity (on VFD)	Pump HP (Ea. Pump)
AESOB	P-1, P-2	Primary CHW	2	125
AESOB	P-4, P-5	2-pipe HHW	2	15
AESOB	P-4, P-5	2-pipe CHW	2	15
AESOB	P-6, P-7, P-8	2-pipe HHW	2	40/30 [1]
AESOB	P-6, P-7, P-8	2-pipe CHW	2	40/30
AESOB	P-9, P-10, P-11	2-pipe HHW	3	30
AESOB	P-9, P-10, P-11	2-pipe CHW	3	30
Capitol	P-1	HW	1	25
Capitol	P-2	HW	1	25
Capitol	P-3	HW	1	25
Capitol	SCWP-1, SCWP-2, SCWP-3, SCWP-4	CHW	4	30
State Ed	P-1, P-2	HW	2	15
State Ed	P-3, P-4	HW	2	15
State Ed	P-5, P-6	HW	2	15
State Ed	P-11, P-12	HW	2	20
State Ed	P-4, P-5	CHW	2	25
State Ed	P-7, P-8	HW	2	20
State Ed	P-7, P-8	CHW	2	20
State Ed	P-9, P-10	HW	2	15
State Ed	P-9, P-10	CHW	2	15

1. Pump 6 is 40 HP, Pump 7 and 8 is 30 HP, however Pump 8 is used as backup

Recommended Action

Differential pressure setpoints for the variable flow pumping systems addressed by this measure are maintained at a constant value through the BAS typically based on original design conditions. At all other conditions a lower setpoint would satisfy all coil loads and reduce pumping energy. This measure considers implementing a differential pressure reset control scheme, which polls the position of each valve in the system through the BAS and dynamically resets the differential pressure setpoint lower until the worst-case valve is nearly fully open. This is the minimum pressure that will satisfy all zones and use the least amount of pumping energy.

Estimated Energy Savings

An hourly analysis was performed to estimate energy savings using Albany International Airport TMY3 (Typical Meteorological Year) hourly weather data. Chilled and hot water flow and pump motor input power were estimated based on assumed load profiles that relate percent flow to outdoor air dry-bulb temperature and a power versus flow curve obtained from the Pacific Northwest National Laboratory PNNL-26917 reference manual document. The baseline analysis uses the "Default (VSD, No Reset)" curve and the proposed differential pressure reset analysis uses the "VSD, DP Reset" curve. The resulting average reduction in differential pressure reduces pump energy use while still maintaining adequate flow through the coils.

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Supporting documents include a summary of the assumptions and monthly baseline and post-retrofit conditions. Table 3 summarizes estimated energy and cost savings, implementation cost, and simple payback period for each building considered for this measure.

The energy savings calculated do not consider backup/standby pumps that rarely run as these pumps were ignored in the calculation. The energy savings are based on the typical operating conditions that were observed during the building audits and BAS.

Table 3. EEM-2 Savings

Building	Annual Electrical Savings (kWh/yr)	Electrical Peak Demand Savings (kW)	Annual Energy Savings (MMBtu/year)	Annual Energy Cost Savings ($/yr)	Estimated Capital Cost	Simple Payback Period (years)
AESOB	68,935	14.25	235	$ 4,843.67	$ 16,310.00	3.4
Capitol	24,566	2.10	84	$ 1,726.15	$ 8,740.00	5.1
State Education Building	41,465	5.99	141	$ 2,913.51	$ 20,970.00	7.2
Total	**134,966**	**22.3**	**461**	**$ 9,483.32**	**$ 46,020.00**	**4.9**

Estimated Project Cost

Costs presented in Table 4 represent the scope of work described previously. The project cost was estimated based on BAS engineering labor costs published in RS Means 2024. Costs include upgrading all pumps in the system to record the VFD output to the BAS system. This also includes upgrading backup/standby pumps in the system that do not typically run during a typical yearly load.

Table 4. EEM-2 Estimated Project Costs

Item Description	Qty	Unit	Unit Cost	Subtotal
BAS I/O Points, Engineering, Calibration, Start-up/Checkout Labor	1.00	Lump Sum	$ 38,037.00	$ 38,037.00
Labor and Materials Subtotal				**$ 38,037.00**
General Conditions	10%			$ 3,803.70
Labor and Materials Cost Total				**$ 41,840.70**
Architectural & Engineering Fees	0%			$ -
Construction Management Fees	0%			$ -
Contingency	10%			$ 4,181.30
Project Cost Subtotal				**$ 46,024.77**
Agency Administrative Fee	0%			$ -
Total Project Cost				**$ 46,020.00**

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EEM-2 – PUMP DIFFERENTIAL PRESSURE RESET CONTROLS

SUPPORTING DOCUMENTS

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SUMMARY INPUTS: EEM-2 PUMP DIFFERENTIAL PRESSURE RESET CONTROLS

Building	Tag	Flow	Motor HP	Head	Motor KW
AESOB	P-1, P-2	3100	125	110	80.16
AESOB	P-4, P-5	-	15	-	8.42
AESOB	P-4, P-5	-	15	-	8.42
AESOB	P-6, P-7, P-8	575/750	30/40	121/108	19.90/23.17
AESOB	P-6, P-7, P-8	575/750	30/40	121/108	19.90/23.17
AESOB	P-9, P-10, P-11	575	30	105	18.31
AESOB	P-9, P-10, P-11	575	30	105	18.31
Capitol	P-1	-	25	-	13.95
Capitol	P-2	-	25	-	13.95
Capitol	P-3	-	25	-	13.95
Capitol	SCWP-1, SCWP-2, SCWP-3, SCWP-4	450	30	155	20.53
State Ed	P-1, P-2	340	15	85	7.05
State Ed	P-3, P-4	340	15	85	7.05
State Ed	P-5, P-6	340	15	85	7.05
State Ed	P-11, P-12	552	20	75	11.03
State Ed	P-4, P-5	600	25	90	14.3
State Ed	P-7, P-8	614	20	80	12.76
State Ed	P-7, P-8	614	20	80	12.76
State Ed	P-9, P-10	-	15	-	8.42
State Ed	P-9, P-10	-	15	-	8.42

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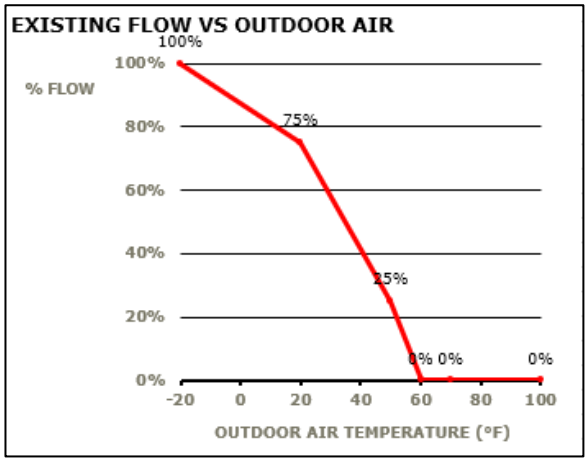
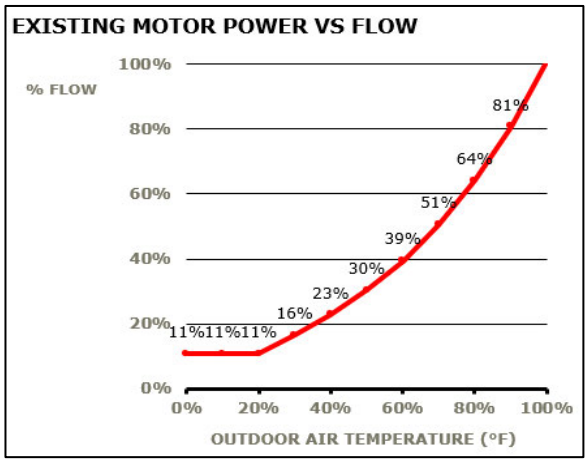
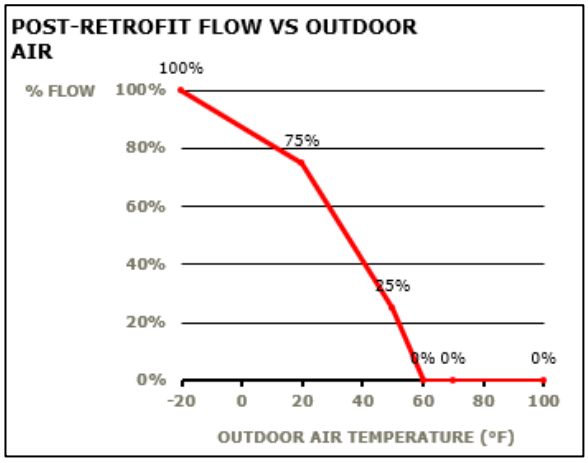
SUMMARY INPUTS: EEM-2 PUMP DIFFERENTIAL PRESSURE RESET CONTROLS

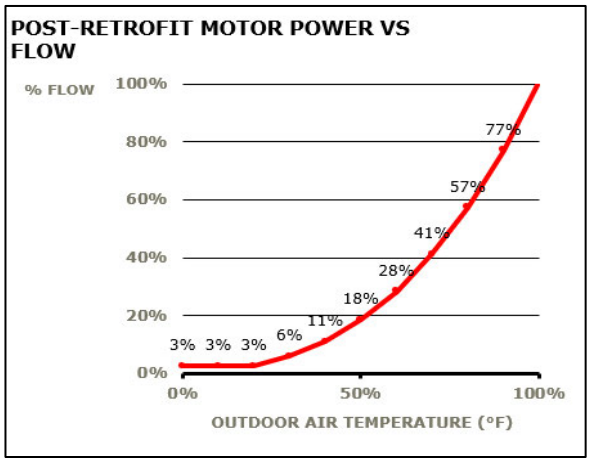
Existing Conditions





Revised Conditions





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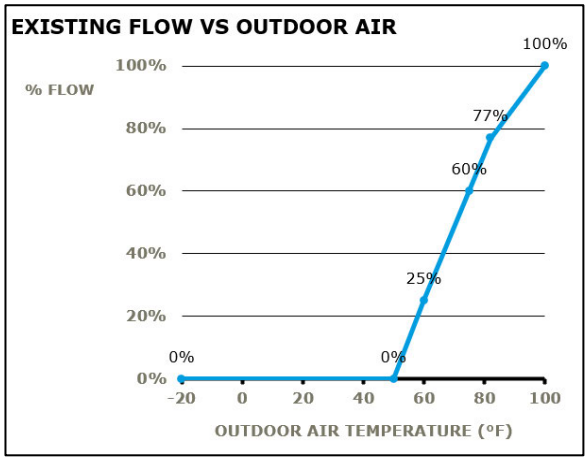
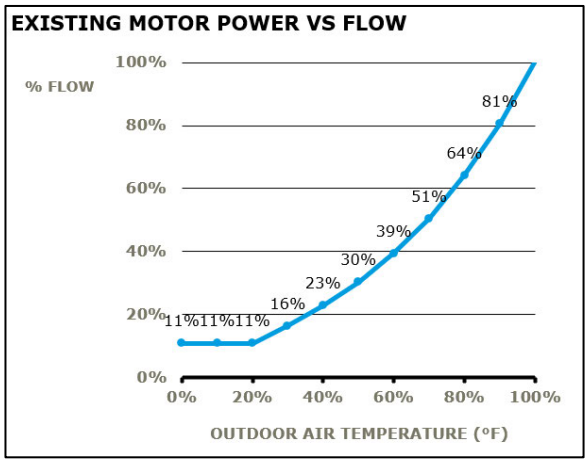
SUMMARY INPUTS: EEM-2 PUMP DIFFERENTIAL PRESSURE RESET CONTROLS

Existing Conditions





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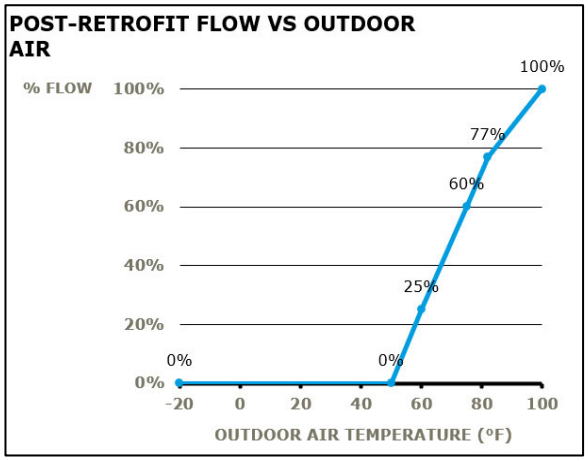

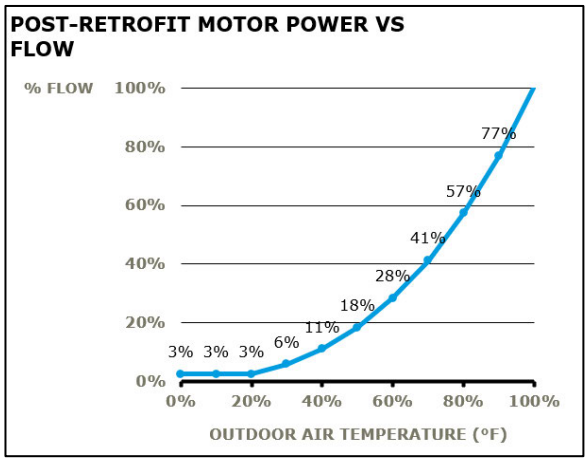

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RESULTS: EEM-2 PUMP DIFFERENTIAL PRESSURE RESET CONTROLS

Building	Service	Baseline Pumping Energy (kWh)	Baseline Demand (kW)	Proposed Pumping Energy (kWh)	Proposed Demand (kW)	Pumping Energy Savings (kWh)	Demand Savings (kW)
AESOB	HW	197,045	75.7	176,379	71.7	20,666	4.0
AESOB	CHW	488,184	202.6	439,917	192.3	48,267	10.3
Capitol	HW	87,855	30.8	67,244	28.7	20,611	2.1
Capitol	CHW	60,214	45.2	56,258	45.2	3,956	0.0
State Ed	HW	272,941	72.3	245,196	67.9	27,745	4.4
State Ed	CHW	153,855	62.8	140,135	61.1	13,720	1.6
Subtotal	**HW**	**557,841**	**178.8**	**488,819**	**168.4**	**69,022**	**10.4**
Subtotal	**CHW**	**702,253**	**310.5**	**636,310**	**298.6**	**65,943**	**11.9**
	Total	**1,260,094**	**489.3**	**1,125,129**	**467.0**	**134,965**	**22.3**

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EMPIRE STATE PLAZA | EEM-3 PNEUMATIC TO DDC CONTROLS CONVERSION

Energy Opportunity Area: HVAC, Building Automation System (BAS)

Buildings Affected: State Education Building

Table 1. EEM-3 Summary Data

Description	Values	Units
Annual Electrical Energy Savings	152,169	kWh/year
Electrical Peak Demand Savings	0.0	kW
Annual Electrical Energy Cost Savings	$10,692	$/year
Annual Natural Gas Savings	0	Therms/year
Annual Natural Gas Cost Savings	$0	$/year
Annual Central CHW Savings	7,646	MMBTU/year
Annual Central CHW Cost Savings	$76,054	$/year
Annual Central Steam Savings	5,679	MMBTU/year
Annual Central Steam Cost Savings	$45,337	$/year
Total Annual Energy Cost Savings	**$132,083**	**$/year**
Estimated Implementation Cost	**$2,068,997**	
Simple Payback Period	**15.7**	**years**

Existing Conditions/Baseline

The Old State Education Building is currently using pneumatic actuators, which operate using compressed air generated by building-level air compressors, to control most dampers and valves on the buildings' respective HVAC systems.

Recommended Action

This measure recommends upgrading the buildings' current pneumatic control systems to a Direct Digital Control (DDC) system, which can lead to significant energy savings. DDC's precise control reduces energy waste while enhancing building occupancy comfort. Building managers can also rely on the system's detailed data monitoring to optimize operation over time.

Unlike pneumatic control systems, DDC systems don't require compressed air, thus the conversion allows for elimination of air compressors and their related energy usage. Furthermore, DDC systems enables implementation of additional Energy Efficiency Measures that are not possible with pneumatic controls, potentially realizing greater energy savings beyond those of this measure. These potential measures include hot water (HW) and chilled water (CHW) supply temperature resets, demand-controlled ventilation, equipment schedule setback, and duct static pressure reset controls.

A DDC system also consists of fewer moving parts, which helps cut down the required maintenance effort traditionally associated with the upkeep of pneumatic-based systems and helps expand overall equipment/component lifespan, thus reducing a system's overall lifetime cost.

Estimated Energy Savings

Energy savings for this measure resulted from more precise HVAC system control and elimination of building-level air compressors. Since precise building energy savings is difficult to quantify without

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detailed energy modelling, it is conservatively estimated to be 10% of the annual weather-normalized HVAC energy. Air compressors are assumed to be running continuously during the buildings' respective HVAC system operating hours. Annual air compressor energy savings are calculated using NEMA premium motor efficiency, as well as an estimated duty cycle of 0.25.

Table 2 summarizes estimated energy and cost savings, implementation cost, and simple payback period for each building considered for this measure.

Table 2. EEM-3 Savings

Building	Annual Electrical Energy Savings (kWh/year)	Annual Central CHW Savings (MMBTU/year)	Annual Central Steam Savings (MMBTU/year)	Total Annual Energy Cost Savings ($/year)	Estimated Implementation Cost	Simple Payback Period
State Education Building	152,169	7,646	5,679	$132,083	$2,068,997	15.66
Total	**152,169**	**7,646**	**5,679**	**$132,083**	**$2,068,997**	**15.66**

Estimated Project Cost

Costs presented in Table 3 represent the scope of work described previously. The project cost was estimated based on costs published in RS Means 2024. Contingency is estimated to be higher compared to other measures to account for other ancillary equipment the buildings might need for the conversion, such as extra workstations or servers.

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Table 3. EEM-3 Estimated Project Costs

Item Description	Qty	Unit	Unit Cost	Subtotal
Water Temperature Input Sensor	32	Ea	$1,455	$46,560
Water Diff. Pressure Input Sensor	6	Ea	$840	$5,040
Duct Temperature Input Sensor	76	Ea	$1,000	$76,000
Duct Humidity Input Sensor	19	Ea	$1,210	$22,990
Duct Static Pressure Input Sensor	19	Ea	$788	$14,972
Space Temperature Input Sensor	12	Ea	$1,510	$18,120
Other Analog Input Sensors	6	Ea	$1,000	$6,000
Digital Input Sensor	6	Ea	$853	$5,118
Valve Actuator	88	Ea	$422	$37,136
Damper Actuator	38	Ea	$1,258	$47,804
Other Output Actuators	6	Ea	$1,200	$7,200
Digital Output	62	Ea	$870	$53,940
48-point MUX	11	Ea	$11,250	$123,750
16-point Controller	2	Ea	$4,925	$9,850
Calibration Labor	596	Point	$166	$98,936
Start-up, Checkout Labor	596	Point	$166	$98,936
Programming Labor	596	Point	$500	$298,000
24-port Switch	1	Ea	$3,037	$3,037
Communication Cable	59,600	LF	$6	$370,116
Labor and Materials Subtotal				**$1,343,505**
General Conditions	10%			$134,350
Labor and Materials Cost Total				**$1,477,855**
Architectural & Engineering Fees	10%			$147,785
Construction Management Fees	10%			$147,785
Contingency	20%			$295,571
Project Cost Subtotal				**$2,068,997**
Agency Administrative Fee	0%			$0
Total Project Cost				**$2,068,997**

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EEM-3 – PNEUMATIC TO DDC CONTROLS CONVERSION

SUPPORTING DOCUMENTS

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LIFE CYCLE COST ANALYSIS

EEM No.:	EEM-3		
EEM Title:	EEM Pneumatic to DDC Controls Conversion		
General Parameters			
Base Date:	1/1/2029		
Service Date:	1/1/2029		
Study Period (Years):	20		
Discount Rate:	3%		
Cost Escalation:	0%		
FEMP UPV Discount Factor (Elect.):	20.03		
FEMP UPV Discount Factor (NG):	18.20		
Calculated UPV Discount Factor (CHW):	20.03		
Calculated UPV Discount Factor (Steam):	18.20		
Cost Data	**Baseline**	**Proposed**	**Savings**
Initial Capital Cost:		$2,068,997	($2,068,997)
Annual Electricity Costs:	$453,676	$442,984	$10,692
Annual Natural Gas Costs:	$690,750	$621,675	$69,075
Annual CHW Costs:	$0	$0	$0
Annual Steam Costs:	$0	$0	$0
Annual Water Costs:	$0	$0	$0
Annual OM&R Costs:	$40,305	$40,305	$0
Other Recurring Annual Costs:	$0	$0	$0
Life Cycle Cost Calculations	**Baseline**	**Proposed**	**Savings**
Present Value Investment Costs, I:	$0	$2,068,997	($2,068,997)
Present-Value Capital Replacement Cost, Repl:	$0	$0	$0
Present Value Residual Cost, Res:	$0	$0	$0
Present Value Energy Costs, E:	$21,660,685	$20,189,297	$1,471,388
Present Value Water Cost, W:	$0	$0	$0
Present Value O&M and Other Recurring Costs, OM&R:	$599,639	$599,639	$0
LCC:	**$22,260,324**	**$22,857,933**	**($597,609)**
Savings to Investment Ratio Calculations			
Present Value Energy Cost Savings, DE:	$1,471,388		
Present Value Water Cost Savings, DW:	$0		
Present Value OM&R Cost Savings, DOM&R:	$0		
SIR:	**0.71**		

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

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EMPIRE STATE PLAZA | EEM-4 STEAM TRAP PROGRAM

Energy Opportunity Area: Campus and Building Steam Distribution Systems

Buildings Affected: Alfred E Smith Office Building, Capitol, State Education Building

Table 1. EEM-4 Summary Data

Description	Values	Units
Annual Electrical Energy Savings	0	kWh/year
Electrical Peak Demand Savings	0.0	kW
Annual Electrical Energy Cost Savings	$0	$/year
Annual Natural Gas Savings	34,388	Therms/year
Annual Natural Gas Cost Savings	$16,128	$/year
Total Annual Energy Cost Savings	**$16,128**	**$/year**
Estimated Implementation Cost	**$66,867**	**$**
Simple Payback Period	**4.1**	**years**

Existing Conditions/Baseline

The Alfred E Smith Office Building (AESOB), the Capitol, and the State Education Building are fed steam from the Sheridan Avenue Steam Plant (SASP). Boilers generate and distribute high pressure steam to the buildings. Within each building, the steam pressure is further reduced for distribution to hot water converters/heat exchangers, domestic water heaters, direct steam humidifiers, heating coils, unit heaters, fin tube radiators and other uses. There are typically one or more steam traps present at every point of steam use and additional traps are present in the distribution piping from the central plant and within the buildings.

Recommended Action

To minimize the loss associated with steam trap failures, it is necessary to apply a well-organized, concerted effort to managing the steam trap population. In order to be successful, a steam trap management program would address the following five areas:

- Training - Personnel must be trained on how to identify faulty steam traps and implement the management program.
- Inventory – Every trap in the system should be located and identified.
- Assessment – An assessment of the operating condition of every trap should be performed at least annually.
- Documentation - A steam trap database and assessment schedule should be developed.
- Follow-up – Faulty steam traps should be quickly replaced.

A steam trap assessment should be conducted by personnel with knowledge in the operation and selection of steam traps. Therefore, training is critical to the success of the management program. The steam trap assessment should cover:

- trap operation,
- trap selection (type and size),
- trap installation, and
- condensate return features/considerations

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- The assessment of steam trap performance is basically concerned with answering the following two questions:
    - Is the trap working correctly?
    - If not, has the trap failed in the open or closed position?

Traps that fail open result in a loss of steam and its energy. Where condensate is not returned, the pure water is lost as well. The result is significant economic loss, directly via increased boiler plant costs, and indirectly via decreased steam heating capacity. Traps that fail closed do not result in energy or water losses but can result in significantly reduced heating capacity and/or damage to steam heating equipment.

Estimated Energy Savings

According to the US Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE), in systems where steam traps have not been inspected or serviced in 3 to 5 years, between 15 and 30 percent of the traps may have failed[1]. Even a well-maintained steam system will typically experience a 10% trap failure in a one-year period. The DOE office of EERE recommends that steam traps be tested at least annually to determine if they are functioning properly.

Implementation of a proactive steam trap management program can save significant energy. Table 2 illustrates the potential savings resulting from the replacement of an estimated 25% of the installed steam traps at Harriman Campus as the result of a proactive steam trap maintenance program. Savings data is based on steam trap leakage data presented in the New York Power Authority (NYPA) Handbook for Clean Energy Initiatives for the equivalent of a 1/4-inch diameter leak in a steam trap using 15 psig steam. Table 3 shows savings from a steam trap program by building.

Table 2. EEM-4 Energy Savings

Description	Values	Units
Total Number of Steam Traps	317	
Estimated Percentage of Traps Failed	25%	
Estimated Number of Traps Failed	80	
Average Steam Pressure	15	psig
Annual Operating Hours	2525	
Steam Loss Through a ¼-inch Orifice at 15 psig (lbs./hr.)	45.0	lbs/hr
Steam Heat of Vaporization at 15 psig (Btu/lb.)	946	BTU/lb
Steam Loss Fraction	20%	
Steam Generating Efficiency Including Transmission Losses	50%	
Annual Energy Saved	**34,388**	**Therms**

[1] Source: US Department of Energy office of Energy Efficiency and Renewable Energy (EERE), Steam Tip Sheet No. 1, January 2006.

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Table 3. Savings by Building

Building	Natural Gas Savings (therms/year)	Total Energy Savings per Year	Implementation Cost	SPB (Years)
AESOB	11,173	$5,240	$21,727	4.1
Capitol	20,611	$9,667	$40,078	4.1
Old Ed. Bldg	2,604	$1,221	$5,063	4.1
Total	**34,388**	**$16,128**	**$66,867**	**4.1**

Estimated Project Cost

The cost of implementing a steam trap maintenance program will vary depending on the number of steam traps surveyed, itemized, tagged, and replaced. For this analysis, the estimated failure percentage for the first year of the steam trap maintenance program was assumed to be 25 percent. Based on a trap population of 317 traps, the number of failed traps was estimated to be 80. It is expected that this number will decrease each year as older traps are replaced.

Table 3 provides the cost basis for a steam trap maintenance and monitoring program for the three buildings adjacent to Empire State Plaza. Costs presented represent the scope of work described previously and are based on costs published in RS Means 2024.

Table 4. EEM-4 Estimated Project Costs

Item Description	Qty	Unit	Unit Cost	Subtotal
Steam trap survey - 70 traps per day technician output for 317 traps (plus 2 extra days for data output/deliverable)	7	Days	$2,280	$15,960
Steam traps for 3/4" pipe	80	Ea.	$367	$29,320
Failed traps demolition	80	Ea.	$113	$9,040
Lift rental	5	Days	$188	$942
Labor and Materials Subtotal				**$55,262**
General Conditions	10%			$5,526
Labor and Materials Cost Total				**$60,788**
Architectural & Engineering Fees	0%			$0
Construction Management Fees	0%			$0
Contingency	10%			$6,079
Project Cost Subtotal				**$66,867**
Agency Administrative Fee	0%			$0
Total Project Cost				**$66,867**

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EEM-4 – STEAM TRAP PROGRAM

SUPPORTING DOCUMENTS

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LIFE CYCLE COST ANALYSIS

EEM No.:	EEM-4		
EEM Title:	Steam Trap Program		
General Parameters			
Base Date:	1/1/2027		
Service Date:	1/1/2027		
Study Period (Years):	5		
Discount Rate:	3%		
Cost Escalation:	0%		
FEMP UPV Discount Factor (Elect.):	4.93		
FEMP UPV Discount Factor (NG):	4.64		
Calculated UPV Discount Factor (CHW):	4.93		
Calculated UPV Discount Factor (Steam):	4.64		

Cost Data	**Baseline**	**Proposed**	**Savings**
Initial Capital Cost:		$66,867	($66,867)
Annual Electricity Costs:	$0	$0	$0
Annual Natural Gas Costs:	$1,325,394	$1,309,266	$16,128
Annual CHW Costs:	$0	$0	$0
Annual Steam Costs:	$0	$0	$0
Annual Water Costs:	$0	$0	$0
Annual OM&R Costs:	$15,960	$15,960	$0
Other Recurring Annual Costs:	$0	$0	$0

Life Cycle Cost Calculations	**Baseline**	**Proposed**	**Savings**
Present Value Investment Costs, I:	$0	$66,867	($66,867)
Present-Value Capital Replacement Cost, Repl:	$0	$0	$0
Present Value Residual Cost, Res:	$0	$0	$0
Present Value Energy Costs, E:	$6,149,351	$6,074,523	$74,828
Present Value Water Cost, W:	$0	$0	$0
Present Value O&M and Other Recurring Costs, OM&R:	$73,092	$73,092	$0
LCC:	**$6,222,443**	**$6,214,482**	**$7,961**

Savings to Investment Ratio Calculations	
Present Value Energy Cost Savings, DE:	$74,828
Present Value Water Cost Savings, DW:	$0
Present Value OM&R Cost Savings, DOM&R:	$0
SIR:	**1.12**

Note:
Calculations are in accordance with the National Institute of Standards and Technology, NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program, 1995.

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Appendix D – Building Upgrades Supporting Documents

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Empire State Plaza

Building	Building Type	GSF	Building Vintage	Building Upgrades for LTHW					Notes
				Replace Finned Tube Radiation	Replace AHU Coils	Replace Terminal Equipment	Complete HVAC Removal and Replacement	Timeframe (approx. year)	
Alfred E Smith Office Building	GOVERNMENT OFFICE	598,866	1928				●	2035	*Renovation contingent upon HW system operating limits (Section D.1.8)*
Capitol	GOVERNMENT OFFICE	572,025	1899				●	2035	*Renovation contingent upon HW system operating limits (Section D.1.8)*
Legislative Office Building	GOVERNMENT OFFICE	650,348	1972				●	2040	
Justice Building	GOVERNMENT OFFICE	261,177	1972				●	2040	
Agency Building 1	GOVERNMENT OFFICE	198,196	1974				●	2040	
Agency Building 2	GOVERNMENT OFFICE	198,196	1974				●	2040	
Agency Building 3	GOVERNMENT OFFICE	198,196	1974				●	2040	
Agency Building 4	GOVERNMENT OFFICE	198,196	1974				●	2040	
Corning Tower	GOVERNMENT OFFICE	927,423	1974				●	2040	
Cultural Education Center (Museum)	ENTERTAINMENT/CULTURE	1,582,504	1976				●	2040	
Health Department Laboratory	LABORATORY	485,210	1908				●	2033	
Meeting Center (The Egg)	ENTERTAINMENT/CULTURE	159,362	1978				●	2040	
Swan Street Office Building	GOVERNMENT OFFICE	842,727	1965				●	2040	
Main Platform	ENCLOSED MALL/OTHER	3,878,694	1970				●	2040	
Old State Education Building	GOVERNMENT OFFICE	750,000	1950				●	2035	*Renovation contingent upon HW system operating limits (Section D.1.8)*
	Total	11,501,120	-	0	0	0	15	-	

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Empire State Plaza

Building	Building Type	GSF	Building Vintage	Replace Double Pane Windows	Lab Exhaust Energy Recovery	Laboratory VAV Exhaust/Supply	Additional Zone Controls on FTR	Laboratory DCV	Retro-commissioning	Pump Differential Pressure Reset	Pneumatic Control to DDC	Steam Trap Program	Replace Finned Tube Radiation	Replace AHU Coils	Replace Terminal Equipment	Complete HVAC Removal and Replacement	Timeframe (approx. year)	Building Cost Total	Notes
				Building Upgrades for LTHW															
Alfred E Smith Office Building	GOVERNMENT OFFICE	598,866	1928						$191.6 k	$16.3 k		$21.7 k				$81.0 M	2035	$81.2 M	1
Capitol	GOVERNMENT OFFICE	572,025	1899							$8.7 k		$40.1 k				$77.4 M	2035	$77.4 M	1
Legislative Office Building	GOVERNMENT OFFICE	650,348	1972	$6,378.1 k			$142.1 k									$88.0 M	2040	$94.5 M	
Justice Building	GOVERNMENT OFFICE	261,177	1972	$3,353.4 k			$46.5 k									$37.1 M	2040	$40.5 M	
Agency Building 1	GOVERNMENT OFFICE	198,196	1974	$4,625.3 k												$31.2 M	2040	$35.8 M	
Agency Building 2	GOVERNMENT OFFICE	198,196	1974	$4,625.3 k												$31.2 M	2040	$35.8 M	
Agency Building 3	GOVERNMENT OFFICE	198,196	1974	$4,625.3 k												$31.2 M	2040	$35.8 M	
Agency Building 4	GOVERNMENT OFFICE	198,196	1974	$4,625.3 k												$31.2 M	2040	$35.8 M	
Corning Tower	GOVERNMENT OFFICE	927,423	1974	$16,124.3 k												$137.2 M	2040	$153.3 M	
Cultural Education Center (Museum)	ENTERTAINMENT/CULTURE	1,582,504	1976	$6,985.1 k			$18.1 k									$193.8 M	2040	$200.8 M	
Health Department Laboratory	LABORATORY	485,210	1908	$3,564.1 k	$17,307.9 k	$21,730.5 k		$1,630.1 k								$62.4 M	2033	$106.7 M	
Meeting Center (The Egg)	ENTERTAINMENT/CULTURE	159,362	1978													$16.5 M	2040	$16.5 M	
Swan Street Office Building	GOVERNMENT OFFICE	842,727	1965	$7,470.9 k			$69.8 k									$104.3 M	2040	$111.8 M	
Main Platform	ENCLOSED MALL/OTHER	3,878,694	1970													$55.3 M	2040	$55.3 M	
Old State Education Building	GOVERNMENT OFFICE	750,000	1950							$21.0 k	$2,068.0 k	$5.1 k				$101.4 M	2035	$103.5 M	1
TOTAL	Total	11,501,120	-	$62,377.0 k	$17,307.9 k	$21,730.5 k	$276.5 k	$1,630.1 k	$191.6 k	$46.0 k	$2,068.0 k	$66.9 k	$0.0 M	$0.0 M	$0.0 M	$1,079.1 M	-	$1,184.8 M	

Notes:

1. Renovation contingent upon HW system operating limits (Section D.1.8)

Energy Efficiency Measure Cost Subtotal:	$105.7 M
Plaza Buildings HVAC Renovations Subtotal:	$819.3 M
HVAC Coil Replacements for 135°F Supply Subtotal:	$259.8 M
Total Building Upgrade Costs:	$1,184.8 M

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Appendix E – Decarbonization Scenario Supporting Documents

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Empire State Plaze
Energy Infrastructure

Modeling: Hot Water Distribution

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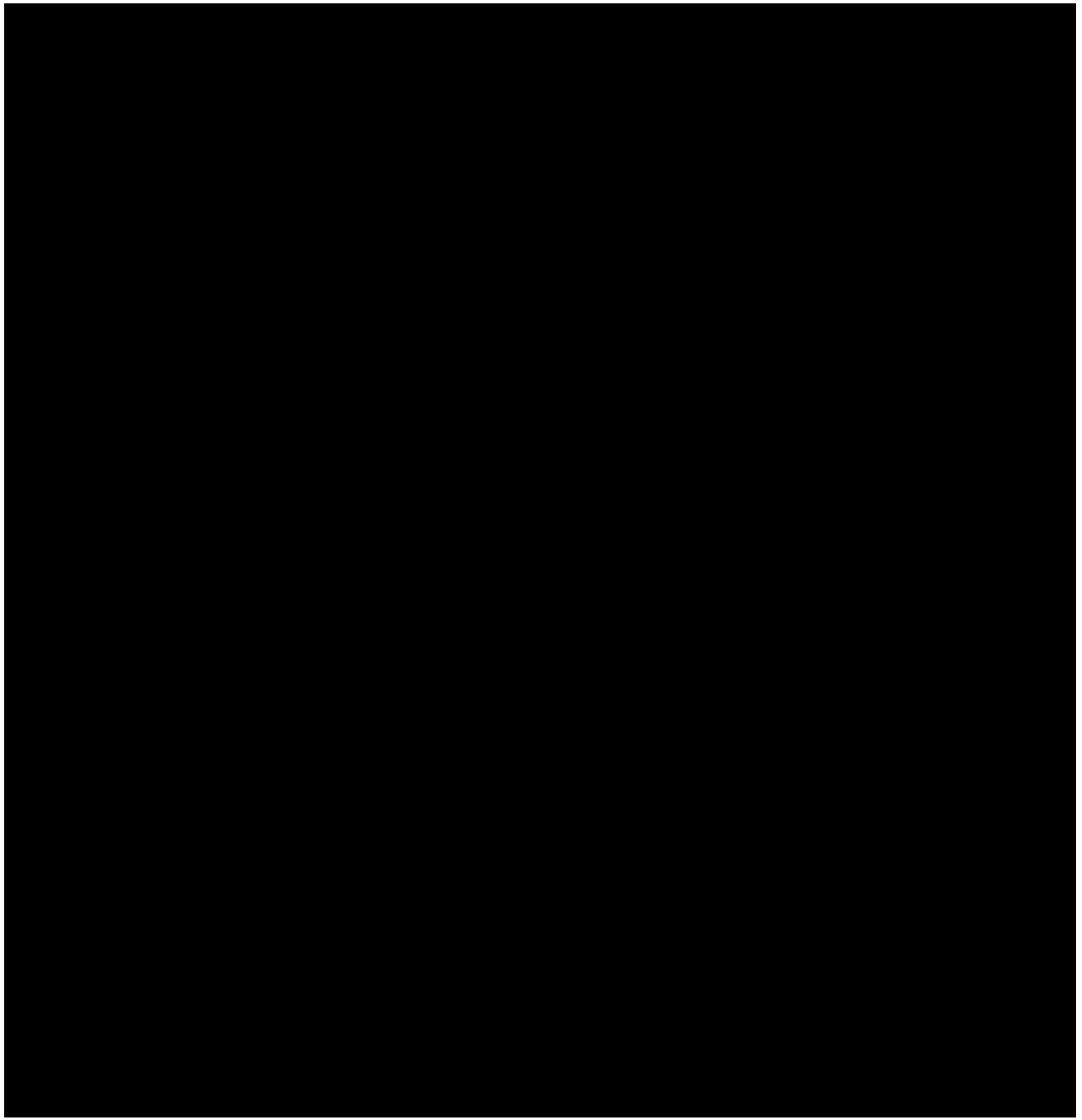
Hydraulic Model (Termis): Utility Tunnels



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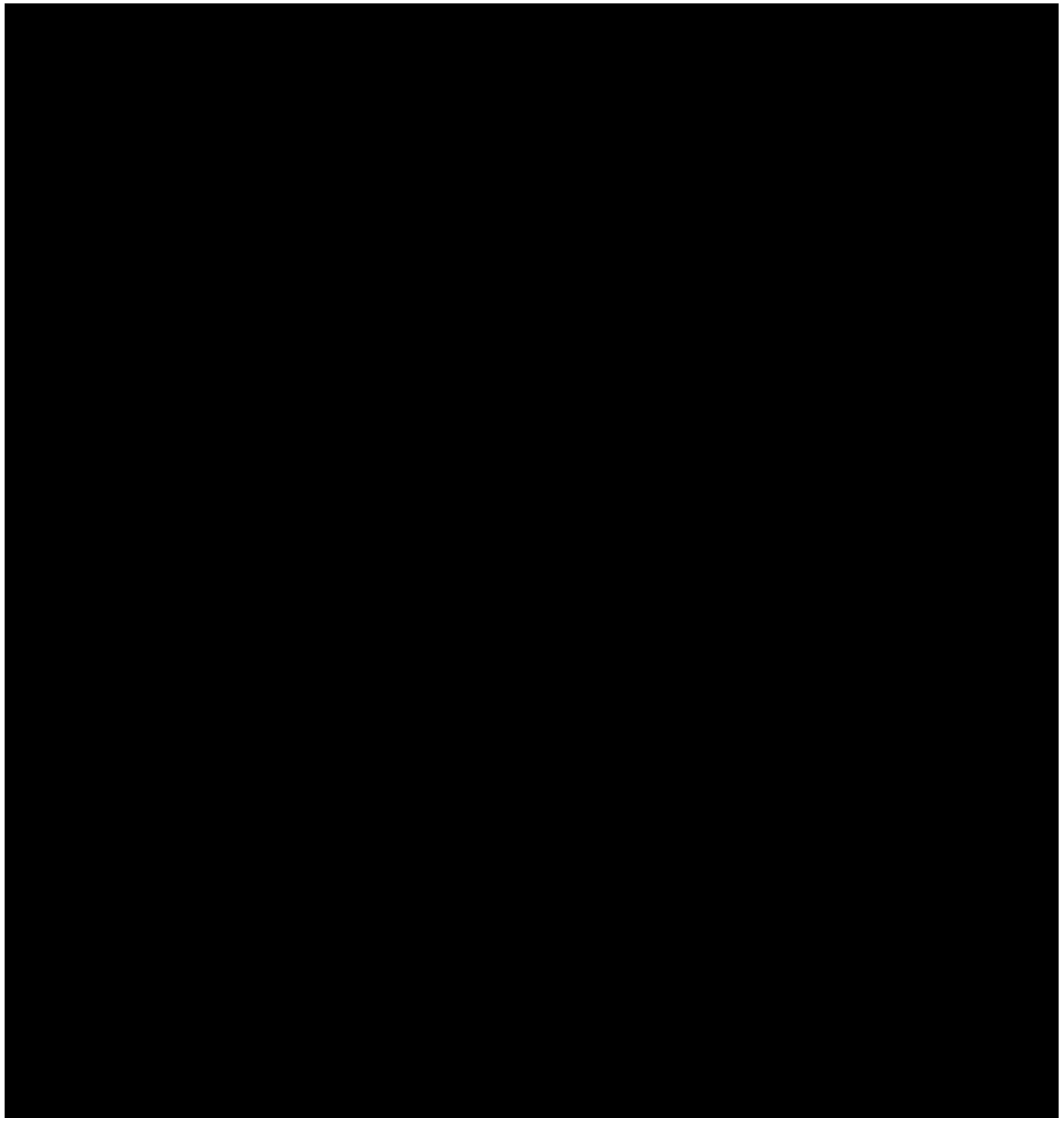
Hydraulic Model (Termis):
ECM Package Hourly Results.xlsx

Building:

Total heat, [kbtu/h]

Building Name	Total, Heat [kBtu/h]
Agency 1	6,062
Agency 2	5,573
Agency 3	5,781
Agency 4	5,278
Alfred E Smith Office Building	7,613
Capitol	7,747
Corning Tower	32,355
Cultural Education Center	17,920
Health Lab	3,320
Justice Building	6,658
Legislative Building	6,957
Main Platform	29,397
Old Education Building	7,636
Swan St Office Building	10,710
The Egg	1,966
SUM	**154,973**



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Theoretical Capacity:

Assumptions:

- Supply Temp.: 140 °F
- Return Temp.: 110 °F

- EN253 (pipedimensions)
- Roughness: 0.0039" (0.1 mm)
- Max. Pressure gradient: 0.006 psi/ft (150 Pa/m)
- Max. Velocities:

Pipe Size ["]	Velocity [Ft/s]
2" - 6"	6.6
8" - 10"	8.2
12" - 14"	9.8
16" <	11.5

Nom. Dia ["]	ex. Dia [mm]	Int. Dia [mm]	Flow	Capacity [kBtu/hr]
			[GPM]	ΔT 30 °F
3"	88.9	82.5	89	1,345
4"	114.3	107.1	178	2,675
5"	139.7	132.5	311	4,685
6"	168.3	160.3	513	7,730
8"	219.1	210.1	1,045	15,735
10"	273.0	263.0	1,881	28,330
12"	323.9	312.7	2,958	44,540
14"	355.6	344.4	3,638	54,780
16"	406.4	393.8	5,405	81,400
18"	457.0	444.4	7,411	111,605
20"	508.0	495.4	9,836	148,120
24"	610.0	595.8	15,185	228,670

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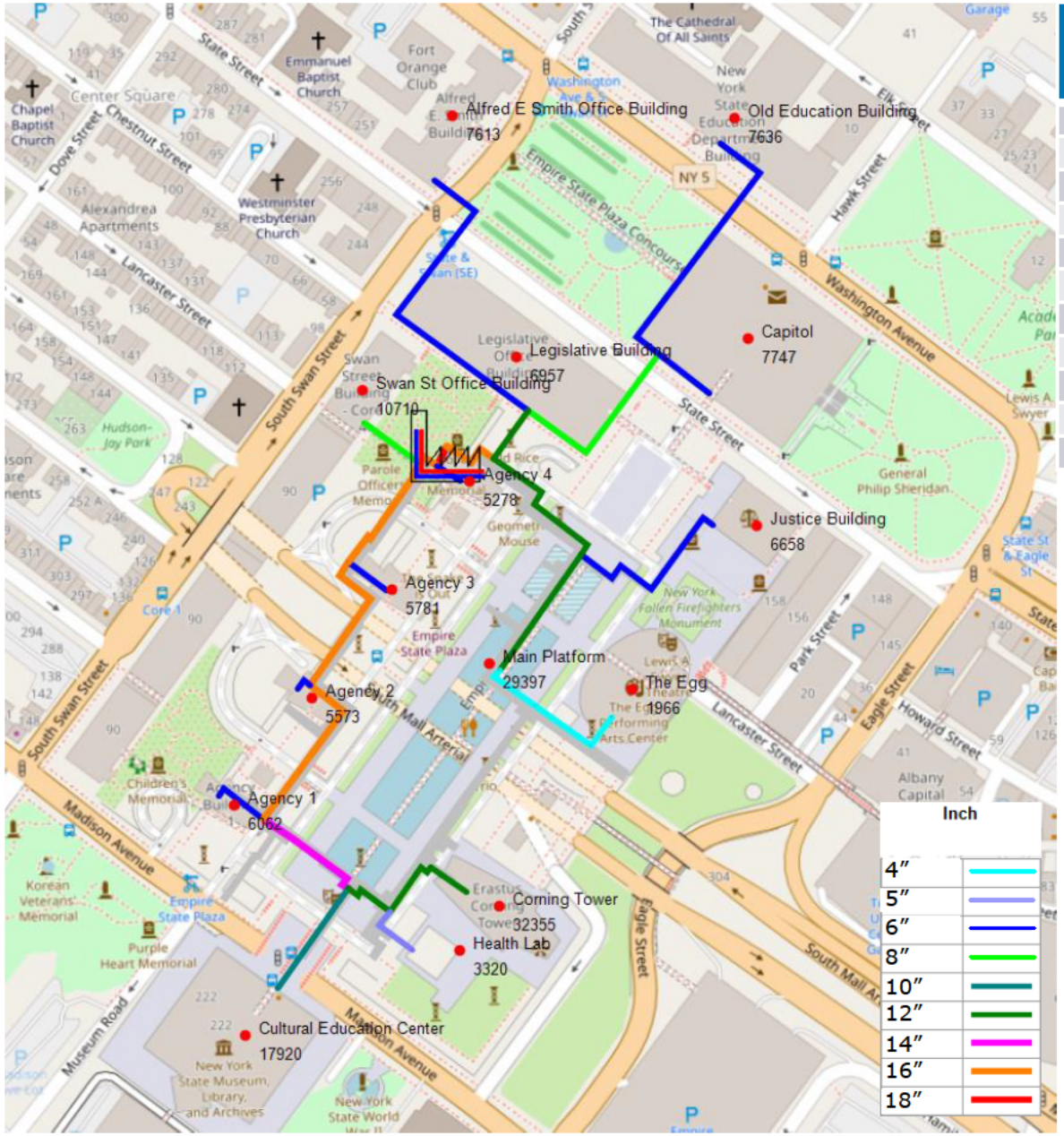
Hydraulic Model (Termis):
Alternative 1

Radial system:

Advantage:
Lower investment than looped system

Disadvantage:
Lower reliability of heat supply than looped system



Pipe Size [”]	Trench [Ft]
4”	360
5”	128
6”	2,287
8”	586
10”	271
12”	1,153
14”	260
16”	1,220
18”	49
20”	-
SUM	6,312

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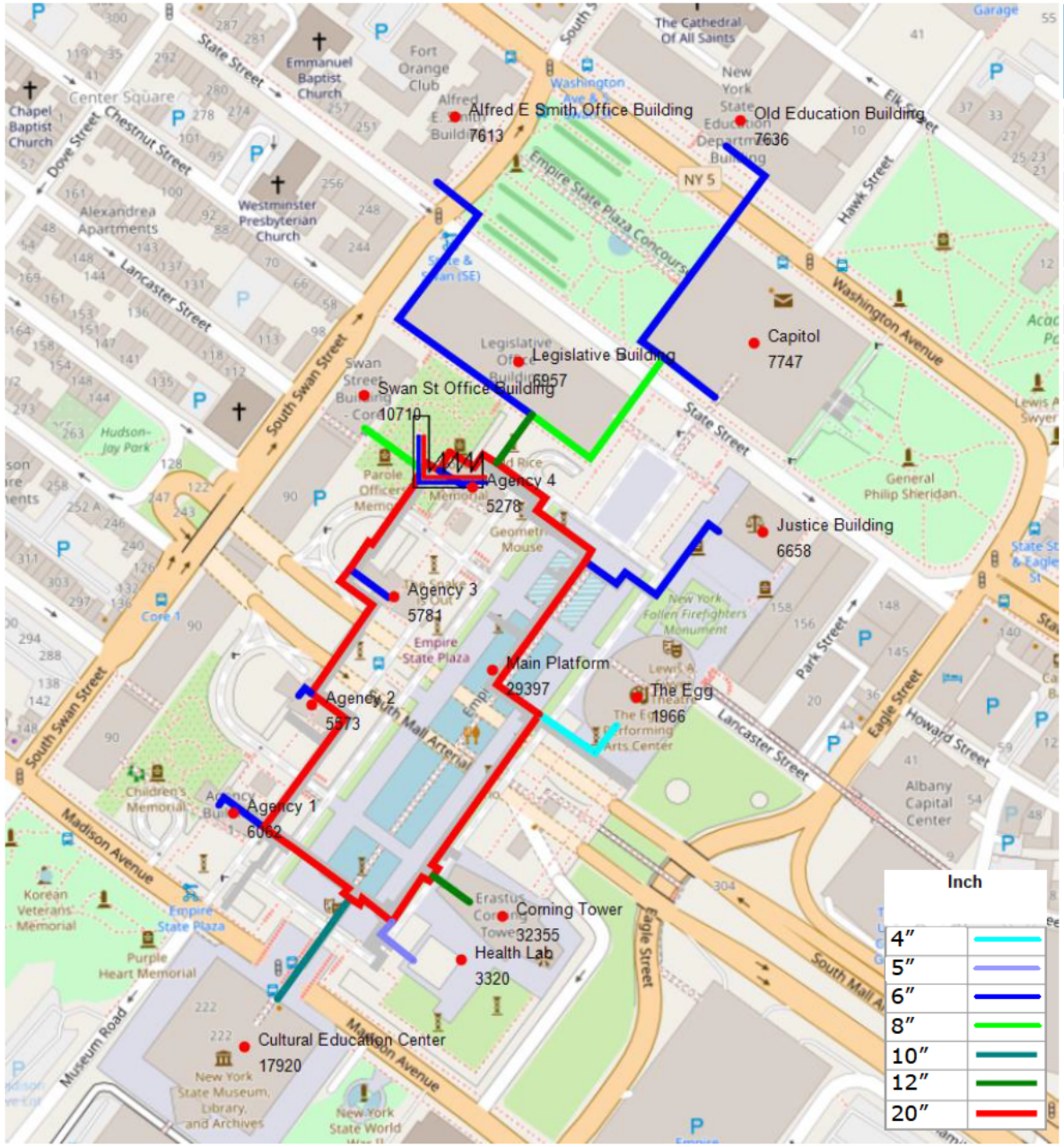
Hydraulic Model (Termis): Alternative 2

Looped system:

Advantage:
Higher reliability of heat supply than radial system

Disadvantage:
Higher investment than radial system

With a looped system it is recommended to install sectioning valves making it possible to operate the system as a radial system as standard operation.



Pipe Size [”]	Trench [Ft]
4”	227
5”	128
6”	2,287
8”	586
10”	271
12”	228
14”	-
16”	-
18”	-
20”	3,029
SUM	6,755

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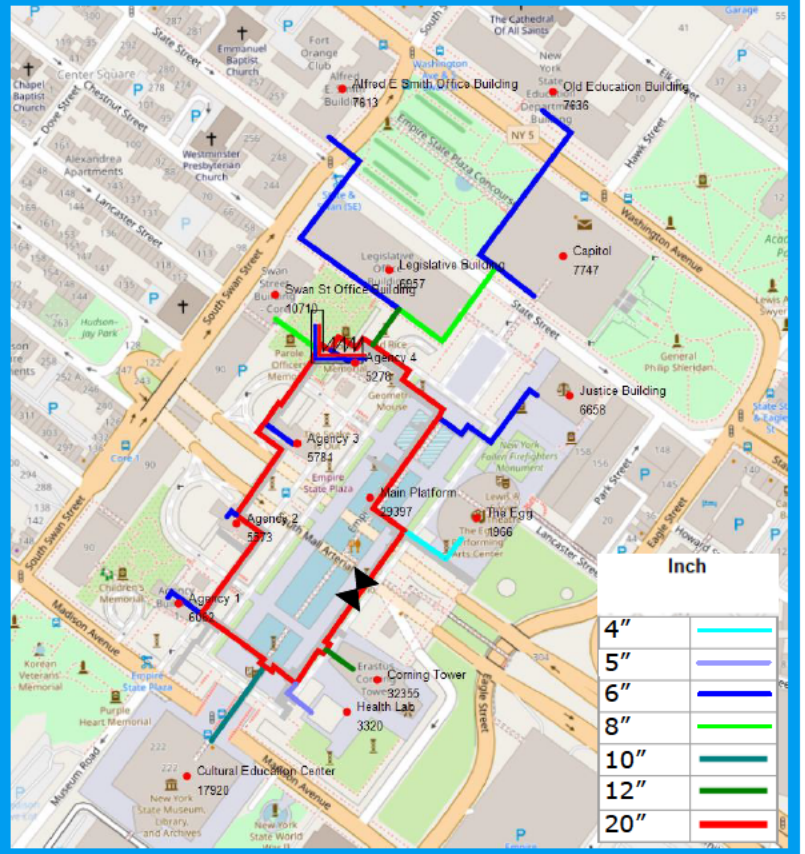
Hydraulic Model (Termis): Alternative 2, Looped System Sc01: 155,265 [Kbtu/h]



Assumption:

- **No simultaneity: ~ building loads = 154,073 [Kbtu/h]**
- Elevations are based on ground level from Google Earth (Highest: 170.6 [ft], Lowest: 101.7 [ft])
- All building will be separated by a heat exchanger at "ground level"
- Minimum required ΔP = 14.5 psi
- Minimum pressure: 14.5 psi(g)
- Loop closed between Corning Tower and The Egg

Production							
Plant	Load [tons]	Flow [GPM]	Temp. Supply [F]	Temp. Return [F]	Pressure Supply [psig]	Pressure Return [psig]	Pressure diff [psi]
Plant	155,265	10,196	**140.0**	109.4	46.9	**18.1**	28.8*
SUM	155,265	10,196					

Note: Bold number are input
* The calculated ΔP at the Plant (pump head) does not account for internal losses, it is recommended to apply an additional 14 to 21 psi

Distribution: Calculated Results			
Node(s)	Units		Comment
Minimum: ΔP	[psi]	14.5	Old Education Building
Maximum: Pressure, Supply	[psig]	65.6	Health Lab (elevation: 101.7 ft)
Minimum: Pressure, Return	[psig]	14.5	Agency 1 (elevation: 164 .0 ft)
Pipe(s)	Units		Comment
Maximum: Pressure Gradient	[psi/ft]	0.006	6" branch for Capitol
Maximum: Velocity	[ft/s]	6.2	20"

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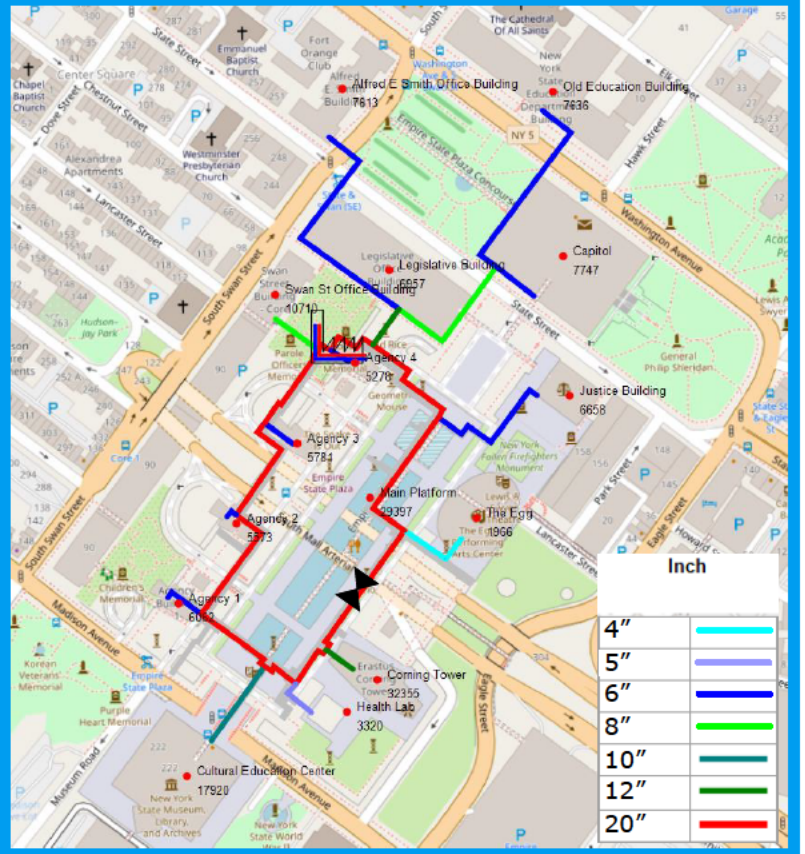
Hydraulic Model (Termis):
Alternative 2, Looped System
Sc02: 122,415 [Kbtu/h]



Assumption:

- **Expected Peak: ~ building loads = 122,415 [Kbtu/h]** (Simultaniety ~ 0,8)
- Elevations are based on ground level from Google Earth (Highest: 170.6 [ft], Lowest: 101.7 [ft])
- All building will be separated by a heat exchanger at "ground level"
- Minimum required ΔP = 14.5 psi
- Minimum pressure: 14.5 psi(g)
- Loop closed between Corning Tower and The Egg

Production							
Plant	Load [tons]	Flow [GPM]	Temp. Supply [F]	Temp. Return [F]	Pressure Supply [psig]	Pressure Return [psig]	Pressure diff [psi]
Plant	122,760	8,060	**140.0**	109.4	43.1	**19.6**	23.5*
SUM	122,760	8,060					

Note: Bold number are input
* The calculated ΔP at the Plant (pump head) does not account for internal losses, it is recommended to apply an additional 14 to 21 psi

Distribution: Calculated Results			
Node(s)	Units		Comment
Minimum: ΔP	[psi]	14.5	Old Education Building
Maximum: Pressure, Supply	[psig]	62.7	Health Lab (elevation: 101.7 ft)
Minimum: Pressure, Return	[psig]	14.5	Alfred E Smith Office Bldg (elevation: 170.6 ft)
Pipe(s)	Units		Comment
Maximum: Pressure Gradient	[psi/ft]	0.004	6" branch for Capitol
Maximum: Velocity	[ft/s]	4.9	20"

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TECHNICAL DATA	Units	Baseline 2019 BaU	Sc. 1A HRC	Sc. 1B HRC+WWHP	Sc. 1C HRC+GSHP	Sc. 1E HRC+ASHP	Sc. 1F HRC+ IHR-HP	Sc. 1C1 HRC+GSHP +bio.boiler	Sc. 1C2 HRC+GSHP +el.boiler	Sc. 1C3 HRC+GSHP w/oTTES
Heat Demand	MMBtu-h		243,390	243,390	243,390	243,390	243,390	243,390	243,390	243,390
Cooling Demand	MMBtu-c		209,907	209,907	209,907	209,907	209,907	209,907	209,907	119
Network Losses	MMBtu-h		0	2,092	0	0	2,092	0	0	0
Total Heat Demand	MMBtu-h		***243,390***	***245,482***	***243,390***	***243,390***	***245,482***	***243,390***	***243,390***	***243,390***
Total Cooling Demand	MMBtu-c		***209,907***	***209,907***	***209,907***	***209,907***	***209,907***	***209,907***	***209,907***	***119***
Heating Production										
HRC	MMBtu-h		121,526	122,317	121,496	121,461	121,352	121,490	121,490	112,578
GSHP_heating	MMBtu-h		0	0	116,829	0	0	117,445	117,445	112,157
WWHP	MMBtu-h		0	118,075	0	0	120,827	0	0	0
ASHP	MMBtu-h		0	0	0	94,563	0	0	0	0
Electric boiler	MMBtu-h		0	0	0	0	0	0	4,625	0
RES boiler	MMBtu-h		0	0	0	0	0	4,624	0	0
Natural gas boiler	MMBtu-h		122,022	5,260	5,234	27,535	3,473	0	0	18,655
Electric DHW	MMBtu-h		11,185	11,185	11,185	11,185	11,185	11,185	11,185	11,185
Total Heating Production	MMBtu-h		***254,733***	***256,837***	***254,744***	***254,744***	***256,837***	***254,744***	***254,745***	***254,575***
Cooling Production										
HRC cooling	MMBtu-c		93,979	94,599	93,956	93,929	93,847	93,951	93,951	86,993
Chillers	MMBtu-c		115,844	115,230	35,551	115,895	115,982	35,547	35,547	46,795
GSHP_cooling	MMBtu-c		0	0	80,349	0	0	80,357	80,357	75,885
Total Cooling Production	MMBtu-c		***209,823***	***209,829***	***209,855***	***209,823***	***209,829***	***209,855***	***209,855***	***209,673***
Fuel Consumption										
HRC	MWh-el	0	8,073	8,124	8,071	8,069	8,061	8,071	8,071	7,498
Chillers	MWh-el	0	9,548	9,497	2,930	9,552	9,559	2,930	2,930	3,857
GSHP_heating	MWh-el	0	0	0	9,254	0	0	9,303	9,303	8,884
GSHP_cooling	MWh-el	0	0	0	5,233	0	0	5,234	5,234	4,942
WWHP	MWh-el	0	0	9,148	0	0	7,035	0	0	0
ASHP	MWh-el	0	0	0	0	9,658	0	0	0	0
Electric boiler	MWh-el	0	0	0	0	0	0	0	1,383	0
RES boiler	MMBtu-f	0	0	0	0	0	0	5,138	0	0
Natural gas boiler	MMBtu-f	1,461,843	152,528	6,575	6,542	34,419	4,342	0	0	23,319
Electric DHW	MWh-el	0	3,278	3,278	3,278	3,278	3,278	3,278	3,278	3,278
Electricity for other uses than heat/cooling generation	MWh-el	0	0	0	0	0	0	0	0	0
Total Fuel Consumption	MWh-el or -f	***1,461,843***	***173,427***	***36,622***	***35,308***	***64,975***	***32,275***	***33,953***	***30,198***	***51,778***
CO2e Emissions										
Imported electricity	MT CO2e	0	556	799	765	813	743	766	803	757
Natural gas	MT CO2e	77,631	8,100	349	347	1,828	231	0	0	1,238
RES fuel	MT CO2e	0	0	0	0	0	0	14	0	0
Total CO2e Emissions	MT CO2e	***77,631***	***8,656***	***1,148***	***1,112***	***2,640***	***973***	***780***	***803***	***1,995***

Legend:	MMBtu-h	Million british thermal units of heating
	MMBtu-c	Million british thermal units of cooling
	MWh-el	Megawatt hours of electricity consumption
	MMBtu-f	Million british thermal units of fuel consumption
	MT CO2e	Metric tons of equivalent carbon emmissions

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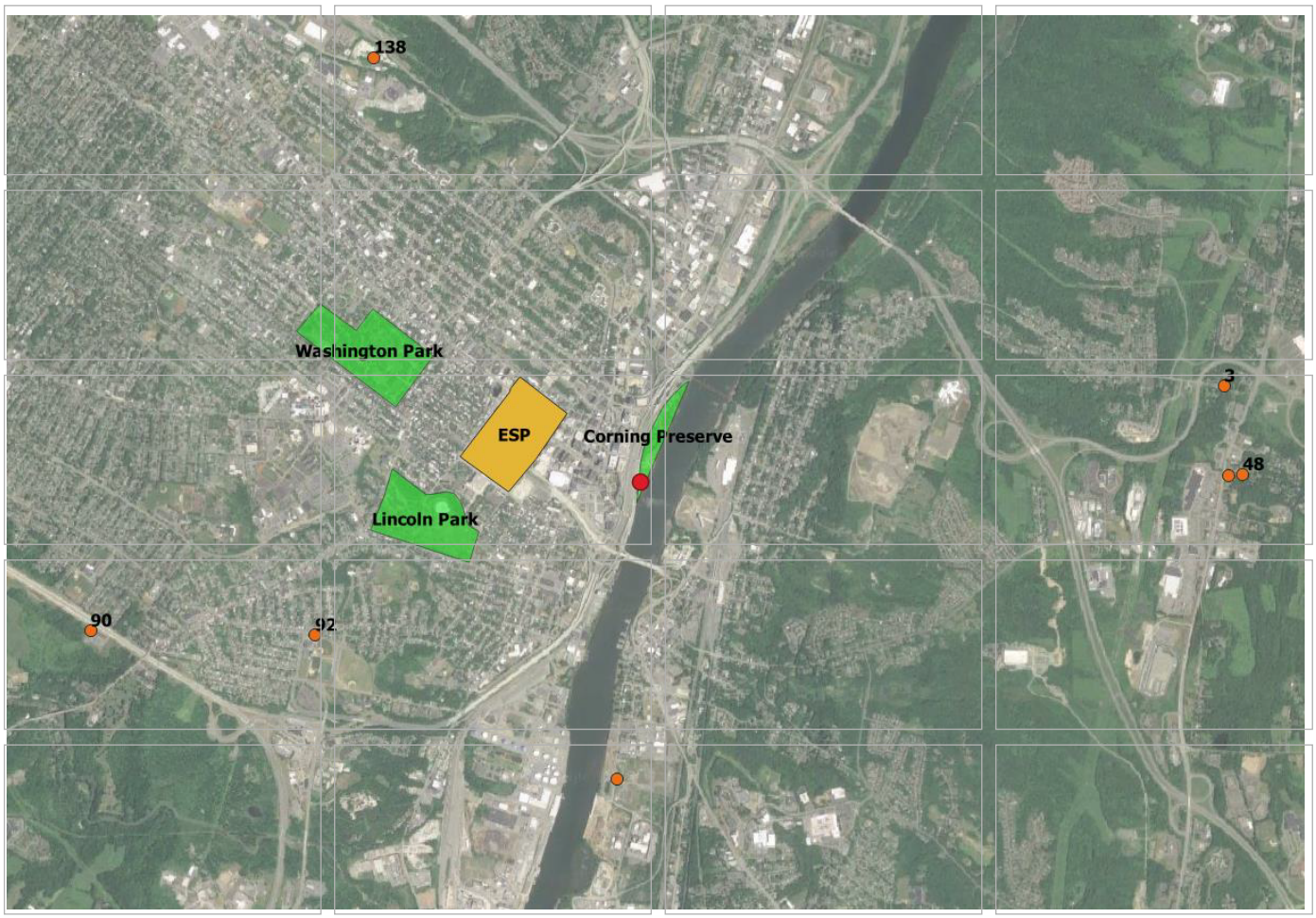

Final Report
Geothermal Assessment

Empire State Plaza
Albany, NY

Prepared for:

RAMBOLL

October 2023

www.underground-energy.com

UE Project No. EGE.2021.03

Pursuing Geothermal Excellence

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Appendix B – Regulatory Requirements for Geothermal Wells in New York
Appendix C – Thermal Response Test Analysis Report

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1.0 Introduction

This Geothermal Assessment of the Empire State Plaza (ESP) in Albany, New York has been prepared for Ramboll by Underground Energy, LLC (UE). Our work for this Geothermal Assessment focused on characterizing ground conditions to identify an appropriate Earth coupling alternatives to form the basis for conceptual design of ground heat exchangers. This report summarizes a Geothermal Conceptual Model (GCM) that was developed to understand ground conditions for a geothermal project including review of a Thermal Response Test that was performed at a test bore location.

2.0 Methodology

UE developed a Geothermal Conceptual Model (GCM) to systematically characterize ground conditions and subsurface heat transfer mechanisms to facilitate conceptual design of an Earth-coupled, low-temperature district heating and cooling system to serve the athletic complex development at the ESP. The GCM began with a desktop study of online hydrogeologic data, which formed the basis for a test bore specification that UE submitted in March 2022. The geothermal test bore specification is included as Appendix A. Ramboll subcontracted with Connecticut Wells/Geothermal Services Inc. who installed a test bore with a 500-foot-deep coaxial heat exchanger, where a thermal Response Test (TRT) was performed. The location of the proposed test borings is depicted below in Figure 1 along with other nearby well locations that informed our understanding of subsurface conditions. Due to the paucity of subsurface data near the ESP, much of the information that UE used in developing the GCM was collected at UAlbany, about four miles west-northwest of the ESP, where the post-glacial stratigraphy and bedrock thermal and hydrogeologic characteristics are similar to the ESP.

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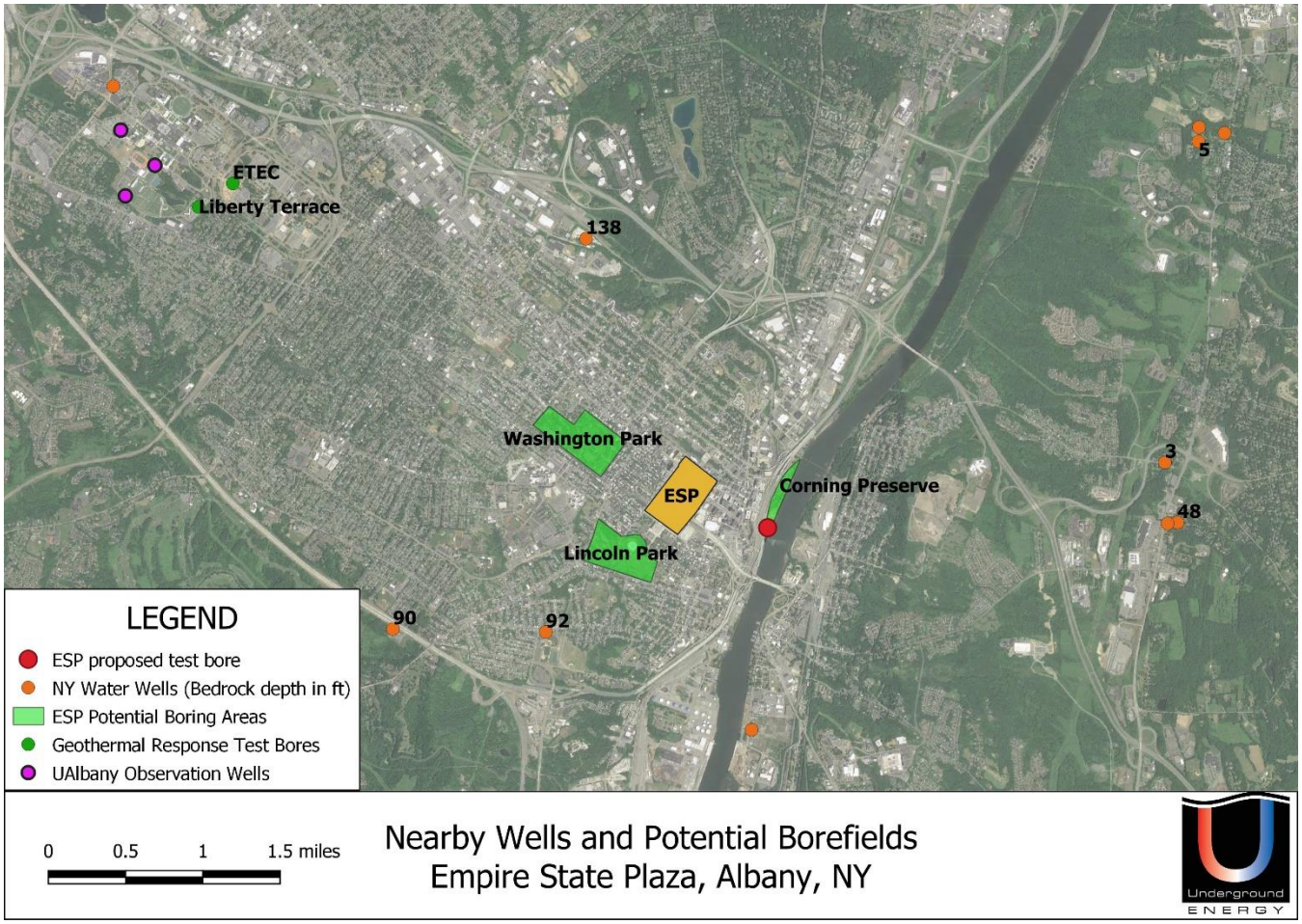

Figure 1 – ESP, test bore, potential borefields, and nearby wells

3.0 Geothermal Conceptual Model Development

Underground Energy developed a feasibility-level GCM for the ESP, which was supplemented by field data and a TRT. A GCM is a graphical and written summary of what is known or hypothesized about ground conditions at a site as they pertain to development of an earth-coupled heating and cooling project. The GCM process is graphically depicted in Figure 2 below.

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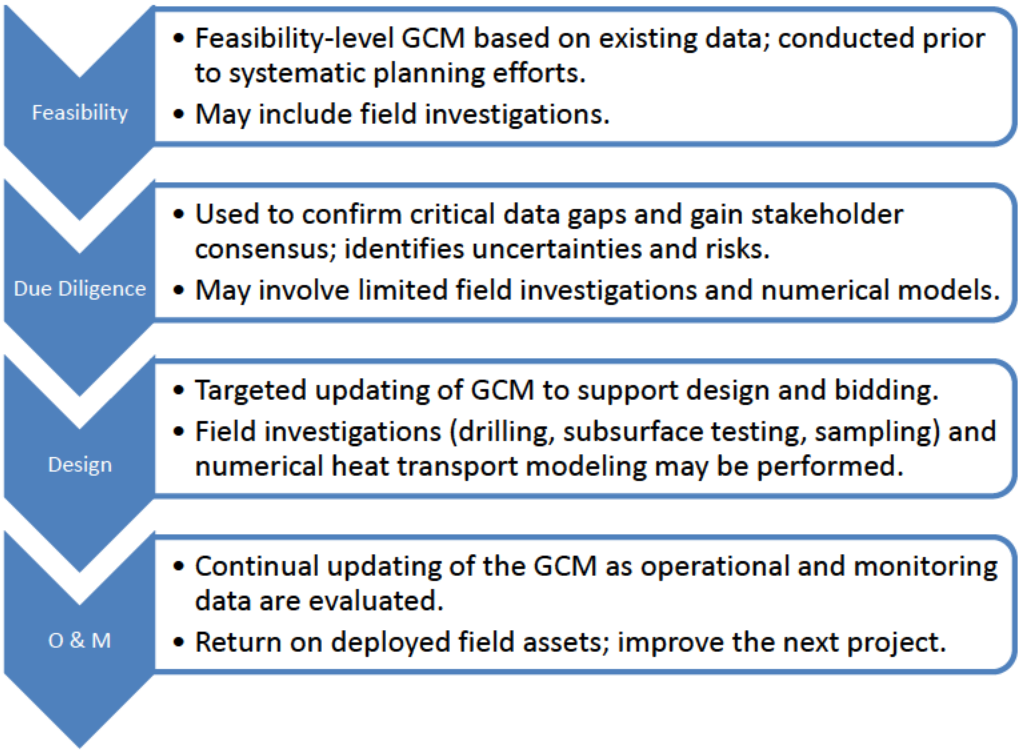

Figure 2 - Geothermal Conceptual Site Model Development Process

3.1 Regional Geology

3.1.1 Bedrock Geology

The unconsolidated surficial deposits overlie Ordovician-aged bedrock comprised primarily of shale to significant depth. The bedrock formation beneath the ESP is the Normanskill Shale, which contains minor amounts of siltstone and sandstone. A regional bedrock geologic map is presented below as Figure 3.

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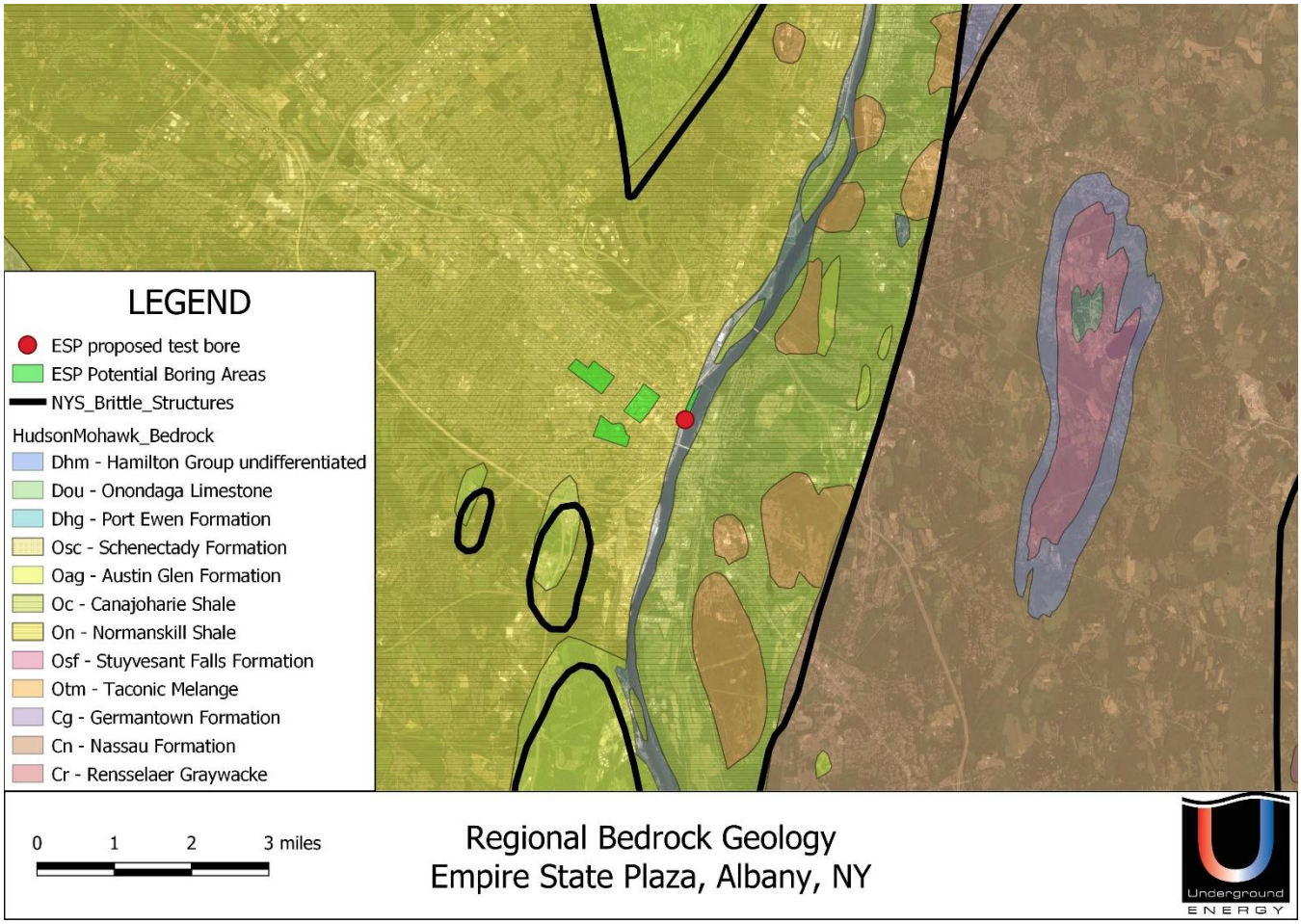

Figure 3 - Regional bedrock geology

3.1.2 Surficial Geology

The surficial geology of the Albany, NY area is characterized by unconsolidated glacial deposits that can be more than 200 feet thick. The thickest surficial deposits occur in bedrock valleys that have been scoured by glacial advance and meltwater runoff, notably the Hudson River valley and its tributaries. A regional surficial geologic map is presented as Figure 4.

The base of the surficial deposits is glacial till deposited during glacial advance. The till is derived primarily from shale and is therefore composed primarily by densely compacted silt and clay and shale fragments. The till is overlain by glaciolacustrine silt and clay deposited in Glacial Lake Albany. The glaciolacustrine unit is overlain by coarse-grained glacial-lake delta and kame terrace deposits. The uppermost unit is aeolian sand dune deposits that formed in high winds following drainage of Glacial Lake Albany. These deposits have been reworked locally during construction activities.

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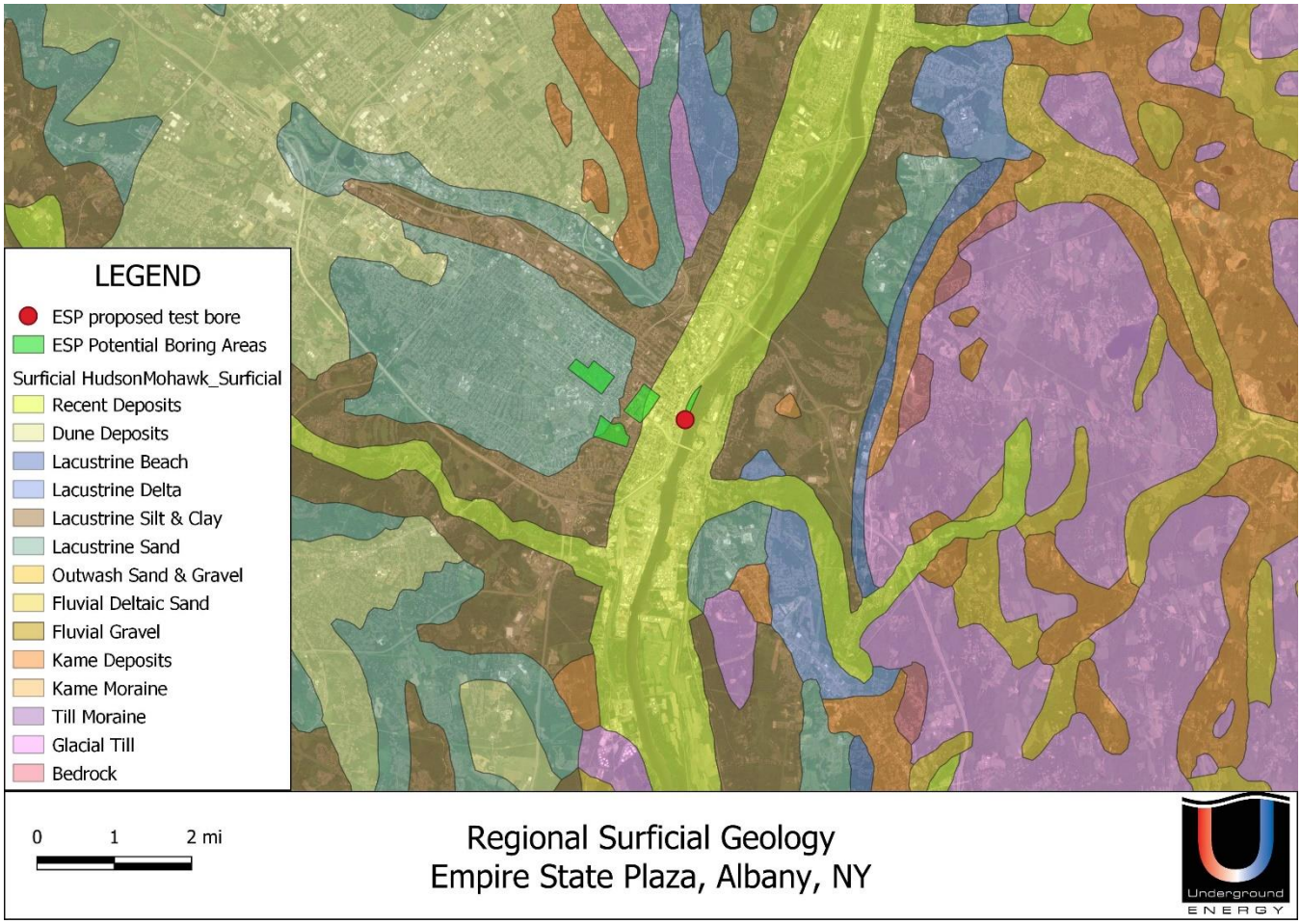

Figure 4 – Regional surficial geology

3.2 Hydrogeology

Groundwater in the area is expected to flow generally east-southeast toward the Hudson River, a regional groundwater discharge area. Due to the ESP's proximity to the Hudson River, a relatively low (10^{-3}) hydraulic gradient is expected at the ESP. Depth to groundwater is expected to be generally less than 15-12 feet below grade. Groundwater flux (the volume of groundwater that flows naturally across a unit area) is higher in the shallow coarse-grained sand units than in the low-permeability fine-grained deposits and shale bedrock at depth. Site specific hydrogeologic conditions are discussed in Section 3.4.

3.3 Geochemistry

Groundwater in this hydrogeologic setting is characterized by freshwater in the surficial and uppermost bedrock units, with increasing salinity with depth within the shale bedrock. Moderate to elevated iron and manganese concentrations are characteristic of groundwater in glacial deposits.

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Localized contamination of soil and groundwater from releases of oil and hazardous materials can complicate or render infeasible geothermal development projects. UE found no evidence of soil or groundwater contamination based on our information request and on historical land uses at the ESP. No geochemical conditions have been identified at the ESP that would materially affect a closed-loop geothermal project.

3.4 Ground Conditions at the ESP

Ground conditions at the ESP were estimated from several sources including the test bore at Corning Preserve, regional stratigraphy, and logs of nearby geotechnical and geothermal borings at UAlbany and elsewhere, as depicted on Figure 1.

3.4.1 Hydrostratigraphy

A driller's log of the test bore is reproduced from the TRT Analysis report (Appendix C) below as Figure 5. The site stratigraphy at the ESP is similar to that at UAlbany (Figure 6), with shallower depth to bedrock and thicknesses of glacial deposits. The regional hydrostratigraphy in Albany can be summarized as:

- Sandy dune and glaciofluvial deposits from ground surface to depths of less than 100 feet;
- Clay and silt glaciolacustrine deposits;
- Clayey glacial till deposits to the bedrock surface at about 100-250 feet deep; and
- Shale at greater depths.

Estimates of hydraulic conductivity and bulk thermal conductivity for each unit are included in Figure 6. Groundwater is unconfined in the surficial glacial aquifer and occurs at shallow depths (about 10-15 feet below grade).

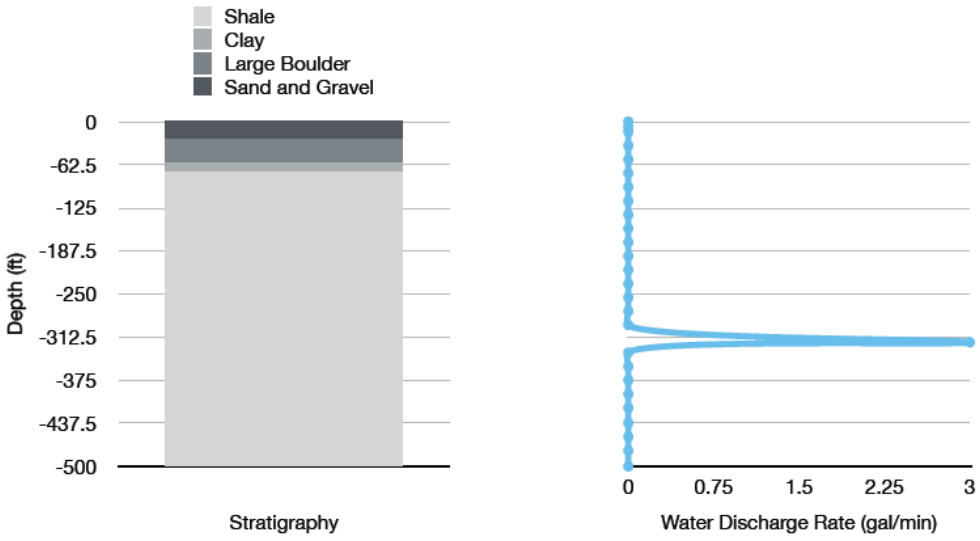

Figure 5 - Boring log for test well at Corning Preserve

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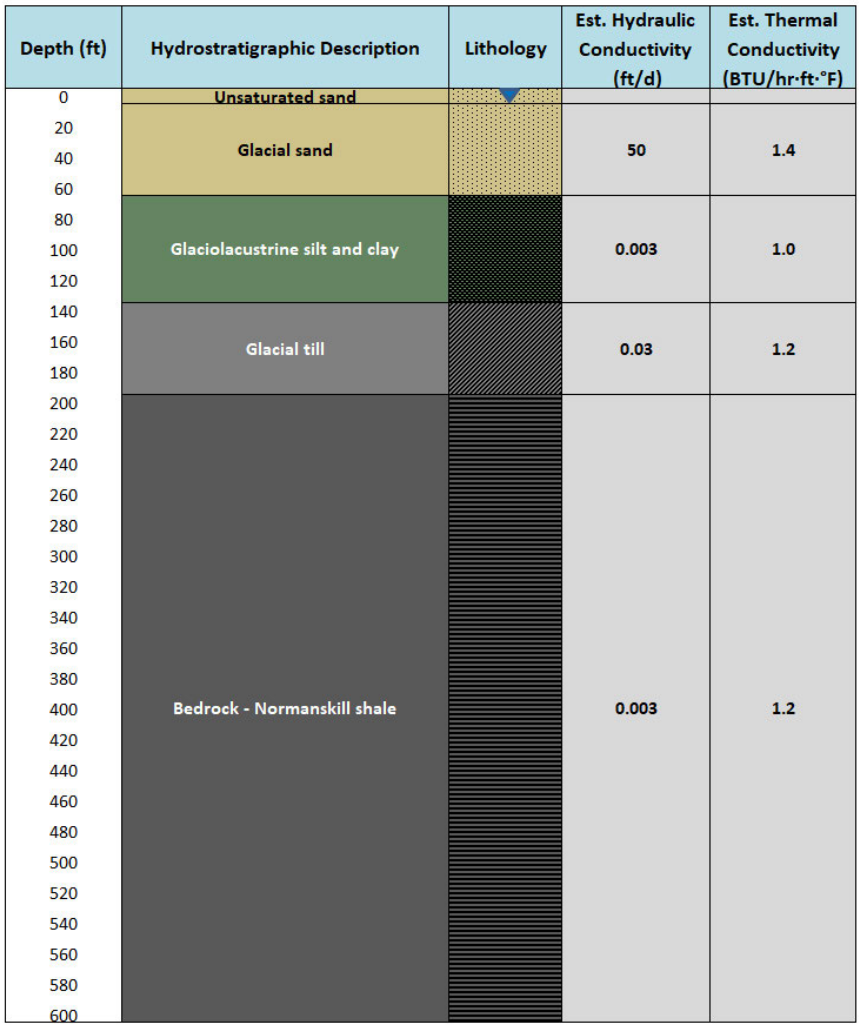

Figure 6 – Comparable hydrostratigraphic section at UAlbany

3.4.2 Subsurface Investigation Results

A 6-inch diameter test bore was drilled at the Corning Preserve in 2023. a 4.3" Rygan® HPGX concentric Borehole Heat Exchanger (BHX). The type of grout used to fill the annular space between the exterior of the BHX and the borehole wall was not communicated by the driller or documented in the TRT Analysis report; UE had specified a quartz sand and water backfill rather than thermally enhanced bentonite grout.

3.4.3 Subsurface Thermal Properties and Heat Transfer

Thermal response test data from the ESP, Liberty Estates and ETEC development at UAlbany are summarized below in Table 1.

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Table 1 - Thermal Response Test results from nearby geothermal test bores

Project	Well Depth (ft)	Thermal Conductivity (Btu/h·ft·°F)	Thermal Diffusivity (ft²/d)	Formation Temperature (°F)
Liberty Estates	402	1.18	0.85	52.5 – 54
ETEC	499	1.35	0.99	52.6 – 55.2
ESP Corning Preserve	**499**	**1.32**	**1.13**	**54.7**

4.0 Earth Couple Selection

A closed-loop coaxial or U-bend BHX will likely be the preferred Earth coupling method at the ESP, subject to further evaluation of economics, borehole thermal resistance, and site-specific ground conditions.

4.1 Open Loop Evaluation

The test bore log depicts about a 20-foot-thick sand layer at the surface, underlain by "large boulder," which we interpret may be glacial till with cobbles or boulders. It is the opinion of UE that ground conditions at the Corning Preserve are not likely to be suitable for an open-loop geothermal application, such as Aquifer Thermal Energy Storage (ATES) because the aquifer is thin, shallow, has low expected transmissivity and in hydraulic communication with the Hudson River.

4.2 Closed Loop Evaluation

4.2.1 Heat Source/Sink and Seasonal Thermal Storage Paradigms

Our evaluation of closed-loop options will be performed in the context of two paradigms for how an Earth couple's function is considered: the Earth couple can be a heat source/sink, or, at scale, it can be a large thermal battery. The evaluation and selection of an optimized Earth couple requires an understanding of site-specific hydrogeologic conditions with respect to subsurface heat transfer by conduction and advection mechanisms. Advection-dominant hydrogeologic settings (permeable aquifers and high groundwater flux) are not well suited for seasonal thermal storage, but they can be highly effective as a heat sink/source, depending on the thermal efficiency of the BHX. Conduction dominates in low permeability formations where groundwater flux and advective heat flow are minimal; and therefore, favorable conditions will exist for seasonal thermal energy storage.

In the Albany area, advection via groundwater flow dominates heat transfer in the shallow glacial sand aquifer, while conduction dominates heat transfer in the deeper silt, clay, till and shale bedrock. The deeper formations at the ESP are believed to be well suited for seasonal thermal energy storage while the glacial sand aquifer could be well used as a heat sink/source. This was depicted using FEFLOW to develop a 3D numerical model simulating a U-bend BHX in a 500-foot-

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deep bore at nearby UAlbany. The model simulates groundwater flow and heat transport in all stratigraphic units. Monthly supply temperatures to the UAlbany borefield (provided by Ramboll) were used as input boundary conditions to the model, and one year of operation was simulated, beginning in January. Figure 7 and Figure 8 are cross sections parallel to groundwater flow in the shallow aquifer depicting the temperature distribution in the surrounding hydrostratigraphic units around the BHX after 90, 180, 270 and 365 days of operation, respectively. Significant advective heat transport in the uppermost glacial sand aquifer is noted from the warmer and cooler temperatures being advected by natural groundwater flow at day 90 and 270, following the heating and cooling seasons. Seasonal thermal storage is evident in the temperature distribution below and above ambient at distances greater than ~3 m from the borehole at day 180 and 365, respectively.

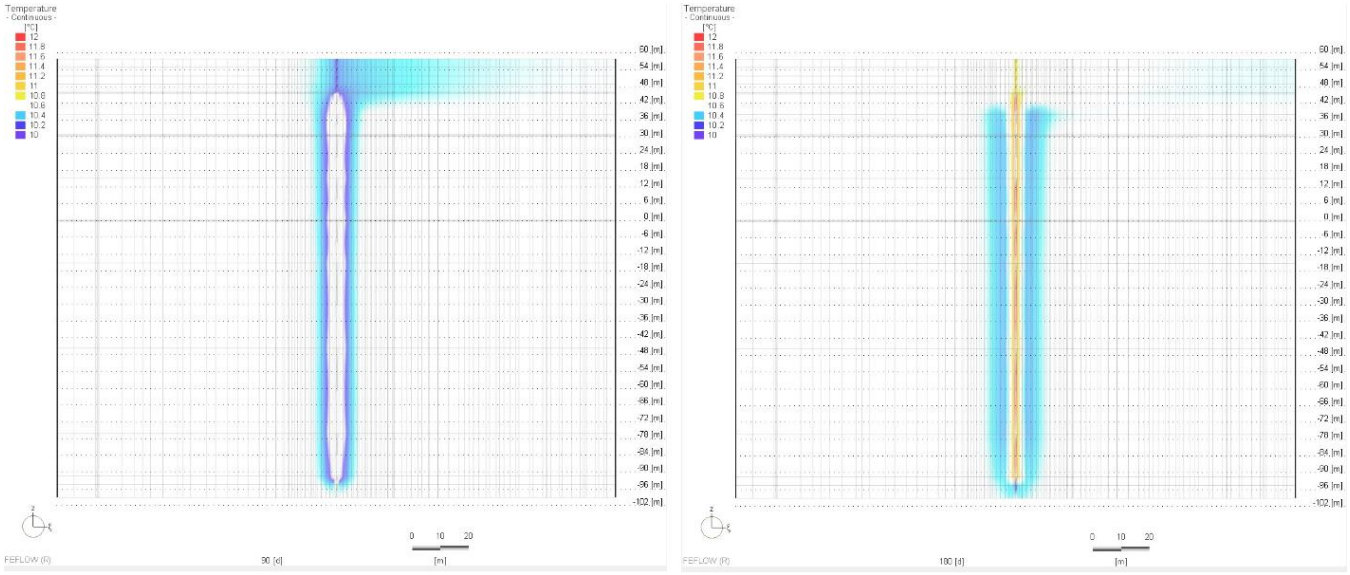

Figure 7 - BHE simulation at 90 and 180 days

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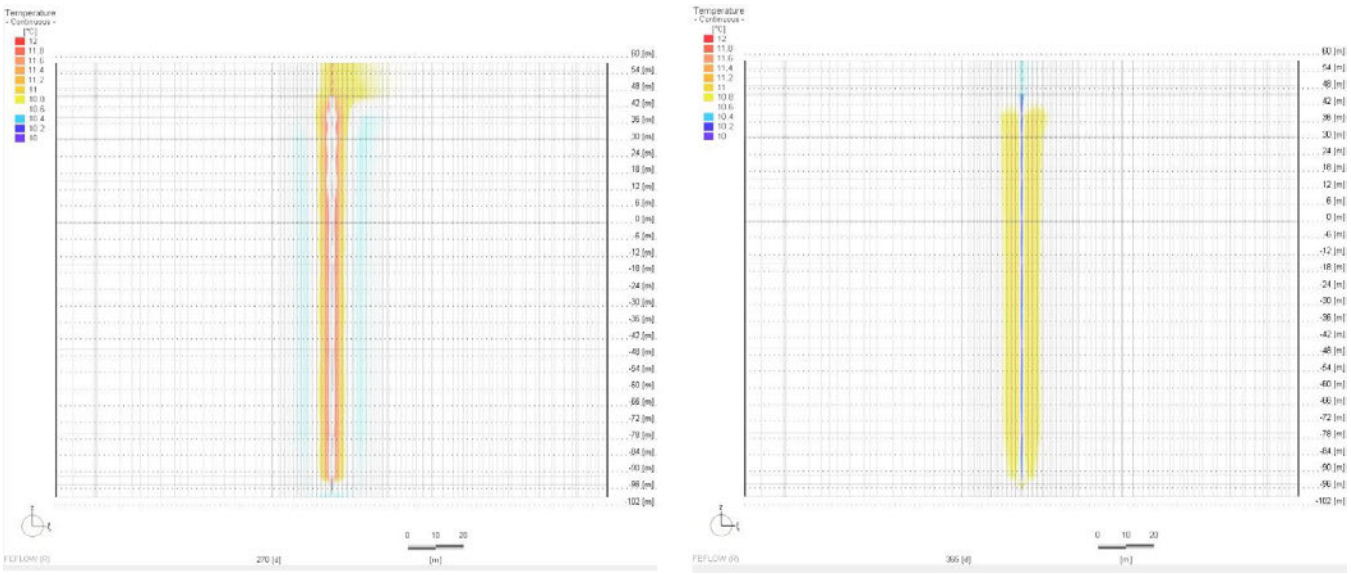

Figure 8 - BHE simulation at 180 and 365 days

5.0 TRT Evaluation

The TRT Analysis report that was prepared by Mathilde Krebbs LLC is included as Appendix C. The TRT analysis method is based on the analytical solution of heat flow from an infinite line source. A multivariate best-fit analysis was performed using multiple values of ground temperature, formation thermal conductivity, formation volumetric heat capacity, and borehole thermal resistance until the lowest mean absolute error resulted from the comparison of model predictions to TRT results. This analytical method, along with the 34 W/ft of input power to the BHX used during the TRT, is best suited to coaxial BHX configurations. The method employed is also able to exclude the period when input power was lost.

From Table 1, the calculated thermal conductivity and diffusivity values for the ESP are in line with although about 10% higher than nearby values at UAlbany. The estimated thermal conductivity value of 1.31 Btu/h·ft·°F at the ESP is consistent with estimates of 1.2 Btu/h·ft·°F based on stratigraphy (from Figure 6). Calculated thermal diffusivity values at ESP are about 13% higher at the ESP compared to at UAlbany.

It is UE's opinion that the TRT analysis performed at the ESP is valid, and that the ~ 10-13 % higher values of thermal conductivity and diffusivity may be due to advective heat transfer to groundwater flow in the upper portions of the BHX that intersect saturated, permeable glacial deposits.

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Appendix A

Geothermal Test Bore Specification

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SPECIFICATION
Vertical Test Bore and Formation Thermal Conductivity Test for a Vertical Coaxial Ground Heat Exchanger on Closed-Loop Ground Source Heat Pump Systems

PART 1 - VERTICAL TEST BORE

1.1 SCOPE

A. A vertical bore and coaxial borehole heat exchanger (BHX) shall be installed according to these specifications at the location depicted on the attached figure. The completed bore shall be located so that it is incorporated into the final ground-loop heat exchanger design. A completed vertical test bore shall consist of a 7-inch diameter vertical bore completed to full depth with a 4-inch diameter Rygan HPGX borehole heat exchanger (or equivalent coaxial borehole heat exchanger subject to approval by Owner's Representative) with an approved grouting material installed in the bore annulus. BHX assembly and grouting material shall be as specified in this document.

B. Vertical bore can be drilled either by a mud-rotary drilling rig or by an air-rotary drilling rig.

C. Drilling contractor shall provide a detailed test bore report. The report shall include the following information:
   1. Legal description of the location of the water well or test hole
   2. Description and depth of geologic materials encountered - Each formation type encountered (drill log), each formation depth (in feet)
   3. Depth of any significant cracks, fissures or caverns encountered
   4. Static water level, all water bearing zones and if encountered:
      a. Zone depths
      b. Estimated flow rate
   5. Type of drilling equipment used (i.e. mud-rotary, air-rotary, air-hammer, etc.), and rig model number
   6. Bag quantity of drill mud used where applicable
   7. Total time to drill the test bore excluding shut-downs to obtain water or mechanical break-downs.
   8. Dates drilling commenced and construction completed. Provide a completed, signed report immediately at the conclusion of the drilling process.

D. Drilling contractor shall be responsible for all following all applicable codes and regulations, exclusive of the permit required from NYSDEC's Division of Mineral Resources (DMN) to drill wells greater than 500 feet deep (ECL § 23-0305.14). Where any discrepancy exists between local codes and regulations and this specification, the most stringent of those documents shall govern.

E. Drilling contractor will deploy swamp mats or other turf damage mitigation measures sufficient for drilling the test bore up to 40 feet from a paved surface.

1.2 BORE DIAMETER

A. The diameter of the vertical bore shall be 7 inches.

1.3 COMPLETED BORE DEPTH

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A. The completed bore depth shall be within 5% of the final estimated design bore depth for the specific project (1,000 feet). The distance from the lowermost portion of the BHX to the ground surface shall constitute the completed bore depth.

1.4 COAXIAL BOREHOLE HEAT EXCHANGER ASSEMBLY

A. A 4-inch diameter Rygan HPGX borehole heat exchanger (or equivalent coaxial BHX subject to approval by Owner's Representative) will be installed in the bore. The construction procedures shall conform to manufacturer's specifications and recommendations.

B. The coaxial BHX shall be filled with clean water (to a level such that freezing of the water will not occur) and terminated with sealing tape at a minimum of five (5) feet above grade.

1.5 GROUTING MATERIAL

A. Grouting material shall be quartz sand and water without bentonite grout.

1.6 WELL HEAD COMPLETION

A. To facilitate thermal response test as well as future use of this bore as part of a larger borefield, the drilling contractor shall complete the well head below grade within a small manway or vault designed and constructed to protect the bore installation from vandalism and damage.

1.7 SPOILS MANAGEMENT

A. Best management practices will be employed in regard to management of water and drill cuttings. Cuttings will be containerized and disposed offsite. Drilling contractor will obtain necessary approvals and employ required management procedures for water discharge.

PART 2 - FORMATION THERMAL CONDUCTIVITY TEST

2.1 SCOPE

A. The formation thermal conductivity test is designed to determine the average thermal conductivity of the formation for the completed bore depth. A contractor and/or affiliated organization, with at least 5 successfully completed tests prior to performing this test, shall perform the test. A list of previous tests shall be supplied upon request.

B. The testing device shall be designed so that a constant rate of heated water is supplied in an uninterrupted fashion to the BHX.

C. The testing device shall have the capability of automatically collecting data at predetermined intervals. Collected data shall be immediately available to the design engineer in an electronic format compatible with Microsoft Excel®.

2.2 INSULATION

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A. The testing device shall be designed to prevent as much heat loss to the environment as possible. All inlet and outlet pipingof the assembly shall be insulated with closed-cell insulation to prevent heat loss or heat gain.

2.3 ELAPSED TIME BEFORE TESTING

A. A minimum delay of seven days between grouting and thermal response testing is required.

2.4 INPUT HEAT RATE

A. The testing device shall be designed so that a constant rate of heat input into the vertical u-bend assembly shall be no less than 60 Btu/hr (17.5 W) per bore foot. If a lower rate is anticipated, prior approval must be obtained beforehand. In any event, the heat rate shall not fall below 51 Btu/hr (15 W) per bore foot. Heat rate shall not be altered during the duration of the thermal conductivity test. The selected heat rate shall not be greater than 85 Btu/hr (25 W) per bore foot.

B. The average input heat rate shall be logged during the test and data shall be reported in the final analysis.

2.5 DATA ACQUISITION FREQUENCY

A. Data shall be taken at a frequency of no more than every 5 minutes throughout the duration of the test. Data collected shall consist of the following as a minimum; temperature into the loop, temperature out of the loop, ambient air temperature within the test unit compartment, ambient outdoor air temperature, and watts.

2.6 TEST DURATION

A. The duration of the formation thermal conductivity test shall be a minimum of 40 hours from the initial starting time. Power interruptions shall be avoided whenever possible.

2.7 CONDUCTIVITY TESTING RESULTS REPORT

A. The engineering services for thermal conductivity testing shall include the following:

Conduct a thermal conductivity test utilizing the BHX installed by the drilling contractor) and prepare a report that documents the thermal response test performance and provides the data collected.

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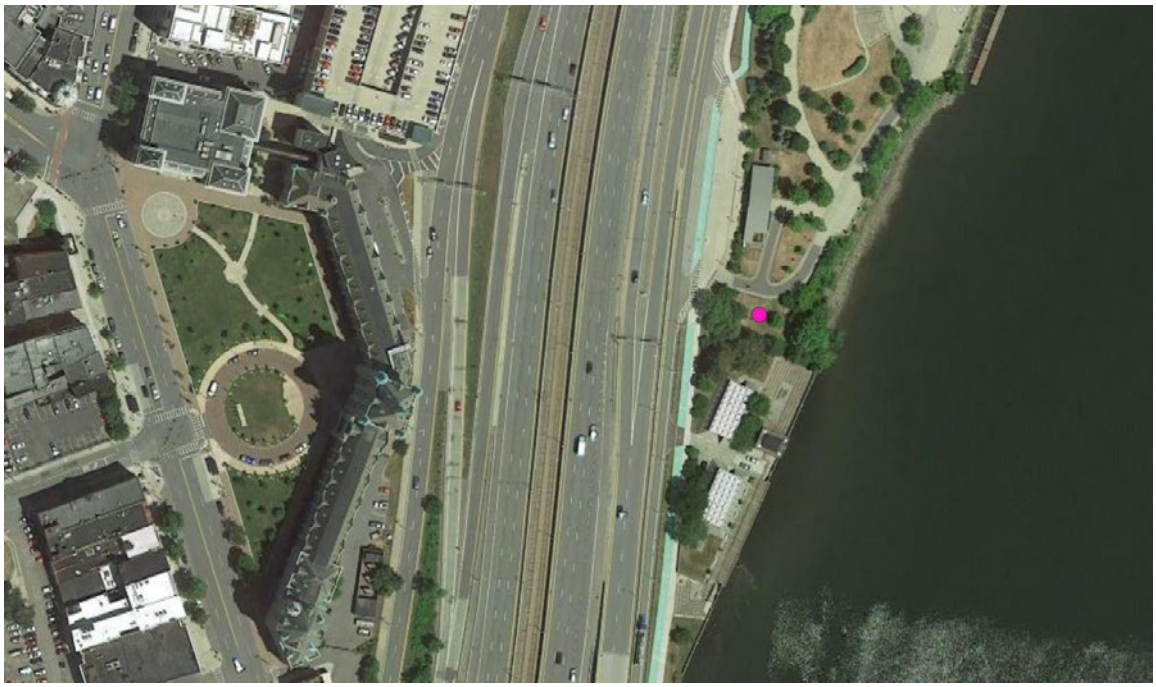

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Appendix B

Regulatory Requirements for Geothermal Wells in New York

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Regulatory Requirements for Geothermal Wells

Permits and notifications are required by various agencies for geothermal wells and systems. Federal, state, and local agencies regulate different aspects of drilling, installation, and operation.

U.S. Environmental Protection Agency

Under the Underground Injection Control program, administered by the U.S. Environmental Protection Agency (USEPA), EPA established minimum requirements to prevent injection wells from contaminating underground sources of drinking water (USDWs). Geothermal wells are considered Class V injection wells. In most cases Class V wells are "authorized by rule." "Authorized by rule" means that an injection well may be operated without a permit if the owners or operators:

- Submit inventory information to their permitting authority and verify that they are authorized (allowed) to inject. **The permitting authority will review the information to be sure that the well will not endanger a USDW.**
- Operate the wells in a way that does not endanger USDWs. **The permitting authority will explain any specific requirements.**
- Properly close their Class V well when it is no longer being used. **The well should be closed in a way that prevents movement of any contaminated fluids into USDWs.**

After reviewing an owner or operator's inventory information the permitting authority may determine that an individual permit is necessary to prevent USDW contamination.

EPA UIC permit application forms are available online. Completed forms should be submitted directly to UIC state primacy programs. In non-primacy states, completed forms should be submitted directly to the regional EPA program. EPA maintains primacy in New York for Class V wells. However, other state programs have regulations for geothermal wells, as described below.

https://www.epa.gov/sites/default/files/2019-05/documents/owner_or_operator_permit_application_for_a_class_v_well_form_7520-6_class_v.pdf

New York State Department of Environmental Conservation **(DEC)**

Geothermal water withdrawal systems are exempt from the DEC requirement to obtain a water withdrawal permit under 6 NYCRR Part 601.9. However, other state regulations apply to construction and operation of geothermal wells.

Division of Water

DEC's Division of Water (DOW) regulates wells up to 500 feet deep. The drilling, construction, operation, and plugging of geothermal wells over 500 feet is regulated by DEC's Division of Mineral Resources (DMN).

NYS law requires driller and pump installer registration and certification with DOW for open-loop or standing column systems. Driller registration and certification is not required for closed-loop geothermal systems with boreholes drilled up to 500 feet deep.

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NYS law requires that preliminary notice and well completion reports be filed with DOW for open-loop or standing column systems with boreholes drilled up to 500 feet deep. NYS law does not require pre-notification or a well completion report for closed-loop geothermal systems with boreholes drilled up to 500 feet deep.

A State Pollutant Discharge Elimination System (SPDES) Permit may also be required for certain open-loop systems. New York State law requires a permit for constructing or using an outlet or discharge pipe (referred to as a "point source") that discharges wastewater into the surface waters or ground waters of the state.

Division of Mineral Resources

The NYSDEC Division of Mineral Resources regulates drilling and operation of all oil, natural gas, underground gas storage, and solution mining wells regardless of depth, as well as brine disposal, geothermal, and stratigraphic wells deeper than 500 feet. Further, the Division requires the plugging and abandonment of these wells after they have fulfilled their intended use and ensures that all sites are properly reclaimed (land is revegetated and restored).

Division of Mineral Resources requires a “mining” permit for any drilling activity below a depth of 500 feet. Well locations, depth, use, casing material, cementing procedures, drilling fluid and cuttings disposal methods must be submitted with the permit application. In addition, the surface casing must extend a minimum of 75 feet beyond the deepest freshwater zone encountered or into competent bedrock, whichever is deeper.

The Division of Mineral Resources also requires that the wells do not drift beneath adjacent properties for which the applicant has not received permission from the property owner. To demonstrate compliance, angular deviation and directional surveys must be performed at 100 ft. intervals during drilling using a gyroscope or other approved method. If the borehole drifts near the property boundary of an adjoining site for which the building owner has not received approval, drilling must stop, and the well must be completed at that depth. Any borehole intersecting such a property boundary must be abandoned and sealed.

The Division of Mineral Resources will consult with the New York State Office of Parks, Recreation and Historic Preservation on whether the location of a well is within a state-listed historic area in which case permission is required. NYS Parks reviews the project to ensure that the installation of wells will not have a negative impact upon cultural resources.

Albany County and City Requirements

No local permit requirements specific to geothermal well drilling were identified. Local permits are required from the Albany Water Department for connection to a water or sewer line. Permits are also required from the Division of General Services for work in a roadway or road right of way.

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Appendix C

Thermal Response Test Analysis Report

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MATHILDE KREBS LLC

Empire Plaza - TRT Analysis

Quay St, Albany, NY

Prepared for: Connecticut Wells

Prepared by: Mathilde Krebs

September 19, 2023

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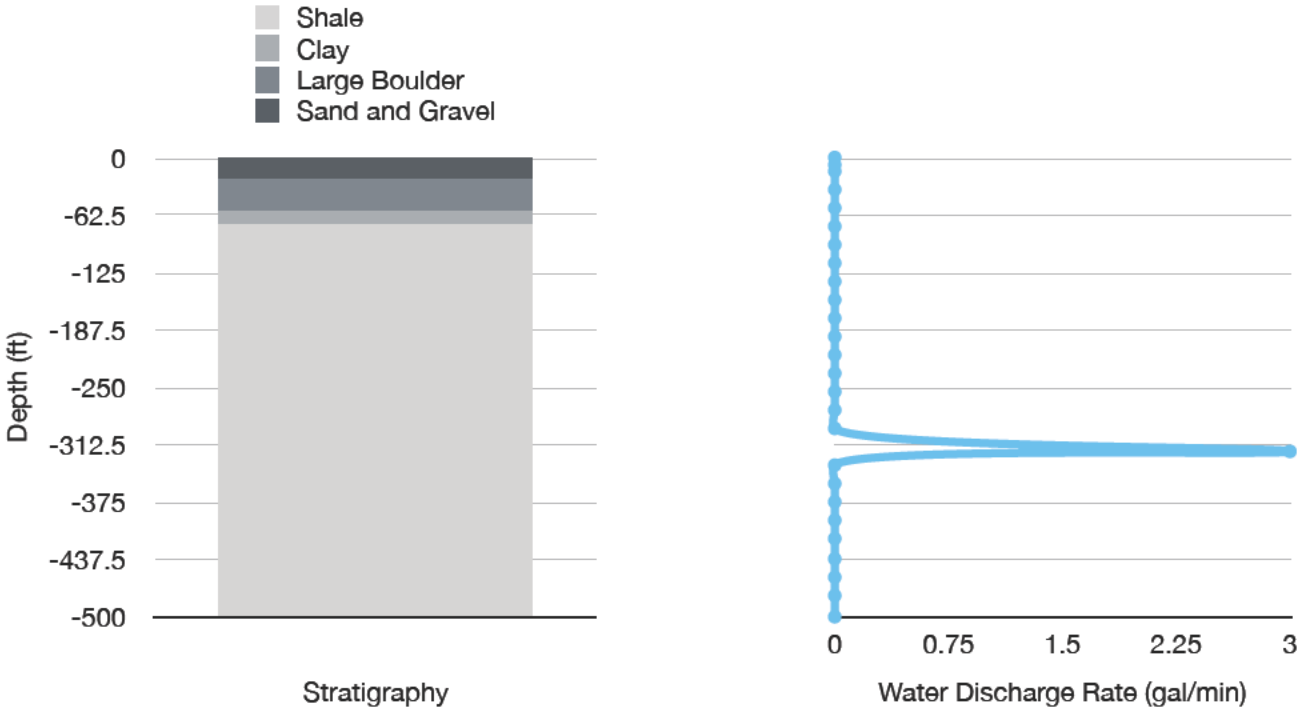
Test Borehole

A 6 inches diameter test borehole was drilled by Connecticut Wells to approximately 500 ft (152 m) below ground surface, and a 4.3" Rygan® HPGX geothermal exchange system. The type of fill used in the borehole annular space was not communicated.

No depth temperature measurements of the ground water in the borehole were taken prior to performing the thermal response test (TRT). The impact of the seasonal effect on the average ground temperature is therefore unknown and the ground temperature estimated in this TRT analysis is most likely overestimating the annual average undisturbed ground temperature.

The data from the undated log of the test well drilling is presented in Figure 1.

FIGURE 1 - GRAPHICAL REPRESENTATION OF DRILLING AND TEMPERATURE LOGS



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Thermal Response Test Analysis

Objectives & Methodologies

The goal of this study is to provide accurate results using an analytical method well suited for the Rygan® HPGX geothermal exchange system. The analytical method also has the advantage of being able to evaluate ground temperature and ground thermal capacity in addition to usual parameters calculated by the more typical graphical method used in the analysis by a GeoCube or GRTI for example.

For this study, an analytical approach applied to the infinite line source (ILS) model was used and is briefly explained in Appendix B. The best result was selected by varying parameters (T_g, k_{eq}, R_b, C_s) and selecting the combination with the lowest mean absolute error when comparing the model predictions to the TRT measurements, with:

- T_g : Initial ground formation temperature (˚F)
- k_{eq} : Equivalent ground formation conductivity (Btu/h.ft.˚F)
- R_b : Equivalent borehole resistance (h.ft.˚F/Btu)
- C_s : Ground formation thermal volumetric capacity (Btu/ft^3.h)
- α : Ground formation diffusivity (ft^2/day) calculated as follows: $\alpha = k_{eq} / C_s$

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Test Data

The test was performed with a GeoCube test unit and by Connecticut Wells staff between August 28th and 31st, 2023 with the following phases:

A. **30 min circulation test** at approximately 14.3 gpm (54 l/min) and with no power to the heating elements.
B. **46 hrs injection test** at approximately 13.3 gpm (50 l/min) and 58 MBH (17 kW) of heat, or 11.6 MBH/100ft (34 W/ft). Ending with a temperature differential between supply and return of approximately 12˚F (6.7˚C), and not clearly reaching a steady state.
C. **Power loss,** heaters and pump shut off while battery-powered data logger continued recording temperatures.
D. **19 hrs relaxation test**, following the injection test and power loss, at approximately 13.6 gpm (51.5 l/min) and no power to the heating elements.

FIGURE 2 - GRAPHICAL REPRESENTATION OF THE TEMPERATURES POWER AND FLOW RECORDED DURING THE 4 PHASES OF THE TEST

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Results

For the TRT performed at Empire Plaza NY between 08/28/23 and 08/31/23, the analytical method applied to the ILS model was used to find the combination of parameters with the lowest mean absolute error presented in Table 1, representing the borehole's behavior the best. A series of figures shows the mapping of the mean absolute error for each combination of variables and an overlay of the model-predicted borehole temperature over the recorded data.

TABLE 1 - ANALYSIS RESULTS

Description	Recommended per this report
Initial formation temperature (T_g, °F)	54.7
Thermal volumetric capacity (C_s, Btu/ft³.h)	27.97
Thermal diffusivity (α, ft²/day)	**1.13**
Equivalent thermal conductivity (k_{eq}, Btu/h.ft.F)	**1.32**
Equivalent borehole thermal resistance (R_b, h.ft.F/Btu)	**0.046**
Mean absolute error*	0.08

**Mean absolute error evaluated using an ILS model including parameters as listed in table, and applied over injection and rejection phases, excluding timeframe of power loss*

An undisturbed ground temperature T_g of 54.7°F is recommended. The minimum temperature recorded by the GeoCube during the circulation test was 55.3°F but this higher value reported a higher mean absolute error when used in the analytical model. Note that the choice of undisturbed ground temperature has a high impact on the evaluation of the equivalent borehole thermal resistance R_b, and is not necessarily a good indicator of the average ground temperature during other seasons than when the test is performed.

A ground formation conductivity k_{eq} of 1.318 Btu/h.ft.F and a thermal diffusivity α of 1.131 ft²/day are consistent with the calculations in Appendix A based on literature data and drilling log for a low density shale bedrock.

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The recommended borehole thermal resistance R_b of 0.046 h.ft.F/Btu is in the order of magnitude of the theoretical value calculated in Appendix C and is inline with the operational data seen on installed system using similar borehole construction.

FIGURE 3 - TEST DATA AND ANALYTICAL METHOD RESULTS COMPARISON

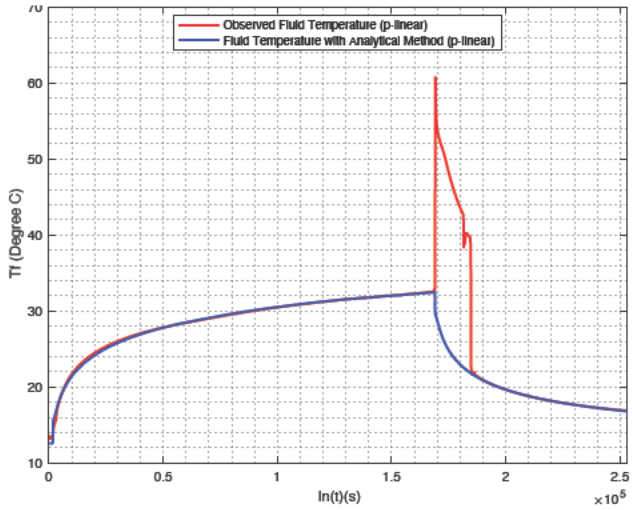


FIGURE 4 - MAE BASED ON "P-LINEAR" FLUID TEMPERATURE (MARCOTTE AND PASQUIER (2008))

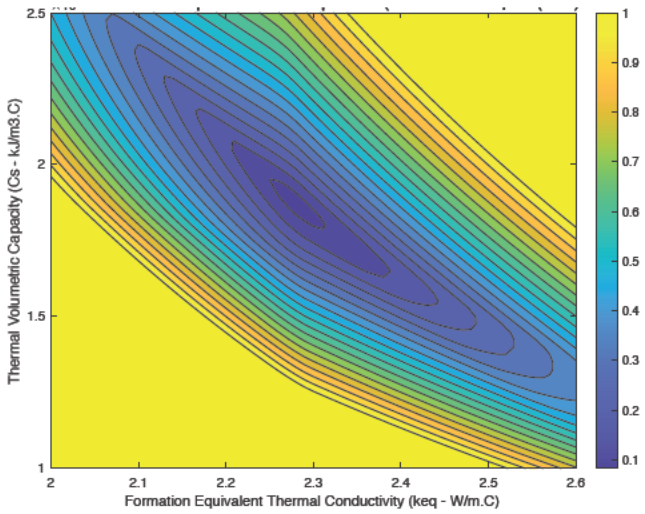


FIGURE 5 - MEA BASED ON "P-LINEAR" FLUID TEMPERATURE (MARCOTTE AND PASQUIER (2008))

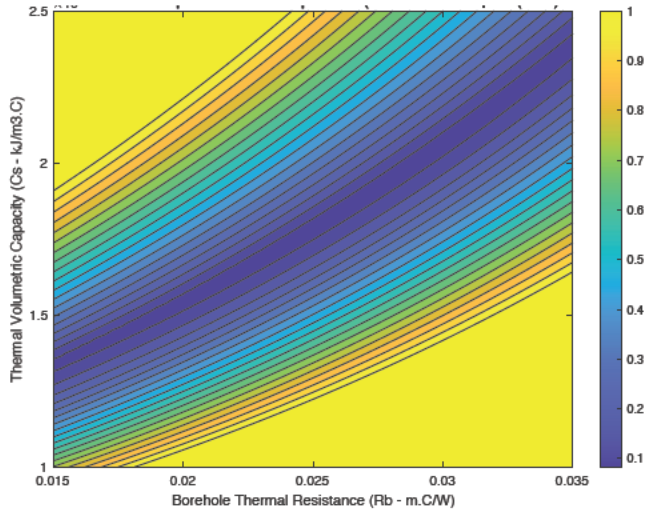
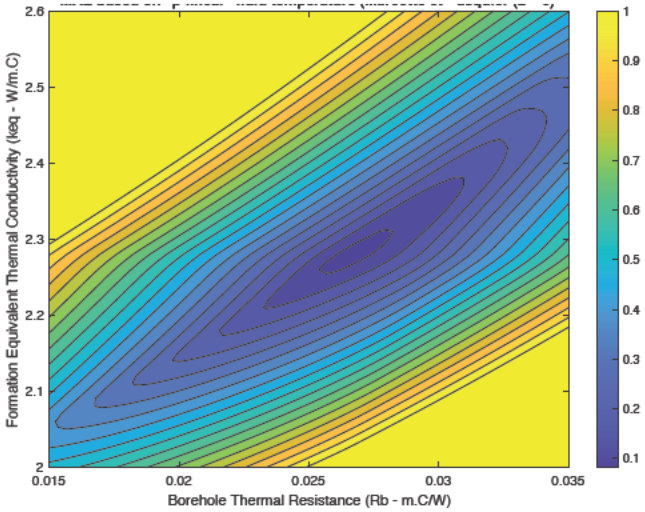


FIGURE 6 - MAE BASED ON "P-LINEAR" FLUID TEMPERATURE (MARCOTTE AND PASQUIER (2008))



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Conclusion & Recommendations

The use of an analytical method to analyze the Empire Plaza TRT, above and beyond the typical graphical method packaged with the GeoCube, allowed to determine instead of assuming the ground diffusivity and/or thermal capacity. It also allowed to confirm the undisturbed ground temperature without having a thermal profile of the borehole provided, but at the cost of additional analysis time due to the addition of another variable. The method also permitted to correlate the model to the injection phase as well as relaxation phase of the test, while excluding the period of power loss.

All the necessary ground formation and borehole properties for designing a geothermal heat exchange system with a high level of confidence are provided below in Table 2.

TABLE 2 - RECOMMENDED DESIGN PARAMETERS FOR WELLS BUILT SIMILARLY TO TEST BORE

Description	Recommended per this report
Initial formation temperature (T_g, °F)	54.7°F if design conditions are for the summer season, or adjust for winter design conditions
Thermal volumetric capacity (C_s, Btu/ft³.h)	27.97
Thermal diffusivity (α, ft²/day)	**1.13**
Equivalent thermal conductivity (k_{eq}, Btu/h.ft.F)	**1.32**
Equivalent borehole thermal resistance (R_b, h.ft.F/Btu)	**0.046**
Mean absolute error*	0.08

For future TRTs and even though this TRT provided sensible results, it recommended to perform a vertical thermal profile as included in the recommended procedures in Appendix D. It increases the level of accuracy of the analysis while minimizing the time required for its execution.

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Appendix A

Rock Formation	Start Depth (m)	End Depth (m)	Conductivity k* (W/m.K)	Capacity C_p* (kJ/kg.K)	Diffusivity α* (m^2/day)
Sand and Gravel (1600 kg/m^3, 10% moisture)	0	7	2.51	1.41	0.096
Boulder (Sandstone)	7	17	3.50	1.00	0.090
Clay (1920 kg/m^3, 10% moisture)	17	22	1.21	1.27	0.043
Shale (Dry, 25% quartz, low density)	22	152	1.90	0.88	0.090
Average Ground Properties**			**1.950**	**0.911**	**0.087**

Rock Formation	Start Depth (ft)	End Depth (ft)	Conductivity k* (BTU/h.ft.˚F)	Capacity C_p* (BTU/lb.˚F)	Diffusivity α* (ft^2/day)
Sand and Gravel (100 lb/m^3, 10% moisture)	0	22	1.450	1.22	1.03
Boulder (Sandstone)	22	57	1.500	0.24	0.95
Clay (120 lb/m^3, 10% moisture)	57	72	0.700	1.10	0.46
Shale (Dry, 25% quartz, low density)	72	500	1.400	0.21	1.23
Average Ground Properties**			**1.367**	**0.226**	**1.140**

*Thermal properties based on values at 300K and 5 MPa from *Robertson (1988)*.

**Average properties of overall ground calculated using a series formula: $k = (\sum_{i=1}^{n} \frac{\phi_i}{k_i})^{-1}$

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Appendix B

Analytical Line Source Explained

The general equation expressing the fluid temperature is:

$$T_f(t) = T_g + q(t)R_b + \Delta T(r_b, t, k_e q, \alpha, q(t))$$

For the infinite line source model, ΔT is expressed by:

$$\Delta T = \frac{q(t)}{4\pi k_{eq}} \int_{r^2/4\alpha t}^{\infty} \frac{e^{-u}}{u} du = \frac{q(t)}{4\pi k_{eq}} E_1\left(\frac{r^2}{4\alpha t}\right)$$

$E_1(x)$ is the exponential integral function which can be evaluated by numerical computing programs such as MATLAB®.

Analyzing a TRT using an analytical method consists in using an iterative process to find the values of k_{eq}, C_p (or indirectly α) and R_b that analytically reproduce the experimental n_t measurements of T_f the best.

Concretely, values of k_{eq}, C_p and R_b are selected, the equations presented above are solved using the selected values, and the error between the calculated T_f^A and the measured T_f^E is evaluated. The process is repeated for a wide panel of values of k_{eq}, C_p and R_b and the combination providing the lowest error is selected.

The Mean Absolute Error (MAE) is calculated as follows:

$$MAE(T_f^E(t_i), T_f^A(t_i)) = \sum_{i=1}^{n_t} \frac{|T_f^E(t_i) - T_f^A(t_i)|}{n_t}$$

If 3 parameters are varied (k_{eq}, C_p and R_b), the MAE is a 3 dimensional matrix that can be represented by 3 color maps.

If 4 parameters are varied (T_g, k_{eq}, C_p and R_b), the MAE is a 4 dimensional matrix that can be represented by 4 color maps.

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Appendix C

Borehole Thermal Resistance Calculation for a Concentric Arrangement

The equivalent thermal resistance for any borehole can be expressed by:

$R_b = R_{grt} + R_{tub} + R_{film}$

R_{grt} the grout resistance: depends on the conductivity of the fill and borehole geometry.

R_{tub} the resistance of the pipe ins contact with the grout: depends on the conductivity and geometry of the pipe.

R_{film} the convective resistance of the fluid.

For a concentric arrangement such as the HPGX (Rafferty and Kavanaugh, 2014):

$R_{film} = 1/\pi d_i h_i$

d_i the inside diameter of the pipe in contact with the grout

h_i the film coefficient: $h_i = Nu\ .\ k_f/d_i$

Nu the Nusselt number. For a transient flow (2300 < Re < 10000) the Gnielinski equation is used:

$Nu = \dfrac{(f/8)(Re - 1000)Pr}{1 + 12.7(f/8)^{1/2}(Pr^{2/3} - 1)}$ where $f = (0.79ln(Re) - 1.64)^{-2}$

Pr the Prandtl number (thermal and hydrodynamic phenomena): $Pr = \mu C_p/k_f$

Re the Reynolds number (inertial and viscous forces): $Re = \rho\nu d_h/\mu$

d_h the hydraulic diameter of the outer water annulus

$R_{tub} = ln(d_o/d_i)/2\pi k_p$

d_o the outside diameter of the pipe in contact with the grout

k_p the pipe conductivity in steady state heat transfer conditions

$R_{grt} = ln(d_b/d_o)/2\pi k_{grt}$

d_b the borehole diameter

k_{grt} the grout conductivity

Note: All models calculating R_b assume that wells do not have any thermal capacity ($\rho C_p = 0$) and heat transfer is done in steady state conditions (independent from time).

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Case Thermal Resistance		
Casing ID (in)	4.360	
Casing OD (in)	4.610	
Casing K (Btu/hr-ft-F)	0.28	
FGS Composite Case (ft-F/BTUH)	**0.0317**	
Fluid Boundary Layer Thermal Resistance		
Flow rate (gpm)	13.30	
Density (lb/ft^3)	62.32	
Viscosity (lb/ft-hr)	2.42	
Volumetric Heat Capacity (Btu/F-ft^3)	62.23	
Thermal Conductivity (Btu/hr-ft-F)	0.34	
Drop Tube OD (in)	2.66	
Friction Factor	172.8611	
Hydraulic Diameter (ft)	0.1417	
Area (ft^2)	0.0651	
Fluid Velocity (ft/hr)	1638.91	
Reynolds	5979.10	
Prandtl	7.05	
Nusselt (Gnielinski Correlation)	4769.49	
Convective Heat Transfer Coefficient (Btu/hr-ft^2-F)	11547.78	
Surface Proturbence Effect (50%-500%)	0%	
Boundary Layer (ft-F/BTUH)	**0.0001**	
Grout Thermal Resistance	**Carbon**	**Sand**
Bore Diameter (in)	6.0	6.0
Casing OD (in)	4.61	4.61
Grout (Btu/hr-ft-F)	3.00	2.10
Grout Ring (ft-F/BTUH)	**0.0140**	**0.0200**
Total Borehole Resistance	**0.0457**	**0.052**

BOREHOLE RESISTANCE CALCULATIONS - RYGAN SPREADSHEET

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Appendix D

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MATHILDE KREBS LLC

August 1, 2023

Thermal Response Test (TRT) Procedures, Equipment Requirements and Recommendations for Typical 1.5” U-bend Geothermal Well and Rygan HPGX 4.3”

Why Specific Recommendations for TRT?

The widely used graphical line-source method is simple to apply and requires very little computing power but has the following shortcomings:

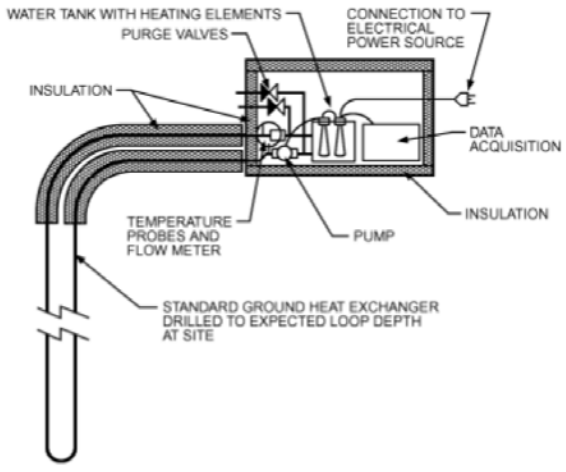
- Ground diffusivity has to be assumed, and heat input has to be constant.
- A thermal steady state has to be achieved for the method to be applicable.
- Constant temperature along the borehole length is assumed.

The error on the borehole equivalent resistance value increases as the flow rate decreases and the borehole length increases, leading in most cases to an overestimation of borehole resistance for deep coaxial heat exchangers such as Rygan HPGX [(1)].

For these reasons we recommend following the below TRT procedures that allow the application of appropriate analytical methods for accurate ground formation and borehole properties’ calculations (ground temperature, conductivity, borehole resistance, etc.).

Test Apparatus

- Accuracy of temperature measurement and recording devices should be less than ±0.5˚F [(2)].
- Accuracy of combined power transducer and recording device should be less than ±2% of the reading [(2)].
- Testing unit should have a system allowing air purging during test [(2)].
- Data acquisition equipment should be capable of recording at least once every 10 minutes (ideally 30 seconds) [(2)].



FROM ASHRAE HANDBOOK 2019 - HVAC APPLICATIONS - CHAP 35

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Test Installation

All aboveground piping should be insulated with a minimum of 0.5in closed cell insulation, or equivalent, with a reflective jacketing material limiting gains/losses through radiation [(2)].

Acceptable Test Results

- Standard deviation of input power should be less than ±1.5% of the average value, and peaks less than ±10% of average [(2)].
- Satisfy criterion listed in below procedures.

Procedures

- Start **tests at least 1 week after test well installation** is complete, and perform all tests in the following sequence, 1 being the first to be performed and 4 last.
- If a well needs to be retested, its fluid temperature should be allowed to return to within 0.5˚F of the pretest initial ground temperature (typically 14 days) [(2)].
- **Provide drilling log** with advancement rate, water discharge rate, and ground material types with their depths to thermal response test analyst.
- **Provide all data logging results in a spreadsheet** format to thermal response test analyst.

---

1. Vertical Thermal Profile (only one well)

- In the liquid filled borehole, insert a probe and record the temperature every 20ft from the bottom to approximately 130fbgl [(3)], and then every 10ft to ground level.
- Wait until fluid temperature stabilizes before recording temperature and exact depth of measurement, then move the probe to next depth.
- This test allows to evaluate the vertical variation of the ground temperature and extract the effect of seasons before calculating the average undisturbed temperature.

---

2. Continuous Circulation Test (before each test)

- Pump ON, Heat OFF
- Duration: 12h or until the temperature is stable.
- Record temperature at inlet and outlet of test apparatus (at a minimum), flow rate and time.
- Allows measuring the average ground temperature at the time of the test and detecting potential sensor bias.

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3. Heating Test

- Pump ON, Heat ON
- Duration: 72h or until thermal static state is achieved (curve of temperature vs time follows a line, not a curve anymore).
- Record temperature at inlet and outlet of test apparatus (at a minimum), power rate, flow rate and time.
- Recommendations per Geothermal system type:

	HPGX 4.3"	**U-bend 1.5"**	**Notes**
Power	17.5 W/ft min.	15 W/ft min.[2]	Watts per foot of total bore depth.
Flow rate	• Adjust flow rate to provide a differential loop temperature of approximately 10˚F. • Flow rate should ensure turbulent flow condition in heat exchanger pipes.		Install balancing valve if testing apparatus is not equipped with a variable speed pump.
Duration	72h	72h	Or until static state is achieved.

4. Relief Test

- Pump ON, Heat OFF
- Duration: 12h minimum.
- Record temperature at inlet and outlet of test apparatus (at a minimum), power rate, flow rate and time.

[1] Beier RA. Vertical temperature profile in ground heat exchanger during in-situ test. Renew Energy 2011;36:1578-87.
[2] recommendation similar to ASHRAE Handbook 2019 - HVAC Applications - Chapter 35
[3] feet below ground level

Sincerely yours,

Mathilde Krebs

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Document type

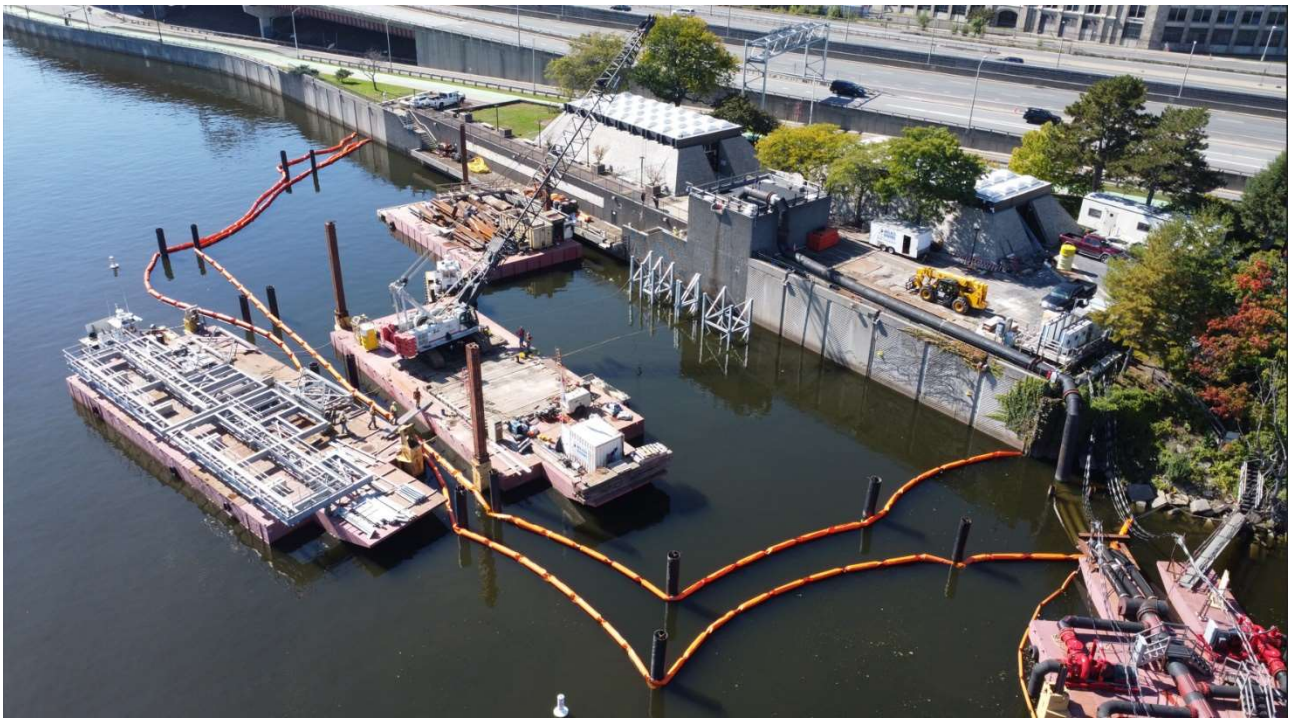
Engineering Report

Date

April 17, 2023

ESP RENEWABLES STUDY SUBMISSION- ESP RIVER WATER TEMPERATURE CONTROL PLAN

RENEWABLES STUDY



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ESP RENEWABLES STUDY SUBMISSION- ESP RIVER WATER TEMPERATURE CONTROL PLAN

RENEWABLES STUDY

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EXECUTIVE SUMMARY

New York State Department of Environmental Conservation (NYSDEC) identified in the 4/1/22 Engineering Report Approval letter three required submissions. The first required submission for the Thermal Study Report was provided on 1/31/23. The second submission is the Renewables Study due on 4/18/23 and this submission is for that requirement. The final submission of the OGS selected physical plant updates/modifications as per "Renewables Study" is due by 8/8/23.

New permitting restrictions for the operation of Empire State Plaza (ESP) river water cooling system predicated a review of compliance certainty. Reviewing historical data for both the plant operations and ambient conditions indicate that extreme heat weather events would yield future operational non-compliance with the permitted system discharge temperature. This report presents current viable alternatives for the next phase of projects at the facility to reduce the discharge temperatures that assist in maintaining operational compliance with the forthcoming permit restrictions.

It's important to note that Phase 1 of the Empire State Plaza Central Air Conditioning Plant (CACP) improvements was the installation of a new electric driven 6,000 ton chiller. The electric chiller replaced one of the five (5) 4,500 ton steam driven chillers at a cost of approximately $25 million. The electric chiller started operation in 2022 and as OGS previously shared with DEC, there was a delay with the startup and commissioning of the chiller. Due to the timing of the delay during startup of the unit, the completion of the planned Thermal Study Update Report for the Empire State Plaza Discharge to the Hudson River was delayed for one year.

The delay was due to a manufacturing error in the construction of the electric chiller at Carrier's Plant and wasn't identified until start-up of the machine in July 2021. Because of this delay, there was limited operational data from the electric chiller and its resultant impact on the river was received and shared with the DEC in the Thermal Study Report submission. Due to the loss in operational data from the delay, the Phase 2 alternatives identified in this report could have begun earlier, progressed further, or completed. This would have allowed additional time to further develop design efforts for flow modeling and hydraulic analysis of the proposed alternatives and also research additional alternatives for this submission. As OGS progresses with the selected alternatives, additional improvements may be identified and implemented.

Ramboll was provided with historical data associated with the river water system including inlet and discharge water temperatures, system flow rates, and chiller plant operations. Additionally, historical Hudson River water temperatures and metrological data were reviewed to understand the local climate and operating conditions.

The analysis identified opportunities to maximize thermal dilution of the discharge water with two alternatives developed to increase river water flow through the system. A third alternative is to support the increased flow demands and also needed redundancy with additional pumping capacity for the system. A final alternative (fourth) was identified to convert additional cooling capacity from steam driven to electrically driven chillers.

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1. PROJECT BACKGROUND AND HISTORY

1.1 Site Information

The Empire State Plaza (ESP) maintains a river water cooling system that operates under NYS DEC SPEDES Permit number NY0104060. The river water cooling system extracts water from the Hudson River and returns it to the Hudson River at an elevated temperature. The river water extraction system consists of six vertical turbine pumps, four strainers, and a flow meter. The river water supplies multiple flow paths with the majority going to the Empire State Plaza Central Air Conditioning Plant (CACP) and the remainder going to irrigation, reflecting pools, MVP arena, SUNY buildings, and two bypasses.

The cooling water is collected and combined with city of Albany storm water prior to its discharge into the Hudson River. There is no flow meter on the storm water; however, there is metering which monitors the cooling water flow and temperature into the CACP, while the permit discharge temperature is monitored at the outfall (immediately south of the U-Haul Building) just prior to entering the Hudson River.

1.2 Ownership and Service Area

The Empire State Plaza river water cooling system is a state-owned facility with OGS responsible for the operations and maintenance of the facility.

1.3 Existing Facilities and Present Condition

The river water cooling system was constructed when the ESP was built in the early to mid-1960's. The equipment is serviceable and continues to be operated. Upgrades to the intake structure are currently underway. The intake tunnel and nearly all the piping is original and is also serviceable. One major upgrade to the Plaza's cooling system was the replacement of one of the 1960's era 4,500 ton steam driven chillers with a 6,000 ton electrically driven chiller, at a cost of $25 million. This project was completed in 2022, after a 1 year delay. OGS discharge data indicated a peak heat load prior to recent investments of about 485 Million British Thermal Units per hour (MBTU/hr), and post Chiller Plant upgrade data indicated a peak heat load of about 350 MBTU/hr. The discharge data show that heat load reductions of approximately 28% have occurred at the Chiller Plant due to OGS investments and improvements over the last several years.

1.4 Definition of the Problem

The NYS DEC imposes three permitting constraints on the system to protect the local waterway. The SPDES Number is NY0104060 and the DEC Number is 4-0101-00010-00001-0 with an effective date of 8/1/2019 and an expiration date of 7/31/2024. Those constraints are:

- Maximum river water use of 92 million gallons per day (MGD) (monitored continuously)
- Maximum discharge temperature of 90 °F; this requirement is identified in the current SPEDES permit as 100 °F but will become 90 °F effective in July of 2024.
- Maximum temperature difference between inlet and outlet temperatures of 24 °F

There was an additional constraint discovered with the conversion of the 4,500 ton steam powered chiller to electric power. Although heat rejection is less due to the removal of the steam

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condenser the new chiller requires more river water flow per cooling ton vs the steam driven chillers. The increase in river water flow for chiller operational purposes reduces available flow which is necessary elsewhere in the system.

The current river water system does not have the ability to exceed the maximum river water use of 92 MGD and is in compliance with this requirement. ESP does not exceed the 24 °F temperature differential and is in compliance with this requirement. On occasion, the discharge temperature exceeds 90 °F. This report identifies several alternatives that would further reduce discharge temperature and heat load rejected to the river in an effort to maintain compliance with the SPDES permit constraints in the future.

1.5 Financial Status

This report will identify the financial implications associated with each alternative proposed.

2. ALTERNATIVES ANALYSIS

2.1 Approach

Ramboll was provided with historical data associated with the river water system including inlet and discharge water temperatures, system flow rates, and chiller plant operations. The data was reviewed for out of compliance events[1]. Additionally, historical Hudson River water temperatures and metrological data were reviewed to understand the local climate and operating conditions. Through this review, Ramboll identified that the river water cooling system does exceed a discharge temperature of 90 °F approximately 8% of the year when high outside air temperatures and high river water temperatures coincide. While undergoing this study a heat wave occurred in August of 2022 which enabled the project team to observe an exceedance which is used as the peak day event reference in this report.

2.1.1 Hudson River Temperature Trends

Daily Hudson River water temperatures recorded from 2003 to 2021 were analyzed to better understand typical and extreme operating conditions. The analysis, including the analysis period average, is included Figure 1. The highest recorded daily river water temperature was approximately 85 °F, while the average high is approximately 78 °F. These conditions generally occur during July and August.

An additional permit constraint states that the differential temperature between the Hudson River water temperature and discharge temperature can be a maximum of 24 °F. At the maximum recorded river water temperature of 85 °F the differential temperature can only be 5 °F to remain in compliance with the permit constraint of 90 °F maximum discharge temperature. This is an 80% reduction in differential temperature from the possible 24 °F. The cooling capacity of the river water system is directly proportional to the change in temperature between the intake water temperature and discharge water, thus at the recorded daily high river water temperature of 85 °F, the cooling capacity is also reduced by approximately 80%, when the cooling demand is generally highest.

[1] Discharge temperature occurrences above 90°F are not currently out of compliance but were identified to understand if the facility could be out of compliance in the future.

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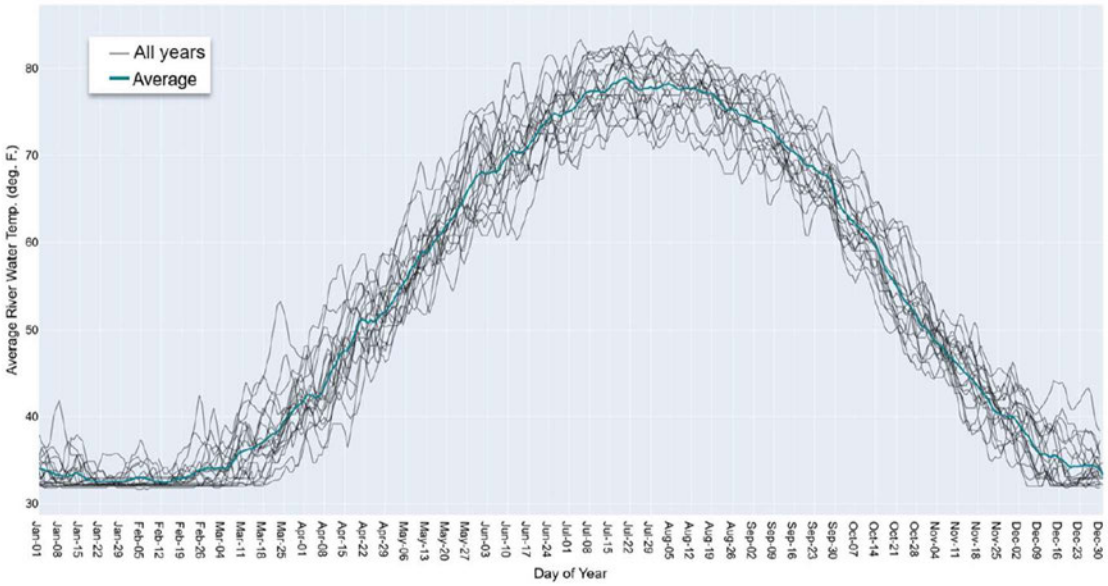

Figure 1. Daily River Water Temperature (USGA Gauge 01359139 From 2003 to 2021)

2.1.2 Peak cooling demand/Analysis Reference Day

On 8/4/22 it was observed that the Albany NY area would see unusually hot weather conditions which would exceed the ASHRAE design day conditions. The observed dry bulb temperature was 97 °F where the ASHRAE Cooling dry bulb temperature for a 0.4% confidence interval is 89 °F. Since the weather conditions were so extreme, the project team monitored and recorded the system performance. These conditions are expected to represent the peak cooling condition.

8/4/22 OPERATING CONDITIONS	
RFPS RIVER WATER FLOW	44,413 GPM[2]
RIVER WATER INLET TEMPERATURE	81.3 F
CACP WATER SUPPLY TEMPERATURE	81.3 F
CACP WATER RETURN TEMPERATURE	95.8 F
RIVER WATER OUTLET TEMPERATURE	92.4 F
RIVER WATER FLOW AT ELECTRIC CHILLER	37,958 GPM[3]
TOTAL CHILLER TONNAGE	14,504 Tons

Table 1. Reference Day Conditions

2.1.3 Temperature Extremes

While the conditions experienced on 8/4/22 resulted in an outlet temperature above the future 2024 permitted level, it is important to note that they are not the most extreme that could be

[2] This instantaneous flow rate equates to 63.95 MGD

[3] As calculated by summing up the three river water flow meters on chillers 2, 3, and 4 at the time of the observation.

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expected for the location during the permit life cycle. The Hudson River has reached temperatures up to 85 °F during times coinciding with the peak cooling season. The 20- and 50-year anticipated extreme ambient dry-bulb conditions are 99 °F and 104 °F, respectively[4]. The coincidence of these extreme ambient conditions combined with resultant increased river water temperatures would lead to additional non-compliance events.

2.2 Cost Estimate

A cost estimate is provided in the comparison of alternatives section of this report.

2.3 Non-Monetary Factors

Non-compliance risk is limited to extreme heat events during the cooling season. If limited flexibility in seasonal compliance were allowable, permit limits would be met with the system in its current state. The river water system has historically only exceeded the permit discharge temperature limit when the river water temperature is above approximately 78.9 °F.

[4] ASHRAE Design Basis Weather Data for Albany, NY.

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3. SUMMARY AND COMPARISON OF ALTERNATIVES

OGS has a daily river water extraction limit of 92 million gallons per day (MGD). The river water pump station has six vertical turbine pumps and during the reference peak day condition, the extraction rate with all six pumps running was 63.95 MGD. OGS will operate all six pumps during the height of the summer when river water temperatures are warmest. This extraction rate occurred on the reference day which led to a discharge temperate of 92.4 °F. This exceeds the 2024 permit's allowable discharge temperature constraint.

The river discharge temperature is a function of the inlet temperature, the heat being rejected, and the volume of water that it is discharged into. By increasing the flowrate, the discharge temperature will be reduced. Current operating conditions of the system were tested to identify opportunities for increasing maximum flow within the existing system. The plant operators were able to identify various opportunities for flow increase which resulted in a maximum flow of 72.96 MGD. Further increasing the flowrate of the system to achieve the maximum permittable would allow for thermal dilution using the river water volume and a reduced discharge temperature.

Table 2 includes the capabilities of thermal dilution to maintain temperature outlet compliance. Importantly, at the systems currently identifiable max flow rate of 72.96 MGD, the plant would be able to maintain outlet temperature compliance up to an 80.27 °F inlet temperature, roughly 1 °F below the inlet temperature experienced on the reference day. To maintain outlet temperature compliance on the reference day, river water flow would need to increase to 81.6 MGD. If the permittable flow of 92 MGD is used the system would be able to maintain outlet temperature compliance with an inlet temperature up to 82.28 °F, 1 °F above the reference day conditions. Three alternatives are discussed to achieve the permitted flow rate through the system.

CASE	RIVER WATER FLOWRATE (MGD)	OUTLET TEMP AT REFERENCE CONDITIONS, 81.3 F INLET TEMP (F)	MAX INLET TEMP. FOR PERMIT COMPLIANCE 90F OUTLET TEMP (F)
Reference Day Condition	63.95	92.40	78.90
Max Flow Immediate Implementation	72.96	91.03	80.27
Outlet Temperature Compliance Flow	81.60	90.00	81.30
Permit Max Flow	92.00	89.02	82.28

Table 2. Various Flow Conditions and Corresponding Outlet Temperature and Maximum Inlet Temperature for Permit Compliance

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3.1 Alternative 1: Enhancement of the system's backpressure valve

3.1.1 Alternative Approach

This approach will modify the system's existing backpressure valve (Ross valve) and decrease the current back pressure. This backpressure valve was installed in 2013 to conserve energy by reducing head pressure on the 800 hp river water pumps by not having to pump water up and over an inverted 36" pipe loop. The loop was originally installed to ensure the chillers' condensing barrels remain flooded during operation. The Ross valve limits head pressure by nearly half the amount realized by the inverted pipe loop due to the chillers' condensing barrels being approximately 30 ft in elevation below the inverted loops high point. Despite being installed in 2013 the Ross Valve has not been utilized successfully due to an inferior control system design. A new and improved valve operation and control system is currently being implemented and awaiting parts scheduled for June 2023 arrival. Once in full operation the reduction in head pressure frees up pump capacity that will allow the system to achieve higher flow rates, necessary elsewhere. This alternative must be completed as a first step as it will inform the other alternatives of what remains necessary to meet the 90 °F discharge limitation. Following the completion of this project, OGS will perform testing to calculate the new maximum flowrate and determine the scope of additional alternatives.

3.1.2 Alternative Implementation Timeline

This activity is currently underway and is expected to be complete and tested in 2023. A firm implementation schedule is pending the availability of parts, the modification, and testing.

3.1.3 Alternative Order of Magnitude Cost

This alternative measure will have a limited cost of approx. of $150,000 to implement and is currently being pursued by OGS.

3.2 Alternative 2: Revise piping flow paths to increase system flow

3.2.1 Alternative Approach

The approach will investigate the full potential of two existing bypass locations between the river water supply and return pipes currently installed in the CACP. It will also investigate the need for additional or alternative flow paths for the system. Piping modifications to the existing system will be investigated and made with the goal of allowing increased flow rates through the system for dilution purposes. The requirements for modifications will be studied in detail once the Ross valve has been repaired and fully tested.

3.2.2 Alternative Implementation Timeline

This alternative could be accomplished over a 1–3 year period depending on the flow path modifications selected from the study. Piping changes are typically scheduled to occur during planned facility shutdowns which occur in the Fall of each year.

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3.2.3 Alternative Order of Magnitude Cost

Substantial changes to infrastructure such as large pipe re-sizing or significant additional piping paths could be more than $1 million, depending on the extent of work. Work under this approach will require flow modeling and a hydraulics analysis, post Ross Valve implementation, before a more refined cost estimate can be provided.

3.3 Alternative 3: Provide additional pumping capacity

3.3.1 Alternative Approach

This approach will install additional pumps or upsize the current pumps to maximize flow and provide redundancy through the system. The alternative requirements will be based on the results of the Ross Valve modifications and Revised Flow Path and analysis. This project has been initiated with NYPA as a Design/Build project. Detailed engineering and design will be required to establish what the system's pumping requirements will be outside of the currently needed redundancy.

3.3.2 Alternative Implementation Timeline

This approach is anticipated to be a multiyear design and installation effort which could occur over a 2–5 year period.

3.3.3 Alternative Order of Magnitude Cost

This approach to increase the flow by increasing the pumping capacity will have a cost impact with the project ranging between $5-$15 million.

3.4 Alternative 4: Additional chiller electrification

3.4.1 Alternative Approach

OGS replaced a steam driven chiller with an electrically driven chiller as part of Phase 1 of the upgrade to the ESP Chill Plant. This project reduced the heat that is rejected into the Hudson River. Performance data collected by OGS during the Summer of 2022 was compared to the three other steam driven machines used over the summer. Figure 2 shows the regressions of the electric chiller (ch4 in yellow) and the three steam driven chillers (ch1, ch2, ch3 in blue, orange, and grey) at the CACP. It shows that the steam driven chillers reject approximately 2.5 tons of heat for every 1 ton of cooling produced while the electric chiller rejects approximately 1.2 tons of heat for every 1 ton of cooling produced. This represents a 50% reduction in rejected heat from electric chillers vs steam driven chillers.

Steam turbine driven chillers have two forms of heat to reject. The first is the heat of refrigeration which is common to all chillers. The second is the heat from the steam condenser which is the latent heat of vaporization which is removed to condense the steam into a liquid. The condensate is recirculated back to the boiler plant to be evaporated again. Because of this second heat source, steam driven chillers reject more heat than electrically driven chillers.

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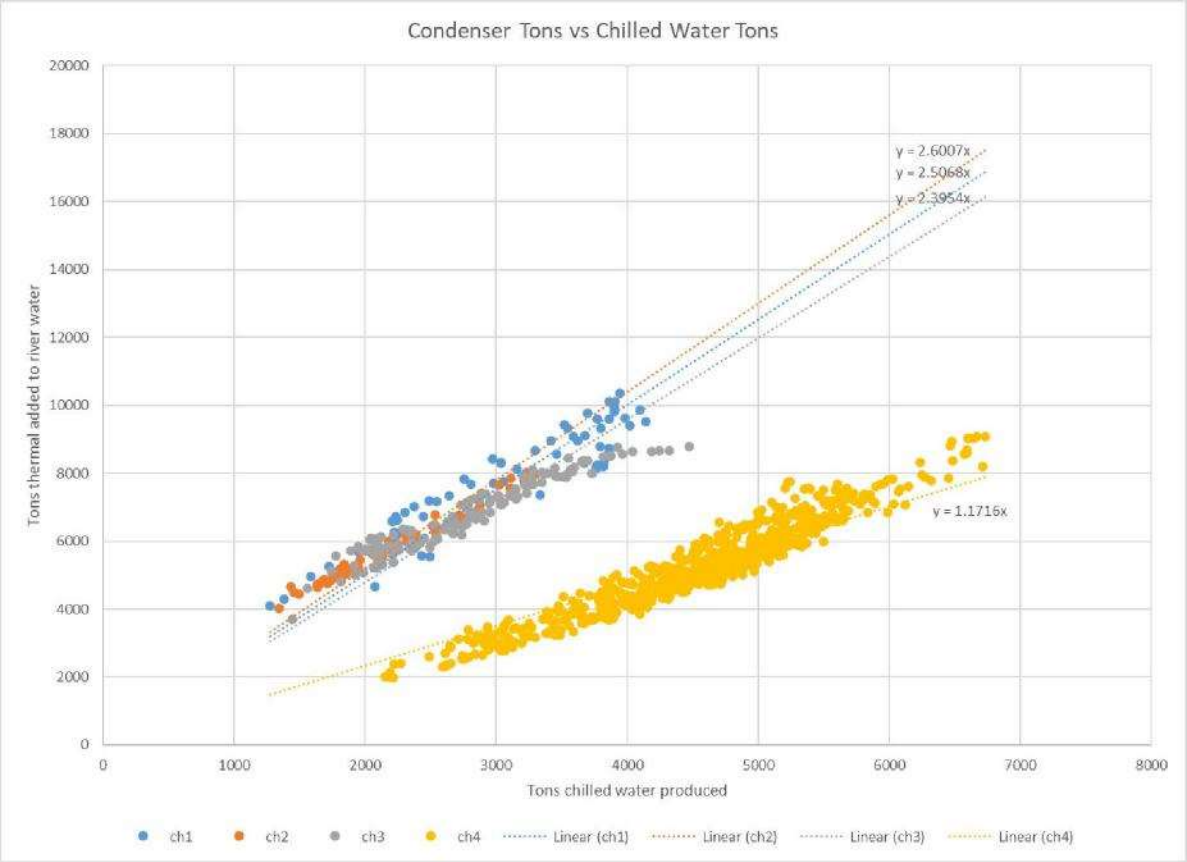

Figure 2. Heat Rejected from Steam and Electric Chillers

The current peak chilled water demand is approximately 14,504 tons, of which 6,000 tons came from the electrically driven chiller. The remaining demand is met with the steam driven machines. There may be an opportunity to convert some of the remaining steam driven cooling capacity to electrically driven chillers to further reduce the heat that is rejected to the Hudson River and improve compliance with the SPDES permit during reference peaking conditions.

Replacing any of the remaining larger steam chillers is limited by the electric supply. Currently there is not enough electrical power available by National Grid for another chiller of the same size while maintaining site redundancy and reliability. This issue will need to be further studied and developed to determine the allowable cooling capacity. Conversations with National Grid to determine if there is capacity in their network for additional electrical supply to OGS have not occurred in detail and may be another potential impact to electric conversion. As noted in the earlier sections of this report pumping capacity will also need to be reviewed to determine if there is capacity to support another change to the system flow to support the electric unit.

3.4.2 Alternative Implementation Timeline

This alternative is expected to be a multiyear effort after the previous alternatives are completed and evaluated to review the impacts to the system flow. The next step would be an evaluation of the potential cooling capacity conversions. For planning purposes, the project is expected to take between 3-6 years after the completion of the previous alternatives.

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3.4.3 Alternative Order of Magnitude Cost

OGS recently completed a project to install a 6,000-ton electrical chiller and that project was valued at approximately $25 million. There may also be additional building modifications needed to the Chill Plant that have not been identified but were a part of the initial chiller replacement project. The cost has not been completely evaluated due to the cost needed for National Grid, building modifications, and a determination of the amount of cooling capacity to convert. Pumping capacity may need to also be improved to support the conversion of more cooling capacity to electric. The expected to cost would between $25 million and $100 million depending on the amount of modifications to existing system capacities.

4. RECOMMENDED ALTERNATIVE

OGS is still evaluating and further developing the engineering behind the identified alternatives. As noted in the specific alternatives, some of these efforts have begun. Since the results of the alternatives will inform the next alternative, there may be other alternatives not noted in this submission that are developed because of the additional engineering work.

OGS is still committed to identifying the selected alternatives for the required submission of the OGS selected physical plant updates/modifications as per "Renewables Study" due to DEC on 8/8/23.

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Appendix F – Total Project Summary (EEMs, Building Upgrades and Decarbonization Scenarios)

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Empire State Plaza
Total Project Summary (EEMs, Building Upgrades, Decarbonization Scenarios)

EEM No.	Potential EEM	Buildings Affected	Annual Electrical Savings (kWh/yr)	Electrical Peak Demand Savings (kW)	Annual Natural Gas Savings (Therms/yr)	Annual Energy Cost Savings (2022 $/yr)	Annual Energy Cost Savings (2025 $/yr)	Estimated Capital Cost (2022 $)	Estimated Capital Cost (2025 $)	Simple Payback Period (years)	SIR	Annual GHG Reduction (MTCO2e)	Cost per MTCO2e Reduction	Percent EUI Reduction	Estimated Implementation Timeframe from Year 0 (years)	Notes
	Energy Efficiency															
PL-EEM-2	**Replace Double Pane Windows**	Plaza Buildings	499,144	20.2	293,184	$176,064	$192,983	$56,908,290	$62,377,011	323.2	0.0	1,612	38,700	1.6%	5-15	3
PL-EEM-4	**Lab Exhaust Energy Recovery**	Plaza Buildings	-1,771,690	-233.2	1,748,480	$834,030	$914,178	$15,790,450	$17,307,866	18.9	0.0	9,092	1,904	8.7%	2-7	3
PL-EEM-5	**Laboratory VAV Exhaust/Supply**	Plaza Buildings	3,111,277	23.6	189,191	$287,622	$315,262	$19,825,297	$21,730,450	68.9	0.0	1,346	16,146	1.5%	2-7	3
PL-EEM-7	**Additional Zone Controls on FTR**	Plaza Buildings	728,488	-21.3	659,237	$379,943	$416,454	$252,221	$276,458	0.7	1.3	3,581	77	3.5%	5-10	3
PL-EEM-8	**Laboratory DCV**	Plaza Buildings	2,801,471	-0.9	190,108	$270,665	$296,675	$1,487,166	$1,630,078	5.5	0.2	1,317	1,238	1.5%	2-5	3
EEM-1	**Retro-commissioning**	AESOB	0	0.0	56,435	$0	$36,859	$0	$191,637	5.2	0.6	300	639	0.3%	0-2	1
EEM-2	**Pump Differential Reset**	AESOB, Capitol, State Education Building	134,966	22.3	0	$0	$9,483	$0	$46,020	4.9	3.1	15	3,110	0.0%	0-2	1
EEM-3	**Pneumatic Control to DDC**	State Education Building	152,169	0.0	147,198	$0	$132,083	$0	$2,068,997	15.7	0.7	798	2,591	0.8%	2-5	1
EEM-4	**Steam Trap Program**	AESOB, Capitol, State Education Building	0	0.0	34,388	$0	$16,128	$0	$66,867	4.1	1.1	183	366	0.2%	0-2	1
	SUBTOTAL		**5,655,825**	**-189.4**	**3,318,222**	**$1,948,324**	**$2,330,106**	**$94,263,423**	**$105,695,385**	**48.4**	**0.0**	**18,243**	**5,167**	**18.2%**		
	Plaza Building Renovations															
PL-EEM Package	**Package Results for EEM-1, EEM-3, EEM-6, and Repurpose of Health Lab**	Plaza Buildings	29,980,252	4,140.6	9,925,110	$7,352,579	$8,059,140	$747,509,773	$819,343,283	101.7	0.0	55,999	14,631	56.7%	2-23	3
	SUBTOTAL		**29,980,252**	**4,140.6**	**9,925,110**	**$7,352,579**	**$8,059,140**	**$747,509,773**	**$819,343,283**	**101.7**	**0.0**	**55,999**	**13,349**	**56.7%**		
	Low Carbon Supply Scenario															
EEM-5	**Low Carbon Supply Scenario**	Empire State Plaza	-30,198,078	-41,797.6	5,399,185	$0	$0	$0	$0	N/A	N/A	25,365	0	22.6%	0-23	
	SUBTOTAL		**-30,198,078**	**-41,797.6**	**5,399,185**	**$0**	**$0**	**$0**	**$0**	**N/A**	**N/A**	**25,365**	**0**	**22.6%**		
	GRAND TOTAL		**5,437,998**	**-37,846.4**	**18,642,517**	**$9,300,903**	**$10,389,246**	**$841,773,196**	**$925,038,668**	**89.0**	**0.0**	**99,607**	**9,287**	**97.4%**		

1	Energy savings may be impacted by interactive effects from other measures. These interactive effects were not considered when calculating energy savings.
2	LCCA performed over the expected useful life of each measure (EUL). Annual escalation rates for the utility costs are based on a US Department of Energy (DOE) rate schedule for commercial buildings in the state of New York (Annual Supplement to Handbook 135, Energy Price Indices and Discount Factors for LCC Analysis, NISTIR 85-3273)
3	Measures were evaluated and quantified in a packaged calculation that took interactive factors into account. No additional interactive factors applied to results.

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Appendix G – Techno-Economic Analysis

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CONCEPT ESTIMATE

ENERGY INFRASTRUCTURE MASTER PLAN
NYPA / OGS EMPIRE STATE PLAZA

ALBANY, NY

PREPARED FOR:
RAMBOLL

PROJECT NO: 21-0385a-0436

October 20, 2022
(Original Estimate)

Trophy Point, LLC
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ESTIMATE NOTES / ASSUMPTIONS / CLARIFICATIONS

- BASED ON RAMBOLL ESP BUILDING ASSESSMENTS RECEIVED ON 9/21/2022.
- NEW YORK STATE PREVAILING WAGE RATES FOR ALBANY COUNTY.
- 2022 COSTS, ESCALATION SHOULD BE ADDED AT 3.75% PER YEAR COMPOUNDED TO THE MID-POINT OF CONSTRUCTION.
- NORMAL WORKING HOURS AND CONDITIONS; NO PREMIUM FOR A CONDENSED CONSTRUCTION SCHEDULE IS INCLUDED.
- BASED ON NORMAL SCHEDULING; PREMIUMS FOR DELAYS OR MATERIAL SHORTAGES NOT INCLUDED.
- STANDARD WORK SHIFTS FOR TRADESMEN (NO SECOND / THIRD SHIFT WORK OR OVERTIME IS INCLUDED).
- COMPETITIVE BIDDING PROCESS.
- PREMISES WILL BE OCCUPIED DURING CONSTRUCTION. WORK AREAS WILL BE VACANT.
- ESTIMATE ASSUMES CONTRACTOR USE OF BUILDING FREIGHT ELEVATOR FOR DURATION OF PROJECT.

EXCLUSIONS:

- SOFT COSTS (DESIGN FEES, ETC.)
- CONSTRUCTION CONTINGENCY (OWNER CHANGE ORDER RESERVE)
- CONSTRUCTION MANAGER FEES, MARKUPS OR GENERAL CONDITIONS IF A CONSTRUCTION MANAGER IS ENGAGED IN ADDITION TO PRIME CONTRACTORS
- PROJECT LABOR AGREEMENTS
- REPLACEMENT OF LIGHTING, CEILING MOUNTED DEVICES AND SPRINKLER HEADS
- WINDOW TREATMENT REPLACEMENT OR REMOVAL AND REINSTALLATION

Note: This estimate represents a reasonable opinion of cost based on several public and proprietary sources of information. It is not a prediction of the successful bid from a contractor as bids will vary due to fluctuating market conditions, errors and omissions, proprietary specifications, lack of surplus bidders, perception of risk, and so on. Consequently, this estimate is expected to fall within the range of bids from multiple competitive contractors or subcontractors. However, we do not warrant that bids or negotiated prices will not vary from the final construction cost estimate.

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PROJECT SUMMARY

BUILDING	GSF	EEM-1 Replace single pane windows with high performance windows	EEM-2 Replace double pane windows with high performance windows	EEM-3 AHU Modernization	EEM-4 Energy Recovery	EEM-5 Laboratory VAV exhaust/supply	EEM-6 Install occupancy based HVAC controls	EEM-7 Additional zone controls on FTR	EEM-8 Laboratory DCV	BUILDING TOTAL
AGENCY BUILDING 1	198,196		$ 4,219,783	$ 27,545,298			$ 889,422			**$ 32,654,503**
AGENCY BUILDING 2	198,196		$ 4,219,783	$ 27,545,298			$ 889,422			**$ 32,654,503**
AGENCY BUILDING 3	198,196		$ 4,219,783	$ 27,545,298			$ 889,422			**$ 32,654,503**
AGENCY BUILDING 4	198,196		$ 4,219,783	$ 27,545,298			$ 889,422			**$ 32,654,503**
CORNING TOWER	927,423		$14,710,641	$ 121,013,922			$ 4,161,892			**$ 139,886,455**
HEALTH LABORATORY	285,000				$15,790,450	$ 19,825,297			$1,487,166	**$ 37,102,913**
REPURPOSED HEALTH LAB (OFFICE SPACE)	485,210		$ 3,251,622	$ 54,779,599			$ 2,177,422			**$ 60,208,644**
SWAN STREET BUILDING	842,727	$ 681,835	$ 6,815,915	$ 90,931,266			$ 3,517,964	$ 63,644		**$ 102,010,624**
THE EGG	159,362	$ 567,788		$ 13,856,047			$ 665,257			**$ 15,089,091**
CEC	1,582,504	$4,463,377	$ 6,372,673	$ 165,764,160			$ 6,606,163	$ 16,500		**$ 183,222,874**
JOB	261,177		$ 3,059,408	$ 32,780,353			$ 1,090,283	$ 42,430		**$ 36,972,474**
LOB	650,348		$ 5,818,898	$ 77,576,677			$ 2,714,878	$ 129,646		**$ 86,240,098**
MAIN PLATFORM	3,878,694			$ 46,374,106			$ 4,047,904			**$ 50,422,010**
EEM TOTAL	**9,865,229**	**$5,713,000**	**$56,908,290**	**$ 713,257,323**	**$15,790,450**	**$ 19,825,297**	**$ 28,539,450**	**$ 252,221**	**$1,487,166**	
TOTAL										**$ 841,773,196**

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AGENCY BUILDINGS 1-4 DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-2						
EXTERIOR DOORS AND WINDOWS						
Replace double pane glazing system with high performance aluminum and glass	15,922 SF	$90.00	$1,432,980	$85.00	$1,353,370	$2,786,350
Replace exterior doors, frames and hardware	6 EA	$5,000.00	$30,000	$770.00	$4,620	$34,620
SUB-TOTAL EEM-2			$1,462,980		$1,357,990	$2,820,970
GENERAL CONDITIONS	10.0%					$282,097
OVERHEAD AND PROFIT	10.0%					$310,307
DESIGN CONTINGENCY	15.0%					$512,006
HIGH RISE PREMIUM	7.5%					$294,403
TOTAL EEM-2						**$4,219,783**
EEM-3						
GENERAL CONSTRUCTION						
Remove lay-in and hard ceilings as asbestos containing to accommodate HVAC ductwork replacement (assume 70% of building area)	138,737 SF	$2.50	$346,843	$12.64	$1,753,636	$2,100,478
New floor penetrations for pipe and duct risers including reframing and abatement (assume 2 per floor)	42 EA	$7,500.00	$315,000	$7,500.00	$315,000	$630,000
2 hour rated duct shaft enclosures	4,032 SF	$7.00	$28,224	$12.25	$49,392	$77,616
New suspended acoustic tile ceilings	138,737 SF	$4.25	$589,632	$3.00	$416,211	$1,005,843
Miscellaneous patch / paint	198,196 SF	$0.50	$99,098	$0.50	$99,098	$198,196
Temporary protection and partitions	198,196 SF	$0.75	$148,647	$1.00	$198,196	$346,843
TOTAL GENERAL CONSTRUCTION			**$1,527,444**		**$2,831,533**	**$4,358,976**

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AGENCY BUILDINGS 1-4 DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
HVAC						
DEMOLITION						
Remove air handlers including ductwork, piping and controls	198,196 SF	$1.25	$247,745	$5.00	$990,980	$1,238,725
EQUIPMENT						
Variable air volume air handling units with energy recovery wheel, hot and chilled water heating and cooling	211,000 CFM	$10.00	$2,110,000	$0.40	$84,400	$2,194,400
Air handling units with hot and chilled water heating and cooling (no energy recovery)	8,600 CFM	$7.50	$64,500	$0.90	$7,740	$72,240
Pumps	4 EA	$24,000.00	$96,000	$6,660.00	$26,640	$122,640
Hydronic accessories (air separators, expansion tanks)	1 LS	$35,000.00	$35,000	$7,500.00	$7,500	$42,500
VAV's	248 EA	$650.00	$161,034	$660.00	$163,512	$324,546
PIPING SYSTEMS						
Hot and chilled water piping including valves fittings and accessories	40,000 LF	$30.50	$1,220,000	$38.00	$1,520,000	$2,740,000
Equipment prefabricated valve assemblies including ball, balance valves, strainers, etc. for supply and return pipe	1 LS	$115,000.00	$115,000	$95,000.00	$95,000	$210,000
SHEET METAL WORKS						
Galvanized steel ductwork	185,000 LBS	$2.10	$388,500	$8.20	$1,517,000	$1,905,500
Ductwork accessories	1 LS	$85,500.00	$85,500	$333,700.00	$333,700	$419,200
Air outlets and inlets	825 EA	$115.00	$94,875	$151.00	$124,575	$219,450
INSULATION						
Duct insulation, mineral-blanket type, fiberglass, FSK vapor barrier including fittings	111,000 SF	$0.80	$88,800	$4.80	$532,800	$621,600
Hydronic piping insulation	40,000 LF	$6.30	$252,000	$11.00	$440,000	$692,000
CONTROLS						
Direct digital controls and temp sensors at AHU's and VAV's						
- ERV	2 EA	$18,000.00	$36,000	$26,000.00	$52,000	$88,000
- AHU	2 SF	$11,500.00	$23,000	$17,200.00	$34,400	$57,400
- Pumps	4 EA	$3,000.00	$12,000	$4,200.00	$16,800	$28,800
- VAV	248 EA	$2,200.00	$545,039	$3,300.00	$817,559	$1,362,598

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AGENCY BUILDINGS 1-4 DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$230,000.00	$230,000	$230,000
MISCELLANEOUS						
Crane, material handling, rigging and hoisting	1 LS	$106,300.00	$106,300	$372,050.00	$372,050	$478,350
Cleaning	1 LS	$45,500.00	$45,500	$136,500.00	$136,500	$182,000
Paint and identification	1 LS	$60,700.00	$60,700	$182,100.00	$182,100	$242,800
Cut, patch and firestop	1 LS	$97,100.00	$97,100	$485,500.00	$485,500	$582,600
TOTAL HVAC			**$5,884,593**		**$8,170,755**	**$14,055,348**
SUB-TOTAL EEM-3			$7,412,037		$11,002,288	$18,414,325
GENERAL CONDITIONS	10.0%					$1,841,432
OVERHEAD AND PROFIT	10.0%					$2,025,576
DESIGN CONTINGENCY	15.0%					$3,342,200
HIGH RISE PREMIUM	7.5%					$1,921,765
TOTAL EEM-3						**$27,545,298**
EEM-6						
HVAC						
Occupancy based HVAC controls	198,196 SF	$0.75	$148,647	$2.25	$445,941	$594,588
SUB-TOTAL EEM-6			$148,647		$445,941	$594,588
GENERAL CONDITIONS	10.0%					$59,459
OVERHEAD AND PROFIT	10.0%					$65,405
DESIGN CONTINGENCY	15.0%					$107,918
HIGH RISE PREMIUM	7.5%					$62,053
TOTAL EEM-6						**$889,422**

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CORNING TOWER DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-2						
EXTERIOR DOORS AND WINDOWS						
Replace double pane glazing system with high performance aluminum and glass	55,668 SF	$90.00	$5,010,120	$85.00	$4,731,780	$9,741,900
Replace exterior doors, frames and hardware	16 EA	$5,000.00	$80,000	$770.00	$12,320	$92,320
SUB-TOTAL EEM-2			$5,090,120		$4,744,100	$9,834,220
GENERAL CONDITIONS	10.0%					$983,422
OVERHEAD AND PROFIT	10.0%					$1,081,764
DESIGN CONTINGENCY	15.0%					$1,784,911
HIGH RISE PREMIUM	7.5%					$1,026,324
TOTAL EEM-2						**$14,710,641**
EEM-3						
GENERAL CONSTRUCTION						
Remove lay-in and hard ceilings as asbestos containing to accommodate HVAC ductwork replacement (assume 70% of building area)	649,196 SF	$2.50	$1,622,990	$12.64	$8,205,837	$9,828,827
New floor penetrations for pipe and duct risers including reframing and abatement (assume 2 per floor)	88 EA	$7,500.00	$660,000	$7,500.00	$660,000	$1,320,000
2 hour rated duct shaft enclosures	8,448 SF	$7.00	$59,136	$12.25	$103,488	$162,624
New suspended acoustic tile ceilings	649,196 SF	$4.25	$2,759,083	$3.00	$1,947,588	$4,706,671
Miscellaneous patch / paint	927,423 SF	$0.50	$463,712	$0.50	$463,712	$927,423
Temporary protection and partitions	927,423 SF	$0.75	$695,567	$1.00	$927,423	$1,622,990
TOTAL GENERAL CONSTRUCTION			**$6,260,488**		**$12,308,048**	**$18,568,536**

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CORNING TOWER DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
HVAC						
DEMOLITION						
Remove air handlers including ductwork, piping and controls	927,423 SF	$1.25	$1,159,279	$5.00	$4,637,115	$5,796,394
EQUIPMENT						
Variable air volume air handling units with energy recovery wheel, hot and chilled water heating and cooling	432,385 CFM	$10.00	$4,323,850	$0.40	$172,954	$4,496,804
Air handling units with hot and chilled water heating and cooling (no energy recovery)	796,420 CFM	$6.00	$4,778,520	$0.90	$716,778	$5,495,298
Pumps	4 EA	$75,000.00	$300,000	$15,540.00	$62,160	$362,160
Hydronic accessories (air separators, expansion tanks)	1 LS	$50,000.00	$50,000	$10,000.00	$10,000	$60,000
VAV's	1,159 EA	$650.00	$753,531	$660.00	$765,124	$1,518,655
PIPING SYSTEMS						
Hot and chilled water piping including valves fittings and accessories	180,000 LF	$30.50	$5,490,000	$38.00	$6,840,000	$12,330,000
Equipment prefabricated valve assemblies including ball, balance valves, strainers, etc. for supply and return pipe	1 LS	$480,000.00	$480,000	$400,000.00	$400,000	$880,000
SHEET METAL WORKS						
Galvanized steel ductwork	985,000 LBS	$2.10	$2,068,500	$8.20	$8,077,000	$10,145,500
Ductwork accessories	1 LS	$434,385.00	$434,385	$1,534,630.00	$1,534,630	$1,969,015
Air outlets and inlets	3,000 EA	$115.00	$345,000	$151.00	$453,000	$798,000
INSULATION						
Duct insulation, mineral-blanket type, fiberglass, FSK vapor barrier including fittings	591,000 SF	$0.80	$472,800	$4.80	$2,836,800	$3,309,600
Hydronic piping insulation	180,000 LF	$6.30	$1,134,000	$11.00	$1,980,000	$3,114,000
CONTROLS						
Direct digital controls and temp sensors at AHU's and VAV's						
- ERV	4 EA	$18,000.00	$72,000	$26,000.00	$104,000	$176,000
- AHU	9 EA	$12,000.00	$108,000	$18,000.00	$162,000	$270,000
- Pumps	4 EA	$3,000.00	$12,000	$4,200.00	$16,800	$28,800
- VAV	1,159 EA	$2,200.00	$2,550,413	$3,300.00	$3,825,620	$6,376,033

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CORNING TOWER DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$1,028,300.00	$1,028,300	$1,028,300
MISCELLANEOUS						
Crane, material handling, rigging and hoisting	1 LS	$320,000.00	$320,000	$1,120,000.00	$1,120,000	$1,440,000
Cleaning	1 LS	$144,000.00	$144,000	$384,000.00	$384,000	$528,000
Paint and identification	1 LS	$192,000.00	$192,000	$576,000.00	$576,000	$768,000
Cut, patch and firestop	1 LS	$288,000.00	$288,000	$1,152,000.00	$1,152,000	$1,440,000
TOTAL HVAC			**$25,476,278**		**$36,854,281**	**$62,330,559**
SUB-TOTAL EEM-3			$31,736,766		$49,162,329	$80,899,095
GENERAL CONDITIONS	10.0%					$8,089,909
OVERHEAD AND PROFIT	10.0%					$8,898,900
DESIGN CONTINGENCY	15.0%					$14,683,186
HIGH RISE PREMIUM	7.5%					$8,442,832
TOTAL EEM-3						**$121,013,922**
EEM-6						
HVAC						
Occupancy based HVAC controls	927,423 SF	$0.75	$695,567	$2.25	$2,086,702	$2,782,269
SUB-TOTAL EEM-6			$695,567		$2,086,702	$2,782,269
GENERAL CONDITIONS	10.0%					$278,227
OVERHEAD AND PROFIT	10.0%					$306,050
DESIGN CONTINGENCY	15.0%					$504,982
HIGH RISE PREMIUM	7.5%					$290,365
TOTAL EEM-6						**$4,161,892**

CONFIDENTIAL AND PROPRIETARY

HEALTH LAB DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-4						
HVAC						
EQUIPMENT						
Energy recovery coils	58 EA	$12,500.00	$725,000	$6,650.00	$385,700	$1,110,700
Pumps and accessories	1 LS	$150,000.00	$150,000	$35,500.00	$35,500	$185,500
Air handling unit upgrades to accommodate additional static pressure	29 EA	$45,000.00	$1,305,000	$15,540.00	$450,660	$1,755,660
PIPING SYSTEMS						
Hot and chilled water piping including valves fittings and accessories	14,500 LF	$48.00	$696,000	$76.00	$1,102,000	$1,798,000
Equipment prefabricated valve assemblies including ball, balance valves, strainers, etc. for supply and return pipe	58 EA	$1,150.00	$66,700	$888.00	$51,504	$118,204
SHEET METAL WORKS						
Ductwork modifications at each energy recovery coil	58 EA	$2,500.00	$145,000	$26,640.00	$1,545,120	$1,690,120
Ductwork accessories	1 LS	$31,900.00	$31,900	$339,900.00	$339,900	$371,800
INSULATION						
Duct insulation, mineral-blanket type, fiberglass, FSK vapor barrier including fittings	3,000 SF	$0.80	$2,400	$4.80	$14,400	$16,800
Hydronic piping insulation	14,500 LF	$8.40	$121,800	$16.20	$234,900	$356,700
CONTROLS						
Direct digital controls						
- Hot water coils	58 EA	$4,400.00	$255,200	$6,600.00	$382,800	$638,000
- Pumps	1 LS	$18,000.00	$18,000	$25,200.00	$25,200	$43,200
- Air handling units	29 EA	$4,800.00	$139,200	$7,200.00	$208,800	$348,000
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$150,000.00	$150,000	$150,000
MISCELLANEOUS						
Material handling, rigging and hoisting	1 LS	$119,600.00	$119,600	$418,600.00	$418,600	$538,200
Cleaning	1 LS	$51,300.00	$51,300	$153,900.00	$153,900	$205,200
Paint and identification	1 LS	$68,400.00	$68,400	$205,200.00	$205,200	$273,600
Cut, patch and firestop	1 LS	$109,400.00	$109,400	$547,000.00	$547,000	$656,400
Additional cutting, patching, ceiling and wall repair associated with new pipe routing	1 ALLOW	$125,000.00	$125,000	$175,000.00	$175,000	$300,000

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HEALTH LAB DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
SUB-TOTAL EEM-4			$4,129,900		$6,426,184	$10,556,084
GENERAL CONDITIONS	10.0%					$1,055,608
OVERHEAD AND PROFIT	10.0%					$1,161,169
DESIGN CONTINGENCY	15.0%					$1,915,929
BID CONTINGENCY	7.5%					$1,101,659
TOTAL EEM-4						**$15,790,450**
EEM-5						
HVAC						
EQUIPMENT						
Lab air valves	741 EA	$3,200.00	$2,371,200	$833.00	$617,253	$2,988,453
PIPING SYSTEMS						
Hot and chilled water piping including valves fittings and accessories	45,000 LF	$21.00	$945,000	$26.00	$1,170,000	$2,115,000
Equipment prefabricated valve assemblies including ball, balance valves, strainers, etc. for supply and return pipe	741 EA	$250.00	$185,250	$222.00	$164,502	$349,752
SHEET METAL WORKS						
Ductwork modifications at each air valve (Stainless steel)	741 EA	$350.00	$259,350	$1,332.00	$987,012	$1,246,362
Ductwork accessories	1 LS	$57,100.00	$57,100	$217,100.00	$217,100	$274,200
Air outlets and inlets	1,480 EA	$115.00	$170,200	$151.00	$223,480	$393,680
INSULATION						
Duct insulation, mineral-blanket type, fiberglass, FSK vapor barrier including fittings	2,500 SF	$0.80	$2,000	$4.80	$12,000	$14,000
Hydronic piping insulation	45,000 LF	$6.30	$283,500	$11.00	$495,000	$778,500
CONTROLS						
Direct digital controls						
- VAV	741 EA	$2,200.00	$1,630,200	$3,300.00	$2,445,300	$4,075,500
TESTING, ADJUSTING AND BALANCING						

CONFIDENTIAL AND PROPRIETARY

HEALTH LAB DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
Testing, adjusting and balancing	1 LS	$0.00	$0	$171,000.00	$171,000	$171,000
MISCELLANEOUS						
Material handling, rigging and hoisting	1 LS	$30,000.00	$30,000	$125,000.00	$125,000	$155,000
Cleaning	1 LS	$15,000.00	$15,000	$60,000.00	$60,000	$75,000
Paint and identification	1 LS	$25,000.00	$25,000	$80,000.00	$80,000	$105,000
Cut, patch and firestop	1 LS	$35,000.00	$35,000	$125,000.00	$125,000	$160,000
Ceiling removal, replacement and productivity markup for air valve replacements	741 EA	$150.00	$111,150	$325.00	$240,825	$351,975
SUB-TOTAL EEM-5			$6,119,950		$7,133,472	$13,253,422
GENERAL CONDITIONS	10.0%					$1,325,342
OVERHEAD AND PROFIT	10.0%					$1,457,876
DESIGN CONTINGENCY	15.0%					$2,405,496
BID CONTINGENCY	7.5%					$1,383,160
TOTAL EEM-5						**$19,825,297**
EEM-8						
Demand controlled ventilation	285,000 SF	$1.25	$356,250	$2.50	$712,500	$1,068,750
SUB-TOTAL EEM-8			$356,250		$712,500	$1,068,750
GENERAL CONDITIONS	10.0%					$106,875
OVERHEAD AND PROFIT	10.0%					$117,563
DESIGN CONTINGENCY	15.0%					$193,978
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-8						**$1,487,166**

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REPURPOSED HEALTH LAB

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-2						
EXTERIOR DOORS AND WINDOWS						
Replace double pane glazing system with high performance aluminum and glass	13,353 SF	$90.00	$1,201,770	$85.00	$1,135,005	$2,336,775
SUB-TOTAL EEM-2			$1,201,770		$1,135,005	$2,336,775
GENERAL CONDITIONS	10.0%					$233,678
OVERHEAD AND PROFIT	10.0%					$257,045
DESIGN CONTINGENCY	15.0%					$424,125
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-2						**$3,251,622**
EEM-3						
GENERAL CONSTRUCTION						
Remove lay-in and hard ceilings to accommodate HVAC ductwork replacement (assume 70% of building area)	339,647 SF	$0.50	$169,824	$2.25	$764,206	$934,029
New floor penetrations for pipe and duct risers including reframing and abatement (assume 4 per floor)	20 EA	$7,500.00	$150,000	$7,500.00	$150,000	$300,000
2 hour rated duct shaft enclosures	1,920 SF	$7.00	$13,440	$12.25	$23,520	$36,960
New suspended acoustic tile ceilings	339,647 SF	$4.25	$1,443,500	$3.00	$1,018,941	$2,462,441
Miscellaneous patch / paint	485,210 SF	$0.50	$242,605	$0.50	$242,605	$485,210
Temporary protection and partitions	485,210 SF	$0.75	$363,908	$1.00	$485,210	$849,118
TOTAL GENERAL CONSTRUCTION			**$2,383,276**		**$2,684,482**	**$5,067,758**
HVAC						
DEMOLITION						
Remove air handlers including ductwork, piping and controls	485,210 SF	$1.25	$606,513	$5.00	$2,426,050	$3,032,563
EQUIPMENT						

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REPURPOSED HEALTH LAB

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
Variable air volume air handling units with energy recovery wheel, hot and chilled water heating and cooling	38,105 CFM	$16.00	$609,680	$0.60	$22,863	$632,543
Air handling units with hot and chilled water heating and cooling (no energy recovery)	421,933 CFM	$7.50	$3,164,498	$1.00	$421,933	$3,586,431
Pumps	4 EA	$75,000.00	$300,000	$15,540.00	$62,160	$362,160
Hydronic accessories (air separators, expansion tanks)	1 LS	$50,000.00	$50,000	$10,000.00	$10,000	$60,000
VAV's	607 EA	$650.00	$394,233	$660.00	$400,298	$794,531
PIPING SYSTEMS						
Hot and chilled water piping including valves fittings and accessories	90,000 LF	$30.50	$2,745,000	$38.00	$3,420,000	$6,165,000
Equipment prefabricated valve assemblies including ball, balance valves, strainers, etc. for supply and return pipe	1 LS	$115,000.00	$115,000	$95,000.00	$95,000	$210,000
SHEET METAL WORKS						
Galvanized steel ductwork	368,000 LBS	$2.10	$772,800	$8.20	$3,017,600	$3,790,400
Ductwork accessories	1 LS	$170,000.00	$170,000	$663,900.00	$663,900	$833,900
Air outlets and inlets	1,617 EA	$115.00	$185,997	$151.00	$244,222	$430,220
INSULATION						
Duct insulation, mineral-blanket type, fiberglass, FSK vapor barrier including fittings	220,800 SF	$0.80	$176,640	$4.80	$1,059,840	$1,236,480
Hydronic piping insulation	90,000 LF	$6.30	$567,000	$11.00	$990,000	$1,557,000
CONTROLS						
Direct digital controls and temp sensors at AHU's and VAV's						
- ERV	1 EA	$18,000.00	$18,000	$26,000.00	$26,000	$44,000
- AHU	28 SF	$12,000.00	$336,000	$18,000.00	$504,000	$840,000
- Pumps	4 EA	$3,000.00	$12,000	$4,200.00	$16,800	$28,800
- VAV	1,617 EA	$2,200.00	$3,558,207	$3,300.00	$5,337,310	$8,895,517
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$495,000.00	$495,000	$495,000
MISCELLANEOUS						
Crane, material handling, rigging and hoisting	1 LS	$100,000.00	$100,000	$350,000.00	$350,000	$450,000
Cleaning	1 LS	$45,000.00	$45,000	$120,000.00	$120,000	$165,000
Paint and identification	1 LS	$60,000.00	$60,000	$180,000.00	$180,000	$240,000

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REPURPOSED HEALTH LAB

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
Cut, patch and firestop	1 LS	$90,000.00	$90,000	$360,000.00	$360,000	$450,000
TOTAL HVAC			**$14,076,567**		**$20,222,977**	**$34,299,544**
SUB-TOTAL EEM-3			$16,459,843		$22,907,458	$39,367,301
GENERAL CONDITIONS	10.0%					$3,936,730
OVERHEAD AND PROFIT	10.0%					$4,330,403
DESIGN CONTINGENCY	15.0%					$7,145,165
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-3						**$54,779,599**

EEM-6

HVAC

Occupancy based HVAC controls	485,210 SF	$0.75	$363,908	$2.25	$1,091,723	$1,455,630
SUB-TOTAL EEM-6			$363,908		$1,091,723	$1,455,630
GENERAL CONDITIONS	10.0%					$145,563
OVERHEAD AND PROFIT	10.0%					$160,119
DESIGN CONTINGENCY	15.0%					$264,197
HIGH RISE PREMIUM	7.5%					$151,913
TOTAL EEM-6						**$2,177,422**

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SWAN ST. DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-1						
EXTERIOR DOORS AND WINDOWS						
Replace single pane glazing system with high performance aluminum and glass	2,800 SF	$90.00	$252,000	$85.00	$238,000	$490,000
SUB-TOTAL EEM-1			$252,000		$238,000	$490,000
GENERAL CONDITIONS	10.0%					$49,000
OVERHEAD AND PROFIT	10.0%					$53,900
DESIGN CONTINGENCY	15.0%					$88,935
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-1						**$681,835**
EEM-2						
EXTERIOR DOORS AND WINDOWS						
Replace single and double pane glazing system with high performance aluminum and glass	30,790 SF	$90.00	$2,771,100	$85.00	$2,617,150	$5,388,250
SUB-TOTAL EEM-2			$2,771,100		$2,617,150	$5,388,250
GENERAL CONDITIONS	10.0%					$538,825
OVERHEAD AND PROFIT	10.0%					$592,708
DESIGN CONTINGENCY	15.0%					$977,967
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-2						**$7,497,750**

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SWAN ST. DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-3						
GENERAL CONSTRUCTION						
Remove lay-in and hard ceilings to accommodate HVAC ductwork replacement (assume 70% of building area)	589,909 SF	$0.50	$294,955	$2.25	$1,327,295	$1,622,250
New floor penetrations for pipe and duct risers including reframing and abatement (assume 6 per floor)	30 EA	$7,500.00	$225,000	$7,500.00	$225,000	$450,000
2 hour rated duct shaft enclosures	2,880 SF	$7.00	$20,160	$12.25	$35,280	$55,440
New suspended acoustic tile ceilings	589,909 SF	$4.25	$2,507,113	$3.00	$1,769,727	$4,276,840
Miscellaneous patch / paint	842,727 SF	$0.50	$421,364	$0.50	$421,364	$842,727
Temporary protection and partitions	842,727 SF	$0.75	$632,045	$1.00	$842,727	$1,474,772
TOTAL GENERAL CONSTRUCTION			**$4,100,637**		**$4,621,393**	**$8,722,029**
HVAC						
DEMOLITION						
Remove air handlers including ductwork, piping and controls	842,727 SF	$1.25	$1,053,409	$5.00	$4,213,635	$5,267,044
EQUIPMENT						
Variable air volume air handling units with energy recovery wheel, hot and chilled water heating and cooling	326,652 CFM	$12.00	$3,919,824	$0.55	$179,659	$4,099,483
Air handling units with hot and chilled water heating and cooling (no energy recovery)	639,076 CFM	$7.50	$4,793,070	$0.90	$575,168	$5,368,238
Pumps	10 EA	$35,000.00	$350,000	$7,500.00	$75,000	$425,000
Hydronic accessories (air separators, expansion tanks)	1 LS	$40,000.00	$40,000	$8,000.00	$8,000	$48,000
VAV's	1,053 EA	$650.00	$684,716	$660.00	$695,250	$1,379,965
PIPING SYSTEMS						
Hot and chilled water piping including valves fittings and accessories	170,000 LF	$30.50	$5,185,000	$38.00	$6,460,000	$11,645,000
Equipment prefabricated valve assemblies including ball, balance valves, strainers, etc. for supply and return pipe	1 LS	$435,000.00	$435,000	$350,000.00	$350,000	$785,000

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SWAN ST. DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
SHEET METAL WORKS						
Galvanized steel ductwork	775,000 LBS	$2.10	$1,627,500	$8.20	$6,355,000	$7,982,500
Ductwork accessories	1 LS	$358,100.00	$358,100	$1,398,100.00	$1,398,100	$1,756,200
Air outlets and inlets	3,700 EA	$115.00	$425,500	$151.00	$558,700	$984,200
INSULATION						
Duct insulation, mineral-blanket type, fiberglass, FSK vapor barrier including fittings	465,000 SF	$0.80	$372,000	$4.80	$2,232,000	$2,604,000
Hydronic piping insulation	170,000 LF	$6.30	$1,071,000	$11.00	$1,870,000	$2,941,000
CONTROLS						
Direct digital controls and temp sensors at AHU's and VAV's						
- ERV	9 EA	$18,000.00	$162,000	$26,000.00	$234,000	$396,000
- AHU	27 SF	$12,000.00	$324,000	$18,000.00	$486,000	$810,000
- Pumps	10 EA	$3,000.00	$30,000	$4,200.00	$42,000	$72,000
- VAV	1,053 EA	$2,200.00	$2,317,499	$3,300.00	$3,476,249	$5,793,748
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$976,000.00	$976,000	$976,000
MISCELLANEOUS						
Crane, material handling, rigging and hoisting	1 LS	$363,400.00	$363,400	$1,271,900.00	$1,271,900	$1,635,300
Cleaning	1 LS	$72,700.00	$72,700	$218,100.00	$218,100	$290,800
Paint and identification	1 LS	$14,500.00	$14,500	$43,500.00	$43,500	$58,000
Cut, patch and firestop	1 LS	$290,700.00	$290,700	$1,017,450.00	$1,017,450	$1,308,150
TOTAL HVAC			**$23,889,918**		**$32,735,711**	**$56,625,628**
SUB-TOTAL EEM-3			$27,990,554		$37,357,103	$65,347,658
GENERAL CONDITIONS	10.0%					$6,534,766
OVERHEAD AND PROFIT	10.0%					$7,188,242
DESIGN CONTINGENCY	15.0%					$11,860,600
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-3						**$90,931,266**

CONFIDENTIAL AND PROPRIETARY

SWAN ST. DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-6						
Occupancy based HVAC controls	842,727 SF	$0.75	$632,045	$2.25	$1,896,136	$2,528,181
SUB-TOTAL EEM-6			$632,045		$1,896,136	$2,528,181
GENERAL CONDITIONS	10.0%					$252,818
OVERHEAD AND PROFIT	10.0%					$278,100
DESIGN CONTINGENCY	15.0%					$458,865
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-6						**$3,517,964**
EEM-7						
Install zone controls for existing fin tube radiators, splice into existing piping	27 EA	$1,250.00	$33,750	$444.00	$11,988	$45,738
SUB-TOTAL EEM-7			$33,750		$11,988	$45,738
GENERAL CONDITIONS	10.0%					$4,574
OVERHEAD AND PROFIT	10.0%					$5,031
DESIGN CONTINGENCY	15.0%					$8,301
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-7						**$63,644**

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THE EGG DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-1						
EXTERIOR DOORS AND WINDOWS						
Replace single pane glazing system with high performance aluminum and glass	1,936 SF	$90.00	$174,240	$85.00	$164,560	$338,800
Replace exterior doors, frames and hardware	12 EA	$5,000.00	$60,000	$770.00	$9,240	$69,240
SUB-TOTAL EEM-1			$234,240		$173,800	$408,040
GENERAL CONDITIONS	10.0%					$40,804
OVERHEAD AND PROFIT	10.0%					$44,884
DESIGN CONTINGENCY	15.0%					$74,059
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-1						**$567,788**
EEM-2						
EXTERIOR DOORS AND WINDOWS						
Replace all windows with high performance windows and doors	1,936 SF	$90.00	$174,240	$85.00	$164,560	$338,800
Replace exterior doors, frames and hardware	12 EA	$5,000.00	$60,000	$770.00	$9,240	$69,240
SUB-TOTAL EEM-2			$234,240		$173,800	$408,040
GENERAL CONDITIONS	10.0%					$40,804
OVERHEAD AND PROFIT	10.0%					$44,884
DESIGN CONTINGENCY	15.0%					$74,059
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-2						**$567,788**

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THE EGG DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-3						
GENERAL CONSTRUCTION						
Remove lay-in and hard ceilings to accommodate HVAC ductwork replacement (assume 70% of building area)	111,553 SF	$0.50	$55,777	$2.25	$250,994	$306,771
New floor penetrations for pipe and duct risers including reframing and abatement (assume 2 per floor)	16 EA	$7,500.00	$120,000	$7,500.00	$120,000	$240,000
2 hour rated duct shaft enclosures	1,536 SF	$7.00	$10,752	$12.25	$18,816	$29,568
New suspended acoustic tile ceilings	111,553 SF	$4.25	$474,100	$3.00	$334,659	$808,759
Miscellaneous patch / paint	159,362 SF	$0.50	$79,681	$0.50	$79,681	$159,362
Temporary protection and partitions	159,362 SF	$0.75	$119,522	$1.00	$159,362	$278,884
TOTAL GENERAL CONSTRUCTION			**$859,831**		**$963,512**	**$1,823,344**
HVAC						
DEMOLITION						
Remove air handlers including ductwork, piping and controls	159,362 SF	$1.25	$199,203	$5.00	$796,810	$996,013
EQUIPMENT						
Variable air volume air handling units with energy recovery wheel, hot and chilled water heating and cooling	43,084 CFM	$19.00	$818,596	$1.00	$43,084	$861,680
Air handling units with hot and chilled water heating and cooling (no energy recovery)	121,599 CFM	$7.50	$911,993	$1.00	$121,599	$1,033,592
Pumps	4 EA	$16,500.00	$66,000	$5,000.00	$20,000	$86,000
Hydronic accessories (air separators, expansion tanks)	1 LS	$20,000.00	$20,000	$5,000.00	$5,000	$25,000
VAV's	199 EA	$650.00	$129,482	$660.00	$131,474	$260,955
PIPING SYSTEMS						
Hot and chilled water piping including valves fittings and accessories	8,000 LF	$24.20	$193,600	$31.00	$248,000	$441,600
Equipment prefabricated valve assemblies including ball, balance valves, strainers, etc. for supply and return pipe	1 LS	$40,000.00	$40,000	$70,000.00	$70,000	$110,000
SHEET METAL WORKS						
Galvanized steel ductwork	125,000 LBS	$2.10	$262,500	$8.20	$1,025,000	$1,287,500

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THE EGG DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
Ductwork accessories	1 LS	$57,800.00	$57,800	$225,500.00	$225,500	$283,300
Air outlets and inlets	600 EA	$115.00	$69,000	$151.00	$90,600	$159,600
INSULATION						
Duct insulation, mineral-blanket type, fiberglass, FSK vapor barrier including fittings	75,000 SF	$0.80	$60,000	$4.80	$360,000	$420,000
Hydronic piping insulation	8,000 LF	$6.30	$50,400	$11.00	$88,000	$138,400
CONTROLS						
Demand controlled ventilation	912 SF	$1.25	$1,140	$2.50	$2,280	$3,420
Direct digital controls and temp sensors at AHU's and VAV's						
- AHU	10 EA	$12,000.00	$120,000	$18,000.00	$180,000	$300,000
- ERV	4 SF	$18,000.00	$72,000	$26,000.00	$104,000	$176,000
- Pumps	4 EA	$3,000.00	$12,000	$4,200.00	$16,800	$28,800
- VAV	199 EA	$2,200.00	$438,246	$3,300.00	$657,368	$1,095,614
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$138,000.00	$138,000	$138,000
MISCELLANEOUS						
Crane, material handling, rigging and hoisting	1 LS	$58,112.00	$58,112	$40,678.40	$40,678	$98,790
Cleaning	1 LS	$26,150.40	$26,150	$13,946.88	$13,947	$40,097
Paint and identification	1 LS	$34,867.20	$34,867	$20,920.32	$20,920	$55,788
Cut, patch and firestop	1 LS	$52,300.80	$52,301	$41,840.64	$41,841	$94,141
TOTAL HVAC			**$3,693,389**		**$4,440,901**	**$8,134,290**
SUB-TOTAL EEM-3			$4,553,220		$5,404,413	$9,957,633
GENERAL CONDITIONS	10.0%					$995,763
OVERHEAD AND PROFIT	10.0%					$1,095,340
DESIGN CONTINGENCY	15.0%					$1,807,310
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-3						**$13,856,047**

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THE EGG DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-6						
EXTERIOR DOORS AND WINDOWS						
Occupancy based HVAC controls	159,362 SF	$0.75	$119,522	$2.25	$358,565	$478,086
SUB-TOTAL EEM-6			$119,522		$358,565	$478,086
GENERAL CONDITIONS	10.0%					$47,809
OVERHEAD AND PROFIT	10.0%					$52,589
DESIGN CONTINGENCY	15.0%					$86,773
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-6						**$665,257**

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CEC

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-1						
EXTERIOR DOORS AND WINDOWS						
Replace single pane glazing system with high performance aluminum and glass	16,325 SF	$90.00	$1,469,250	$85.00	$1,387,625	$2,856,875
Replace exterior doors, frames and hardware	22 EA	$5,000.00	$110,000	$770.00	$16,940	$126,940
SUB-TOTAL EEM-1			$1,579,250		$1,404,565	$2,983,815
GENERAL CONDITIONS	10.0%					$298,382
OVERHEAD AND PROFIT	10.0%					$328,220
DESIGN CONTINGENCY	15.0%					$541,562
HIGH RISE PREMIUM	7.5%					$311,398
TOTAL EEM-1						**$4,463,377**
EEM-2						
EXTERIOR DOORS AND WINDOWS						
Replace all windows with high performance aluminum and glass	40,669 SF	$90.00	$3,660,210	$85.00	$3,456,865	$7,117,075
Replace exterior doors, frames and hardware	22 EA	$5,000.00	$110,000	$770.00	$16,940	$126,940
SUB-TOTAL EEM-2			$3,770,210		$3,473,805	$7,244,015
GENERAL CONDITIONS	10.0%					$724,402
OVERHEAD AND PROFIT	10.0%					$796,842
DESIGN CONTINGENCY	15.0%					$1,314,789
HIGH RISE PREMIUM	7.5%					$756,004
TOTAL EEM-2						**$10,836,050**

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CEC

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-3						
GENERAL CONSTRUCTION						
Remove lay-in and hard ceilings as asbestos containing to accommodate HVAC ductwork replacement (assume 70% of building area)	1,107,753 SF	$2.50	$2,769,383	$12.64	$14,001,998	$16,771,380
New floor penetrations for pipe and duct risers including reframing and abatement (assume 5 per floor)	65 EA	$7,500.00	$487,500	$7,500.00	$487,500	$975,000
2 hour rated duct shaft enclosures	6,240 SF	$7.00	$43,680	$12.25	$76,440	$120,120
New suspended acoustic tile ceilings	1,107,753 SF	$4.25	$4,707,950	$3.00	$3,323,259	$8,031,209
Miscellaneous patch / paint	1,582,504 SF	$0.50	$791,252	$0.50	$791,252	$1,582,504
Temporary protection and partitions	1,582,504 SF	$0.75	$1,186,878	$1.00	$1,582,504	$2,769,382
TOTAL GENERAL CONSTRUCTION			**$9,986,643**		**$20,262,953**	**$30,249,596**
HVAC						
DEMOLITION						
Remove air handlers including ductwork, piping and controls	1,582,504 SF	$1.10	$1,740,754	$4.50	$7,121,268	$8,862,022
EQUIPMENT						
Variable air volume air handling units with energy recovery wheel, hot and chilled water heating and cooling	786,285 CFM	$12.50	$9,828,563	$0.45	$353,828	$10,182,391
Air handling units with hot and chilled water heating and cooling (no energy recovery)	252,999 CFM	$7.50	$1,897,493	$0.65	$164,449	$2,061,942
Pumps	6 EA	$50,000.00	$300,000	$15,640.00	$93,840	$393,840
Hydronic accessories (air separators, expansion tanks)	1 LS	$40,000.00	$40,000	$8,000.00	$8,000	$48,000
VAV's	1,978 EA	$650.00	$1,285,785	$660.00	$1,305,566	$2,591,350
PIPING SYSTEMS						
Hot and chilled water piping including valves fittings and accessories	240,000 LF	$26.00	$6,240,000	$34.00	$8,160,000	$14,400,000
Equipment prefabricated valve assemblies including ball, balance valves, strainers, etc. for supply and return pipe	1 LS	$700,000.00	$700,000	$600,000.00	$600,000	$1,300,000

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CEC

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
SHEET METAL WORKS						
Galvanized steel ductwork	1,048,828 LBS	$2.10	$2,202,539	$8.20	$8,600,390	$10,802,928
Ductwork accessories	1 LS	$484,600.00	$484,600	$1,892,100.00	$1,892,100	$2,376,700
Air outlets and inlets	5,280 EA	$115.00	$607,200	$151.00	$797,280	$1,404,480
INSULATION						
Duct insulation, mineral-blanket type, fiberglass, FSK vapor barrier including fittings	629,297 SF	$0.80	$503,437	$4.80	$3,020,625	$3,524,062
Hydronic piping insulation	240,000 LF	$6.30	$1,512,000	$11.00	$2,640,000	$4,152,000
CONTROLS						
Demand controlled ventilation	6,381 SF	$1.25	$7,976	$2.50	$15,953	$23,929
Direct digital controls and temp sensors at AHU's and VAV's						
- AHU	12 EA	$12,000.00	$144,000	$18,000.00	$216,000	$360,000
- ERV	20 SF	$18,000.00	$360,000	$26,000.00	$520,000	$880,000
- Pumps	6 EA	$3,000.00	$18,000	$4,200.00	$25,200	$43,200
- VAV	1,978 EA	$2,200.00	$4,351,886	$3,300.00	$6,527,829	$10,879,715
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$1,331,000.00	$1,331,000	$1,331,000
MISCELLANEOUS						
Crane, material handling, rigging and hoisting	1 LS	$546,200.00	$546,200	$1,911,700.00	$1,911,700	$2,457,900
Cleaning	1 LS	$109,200.00	$109,200	$327,600.00	$327,600	$436,800
Paint and identification	1 LS	$21,800.00	$21,800	$65,400.00	$65,400	$87,200
Cut, patch and firestop	1 LS	$436,900.00	$436,900	$1,529,150.00	$1,529,150	$1,966,050
TOTAL HVAC			**$33,338,332**		**$47,227,177**	**$80,565,510**
SUB-TOTAL EEM-3			$43,324,975		$67,490,130	$110,815,105
GENERAL CONDITIONS	10.0%					$11,081,511
OVERHEAD AND PROFIT	10.0%					$12,189,662
DESIGN CONTINGENCY	15.0%					$20,112,942
HIGH RISE PREMIUM	7.5%					$11,564,941
TOTAL EEM-3						**$165,764,160**

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CEC

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-6						
EXTERIOR DOORS AND WINDOWS						
Occupancy based HVAC controls	1,582,504 SF	$0.75	$1,186,878	$2.25	$3,560,634	$4,747,512
SUB-TOTAL EEM-6			$1,186,878		$3,560,634	$4,747,512
GENERAL CONDITIONS	10.0%					$474,751
OVERHEAD AND PROFIT	10.0%					$522,226
DESIGN CONTINGENCY	15.0%					$861,673
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-6						**$6,606,163**
EEM-7						
Install zone controls for existing fin tube radiators, splice into existing piping	7 EA	$1,250.00	$8,750	$444.00	$3,108	$11,858
SUB-TOTAL EEM-7			$8,750		$3,108	$11,858
GENERAL CONDITIONS	10.0%					$1,186
OVERHEAD AND PROFIT	10.0%					$1,304
DESIGN CONTINGENCY	15.0%					$2,152
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-7						**$16,500**

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JOB DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-2						
EXTERIOR DOORS AND WINDOWS						
Replace all windows with high performance glazing system	12,168 SF	$90.00	$1,095,120	$85.00	$1,034,280	$2,129,400
Replace exterior doors, frames and hardware	12 EA	$5,000.00	$60,000	$770.00	$9,240	$69,240
SUB-TOTAL EEM-2			$1,155,120		$1,043,520	$2,198,640
GENERAL CONDITIONS	10.0%					$219,864
OVERHEAD AND PROFIT	10.0%					$241,850
DESIGN CONTINGENCY	15.0%					$399,053
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-2						**$3,059,408**
EEM-3						
GENERAL CONSTRUCTION						
Remove lay-in and hard ceilings as asbestos containing to accommodate HVAC ductwork replacement (assume 70% of building area)	182,824 SF	$2.50	$457,060	$12.64	$2,310,895	$2,767,955
New floor penetrations for pipe and duct risers including reframing and abatement (assume 2 per floor)	20 EA	$7,500.00	$150,000	$7,500.00	$150,000	$300,000
2 hour rated duct shaft enclosures	1,920 SF	$7.00	$13,440	$12.25	$23,520	$36,960
New suspended acoustic tile ceilings	182,824 SF	$4.25	$777,002	$3.00	$548,472	$1,325,474
Miscellaneous patch / paint	261,177 SF	$0.50	$130,589	$0.50	$130,589	$261,177
Temporary protection and partitions	261,177 SF	$0.75	$195,883	$1.00	$261,177	$457,060
TOTAL GENERAL CONSTRUCTION			**$1,723,973**		**$3,424,653**	**$5,148,626**

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JOB DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
HVAC						
DEMOLITION						
Remove air handlers including ductwork, piping and controls	261,177 SF	$1.10	$287,295	$4.50	$1,175,297	$1,462,591
EQUIPMENT						
Variable air volume air handling units with energy recovery wheel, hot and chilled water heating and cooling	221,093 CFM	$12.50	$2,763,663	$0.70	$154,765	$2,918,428
Air handling units with hot and chilled water heating and cooling (no energy recovery)	104,088 CFM	$7.50	$780,660	$0.95	$98,884	$879,544
Pumps	4 EA	$35,000.00	$140,000	$7,500.00	$30,000	$170,000
Hydronic accessories (air separators, expansion tanks)	1 LS	$25,000.00	$25,000	$5,500.00	$5,500	$30,500
VAV's	326 EA	$650.00	$212,206	$660.00	$215,471	$427,677
PIPING SYSTEMS						
Hot and chilled water piping including valves fittings and accessories	52,500 LF	$26.00	$1,365,000	$34.00	$1,785,000	$3,150,000
Equipment prefabricated valve assemblies including ball, balance valves, strainers, etc. for supply and return pipe	1 LS	$145,000.00	$145,000	$123,081.00	$123,081	$268,081
SHEET METAL WORKS						
Galvanized steel ductwork	260,000 LBS	$2.10	$546,000	$8.20	$2,132,000	$2,678,000
Ductwork accessories	1 LS	$120,100.00	$120,100	$469,000.00	$469,000	$589,100
Air outlets and inlets	875 EA	$115.00	$100,625	$151.00	$132,125	$232,750
INSULATION						
Duct insulation, mineral-blanket type, fiberglass, FSK vapor barrier including fittings	156,000 SF	$0.80	$124,800	$4.80	$748,800	$873,600
Hydronic piping insulation	52,500 LF	$6.30	$330,750	$11.00	$577,500	$908,250
CONTROLS						
Demand controlled ventilation	9,194 SF	$1.25	$11,493	$2.50	$22,985	$34,478
Direct digital controls and temp sensors at AHU's and VAV's						
- AHU	11 EA	$12,000.00	$132,000	$18,000.00	$198,000	$330,000
- ERV	5 SF	$18,000.00	$90,000	$26,000.00	$130,000	$220,000
- Pumps	4 EA	$3,000.00	$12,000	$4,200.00	$16,800	$28,800
- VAV	326 EA	$2,200.00	$718,237	$3,300.00	$1,077,355	$1,795,592

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JOB DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$319,000.00	$319,000	$319,000
MISCELLANEOUS						
Crane, material handling, rigging and hoisting	1 LS	$120,600.00	$120,600	$422,100.00	$422,100	$542,700
Cleaning	1 LS	$24,100.00	$24,100	$72,300.00	$72,300	$96,400
Paint and identification	1 LS	$4,800.00	$4,800	$14,400.00	$14,400	$19,200
Cut, patch and firestop	1 LS	$96,500.00	$96,500	$337,750.00	$337,750	$434,250
TOTAL HVAC			**$8,150,828**		**$10,258,112**	**$18,408,940**
SUB-TOTAL EEM-3			$9,874,801		$13,682,765	$23,557,566
GENERAL CONDITIONS	10.0%					$2,355,757
OVERHEAD AND PROFIT	10.0%					$2,591,332
DESIGN CONTINGENCY	15.0%					$4,275,698
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-3						**$32,780,353**
EEM-6						
EXTERIOR DOORS AND WINDOWS						
Occupancy based HVAC controls	261,177 SF	$0.75	$195,883	$2.25	$587,648	$783,531
SUB-TOTAL EEM-6			$195,883		$587,648	$783,531
GENERAL CONDITIONS	10.0%					$78,353
OVERHEAD AND PROFIT	10.0%					$86,188
DESIGN CONTINGENCY	15.0%					$142,211
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-6						**$1,090,283**

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JOB DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-7						
Install zone controls for existing fin tube radiators, splice into existing piping	18 EA	$1,250.00	$22,500	$444.00	$7,992	$30,492
SUB-TOTAL EEM-7			$22,500		$7,992	$30,492
GENERAL CONDITIONS	10.0%					$3,049
OVERHEAD AND PROFIT	10.0%					$3,354
DESIGN CONTINGENCY	15.0%					$5,534
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-7						**$42,430**

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LOB DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-2						
EXTERIOR DOORS AND WINDOWS						
Replace all windows with high performance aluminum and glass	21,701 SF	$90.00	$1,953,090	$85.00	$1,844,585	$3,797,675
Replace exterior doors, frames and hardware	16 EA	$5,000.00	$80,000	$770.00	$12,320	$92,320
SUB-TOTAL EEM-2			$2,033,090		$1,856,905	$3,889,995
GENERAL CONDITIONS	10.0%					$389,000
OVERHEAD AND PROFIT	10.0%					$427,899
DESIGN CONTINGENCY	15.0%					$706,034
HIGH RISE PREMIUM	7.5%					$405,970
TOTAL EEM-2						**$5,818,898**
EEM-3						
GENERAL CONSTRUCTION						
Remove lay-in and hard ceilings as asbestos containing to accommodate HVAC ductwork replacement (assume 70% of building area)	455,174 SF	$2.50	$1,137,935	$12.64	$5,753,399	$6,891,334
New floor penetrations for pipe and duct risers including reframing and abatement (assume 2 per floor)	26 EA	$7,500.00	$195,000	$7,500.00	$195,000	$390,000
2 hour rated duct shaft enclosures	2,496 SF	$7.00	$17,472	$12.25	$30,576	$48,048
New suspended acoustic tile ceilings	455,174 SF	$4.25	$1,934,490	$3.00	$1,365,522	$3,300,012
Miscellaneous patch / paint	650,248 SF	$0.50	$325,124	$0.50	$325,124	$650,248
Temporary protection and partitions	650,248 SF	$0.75	$487,686	$1.00	$650,248	$1,137,934
TOTAL GENERAL CONSTRUCTION			**$4,097,707**		**$8,319,869**	**$12,417,576**

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LOB DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
HVAC						
DEMOLITION						
Remove air handlers including ductwork, piping and controls	650,348 SF	$1.10	$715,383	$4.50	$2,926,566	$3,641,949
EQUIPMENT						
Variable air volume air handling units with energy recovery wheel, hot and chilled water heating and cooling	433,552 CFM	$15.50	$6,720,056	$0.75	$325,164	$7,045,220
Air handling units with hot and chilled water heating and cooling (no energy recovery)	93,946 CFM	$7.50	$704,595	$1.10	$103,341	$807,936
Pumps	8 EA	$24,000.00	$192,000	$6,660.00	$53,280	$245,280
Hydronic accessories (air separators, expansion tanks)	1 LS	$35,000.00	$35,000	$7,500.00	$7,500	$42,500
VAV's	813 EA	$650.00	$528,408	$660.00	$536,537	$1,064,945
PIPING SYSTEMS						
Hot and chilled water piping including valves fittings and accessories	115,000 LF	$26.00	$2,990,000	$34.00	$3,910,000	$6,900,000
Equipment prefabricated valve assemblies including ball, balance valves, strainers, etc. for supply and return pipe	1 LS	$700,000.00	$700,000	$600,000.00	$600,000	$1,300,000
SHEET METAL WORKS						
Galvanized steel ductwork	421,999 LBS	$2.10	$886,198	$8.20	$3,460,392	$4,346,590
Ductwork accessories	1 LS	$195,000.00	$195,000	$761,300.00	$761,300	$956,300
Air outlets and inlets	5,280 EA	$115.00	$607,200	$151.00	$797,280	$1,404,480
INSULATION						
Duct insulation, mineral-blanket type, fiberglass, FSK vapor barrier including fittings	253,199 SF	$0.80	$202,560	$4.80	$1,215,357	$1,417,917
Hydronic piping insulation	115,000 LF	$6.30	$724,500	$11.00	$1,265,000	$1,989,500
CONTROLS						
Direct digital controls and temp sensors at AHU's and VAV's						
- AHU	11 EA	$12,000.00	$132,000	$18,000.00	$198,000	$330,000
- ERV	15 SF	$18,000.00	$270,000	$26,000.00	$390,000	$660,000
- Pumps	8 EA	$3,000.00	$24,000	$4,200.00	$33,600	$57,600
- VAV	813 EA	$2,200.00	$1,788,457	$3,300.00	$2,682,686	$4,471,143

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LOB DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$675,000.00	$675,000	$675,000
MISCELLANEOUS						
Crane, material handling, rigging and hoisting	1 LS	$230,300.00	$230,300	$806,050.00	$806,050	$1,036,350
Cleaning	1 LS	$46,100.00	$46,100	$138,300.00	$138,300	$184,400
Paint and identification	1 LS	$9,200.00	$9,200	$27,600.00	$27,600	$36,800
Cut, patch and firestop	1 LS	$184,300.00	$184,300	$645,050.00	$645,050	$829,350
TOTAL HVAC			**$17,885,256**		**$21,558,002**	**$39,443,258**
SUB-TOTAL EEM-3			$21,982,962		$29,877,871	$51,860,834
GENERAL CONDITIONS	10.0%					$5,186,083
OVERHEAD AND PROFIT	10.0%					$5,704,692
DESIGN CONTINGENCY	15.0%					$9,412,741
HIGH RISE PREMIUM	7.5%					$5,412,326
TOTAL EEM-3						**$77,576,677**
EEM-6						
EXTERIOR DOORS AND WINDOWS						
Occupancy based HVAC controls	650,348 SF	$0.75	$487,761	$2.25	$1,463,283	$1,951,044
SUB-TOTAL EEM-6			$487,761		$1,463,283	$1,951,044
GENERAL CONDITIONS	10.0%					$195,104
OVERHEAD AND PROFIT	10.0%					$214,615
DESIGN CONTINGENCY	15.0%					$354,114
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-6						**$2,714,878**

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LOB DETAIL

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-7						
Install zone controls for existing fin tube radiators, splice into existing piping	55 EA	$1,250.00	$68,750	$444.00	$24,420	$93,170
SUB-TOTAL EEM-7			$68,750		$24,420	$93,170
GENERAL CONDITIONS	10.0%					$9,317
OVERHEAD AND PROFIT	10.0%					$10,249
DESIGN CONTINGENCY	15.0%					$16,910
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-7						**$129,646**

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MAIN PLATFORM

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-3						
GENERAL CONSTRUCTION						
Remove lay-in and hard ceilings as asbestos containing to accommodate HVAC ductwork replacement (assume 50% of building area)	484,837 SF	$2.50	$1,212,093	$12.64	$6,128,340	$7,340,432
New suspended acoustic tile ceilings	484,837 SF	$4.25	$2,060,557	$3.00	$1,454,511	$3,515,068
Miscellaneous patch / paint	969,674 SF	$0.50	$484,837	$0.50	$484,837	$969,674
Temporary protection and partitions	969,674 SF	$0.75	$727,256	$1.00	$969,674	$1,696,930
TOTAL GENERAL CONSTRUCTION			**$4,484,742**		**$9,037,362**	**$13,522,104**
HVAC						
DEMOLITION						
Remove air handlers including ductwork, piping and controls	1 LS	$300,000.00	$300,000	$1,200,000.00	$1,200,000	$1,500,000
EQUIPMENT						
Variable air volume air handling units with energy recovery wheel, hot and chilled water heating and cooling	100,922 CFM	$17.00	$1,715,674	$0.80	$80,738	$1,796,412
Air handling units with hot and chilled water heating and cooling (no energy recovery)	356,512 CFM	$7.50	$2,673,840	$0.90	$320,861	$2,994,701
Pumps	68 EA	$7,500.00	$510,000	$3,552.00	$241,536	$751,536
Hydronic accessories (air separators, expansion tanks)	1 LS	$35,000.00	$35,000	$7,500.00	$7,500	$42,500
VAV's	100 EA	$650.00	$65,000	$660.00	$66,000	$131,000
PIPING SYSTEMS						
Hot and chilled water piping including valves fittings and accessories	15,000 LF	$40.00	$600,000	$55.00	$825,000	$1,425,000
Equipment prefabricated valve assemblies including ball, balance valves, strainers, etc. for supply and return pipe	1 LS	$100,000.00	$100,000	$450,000.00	$450,000	$550,000
SHEET METAL WORKS						
Galvanized steel ductwork	300,000 LBS	$2.10	$630,000	$8.20	$2,460,000	$3,090,000
Ductwork accessories	1 LS	$138,600.00	$138,600	$541,200.00	$541,200	$679,800
Air outlets and inlets	3,700 EA	$115.00	$425,500	$151.00	$558,700	$984,200

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MAIN PLATFORM

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
INSULATION						
Duct insulation, mineral-blanket type, fiberglass, FSK vapor barrier including fittings	180,000 SF	$0.80	$144,000	$4.80	$864,000	$1,008,000
Hydronic piping insulation	15,000 LF	$6.30	$94,500	$11.00	$165,000	$259,500
CONTROLS						
Direct digital controls and temp sensors at AHU's and VAV's						
- ERV	6 EA	$18,000.00	$108,000	$26,000.00	$156,000	$264,000
- AHU	46 SF	$12,000.00	$552,000	$18,000.00	$828,000	$1,380,000
- Pumps	68 EA	$2,200.00	$149,600	$3,300.00	$224,400	$374,000
- VAV	100 EA	$2,200.00	$220,000	$3,300.00	$330,000	$550,000
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$354,000.00	$354,000	$354,000
MISCELLANEOUS						
Crane, material handling, rigging and hoisting	1 LS	$152,000.00	$152,000	$532,000.00	$532,000	$684,000
Cleaning	1 LS	$48,000.00	$48,000	$144,000.00	$144,000	$192,000
Paint and identification	1 LS	$42,000.00	$42,000	$126,000.00	$126,000	$168,000
Cut, patch and firestop	1 LS	$139,100.00	$139,100	$486,850.00	$486,850	$625,950
TOTAL HVAC			**$8,842,814**		**$10,961,784**	**$19,804,598**
SUB-TOTAL EEM-3			$13,327,556		$19,999,146	$33,326,702
GENERAL CONDITIONS	10.0%					$3,332,670
OVERHEAD AND PROFIT	10.0%					$3,665,937
DESIGN CONTINGENCY	15.0%					$6,048,796
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-3						**$46,374,106**

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MAIN PLATFORM

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
EEM-6						
EXTERIOR DOORS AND WINDOWS						
Occupancy based HVAC controls	969,674 SF	$0.75	$727,256	$2.25	$2,181,767	$2,909,022
SUB-TOTAL EEM-6			$727,256		$2,181,767	$2,909,022
GENERAL CONDITIONS	10.0%					$290,902
OVERHEAD AND PROFIT	10.0%					$319,992
DESIGN CONTINGENCY	15.0%					$527,987
HIGH RISE PREMIUM						NOT REQUIRED
TOTAL EEM-6						**$4,047,904**

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TROPHY POINT

Construction Services & Consulting

CONCEPT ESTIMATE

ENERGY UPGRADE ESTIMATE
NYPA / OGS EMPIRE STATE PLAZA

ALBANY, NY

PREPARED FOR:
RAMBOLL

PROJECT NO: 21-0385a-0436

January 12, 2023
(Original Estimate)

Trophy Point, LLC
Construction Services & Consulting

4588 South Park Avenue
Blasdell, NY 14219

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ESTIMATE NOTES / ASSUMPTIONS / CLARIFICATIONS

- BASED ON RAMBOLL CONCEPT DOCUMENTS DATED 12/01/2022.
- NEW YORK STATE PREVAILING WAGE RATES FOR ALBANY COUNTY.
- SINGLE PRIME CONTRACT (COMPETITIVELY BID).
- PREMISES TO BE VACANT DURING CONSTRUCTION.

EXCLUSIONS:

- SOFT COSTS (DESIGN FEES, ETC.)
- CONSTRUCTION CONTINGENCY (OWNER CHANGE ORDER RESERVE)
- CONSTRUCTION MANAGER FEES, MARKUPS OR GENERAL CONDITIONS
- PROJECT LABOR AGREEMENTS
- ROCK EXCAVATION
- NO PROVISIONS FOR UNSTABLE SOILS
- SOIL REMEDIATION
- ASBESTOS AND HAZARDOUS MATERIALS ABATEMENT (IF APPLICABLE)
- FF&E
- ESCALATION TO MID-POINT OF CONSTRUCTION

Note: This estimate represents a reasonable opinion of cost based on several public and proprietary sources of information. It is not a prediction of the successful bid from a contractor as bids will vary due to fluctuating market conditions, errors and omissions, proprietary specifications, lack of surplus bidders, perception of risk, and so on. Consequently, this estimate is expected to fall within the range of bids from multiple competitive contractors or subcontractors. However, we do not warrant that bids or negotiated prices will not vary from the final construction cost estimate.

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PROJECT SUMMARY		TOTAL COST
3.1 THERMAL ENERGY STORAGE TANK		**$ 17,816,941**
3.2 HEAT RECOVERY CHILLER		**$ 6,829,915**
3.3 GROUND SOURCE HEAT PUMP		**$ 65,683,021**
3.4 WASTEWATER HEAT PUMP		**$ 120,598,724**
3.5 INDUSTRIAL HEAT RECOVERY		**$ 15,094,099**
3.6 AIR SOURCE HEAT PUMP		**$ 17,763,818**
3.7 PEAKING BIOFUEL BOILER		**$ 9,353,916**
3.8 PEAKING ELECTRIC BOILER		**$ 10,862,774**
3.10 CENTRAL AC PLANT		**$ 20,063,102**

ALTERNATES

ALT #1 - LARGER DIAMETER PIPE (3.4)	**ADD**	**$**	**16,360,700**
ALT #2 - LARGER DIAMETER PIPE (3.5)	**ADD**	**$**	**4,401,282**

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3.1 THERMAL ENERGY STORAGE TANK

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
DIVISION 2-14 - CONSTRUCTION						
New mechanical building/vault, assume 15' into ground, 25' above ground, includes sheet piling, foundations and insulated metal building	2,000 SF	$500.00	$1,000,000	$350.00	$700,000	$1,700,000
Reinforced concrete foundations at tanks, 52' diameter	2 EA	$200,000.00	$400,000	$175,000.00	$350,000	$750,000
Site cut, patch and restoration	1 ALLOW	$125,000.00	$125,000	$100,000.00	$100,000	$225,000
TOTAL DIVISION 2-14 - CONSTRUCTION			**$1,525,000**		**$1,150,000**	**$2,675,000**
DIVISION 23 - HVAC						
EQUIPMENT						
Liquid storage tanks, cylindrical, insulated, 1,000,000 gallon capacity (52' diameter, 65' height)	2 EA	$2,500,000.00	$5,000,000	$150,000.00	$300,000	$5,300,000
Hot and chilled water pumps, 2,000 GPM, with VFD	8 EA	$55,000.00	$440,000	$10,500.00	$84,000	$524,000
Electric heaters in valve vault	1 LS	$12,000.00	$12,000	$4,500.00	$4,500	$16,500
Mechanical ventilation in vault (fans, louvers, etc)	1 LS	$8,000.00	$8,000	$5,000.00	$5,000	$13,000
PIPING SYSTEMS						
Pre-insulated and jacketed steel pipe with integral leak detection control wiring (below grade)						
- 12" diameter	2,800 LF	$135.00	$378,000	$228.00	$638,400	$1,016,400
Valve assemblies	1 LS	$45,000.00	$45,000	$12,000.00	$12,000	$57,000
Field joints (estimated quantity)						
- 12" diameter	80 EA	$150.00	$12,000	$600.00	$48,000	$60,000
Fittings, elbows (estimated quantity)						
- 12" diameter	20 EA	$1,805.00	$36,100	$1,525.00	$30,500	$66,600
Site utilities earthwork including excavation, backfill and disposal off site	5,005 CY	$74.00	$370,370	$49.00	$245,245	$615,615
CONTROLS						
Direct Digital Controls						
- Tanks	2 EA	$7,500.00	$15,000	$11,500.00	$23,000	$38,000

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3.1 THERMAL ENERGY STORAGE TANK

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
- Pumps and VFD's	8 EA	$3,500.00	$28,000	$5,000.00	$40,000	$68,000
- Electric heaters	1 LS	$7,000.00	$7,000	$10,500.00	$10,500	$17,500
- Ventilation controls	1 LS	$10,000.00	$10,000	$12,000.00	$12,000	$22,000
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$50,000.00	$50,000	$50,000
MISCELLANEOUS						
Crane, material handling, rigging and hoisting	1 LS	$45,000.00	$45,000	$150,000.00	$150,000	$195,000
Cleaning, cutting, patching, paint and identification	1 LS	$20,000.00	$20,000	$60,000.00	$60,000	$80,000
TOTAL DIVISION 23 - HVAC			**$6,426,470**		**$1,713,145**	**$8,139,615**
DIVISION 26 - ELECTRICAL						
480v motor control center including feeder breaker requirements at source, rigging, and setting	1 ALLOW	$225,000.00	$225,000	$75,000.00	$75,000	$300,000
480v service feeder originating at CACP, routed through tunnels to mechanical vault including hangers, hardware, penetrations, and seals (distance assumed)	550 LF	$400.00	$220,000	$350.00	$192,500	$412,500
Hot / chilled water pump and associated VFD connection including local disconnect, conduit, and circuiting back to new MCC	8 EA	$7,500.00	$60,000	$12,500.00	$100,000	$160,000
General electrical work at new mechanical vault including LED lighting, convenience receptacles, equipment connections, associated conduit, and circuiting	1 ALLOW	$25,000.00	$25,000	$25,000.00	$25,000	$50,000
TOTAL DIVISION 26 - ELECTRICAL			**$530,000**		**$392,500**	**$922,500**
SUB-TOTAL			$8,481,470		$3,255,645	$11,737,115
GENERAL CONDITIONS	15.0%					$1,760,567
OVERHEAD AND PROFIT	10.0%					$1,349,768
DESIGN CONTINGENCY	20.0%					$2,969,490
TOTAL 3.1 THERMAL ENERGY STORAGE TANK						**$17,816,941**

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3.2 HEAT RECOVERY CHILLER

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
DIVISION 2-14 - CONSTRUCTION						
Foundations/pads for chillers	4 EA	$15,000.00	$60,000	$10,000.00	$40,000	$100,000
TOTAL DIVISION 2-14 - CONSTRUCTION			**$60,000**		**$40,000**	**$100,000**
DIVISION 23 - HVAC						
EQUIPMENT						
Heat recovery chillers, 300 tons	4 EA	$600,000.00	$2,400,000	$110,000.00	$440,000	$2,840,000
PIPING SYSTEMS						
Pre-insulated and jacketed steel pipe with integral leak detection control wiring						
- 24" diameter (chilled water)	120 LF	$387.00	$46,440	$405.00	$48,600	$95,040
- 24" diameter (hot water)	240 LF	$387.00	$92,880	$405.00	$97,200	$190,080
Valve assemblies and connections	4 EA	$17,500.00	$70,000	$6,500.00	$26,000	$96,000
Pipe supports and hangers	1 LS	$10,000.00	$10,000	$12,500.00	$12,500	$22,500
Field joints (estimated quantity)						
- 24" diameter	8 EA	$335.00	$2,680	$850.00	$6,800	$9,480
Fittings, elbows (estimated quantity)						
- 24" diameter	48 EA	$6,800.00	$326,400	$3,360.00	$161,280	$487,680
CONTROLS						
Direct Digital Controls						
- Heat recovery chillers	4 EA	$10,000.00	$40,000	$14,000.00	$56,000	$96,000
- Leak detection	1 LS	$20,000.00	$20,000	$50,000.00	$50,000	$70,000
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$75,000.00	$75,000	$75,000
MISCELLANEOUS						
Core drilling, 24" diameter	4 EA	$2,500.00	$10,000	$3,500.00	$14,000	$24,000
Crane, material handling, rigging and hoisting	1 LS	$25,000.00	$25,000	$80,000.00	$80,000	$105,000
Cleaning, cutting, patching, paint and identification	1 LS	$10,000.00	$10,000	$35,000.00	$35,000	$45,000
TOTAL DIVISION 23 - HVAC			**$3,053,400**		**$1,102,380**	**$4,155,780**

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3.2 HEAT RECOVERY CHILLER

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
DIVISION 26 - ELECTRICAL						
Modifications / upgrades at existing distribution equipment as required to serve new chillers	1 ALLOW	$25,000.00	$25,000	$25,000.00	$25,000	$50,000
Heat recovery chiller and associated VFD connection including local disconnect, conduit, and circuiting back to source	4 EA	$17,500.00	$70,000	$25,000.00	$100,000	$170,000
Miscellaneous electrical removals, relocations, and installations to allow for chiller system installation	1 ALLOW	$7,500.00	$7,500	$7,500.00	$7,500	$15,000
TOTAL DIVISION 26 - ELECTRICAL			**$102,500**		**$132,500**	**$235,000**
SUB-TOTAL			$3,215,900		$1,274,880	$4,490,780
GENERAL CONDITIONS	15.0%					$673,617
OVERHEAD AND PROFIT	10.0%					$774,660
DESIGN CONTINGENCY	20.0%					$890,858
TOTAL 3.2 HEAT RECOVERY CHILLER						**$6,829,915**

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3.3 GROUND SOURCE HEAT PUMP

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
DIVISION 2-14 - CONSTRUCTION						
Break out slab, install new piles and cap, patch slab	3 EA	$35,000.00	$105,000	$20,000.00	$60,000	$165,000
New mechanical room inside existing space including new foundations, CMU walls, steel frame and metal deck	2,400 SF	$120.00	$288,000	$80.00	$192,000	$480,000
Strip site, excavate for well field, backfill with select fill and restore site	67,667 CY	$75.00	$5,075,025	$24.25	$1,640,925	$6,715,950
TOTAL DIVISION 2-14 - CONSTRUCTION			**$5,468,025**		**$1,892,925**	**$7,360,950**
DIVISION 23 - HVAC						
EQUIPMENT						
Ground source heat pumps, 950 tons	3 EA	$1,500,000.00	$4,500,000	$110,000.00	$330,000	$4,830,000
Hydronic pumps, 2,000 GPM, with VFD	3 EA	$55,000.00	$165,000	$10,500.00	$31,500	$196,500
PIPING SYSTEMS						
GSHP piping, uninsulated, below grade, welded black steel, schedule 40						
- 18" diameter	2,400 LF	$202.00	$484,800	$278.00	$667,200	$1,152,000
Site utilities earthwork including excavation, backfill and disposal off site	10,205 CY	$42.00	$428,610	$33.50	$341,868	$770,478
Pre-insulated and jacketed steel pipe with integral leak detection control wiring						
- 10" diameter	120 LF	$107.00	$12,840	$129.00	$15,480	$28,320
- 14" diameter	120 LF	$185.00	$22,200	$292.00	$35,040	$57,240
- 16" diameter	1,200 LF	$225.00	$270,000	$305.00	$366,000	$636,000
- 18" diameter (in tunnels)	2,000 LF	$292.00	$584,000	$348.00	$696,000	$1,280,000
- 20" diameter	1,200 LF	$307.00	$368,400	$365.00	$438,000	$806,400
Valve assemblies and connections	6 EA	$13,500.00	$81,000	$5,500.00	$33,000	$114,000
Control valves	6 EA	$10,000.00	$60,000	$3,500.00	$21,000	$81,000
Pipe support system	1 LS	$60,000.00	$60,000	$75,000.00	$75,000	$135,000
Field joints (estimated quantity)						
- 10" diameter	6 EA	$145.00	$870	$450.00	$2,700	$3,570
- 14" diameter	6 EA	$175.00	$1,050	$600.00	$3,600	$4,650
- 16" diameter	32 EA	$215.00	$6,880	$600.00	$19,200	$26,080

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3.3 GROUND SOURCE HEAT PUMP

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
- 18" diameter	100 EA	$248.00	$24,800	$800.00	$80,000	$104,800
- 20" diameter	32 EA	$265.00	$8,480	$800.00	$25,600	$34,080
Fittings, elbows (estimated quantity)						
- 10" diameter	12 EA	$1,345.00	$16,140	$1,525.00	$18,300	$34,440
- 14" diameter	12 EA	$2,260.00	$27,120	$1,760.00	$21,120	$48,240
- 16" diameter	20 EA	$3,180.00	$63,600	$2,640.00	$52,800	$116,400
- 18" diameter	40 EA	$4,200.00	$168,000	$3,050.00	$122,000	$290,000
- 20" diameter	20 EA	$5,130.00	$102,600	$3,050.00	$61,000	$163,600
Butterfly valves, flanged (estimated quantity)						
- 10" diameter	6 EA	$3,050.00	$18,300	$1,525.00	$9,150	$27,450
- 14" diameter	6 EA	$3,300.00	$19,800	$1,525.00	$9,150	$28,950
- 16" diameter	4 EA	$3,900.00	$15,600	$1,760.00	$7,040	$22,640
- 18" diameter	4 EA	$4,200.00	$16,800	$2,200.00	$8,800	$25,600
- 20" diameter	4 EA	$4,500.00	$18,000	$2,640.00	$10,560	$28,560
Geothermal borehole field, 800' deep wells, includes drilling, pipe, grout and piping between each well (Geotech report may affect pricing)	914 EA	$5,500.00	$5,027,000	$18,500.00	$16,909,000	$21,936,000
CONTROLS						
Direct Digital Controls						
- Ground source heat pumps	3 EA	$10,000.00	$30,000	$14,000.00	$42,000	$72,000
- Pumps and VFD's	3 EA	$3,500.00	$10,500	$5,000.00	$15,000	$25,500
- Geothermal well field	1 LS	$50,000.00	$50,000	$75,000.00	$75,000	$125,000
- Leak detection	1 LS	$20,000.00	$20,000	$50,000.00	$50,000	$70,000
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$250,000.00	$250,000	$250,000
MISCELLANEOUS						
Core drilling, 24" diameter	4 EA	$2,500.00	$10,000	$3,500.00	$14,000	$24,000
Crane, material handling, rigging and hoisting	1 LS	$35,000.00	$35,000	$100,000.00	$100,000	$135,000
Cleaning, cutting, patching, paint and identification	1 LS	$15,000.00	$15,000	$50,000.00	$50,000	$65,000
TOTAL DIVISION 23 - HVAC			**$12,742,390**		**$21,006,108**	**$33,748,498**

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3.3 GROUND SOURCE HEAT PUMP

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
DIVISION 26 - ELECTRICAL						
5 kV service feeder to serve GSHP system equipment at new mechanical room including excavation, concrete ductbank, penetrations, seals, and earthwork (distance assumed)	3,000 LF	$275.00	$825,000	$200.00	$600,000	$1,425,000
Mechanical room electrical distribution equipment including transformers, power panels, and secondary feeders	1 ALLOW	$175,000.00	$175,000	$75,000.00	$75,000	$250,000
480v motor control center including feeder back to source distribution panel, rigging, and setting	1 ALLOW	$225,000.00	$225,000	$75,000.00	$75,000	$300,000
GSHP / hydronic pump and associated VFD connection including local disconnect, conduit, and circuiting back to new MCC	6 EA	$7,500.00	$45,000	$12,500.00	$75,000	$120,000
General electrical work at new mechanical room including LED lighting, convenience receptacles, equipment connections, fire alarm, associated conduit, and circuiting	1 ALLOW	$25,000.00	$25,000	$25,000.00	$25,000	$50,000
Miscellaneous electrical removals, relocations, and installations to allow for construction of new mechanical space	1 ALLOW	$7,500.00	$7,500	$7,500.00	$7,500	$15,000
TOTAL DIVISION 26 - ELECTRICAL			**$1,302,500**		**$857,500**	**$2,160,000**
SUB-TOTAL			$19,512,915		$23,756,532	$43,269,447
GENERAL CONDITIONS	15.0%					$6,490,417
OVERHEAD AND PROFIT	10.0%					$4,975,986
DESIGN CONTINGENCY	20.0%					$10,947,170
TOTAL 3.3 GROUND SOURCE HEAT PUMP						**$65,683,021**

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3.4 WASTEWATER HEAT PUMP

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
DIVISION 2-14 - CONSTRUCTION						
New energy plant including foundations, steel framed insulated metal building, interior spaces and MEP's	100,000 SF	$275.00	$27,500,000	$200.00	$20,000,000	$47,500,000
TOTAL DIVISION 2-14 - CONSTRUCTION			**$27,500,000**		**$20,000,000**	**$47,500,000**
DIVISION 23 - HVAC						
EQUIPMENT						
Wastewater heat pumps, 1,000 tons	4 EA	$1,500,000.00	$6,000,000	$110,000.00	$440,000	$6,440,000
Clean in place system between effluent and evaporator	1 LS	$150,000.00	$150,000	$40,000.00	$40,000	$190,000
Hydronic pumps, 800 GPM, with VFD	8 EA	$40,000.00	$320,000	$8,000.00	$64,000	$384,000
Plate and frame heat exchangers, 4,170 GPM	8 EA	$65,000.00	$520,000	$15,500.00	$124,000	$644,000
PIPING SYSTEMS						
Hydraulic loop piping between effluent and evaporator	1 ALLOW	$75,000.00	$75,000	$85,000.00	$85,000	$160,000
Heat exchanger pipe, SCH 40 steel, 40" diameter	400 LF	$405.00	$162,000	$436.00	$174,400	$336,400
- Elbows, 40" diameter	16 EA	$9,500.00	$152,000	$5,200.00	$83,200	$235,200
- Gate valves, 40" diameter	4 EA	$60,000.00	$240,000	$6,000.00	$24,000	$264,000
Concrete pipe, 60" diameter	100 LF	$365.00	$36,500	$390.00	$39,000	$75,500
- Elbows, 60" diameter	4 EA	$17,500.00	$70,000	$6,000.00	$24,000	$94,000
- Gate valves, 60" diameter	3 EA	$85,000.00	$255,000	$8,000.00	$24,000	$279,000
Pre-insulated and jacketed steel pipe with integral leak detection control wiring (below grade)						
- 14" diameter	7,400 LF	$185.00	$1,369,000	$234.00	$1,731,600	$3,100,600
Site utilities earthwork including excavation, backfill and disposal off site	30,400 CY	$74.00	$2,249,600	$49.00	$1,489,600	$3,739,200
Pre-insulated and jacketed steel pipe with integral leak detection control wiring (pipe to be suspended/attached to highway overpass)						
- 14" diameter	14,300 LF	$185.00	$2,645,500	$448.00	$6,406,400	$9,051,900
Valve assemblies and connections	1 ALLOW	$125,000.00	$125,000	$85,000.00	$85,000	$210,000

CONFIDENTIAL AND PROPRIETARY

3.4 WASTEWATER HEAT PUMP

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
Pipe support system	1 LS	$300,000.00	$300,000	$380,000.00	$380,000	$680,000
Structural reinforcements for highway suspended piping	34 TONS	$12,000.00	$408,000	$13,000.00	$442,000	$850,000
Field joints (estimated quantity)						
- 14" diameter	220 EA	$175.00	$38,500	$900.00	$198,000	$236,500
Fittings, elbows (estimated quantity)						
- 14" diameter	60 EA	$2,260.00	$135,600	$2,640.00	$158,400	$294,000
CONTROLS						
- Wastewater heat pumps	4 EA	$10,000.00	$40,000	$14,000.00	$56,000	$96,000
- Clean in place system	1 LS	$7,500.00	$7,500	$10,000.00	$10,000	$17,500
- Pumps and VFD's	8 EA	$3,500.00	$28,000	$5,000.00	$40,000	$68,000
- Leak detection	1 ALLOW	$25,000.00	$25,000	$35,000.00	$35,000	$60,000
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$150,000.00	$150,000	$150,000
MISCELLANEOUS						
Overnight/off hours premium for work associated highway	1 LS	$0.00	$0	$1,850,000.00	$1,850,000	$1,850,000
Crane, material handling, rigging and hoisting	1 LS	$150,000.00	$150,000	$500,000.00	$500,000	$650,000
Cleaning, cutting, patching, paint and identification	1 LS	$50,000.00	$50,000	$250,000.00	$250,000	$300,000
TOTAL DIVISION 23 - HVAC			**$15,552,200**		**$14,903,600**	**$30,455,800**

DIVISION 26 - ELECTRICAL

Primary electrical service to serve new WWHP plant including feeders, pad mount transformers, excavation, backfill, and concrete ductbank	1 ALLOW	$500,000.00	$500,000	$250,000.00	$250,000	$750,000
Secondary electrical service to serve new WWHP plant including feeders, excavation, backfill, and concrete ductbank	1 ALLOW	$225,000.00	$225,000	$125,000.00	$125,000	$350,000
Incoming communications / fiber optic service to serve new WWHP plant including below grade conduits, cabling, excavation, backfill, and concrete ductbank	1 ALLOW	$50,000.00	$50,000	$50,000.00	$50,000	$100,000

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3.4 WASTEWATER HEAT PUMP

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
General electrical work at new WWHP plant including distribution system, LED lighting, convenience receptacles, general equipment connections, security, fire alarm, associated conduit, and circuiting	100,000 SF			INCLUDED WITH GENERAL CONSTRUCTION		
Wastewater heat pump and associated VFD connection including local disconnect, conduit, and circuiting back to new MCC	4 EA	$12,500.00	$50,000	$20,000.00	$80,000	$130,000
Hydronic pump and associated VFD connection including local disconnect, conduit, and circuiting back to new MCC	8 EA	$7,500.00	$60,000	$12,500.00	$100,000	$160,000
TOTAL DIVISION 26 - ELECTRICAL			**$885,000**		**$605,000**	**$1,490,000**
SUB-TOTAL			$43,937,200		$35,508,600	$79,445,800
GENERAL CONDITIONS	15.0%					$11,916,870
OVERHEAD AND PROFIT	10.0%					$9,136,267
DESIGN CONTINGENCY	20.0%					$20,099,787
TOTAL 3.4 WASTEWATER HEAT PUMP						**$120,598,724**

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3.5 INDUSTRIAL HEAT RECOVERY

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
DIVISION 23 - HVAC						
PIPING SYSTEMS						
Pre-insulated and jacketed steel pipe with integral leak detection control wiring (below grade)						
- 18" diameter	5,900 LF	$292.00	$1,722,800	$210.00	$1,239,000	$2,961,800
Valve assemblies and connections	1 ALLOW	$150,000.00	$150,000	$100,000.00	$100,000	$250,000
Site utilities earthwork including excavation, backfill and disposal off site	25,400 CY	$74.00	$1,879,600	$49.00	$1,244,600	$3,124,200
Directional boring under river	1,800 LF	$525.00	$945,000	$600.00	$1,080,000	$2,025,000
Field joints (estimated quantity)						
- 18" diameter	185 EA	$248.00	$45,880	$800.00	$148,000	$193,880
Fittings, elbows (estimated quantity)						
- 18" diameter	50 EA	$4,200.00	$210,000	$3,050.00	$152,500	$362,500
Gate valves, flanged steel						
- 32" diameter	4 EA	$40,000.00	$160,000	$5,200.00	$20,800	$180,800
- 48" diameter	2 EA	$70,000.00	$140,000	$6,500.00	$13,000	$153,000
Flow meters						
- 32" diameter	2 EA	$15,000.00	$30,000	$2,616.00	$5,232	$35,232
CONTROLS						
- Flow meters	2 EA	$8,500.00	$17,000	$12,500.00	$25,000	$42,000
- Leak detection	1 LS	$15,000.00	$15,000	$25,000.00	$25,000	$40,000
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$50,000.00	$50,000	$50,000
MISCELLANEOUS						
Crane, material handling, rigging and hoisting	1 LS	$75,000.00	$75,000	$250,000.00	$250,000	$325,000
Cleaning, cutting, patching, paint and identification	1 LS	$25,000.00	$25,000	$125,000.00	$125,000	$150,000
TOTAL DIVISION 23 - HVAC			**$5,415,280**		**$4,478,132**	**$9,893,412**

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3.5 INDUSTRIAL HEAT RECOVERY

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
DIVISION 26 - ELECTRICAL						
Miscellaneous electrical removals, relocations, and installations to allow for installation of new HVAC piping	1 ALLOW	$25,000.00	$25,000	$25,000.00	$25,000	$50,000
TOTAL DIVISION 26 - ELECTRICAL			**$25,000**		**$25,000**	**$50,000**
SUB-TOTAL			$5,440,280		$4,503,132	$9,943,412
GENERAL CONDITIONS	15.0%					$1,491,512
OVERHEAD AND PROFIT	10.0%					$1,143,492
DESIGN CONTINGENCY	20.0%					$2,515,683
TOTAL 3.5 INDUSTRIAL HEAT RECOVERY						**$15,094,099**

CONFIDENTIAL AND PROPRIETARY

3.6 AIR SOURCE HEAT PUMP

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
DIVISION 2-14 - CONSTRUCTION						
Break out slab, install new piles and cap, patch slab	3 EA	$35,000.00	$105,000	$20,000.00	$60,000	$165,000
New mechanical room inside existing space including new foundations, CMU walls, steel frame and metal deck	2,400 SF	$120.00	$288,000	$80.00	$192,000	$480,000
TOTAL DIVISION 2-14 - CONSTRUCTION			**$393,000**		**$252,000**	**$645,000**
DIVISION 23 - HVAC						
EQUIPMENT						
Custom built air source chiller including evaporator coils, compressors, refrigerant piping, internal sensors and controls, condensate drain pans and accessories, estimated 3,600 ton capacity	1 LS	$3,500,000.00	$3,500,000	$2,500,000.00	$2,500,000	$6,000,000
Sump pump to discharge condensate	1 EA	$5,500.00	$5,500	$3,500.00	$3,500	$9,000
PIPING SYSTEMS						
Condensate drain piping, welded galvanized steel, schedule 40, includes insulation and heat trace						
- 4" diameter	1,000 LF	$56.00	$56,000	$63.00	$63,000	$119,000
Pre-insulated and jacketed steel pipe with integral leak detection control wiring						
- 10" diameter	120 LF	$107.00	$12,840	$129.00	$15,480	$28,320
- 14" diameter	120 LF	$185.00	$22,200	$292.00	$35,040	$57,240
- 16" diameter	1,200 LF	$225.00	$270,000	$305.00	$366,000	$636,000
- 20" diameter	1,200 LF	$307.00	$368,400	$365.00	$438,000	$806,400
Valve assemblies and connections	6 EA	$13,500.00	$81,000	$5,500.00	$33,000	$114,000
Control valves	6 EA	$10,000.00	$60,000	$3,500.00	$21,000	$81,000
Pipe support system	1 LS	$60,000.00	$60,000	$75,000.00	$75,000	$135,000
Field joints (estimated quantity)						
- 10" diameter	6 EA	$145.00	$870	$450.00	$2,700	$3,570
- 14" diameter	6 EA	$175.00	$1,050	$600.00	$3,600	$4,650
- 16" diameter	32 EA	$215.00	$6,880	$600.00	$19,200	$26,080
- 20" diameter	32 EA	$265.00	$8,480	$800.00	$25,600	$34,080

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3.6 AIR SOURCE HEAT PUMP

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
Fittings, elbows (estimated quantity)						
- 10" diameter	12 EA	$1,345.00	$16,140	$1,525.00	$18,300	$34,440
- 14" diameter	12 EA	$2,260.00	$27,120	$1,760.00	$21,120	$48,240
- 16" diameter	20 EA	$3,180.00	$63,600	$2,640.00	$52,800	$116,400
- 20" diameter	20 EA	$5,130.00	$102,600	$3,050.00	$61,000	$163,600
Butterfly valves, flanged (estimated quantity)						
- 10" diameter	6 EA	$3,050.00	$18,300	$1,525.00	$9,150	$27,450
- 14" diameter	6 EA	$3,300.00	$19,800	$1,525.00	$9,150	$28,950
- 16" diameter	4 EA	$3,900.00	$15,600	$1,760.00	$7,040	$22,640
- 20" diameter	4 EA	$4,500.00	$18,000	$2,640.00	$10,560	$28,560
CONTROLS						
Direct Digital Controls						
- Ground source heat pumps	1 EA	$30,000.00	$30,000	$45,000.00	$45,000	$75,000
- Leak detection	1 LS	$5,000.00	$5,000	$7,500.00	$7,500	$12,500
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$75,000.00	$75,000	$75,000
MISCELLANEOUS						
Crane, material handling, rigging and hoisting	1 LS	$25,000.00	$25,000	$80,000.00	$80,000	$105,000
Cleaning, cutting, patching, paint and identification	1 LS	$15,000.00	$15,000	$50,000.00	$50,000	$65,000
TOTAL DIVISION 23 - HVAC			**$4,809,380**		**$4,047,740**	**$8,857,120**
DIVISION 26 - ELECTRICAL						
5 kV service feeder to serve ASHP system equipment at new mechanical room including excavation, concrete ductbank, penetrations, seals, and earthwork (distance assumed)	3,000 LF	$275.00	$825,000	$200.00	$600,000	$1,425,000
Mechanical room electrical distribution equipment including transformers, power panels, and secondary feeders	1 ALLOW	$175,000.00	$175,000	$75,000.00	$75,000	$250,000

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3.6 AIR SOURCE HEAT PUMP

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
480v motor control center including feeder back to source distribution panel, rigging, and setting	1 ALLOW	$225,000.00	$225,000	$75,000.00	$75,000	$300,000
Hot / chilled water pump and associated VFD connection including local disconnect, conduit, and circuiting back to new MCC	8 EA	$7,500.00	$60,000	$12,500.00	$100,000	$160,000
General electrical work at new mechanical room including LED lighting, convenience receptacles, equipment connections, fire alarm, associated conduit, and circuiting	1 ALLOW	$25,000.00	$25,000	$25,000.00	$25,000	$50,000
Miscellaneous electrical removals, relocations, and installations to allow for construction of new mechanical space	1 ALLOW	$7,500.00	$7,500	$7,500.00	$7,500	$15,000
TOTAL DIVISION 26 - ELECTRICAL			**$1,317,500**		**$882,500**	**$2,200,000**

SUB-TOTAL		$6,519,880	$5,182,240	$11,702,120
GENERAL CONDITIONS	15.0%			$1,755,318
OVERHEAD AND PROFIT	10.0%			$1,345,744
DESIGN CONTINGENCY	20.0%			$2,960,636
TOTAL 3.6 AIR SOURCE HEAT PUMP				**$17,763,818**

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3.7 PEAKING BIOFUEL BOILER

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
DIVISION 23 - HVAC						
EQUIPMENT						
Replacement of existing biofuel boiler burners, boilers to remain, sized for 80,000 PPH, includes integral controller	6 EA	$950,000.00	$5,700,000	$55,000.00	$330,000	$6,030,000
CONTROLS						
Connection to existing controls	6 EA	$3,500.00	$21,000	$5,500.00	$33,000	$54,000
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$18,000.00	$18,000	$18,000
TOTAL DIVISION 23 - HVAC			**$5,721,000**		**$381,000**	**$6,102,000**
DIVISION 26 - ELECTRICAL						
Electrical work associated with burner replacement at existing boiler including temporary shutdowns and component replacement as required - allowance per boiler	6 EA	$5,000.00	$30,000	$5,000.00	$30,000	$60,000
TOTAL DIVISION 26 - ELECTRICAL			**$30,000**		**$30,000**	**$60,000**
SUB-TOTAL			$5,751,000		$411,000	$6,162,000
GENERAL CONDITIONS	15.0%					$924,300
OVERHEAD AND PROFIT	10.0%					$708,630
DESIGN CONTINGENCY	20.0%					$1,558,986
TOTAL 3.7 PEAKING BIOFUEL BOILER						**$9,353,916**

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3.8 PEAKING ELECTRIC BOILER

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
DIVISION 23 - HVAC						
DEMOLITION						
Boiler removals	1 LS	$10,000.00	$10,000	$45,000.00	$45,000	$55,000
EQUIPMENT						
Electric hot water boilers, 3,360 kW	7 EA	$180,000.00	$1,260,000	$30,000.00	$210,000	$1,470,000
Boiler accessories, pumps, air separators, expansion tanks etc.	1 LS	$100,000.00	$100,000	$60,000.00	$60,000	$160,000
PIPING SYSTEMS						
Pre-insulated and jacketed steel pipe with integral leak detection control wiring						
- 14" diameter	850 LF	$185.00	$157,250	$438.00	$372,300	$529,550
- 20" diameter	1,200 LF	$307.00	$368,400	$365.00	$438,000	$806,400
Valve assemblies and connections	6 EA	$13,500.00	$81,000	$5,500.00	$33,000	$114,000
Pipe supports	1 LS	$15,000.00	$15,000	$25,000.00	$25,000	$40,000
Field joints (estimated quantity)						
- 14" diameter	6 EA	$175.00	$1,050	$600.00	$3,600	$4,650
- 20" diameter	32 EA	$265.00	$8,480	$800.00	$25,600	$34,080
Fittings, elbows (estimated quantity)						
- 14" diameter	28 EA	$2,260.00	$63,280	$1,760.00	$49,280	$112,560
- 20" diameter	20 EA	$5,130.00	$102,600	$3,050.00	$61,000	$163,600
Butterfly valves, flanged (estimated quantity)						
- 14" diameter	14 EA	$3,300.00	$46,200	$1,525.00	$21,350	$67,550
- 20" diameter	4 EA	$4,500.00	$18,000	$2,640.00	$10,560	$28,560
CONTROLS						
- Boilers and accessories	7 EA	$10,000.00	$70,000	$12,000.00	$84,000	$154,000
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$25,000.00	$25,000	$25,000
MISCELLANEOUS						
Crane, material handling, rigging and hoisting	1 LS	$15,000.00	$15,000	$40,000.00	$40,000	$55,000
Cleaning, cutting, patching, paint and identification	1 LS	$7,500.00	$7,500	$25,000.00	$25,000	$32,500
TOTAL DIVISION 23 - HVAC			**$2,323,760**		**$1,528,690**	**$3,852,450**

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3.8 PEAKING ELECTRIC BOILER

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
DIVISION 26 - ELECTRICAL						
480v electrical distribution upgrades including substation and feeder to serve electric boiler system equipment including equipment, conduits, conductors, penetrations, seals, and hardware	1 ALLOW	$1,250,000.00	$1,250,000	$500,000.00	$500,000	$1,750,000
480v motor control center including feeder back to source distribution panel, rigging, and setting	1 ALLOW	$225,000.00	$225,000	$75,000.00	$75,000	$300,000
Electric boiler connection including local disconnect, conduit, and circuiting back to new MCC	7 EA	$75,000.00	$525,000	$75,000.00	$525,000	$1,050,000
Electric boiler pump connection including local disconnect, conduit, and circuiting back to new MCC	7 EA	$7,500.00	$52,500	$12,500.00	$87,500	$140,000
Miscellaneous electrical removals, relocations, and installations to allow for installation of new electric boiler connection	1 ALLOW	$25,000.00	$25,000	$25,000.00	$25,000	$50,000
TOTAL DIVISION 26 - ELECTRICAL			**$2,077,500**		**$1,212,500**	**$3,290,000**
SUB-TOTAL			$4,401,260		$2,741,190	$7,142,450
GENERAL CONDITIONS	15.0%					$1,071,368
OVERHEAD AND PROFIT	10.0%					$1,232,073
DESIGN CONTINGENCY	20.0%					$1,416,884
TOTAL 3.8 PEAKING ELECTRIC BOILER						**$10,862,774**

CONFIDENTIAL AND PROPRIETARY

3.10 CENTRAL AC PLANT

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
DIVISION 2-14 - CONSTRUCTION						
Break out slab, install new piles and cap, patch slab	3 EA	$35,000.00	$105,000	$20,000.00	$60,000	$165,000
New mechanical room inside existing space including new foundations, CMU walls, steel frame and metal deck	2,400 SF	$120.00	$288,000	$80.00	$192,000	$480,000
TOTAL DIVISION 2-14 - CONSTRUCTION			**$393,000**		**$252,000**	**$645,000**
DIVISION 23 - HVAC						
DEMOLITION						
Remove steam driven chillers	4 EA	$5,000.00	$20,000	$15,000.00	$60,000	$80,000
Remove steam condensers	4 EA	$3,000.00	$12,000	$10,000.00	$40,000	$52,000
Remove steam pipe, 16" diameter	400 LF	$12.00	$4,800	$55.00	$22,000	$26,800
Remove condensate receiver and pumps	4 EA	$2,000.00	$8,000	$5,000.00	$20,000	$28,000
EQUIPMENT						
Chillers, 2,000 tons	3 EA	$2,400,000.00	$7,200,000	$110,000.00	$330,000	$7,530,000
Steam to hot water energy transfer stations, 125,000 PPH	2 EA	$600,000.00	$1,200,000	$110,000.00	$220,000	$1,420,000
Condensate receivers and pumps	2 EA	$200,000.00	$400,000	$35,000.00	$70,000	$470,000
Hydronic accessories	1 LS	$150,000.00	$150,000	$50,000.00	$50,000	$200,000
PIPING SYSTEMS						
Hydronic piping (estimated average size and quantity)	2,000 LF	$200.00	$400,000	$350.00	$700,000	$1,100,000
Valves and fittings	1 LS	$250,000.00	$250,000	$200,000.00	$200,000	$450,000
CONTROLS						
Direct Digital Controls						
- Chillers	3 EA	$10,000.00	$30,000	$14,000.00	$42,000	$72,000
- Condensate receivers and pumps	1 LS	$20,000.00	$20,000	$30,000.00	$30,000	$50,000
- Steam to hot water stations	1 LS	$35,000.00	$35,000	$50,000.00	$50,000	$85,000
- Leak detection	1 LS	$10,000.00	$10,000	$30,000.00	$30,000	$40,000
TESTING, ADJUSTING AND BALANCING						
Testing, adjusting and balancing	1 LS	$0.00	$0	$100,000.00	$100,000	$100,000
MISCELLANEOUS						

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3.10 CENTRAL AC PLANT

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
Crane, material handling, rigging and hoisting	1 LS	$40,000.00	$40,000	$150,000.00	$150,000	$190,000
Cleaning, cutting, patching, paint and identification	1 LS	$15,000.00	$15,000	$75,000.00	$75,000	$90,000
TOTAL DIVISION 23 - HVAC			**$9,794,800**		**$2,189,000**	**$11,983,800**
DIVISION 26 - ELECTRICAL						
Disconnect CASP equipment for removal by others - remove motor starters, conduit, and circuiting back to source	12 EA	$1,500.00	$18,000	$5,000.00	$60,000	$78,000
480v motor control center including feeder back to source distribution panel, rigging, and setting	1 ALLOW	$225,000.00	$225,000	$75,000.00	$75,000	$300,000
Electric chiller and associated VFD connection including local disconnect, conduit, and circuiting back to source	3 EA	$15,000.00	$45,000	$25,000.00	$75,000	$120,000
Pump and associated VFD connection including local disconnect, conduit, and circuiting back to new MCC	2 EA	$7,500.00	$15,000	$12,500.00	$25,000	$40,000
General electrical work at new mechanical room including LED lighting, convenience receptacles, equipment connections, fire alarm, associated conduit, and circuiting	1 ALLOW	$25,000.00	$25,000	$25,000.00	$25,000	$50,000
TOTAL DIVISION 26 - ELECTRICAL			**$328,000**		**$260,000**	**$588,000**

SUB-TOTAL		$10,515,800	$2,701,000	$13,216,800
GENERAL CONDITIONS	15.0%			$1,982,520
OVERHEAD AND PROFIT	10.0%			$1,519,932
DESIGN CONTINGENCY	20.0%			$3,343,850
TOTAL 3.10 CENTRAL AC PLANT				**$20,063,102**

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ALTERNATES & OPTIONS

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
ALT #1 - LARGER DIAMETER PIPE (3.4)						
HVAC						
DEDUCT						
Pre-insulated and jacketed steel pipe with integral leak detection control wiring (below grade)						
- 14" diameter	7,400 LF	($185.00)	($1,369,000)	($234.00)	($1,731,600)	($3,100,600)
Pre-insulated and jacketed steel pipe with integral leak detection control wiring						
- 14" diameter	14,300 LF	($185.00)	($2,645,500)	($292.00)	($4,175,600)	($6,821,100)
Valve assemblies	1 ALLOW	($50,000.00)	($50,000)	($20,000.00)	($20,000)	($70,000)
Pipe support system	1 LS	($300,000.00)	($300,000)	($380,000.00)	($380,000)	($680,000)
Field joints (estimated quantity)						
- 14" diameter	220 EA	($175.00)	($38,500)	($900.00)	($198,000)	($236,500)
Fittings, elbows (estimated quantity)						
- 14" diameter	60 EA	($2,260.00)	($135,600)	($2,640.00)	($158,400)	($294,000)
ADD						
Pre-insulated and jacketed steel pipe with integral leak detection control wiring (below grade)						
- 24" diameter	7,400 LF	$387.00	$2,863,800	$324.00	$2,397,600	$5,261,400
Pre-insulated and jacketed steel pipe with integral leak detection control wiring						
- 24" diameter	14,300 LF	$387.00	$5,534,100	$608.00	$8,694,400	$14,228,500
Valve assemblies	1 ALLOW	$80,000.00	$80,000	$40,000.00	$40,000	$120,000
Pipe support system	1 LS	$400,000.00	$400,000	$900,000.00	$900,000	$1,300,000
Field joints (estimated quantity)						
- 24" diameter	220 EA	$335.00	$73,700	$1,300.00	$286,000	$359,700
Fittings, elbows (estimated quantity)						
- 24" diameter	60 EA	$6,800.00	$408,000	$5,040.00	$302,400	$710,400

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ALTERNATES & OPTIONS

DESCRIPTION	QUANTITY	MATERIAL UNIT PRICE	MATERIAL TOTAL	LABOR UNIT PRICE	LABOR TOTAL	TOTAL
SUB-TOTAL			$4,821,000		$5,956,800	$10,777,800
GENERAL CONDITIONS	15.0%					$1,616,670
OVERHEAD AND PROFIT	10.0%					$1,239,447
DESIGN CONTINGENCY	20.0%					$2,726,783
TOTAL ALT #1 - LARGER DIAMETER PIPE (3.4)						**$16,360,700**
ALT #2 - LARGER DIAMETER PIPE (3.5)						
HVAC						
DEDUCT						
Pre-insulated and jacketed steel pipe with integral leak detection control wiring (below grade)						
- 18" diameter	5,900 LF	($292.00)	($1,722,800)	($210.00)	($1,239,000)	($2,961,800)
Field joints (estimated quantity)						
- 18" diameter	185 EA	($248.00)	($45,880)	($800.00)	($148,000)	($193,880)
Fittings, elbows (estimated quantity)						
- 18" diameter	50 EA	($4,200.00)	($210,000)	($3,050.00)	($152,500)	($362,500)
ADD						
Pre-insulated and jacketed steel pipe with integral leak detection control wiring (below grade)						
- 32" diameter	5,900 LF	$561.00	$3,309,900	$348.00	$2,053,200	$5,363,100
Field joints (estimated quantity)						
- 32" diameter	185 EA	$485.00	$89,725	$1,250.00	$231,250	$320,975
Fittings, elbows (estimated quantity)						
- 32" diameter	50 EA	$9,800.00	$490,000	$4,870.00	$243,500	$733,500
SUB-TOTAL			$1,910,945		$988,450	$2,899,395
GENERAL CONDITIONS	15.0%					$434,909
OVERHEAD AND PROFIT	10.0%					$333,430
DESIGN CONTINGENCY	20.0%					$733,547
TOTAL ALT #2 - LARGER DIAMETER PIPE (3.5)						**$4,401,282**

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Techno-Economic Analysis

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CAPEX	Baseline 2019	Sc.1A	Sc.1B	Sc.1C	Sc.1E	Sc.1F	Sc.1C1	Sc.1C2	Sc.1C3
	BaU	HRC	HRC+WWHP	HRC+GSHP	HRC+ASHP	HRC+ IHR-HP	HRC+GSHP +bio.boiler	HRC+GSHP +el.boiler	HRC+GSHP w/oTTES
Building renovation	$ 458,129,142	$ 1,096,002,733	$ 1,096,002,733	$ 1,096,002,733	$ 1,096,002,733	$ 1,096,002,733	$ 1,096,002,733	$ 1,096,002,733	$ 1,096,002,733
Hot Water Piping Costs	$ -	$ 21,920,055	$ 21,920,055	$ 21,920,055	$ 21,920,055	$ 21,920,055	$ 21,920,055	$ 21,920,055	$ 21,920,055
CACP	$ -	$ 27,509,669	$ 27,509,669	$ 27,509,669	$ 27,509,669	$ 27,509,669	$ 27,509,669	$ 27,509,669	$ 27,509,669
HRC	$ -	$ 9,425,624	$ 9,425,624	$ 9,425,624	$ 9,425,624	$ 9,425,624	$ 9,425,624	$ 9,425,624	$ 9,425,624
WWHP	$ -	$ -	$ 165,277,212	$ -	$ -	$ 165,277,212	$ -	$ -	$ -
GSHP	$ -	$ -	$ -	$ 90,091,425	$ -	$ -	$ 90,091,425	$ 90,091,425	$ 90,091,425
IHR	$ -	$ -	$ -	$ -	$ -	$ 20,714,452	$ -	$ -	$ -
ASHP	$ -	$ -	$ -	$ -	$ 24,440,861	$ -	$ -	$ -	$ -
Bio Peak	$ -	$ -	$ -	$ -	$ -	$ -	$ 12,823,232	$ -	$ -
Electric peak	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 14,905,637	$ -
TTES	$ -	$ 24,440,861	$ 24,440,861	$ 24,440,861	$ 24,440,861	$ 24,440,861	$ 24,440,861	$ 24,440,861	$ -
Total	**$ 458,129,142**	**$ 1,179,298,941**	**$ 1,344,576,153**	**$ 1,269,390,366**	**$ 1,203,739,802**	**$ 1,365,290,605**	**$ 1,282,213,598**	**$ 1,284,296,003**	**$ 1,244,949,505**

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NPV COSTS	Baseline 2019	Sc.1A	Sc.1B	Sc.1C	Sc.1E	Sc.1F	Sc.1C1	Sc.1C2	Sc.1C3
	BaU	HRC	HRC+WWHP	HRC+GSHP	HRC+ASHP	HRC+ IHR-HP	HRC+GSHP +bio.boiler	HRC+GSHP +el.boiler	HRC+GSHP w/oTTES
Fuel Costs									
HRC	$ -	$ 12,212,732	$ 10,552,236	$ 10,490,932	$ 12,196,522	$ 12,129,743	$ 12,205,176	$ 12,205,176	$ 12,123,100
Chillers	$ -	$ 13,383,894	$ 11,351,953	$ 3,623,520	$ 13,394,301	$ 13,439,025	$ 4,231,555	$ 4,231,555	$ 6,036,144
GSHP_heating	$ -	$ -	$ -	$ 13,613,014	$ -	$ -	$ 15,745,265	$ 15,745,265	$ 15,384,199
GSHP_cooling	$ -	$ -	$ -	$ 6,435,647	$ -	$ -	$ 7,514,140	$ 7,514,140	$ 7,286,645
WWHP	$ -	$ -	$ 13,430,385	$ -	$ -	$ 11,973,447	$ -	$ -	$ -
ASHP	$ -	$ -	$ -	$ -	$ 14,534,854	$ -	$ -	$ -	$ -
Electric boiler	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,534,538	$ -
RES boiler	$ -	$ -	$ -	$ -	$ -	$ -	$ 4,723,327	$ -	$ -
Natural gas boiler	$ 163,083,618	$ 17,756,006	$ 671,635	$ 614,665	$ 3,797,338	$ 409,624	$ -	$ -	$ 2,394,618
Electric DHW	$ -	$ 4,926,985	$ 4,926,985	$ 4,926,985	$ 4,926,985	$ 4,926,985	$ 4,926,985	$ 4,926,985	$ 4,926,985
Total Fuel Cost	***$ 163,083,618***	***$ 48,279,617***	***$ 40,933,193***	***$ 39,704,762***	***$ 48,850,000***	***$ 42,878,824***	***$ 49,346,448***	***$ 46,157,659***	***$ 48,151,691***
O&M Cost									
HRC	$ -	$ 1,015,536	$ 1,022,151	$ 1,015,293	$ 1,014,994	$ 1,014,081	$ 1,015,236	$ 1,015,236	$ 940,759
Chillers	$ -	$ 871,258	$ 866,638	$ 267,371	$ 871,628	$ 872,298	$ 267,342	$ 267,342	$ 351,942
GSHP_heating	$ -	$ -	$ -	$ 976,287	$ -	$ -	$ 981,434	$ 981,434	$ 937,252
GSHP_cooling	$ -	$ -	$ -	$ 820,646	$ -	$ -	$ 820,732	$ 820,732	$ 775,067
WWHP	$ -	$ -	$ 986,694	$ -	$ -	$ 1,009,705	$ -	$ -	$ -
ASHP	$ -	$ -	$ -	$ -	$ 790,222	$ -	$ -	$ -	$ -
Electric boiler	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 18,163	$ -
RES boiler	$ -	$ -	$ -	$ -	$ -	$ -	$ 44,438	$ -	$ -
Natural gas boiler	$ -	$ 662,796	$ 28,570	$ 28,428	$ 149,567	$ 18,862	$ -	$ -	$ 101,337
Electric DHW	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total O&M Cost	***$ -***	***$ 2,549,589***	***$ 2,904,054***	***$ 3,108,025***	***$ 2,826,412***	***$ 2,914,946***	***$ 3,129,182***	***$ 3,102,907***	***$ 3,106,357***
CO2e Cost									
Imported electricity	$ -	$ 456,629	$ 656,505	$ 628,529	$ 667,642	$ 610,320	$ 629,586	$ 659,811	$ 621,817
Natural gas	$ 190,669,175	$ 19,894,282	$ 857,665	$ 853,244	$ 4,489,231	$ 566,373	$ -	$ -	$ 3,041,615
RES fuel	$ -	$ -	$ -	$ -	$ -	$ -	$ 33,403	$ -	$ -
Total CO2e Cost	***$ 190,669,175***	***$ 20,350,911***	***$ 1,514,170***	***$ 1,481,773***	***$ 5,156,872***	***$ 1,176,693***	***$ 662,989***	***$ 659,811***	***$ 3,663,432***
CAPEX									
Building renovation	$ 458,129,142	$ 1,096,002,733	$ 1,096,002,733	$ 1,096,002,733	$ 1,096,002,733	$ 1,096,002,733	$ 1,096,002,733	$ 1,096,002,733	$ 1,096,002,733
Hot Water Piping Costs	$ -	$ 21,920,055	$ 21,920,055	$ 21,920,055	$ 21,920,055	$ 21,920,055	$ 21,920,055	$ 21,920,055	$ 21,920,055
CACP	$ -	$ 27,509,669	$ 27,509,669	$ 27,509,669	$ 27,509,669	$ 27,509,669	$ 27,509,669	$ 27,509,669	$ 27,509,669
HRC	$ -	$ 9,425,624	$ 9,425,624	$ 9,425,624	$ 9,425,624	$ 9,425,624	$ 9,425,624	$ 9,425,624	$ 9,425,624
WWHP	$ -	$ -	$ 165,277,212	$ -	$ -	$ 165,277,212	$ -	$ -	$ -
GSHP	$ -	$ -	$ -	$ 90,091,425	$ -	$ -	$ 90,091,425	$ 90,091,425	$ 90,091,425
IHR	$ -	$ -	$ -	$ -	$ -	$ 20,714,452	$ -	$ -	$ -
ASHP	$ -	$ -	$ -	$ -	$ 24,440,861	$ -	$ -	$ -	$ -
Bio Peak	$ -	$ -	$ -	$ -	$ -	$ -	$ 12,823,232	$ -	$ -
Electric peak	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 14,905,637	$ -
TTES	$ -	$ 24,440,861	$ 24,440,861	$ 24,440,861	$ 24,440,861	$ 24,440,861	$ 24,440,861	$ 24,440,861	$ -
Total CAPEX Cost	***$ 458,129,142***	***$ 1,179,298,941***	***$ 1,344,576,153***	***$ 1,269,390,366***	***$ 1,203,739,802***	***$ 1,365,290,605***	***$ 1,282,213,598***	***$ 1,284,296,003***	***$ 1,244,949,505***
Residual Value									
Building renovation	$ (17,865,736)	$ (42,740,995)	$ (42,740,995)	$ (42,740,995)	$ (42,740,995)	$ (42,740,995)	$ (42,740,995)	$ (42,740,995)	$ (42,740,995)
Hot Water Piping Costs	$ -	$ (4,843,979)	$ (4,843,979)	$ (4,843,979)	$ (4,843,979)	$ (4,843,979)	$ (4,843,979)	$ (4,843,979)	$ (4,843,979)
CACP	$ -	$ (715,199)	$ (715,199)	$ (715,199)	$ (715,199)	$ (715,199)	$ (715,199)	$ (715,199)	$ (715,199)
Scenarios	$ -	$ (4,302,593)	$ (34,380,856)	$ (18,355,833)	$ (4,302,593)	$ (37,612,076)	$ (20,207,942)	$ (19,518,388)	$ (14,543,336)
Total Residual Value	***$ (17,865,736)***	***$ (52,602,767)***	***$ (82,681,030)***	***$ (66,656,006)***	***$ (52,602,767)***	***$ (85,912,249)***	***$ (68,508,116)***	***$ (67,818,561)***	***$ (62,843,510)***
Total Net Present Value	**$ 794,016,200**	**$ 1,197,876,290**	**$ 1,307,246,539**	**$ 1,247,028,918**	**$ 1,207,970,319**	**$ 1,326,348,818**	**$ 1,266,844,101**	**$ 1,266,397,818**	**$ 1,237,027,475**

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Annual Cash Flow (2025 USD)	NPV	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049
Scenario 1A HRC																					
Fuel Costs	$ 48,279,617	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443	$ 3,386,443
O&M Costs	$ 2,549,589	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834	$ 178,834
CO2e Costs	$ 20,350,911	$ 1,350,296	$ 1,358,826	$ 1,375,679	$ 1,375,221	$ 1,383,085	$ 1,390,726	$ 1,398,146	$ 1,405,343	$ 1,412,317	$ 1,410,914	$ 1,425,600	$ 1,441,800	$ 1,458,000	$ 1,474,200	$ 1,498,500	$ 1,514,700	$ 1,530,900	$ 1,539,000	$ 1,563,300	$ 1,571,400
CAPEX	$ 1,179,298,941	$ 1,076,000,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Residual Value	$ (52,602,767)	$ (110,766,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	**$ 1,197,876,290**	**$ 970,149,573**	**$ 4,924,103**	**$ 4,940,956**	**$ 4,940,498**	**$ 4,948,362**	**$ 4,956,003**	**$ 4,963,423**	**$ 4,970,620**	**$ 4,977,594**	**$ 4,976,191**	**$ 4,990,877**	**$ 5,007,077**	**$ 5,023,277**	**$ 5,039,477**	**$ 5,063,777**	**$ 5,079,977**	**$ 5,096,177**	**$ 5,104,277**	**$ 5,128,577**	**$ 5,136,677**
Scenario 1B HRC+WWHP																					
Fuel Costs	$ 40,933,193	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148	$ 2,871,148
O&M Costs	$ 2,904,054	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697	$ 203,697
CO2e Costs	$ 1,514,170	$ 179,119	$ 168,791	$ 159,132	$ 147,177	$ 135,890	$ 124,284	$ 112,358	$ 100,113	$ 87,548	$ 74,234	$ 61,459	$ 62,158	$ 62,856	$ 63,554	$ 64,602	$ 65,300	$ 65,999	$ 66,348	$ 67,396	$ 67,745
CAPEX	$ 1,344,576,153	$ 1,226,800,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Residual Value	$ (82,681,030)	$ (174,102,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	**$ 1,307,246,539**	**$ 1,055,951,964**	**$ 3,243,636**	**$ 3,233,977**	**$ 3,222,022**	**$ 3,210,735**	**$ 3,199,129**	**$ 3,187,203**	**$ 3,174,958**	**$ 3,162,393**	**$ 3,149,079**	**$ 3,136,304**	**$ 3,137,003**	**$ 3,137,701**	**$ 3,138,399**	**$ 3,139,447**	**$ 3,140,145**	**$ 3,140,844**	**$ 3,141,193**	**$ 3,142,241**	**$ 3,142,590**
Scenario 1C HRC+GSHP																					
Fuel Costs	$ 39,704,762	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983	$ 2,784,983
O&M Costs	$ 3,108,025	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004	$ 218,004
CO2e Costs	$ 1,481,773	$ 173,527	$ 163,665	$ 154,457	$ 143,024	$ 132,245	$ 121,159	$ 109,768	$ 98,071	$ 86,067	$ 73,334	$ 61,142	$ 61,837	$ 62,532	$ 63,227	$ 64,269	$ 64,964	$ 65,659	$ 66,006	$ 67,048	$ 67,396
CAPEX	$ 1,269,390,366	$ 1,158,200,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Residual Value	$ (66,656,006)	$ (140,358,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	**$ 1,247,028,918**	**$ 1,021,018,514**	**$ 3,166,652**	**$ 3,157,444**	**$ 3,146,011**	**$ 3,135,232**	**$ 3,124,146**	**$ 3,112,755**	**$ 3,101,058**	**$ 3,089,054**	**$ 3,076,321**	**$ 3,064,129**	**$ 3,064,824**	**$ 3,065,519**	**$ 3,066,214**	**$ 3,067,256**	**$ 3,067,951**	**$ 3,068,646**	**$ 3,068,993**	**$ 3,070,035**	**$ 3,070,383**
Scenario 1E HRC+ASHP																					
Fuel Costs	$ 48,850,000	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451	$ 3,426,451
O&M Costs	$ 2,826,412	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251	$ 198,251
CO2e Costs	$ 5,156,872	$ 411,895	$ 404,338	$ 398,933	$ 388,247	$ 379,715	$ 370,857	$ 361,674	$ 352,166	$ 342,333	$ 330,267	$ 321,693	$ 325,348	$ 329,004	$ 332,660	$ 338,143	$ 341,799	$ 345,454	$ 347,282	$ 352,765	$ 354,593
CAPEX	$ 1,203,739,802	$ 1,098,300,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Residual Value	$ (52,602,767)	$ (110,766,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	**$ 1,207,970,319**	**$ 991,570,597**	**$ 4,029,040**	**$ 4,023,635**	**$ 4,012,949**	**$ 4,004,417**	**$ 3,995,559**	**$ 3,986,376**	**$ 3,976,868**	**$ 3,967,035**	**$ 3,954,969**	**$ 3,946,395**	**$ 3,950,050**	**$ 3,953,706**	**$ 3,957,362**	**$ 3,962,845**	**$ 3,966,501**	**$ 3,970,156**	**$ 3,971,984**	**$ 3,977,467**	**$ 3,979,295**
Scenario 1F HRC+IHR-HP																					
Fuel Costs	$ 42,878,824	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619	$ 3,007,619
O&M Costs	$ 2,914,946	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461	$ 204,461
CO2e Costs	$ 1,176,693	$ 151,849	$ 142,060	$ 132,798	$ 121,590	$ 110,909	$ 99,931	$ 88,656	$ 77,084	$ 65,215	$ 52,744	$ 40,586	$ 41,047	$ 41,508	$ 41,969	$ 42,661	$ 43,122	$ 43,583	$ 43,814	$ 44,506	$ 44,736
CAPEX	$ 1,365,290,605	$ 1,245,700,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Residual Value	$ (85,912,249)	$ (180,906,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	**$ 1,326,348,818**	**$ 1,068,157,929**	**$ 3,354,140**	**$ 3,344,878**	**$ 3,333,670**	**$ 3,322,989**	**$ 3,312,011**	**$ 3,300,736**	**$ 3,289,164**	**$ 3,277,295**	**$ 3,264,824**	**$ 3,252,666**	**$ 3,253,127**	**$ 3,253,588**	**$ 3,254,049**	**$ 3,254,741**	**$ 3,255,202**	**$ 3,255,663**	**$ 3,255,894**	**$ 3,256,586**	**$ 3,256,816**
Scenario 1C1 HRC+GSHP+bio. boiler																					
Fuel Costs	$ 49,346,448	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273	$ 3,461,273
O&M Costs	$ 3,129,182	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488	$ 219,488
CO2e Costs	$ 662,989	$ 121,655	$ 111,108	$ 100,881	$ 89,095	$ 77,628	$ 65,855	$ 53,776	$ 41,390	$ 28,698	$ 15,609	$ 2,394	$ 2,421	$ 2,448	$ 2,475	$ 2,516	$ 2,543	$ 2,570	$ 2,584	$ 2,625	$ 2,638
CAPEX	$ 1,282,213,598	$ 1,169,900,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Residual Value	$ (68,508,116)	$ (144,258,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	**$ 1,266,844,101**	**$ 1,029,444,416**	**$ 3,791,869**	**$ 3,781,642**	**$ 3,769,856**	**$ 3,758,389**	**$ 3,746,616**	**$ 3,734,537**	**$ 3,722,151**	**$ 3,709,459**	**$ 3,696,370**	**$ 3,683,155**	**$ 3,683,182**	**$ 3,683,209**	**$ 3,683,236**	**$ 3,683,277**	**$ 3,683,304**	**$ 3,683,331**	**$ 3,683,345**	**$ 3,683,386**	**$ 3,683,399**
Scenario 1C2 HRC+GSHP+el. Boiler																					
Fuel Costs	$ 46,157,659	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604	$ 3,237,604
O&M Costs	$ 3,102,907	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645	$ 217,645
CO2e Costs	$ 659,811	$ 125,272	$ 114,190	$ 103,429	$ 91,063	$ 79,018	$ 66,651	$ 53,963	$ 40,954	$ 27,624	$ 13,892	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CAPEX	$ 1,284,296,003	$ 1,171,800,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Residual Value	$ (67,818,561)	$ (142,806,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	**$ 1,266,397,818**	**$ 1,032,574,521**	**$ 3,569,439**	**$ 3,558,678**	**$ 3,546,312**	**$ 3,534,267**	**$ 3,521,900**	**$ 3,509,212**	**$ 3,496,203**	**$ 3,482,873**	**$ 3,469,141**	**$ 3,455,249**	**$ 3,455,249**	**$ 3,455,249**	**$ 3,455,249**	**$ 3,455,249**	**$ 3,455,249**	**$ 3,455,249**	**$ 3,455,249**	**$ 3,455,249**	**$ 3,455,249**
Scenario 1C3 HRC+GSHP w/o TTES																					
Fuel Costs	$ 48,151,691	$ 3,377,470	$ 3,377,470	$ 3,377,470	$ 3,377,470	$ 3,377,470	$ 3,377,470	$ 3,377,470	$ 3,377,470	$ 3,377,470	$ 3,377,470	$ 3,377,470	$ 3,377,470	$ 3,377,470.0	$ 3,377,470	$ 3,377,470	$ 3,377,470	$ 3,377,470	$ 3,377,470	$ 3,377,470	$ 3,377,470
O&M Costs	$ 3,106,357	$ 217,887	$ 217,887	$ 217,887	$ 217,887	$ 217,887	$ 217,887	$ 217,887	$ 217,887	$ 217,887	$ 217,887	$ 217,887	$ 217,887	$ 217,887.0	$ 217,887	$ 217,887	$ 217,887	$ 217,887	$ 217,887	$ 217,887	$ 217,887
CO2e Costs	$ 3,663,432	$ 311,249	$ 303,282	$ 296,856	$ 286,440	$ 277,565	$ 268,387	$ 258,907	$ 249,124	$ 239,038	$ 227,336	$ 217,958	$ 220,435	$ 222,912.0	$ 225,389	$ 229,104	$ 231,581	$ 234,058	$ 235,296	$ 239,011	$ 240,250
CAPEX	$ 1,244,949,505	$ 1,135,900,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Residual Value	$ (62,843,510)	$ (132,330,000)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	**$ 1,237,027,475**	**$ 1,007,476,606**	**$ 3,898,639**	**$ 3,892,213**	**$ 3,881,797**	**$ 3,872,922**	**$ 3,863,744**	**$ 3,854,264**	**$ 3,844,481**	**$ 3,834,395**	**$ 3,822,693**	**$ 3,813,315**	**$ 3,815,792**	**$ 3,818,269**	**$ 3,820,746**	**$ 3,824,461**	**$ 3,826,938**	**$ 3,829,415**	**$ 3,830,653**	**$ 3,834,368**	**$ 3,835,607**

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Appendix H – Fleet Vehicle Inventory

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EMPIRE STATE PLAZA | FLEET VEHICLE INVENTORY

Energy Opportunity Area: Transportation

A comprehensive list of Empire State Plaza's existing fleet vehicles, provided by OGS, is shown in Table 1. The column labeled DOE EV Category indicates the most appropriate electric vehicle classification based on categories defined by the U.S. Department of Energy's Alternative Fuels Data Center (AFDC)[1].

Table 1. 2024 Fleet Vehicle Inventory

Vehicle ID	Description	Date Purchased	Make	Model	EPA MOVES Class	Fuel	DOE EV Category
[redacted]	MID-SIZE MPV	2024	CHEVROLET	SILVERADO EV	Light-duty truck	Electric	Pickup
[redacted]	FULL-SIZE PICKUP	2007	CHEVROLET	AVALANCHE	Light-duty truck	Gasoline	Pickup
[redacted]	MINI VAN	2016	DODGE	GRAND CARAVAN	Light-duty vehicle	Gasoline	Van
[redacted]	FULL-SIZE PICKUP	2023	CHEVROLET	SILVERADO 4500HD / SILVERADO 5500HD	Heavy-duty truck	Diesel	Vocational/Cab Chassis
[redacted]	FULL-SIZE PICKUP	2018	CHEVROLET	SILVERADO	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2018	CHEVROLET	SILVERADO	Light-duty truck	Diesel	Pickup
[redacted]	TRUCK DELIVERY	2018	RAM	5500 CHASSIS	Heavy-duty truck	Diesel	Vocational/Cab Chassis
[redacted]	TRUCK DELIVERY	2018	RAM	5500 CHASSIS	Heavy-duty truck	Diesel	Vocational/Cab Chassis
[redacted]	TRUCK DELIVERY	2018	INTERNATIONAL	WORKSTAR 7300	Heavy-duty truck	Diesel	Vocational/Cab Chassis
[redacted]	TRUCK DELIVERY	2018	INTERNATIONAL	WORKSTAR 7300	Heavy-duty truck	Diesel	Vocational/Cab Chassis
[redacted]	TRUCK DELIVERY	2018	INTERNATIONAL	WORKSTAR 7300	Heavy-duty truck	Diesel	Vocational/Cab Chassis
[redacted]	MINI PICKUP	2018	CHEVROLET	COLORADO	Light-duty vehicle	Gasoline	Pickup
[redacted]	TRUCK DELIVERY	2017	RAM	5500 CHASSIS	Heavy-duty truck	Diesel	Vocational/Cab Chassis
[redacted]	TRUCK DELIVERY	2017	RAM	5500 CHASSIS	Heavy-duty truck	Diesel	Vocational/Cab Chassis
[redacted]	TRUCK DELIVERY	2017	FREIGHTLINER	M2 106 MEDIUM DUTY	Heavy-duty truck	Diesel	Vocational/Cab Chassis
[redacted]	TRUCK DELIVERY	2017	INTERNATIONAL	DURASTAR 4400	Heavy-duty truck	Diesel	Vocational/Cab Chassis
[redacted]	FULL-SIZE PICKUP	2017	FORD	F-250	Light-duty truck	Gasoline	Pickup
[redacted]	FULL-SIZE PICKUP	2017	FORD	F-250	Light-duty truck	Gasoline	Pickup
[redacted]	FULL-SIZE PICKUP	2017	FORD	F-250	Light-duty truck	Gasoline	Pickup
[redacted]	FULL-SIZE PICKUP	2017	FORD	F-250	Light-duty truck	Gasoline	Pickup
[redacted]	FULL-SIZE PICKUP	2017	FORD	F-250	Light-duty truck	Gasoline	Pickup
[redacted]	TRUCK DELIVERY	2016	FORD	F-550	Heavy-duty truck	Diesel	Vocational/Cab Chassis
[redacted]	TRUCK DELIVERY	2016	INTERNATIONAL	WORKSTAR 7500	Heavy-duty truck	Diesel	Vocational/Cab Chassis

[1] https://afdc.energy.gov/vehicles/search

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[redacted]	TRUCK DELIVERY	2016	INTERNATIONAL	WORKSTAR 7500	Heavy-duty truck	Diesel	Vocational/Cab Chassis
[redacted]	FULL-SIZE PICKUP	2015	FORD	F250	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2015	FORD	F250	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2015	FORD	F250	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2015	FORD	F250	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2015	FORD	F250	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2015	FORD	F250	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2015	FORD	F250	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2015	FORD	F350	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2015	FORD	F350	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE VAN	2014	FORD	ECONOLINE	Light-duty truck	Gasoline	Van
[redacted]	TRUCK DELIVERY	2008	INTERNATIONAL	7300	Heavy-duty truck	Diesel	Vocational/Cab Chassis
[redacted]	TRUCK DELIVERY	2008	STERLING	L9500 SERIES	Heavy-duty truck	Diesel	Vocational/Cab Chassis
[redacted]	FULL-SIZE PICKUP	2017	FORD	F-450	Heavy-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2017	FORD	F-250	Light-duty truck	Gasoline	Pickup
[redacted]	FULL-SIZE PICKUP	2017	FORD	F-250	Light-duty truck	Gasoline	Pickup
[redacted]	FULL-SIZE PICKUP	2016	FORD	F-250	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2016	CHEVROLET	SILVERADO	Light-duty truck	Gasoline	Pickup
[redacted]	MINI VAN	2016	FORD	TRANSIT CONNECT	Light-duty truck	Gasoline	Van
[redacted]	MINI VAN	2016	FORD	TRANSIT CONNECT	Light-duty truck	Gasoline	Van
[redacted]	MINI VAN	2016	FORD	TRANSIT CONNECT	Light-duty truck	Gasoline	Van
[redacted]	FULL-SIZE VAN	2015	FORD	ECONOLINE	Light-duty truck	Gasoline	Van
[redacted]	FULL-SIZE PICKUP	2015	FORD	F250	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2015	FORD	F250	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2015	FORD	F250	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2015	FORD	F250	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE VAN	2008	CHEVROLET	EXPRESS	Light-duty truck	Gasoline	Van
[redacted]	FULL-SIZE PICKUP	2006	CHEVROLET	SILVERADO	Light-duty truck	Gasoline	Pickup
[redacted]	FULL-SIZE PICKUP	2005	CHEVROLET	SILVERADO	Light-duty truck	Gasoline	Pickup
[redacted]	FULL-SIZE VAN	2018	FORD	TRANSIT VAN	Light-duty truck	Gasoline	Van
[redacted]	FULL-SIZE PICKUP	2018	CHEVROLET	SILVERADO	Light-duty truck	Gasoline	Pickup
[redacted]	SMALL MPV	2017	CHEVROLET	EQUINOX	Light-duty vehicle	Gasoline	SUV
[redacted]	FULL-SIZE PICKUP	2015	FORD	F250	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2014	FORD	F150	Light-duty truck	Gasoline	Pickup
[redacted]	FULL-SIZE PICKUP	2014	FORD	F150	Light-duty truck	Gasoline	Pickup
[redacted]	TRUCK DELIVERY	2018	RAM	5500 CHASSIS	Heavy-duty truck	Diesel	Vocational/Cab Chassis
[redacted]	FULL-SIZE PICKUP	2018	FORD	F-350	Light-duty truck	Gasoline	Pickup
[redacted]	MINI VAN	2016	DODGE	GRAND CARAVAN	Light-duty vehicle	Gasoline	Van
[redacted]	FULL-SIZE PICKUP	2014	FORD	F350	Light-duty truck	Gasoline	Pickup

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[redacted]	FULL-SIZE PICKUP	2015	FORD	F250	Light-duty truck	Diesel	Pickup
[redacted]	SMALL MPV	2024	DODGE	HORNET	Light-duty vehicle	Gasoline	SUV
[redacted]	SMALL MPV	2024	DODGE	HORNET	Light-duty vehicle	Gasoline	SUV
[redacted]	FULL-SIZE PICKUP	2019	RAM	1500	Light-duty truck	Gasoline	Pickup
[redacted]	FULL-SIZE PICKUP	2019	RAM	1500	Light-duty truck	Gasoline	Pickup
[redacted]	MID-SIZE CAR	2019	FORD	FUSION	Light-duty truck	Gasoline	SUV
[redacted]	SMALL MPV	2019	NISSAN	ROGUE	Light-duty vehicle	Gasoline	SUV
[redacted]	FULL-SIZE PICKUP	2017	FORD	F-350	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2017	CHEVROLET	SILVERADO	Light-duty truck	Diesel	Pickup
[redacted]	MINI VAN	2017	TOYOTA	SIENNA	Light-duty vehicle	Gasoline	Van
[redacted]	MINI VAN	2017	TOYOTA	SIENNA	Light-duty vehicle	Gasoline	Van
[redacted]	FULL-SIZE PICKUP	2016	FORD	F-250	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2016	FORD	F-250	Light-duty truck	Diesel	Pickup
[redacted]	SMALL MPV	2016	CHEVROLET	EQUINOX	Light-duty vehicle	Gasoline	SUV
[redacted]	SMALL MPV	2016	CHEVROLET	EQUINOX	Light-duty vehicle	Gasoline	SUV
[redacted]	FULL-SIZE PICKUP	2015	FORD	F250	Light-duty truck	Diesel	Pickup
[redacted]	FULL-SIZE PICKUP	2015	FORD	F250	Light-duty truck	Diesel	Pickup

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