New York Police Academy

College Point, New York

Final Report

East Campus Ground Source Heat Pump Re-Design w/ Photovoltaic Array Analysis & Construction Evaluation

Prepared for: Professor William Bahnfleth, PhD, PE

Date: April 7th, 2011

Mechanical Option
Senior Thesis 2010- 2011

John M. Scavelli
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Master of Architectural Engineering
Bachelor of Architectural Engineering

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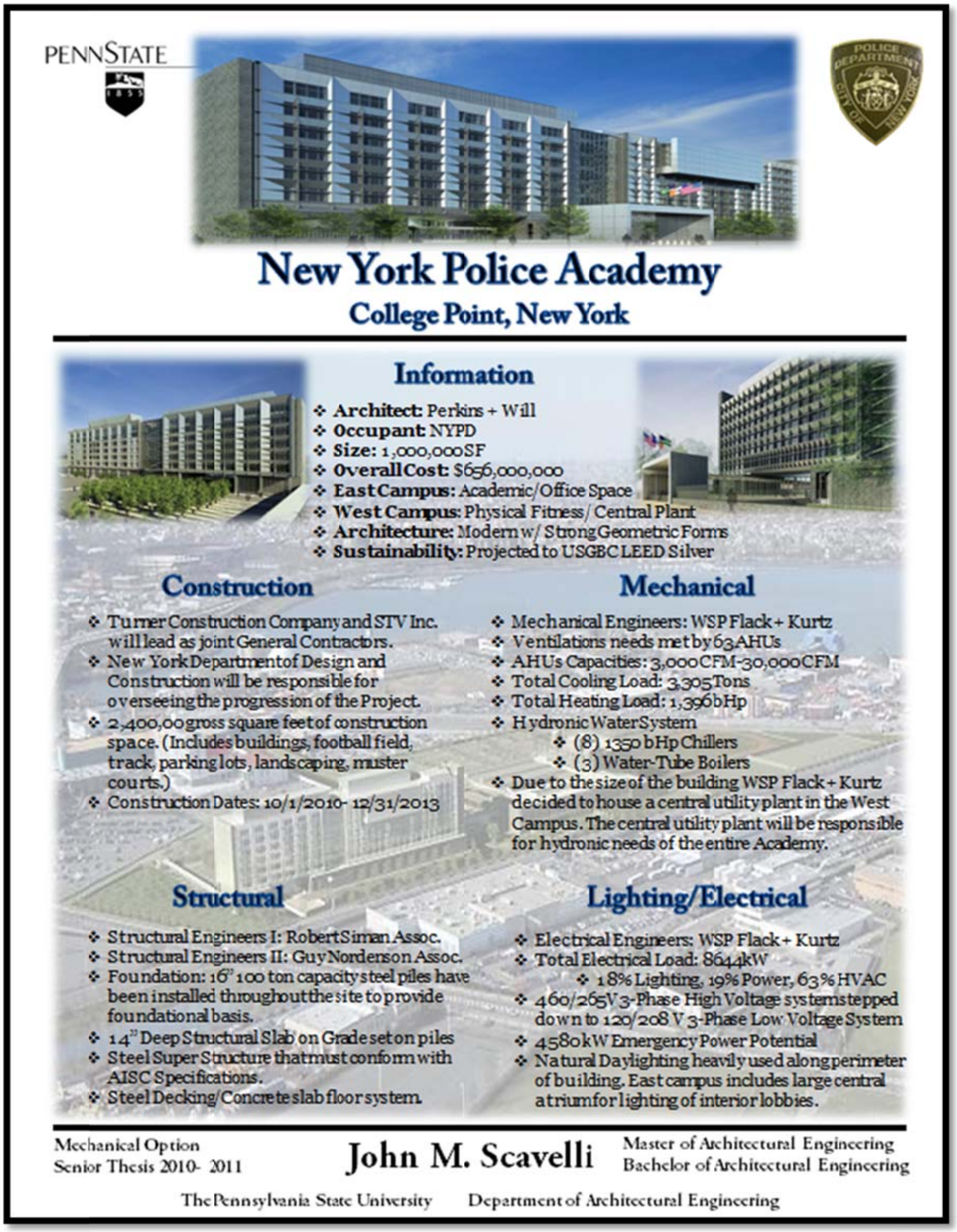
Abstract


PENNSTATE
1855
New York Police Academy
College Point, New York
Information
❖ Architect: Perkins + Will
❖ Occupant: NYPD
❖ Size: 1,000,000SF
❖ Overall Cost: $656,000,000
❖ East Campus: Academic/Office Space
❖ West Campus: Physical Fitness/ Central Plant
❖ Architecture: Modern w/ Strong Geometric Forms
❖ Sustainability: Projected to USGBC LEED Silver
Construction
❖ Turner Construction Company and STV Inc. will lead as joint General Contractors.
❖ New York Department of Design and Construction will be responsible for overseeing the progression of the Project.
❖ 2,400,00 gross square feet of construction space. (Includes buildings, football field, track, parking lots, landscaping, muster courts.)
❖ Construction Dates: 10/1/2010- 12/31/2013
Mechanical
❖ Mechanical Engineers: WSP Flack + Kurtz
❖ Ventilations needs met by 63 AHUs
❖ AHUs Capacities: 3,000CFM-30,000CFM
❖ Total Cooling Load: 3,305Tons
❖ Total Heating Load: 1,396bHp
❖ Hydronic Water System
❖ (8) 1350 bHp Chillers
❖ (3) Water-Tube Boilers
❖ Due to the size of the building WSP Flack + Kurtz decided to house a central utility plant in the West Campus. The central utility plant will be responsible for hydronic needs of the entire Academy.
Structural
❖ Structural Engineers I: Robert Siman Assoc.
❖ Structural Engineers II: Guy Nordenson Assoc.
❖ Foundation: 16" 100 ton capacity steel piles have been installed throughout the site to provide foundational basis.
❖ 14" Deep Structural Slab on Grade set on piles
❖ Steel Super Structure that must conform with AISC Specifications.
❖ Steel Decking/Concrete slab floor system.
Lighting/Electrical
❖ Electrical Engineers: WSP Flack + Kurtz
❖ Total Electrical Load: 8644kW
❖ 18% Lighting, 19% Power, 63% HVAC
❖ 460/265V 3-Phase High Voltage system stepped down to 120/208 V 3-Phase Low Voltage System
❖ 4580kW Emergency Power Potential
❖ Natural Daylighting heavily used along perimeter of building. East campus includes large central atrium for lighting of interior lobbies.
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Executive Summary

This report is a senior thesis capstone design project for The Pennsylvania State University's Architectural Engineering Department. This report is a culmination of a yearlong architectural engineering analysis of the New York Police Academy (NYPA). Specifically, this report focuses on the mechanical systems of NYPA. An analysis has been done regarding the designed mechanical system as well as a proposed redesign which consists of a ground source heat pump system along with an electrical photovoltaic array. The systems were also analyzed from a construction management standpoint.

The New York Police Academy is a building project which started construction in October of 2010 and will be completed by the end of 2013. This Academy is intended to consolidate the New York Police Department's training and academic center into one campus. The NYPA is going to be built in College Point, New York, which is a subsection of Queens, New York. The total site consists of 2,400,000 gross square feet which will consist of an East Campus Building, West Campus Building, football field, outdoor track, muster court, parking lots, and landscaped areas. There will be an exposed drainage ditch that will physically separate the East and West campus. The East Campus Building will house the academic and office spaces of the academy. The West Campus Building will house the athletic facilities, training facilities, and the central mechanical plant.

The air conditioning needs of the building will be met by 63 chilled water Air Handling Units (AHUs). The capacity of the AHUs range from 3,000 CFM to 30,000 CFM. The 63 Air Handling Units will be housed in different sections of the campus. A central utility plant located in the West Campus will serve the AHUs. There are five water tube boilers that are located in the central plant that will be responsible for introducing the hot water for the entire campus. Along with the boilers there will be six chillers that will supply all the cold water needs of the Academy. The central plant serves both the East and West Campus.

After analyzing the existing mechanical system, a proposed alternative mechanical system was explored. The major design proposal is to incorporate a ground source heat pump (GSHP) system to serve the East Campus building. The proposed design alternative will be compared to the actual designed systems in areas such as energy efficiency and cost. Aside from the mechanical system, there were other proposed systems. In regards to the electrical system, a photovoltaic array located on the roof of the West Campus was designed and evaluated. Also the construction and economic impacts of these proposed systems were analyzed.

Overall, it was discovered that implementing a GSHP system along with the photovoltaic array could help significantly reduce utility costs. Also it was estimated that the payback period for these system would be 16 years. Implementing these system would increase the first costs of the building. However, it is believed that the benefits of reduced energy use, utility costs, and reduced emissions would suggest that these alternatives could be beneficial for the New York Police Academy.

Building Overview

The New York Police Academy (NYPA) is a building project which is to start construction in October of 2010 and be completed by the end of 2013. This Academy is intended to consolidate the New York Police Department's training and academic center into one campus. The NYPA is going to be built in College Point, New York, which is a subsection of Queens, New York. The total site consists of 2,400,000 gross square feet which will consist of an East Campus Building, West Campus Building, football field, outdoor track, muster court, parking lots, and landscaped areas. There will be an exposed drainage ditch that will symbolically and physically separate the East and West campus. The East Campus Building will house the academic and office spaces of the academy. The West Campus Building will house the athletic facilities, training facilities, and the central mechanical plant.

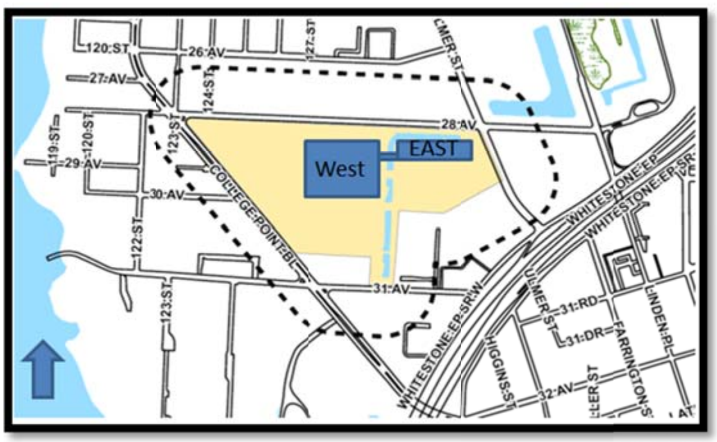

Figure 1: Site Plan Courtesy of New York City Department of Design and Construction

Figure 2: New York Police Academy Aerial Rendering Courtesy of Perkins + Will

Architecture

The New York Police Academy is a building consisting of an academic building on the east side of the site and a physical training building on the west side of the site. The two separate building are connected by a bridge that runs over a flowing stream which is actually a water management stream.

The Architectural aesthetics of the building has been designed to assure a modern and clean look. The sharp aluminum paneling mixed with a pre-cast concrete facade offers a complementing facade with a strong character which is all built upon a simple rectangular shape.

Sustainability

The New York City Department of Design & Construction (DDC) is responsible for the construction of the civic facilities and structures of New York. The New York City DDC has taken an initiative to develop sustainable and high performing buildings. The New York Police Academy which will be built in College Point, Queens falls under the DDC jurisdiction and is to be constructed with conscientious attempt towards sustainability.

The New York Police Academy has a minimum project requirement of reaching LEED Silver. However, the project also has the potential to be LEED Gold. Perkins + Will and associate architect Michael Fieldman have developed a design for the Academy that introduces an all inclusive sustainable design that relies on high performing equipment, waste water management and innovative and creative design techniques.

The Academy is providing a minimum of 14% energy cost reduction with hopes of a 30% energy reduction to comply with the 2030 Challenge. Energy simulations will be performed on the building and the impact of certain energy efficient measures will prove the cost reduction values. Just a few of the energy efficient measures integrated into this building include a high performance envelope/glazing, carbon dioxide sensor for control of ventilation, and variable speed chillers, equipment and pumps.

Also the buildings site has a very unique drainage ditch that separates the East and West campuses. The drainage ditch appears to be a stream flowing through the site but it is actual an integral part to a sustainable waste water management system. Storm water discharge from this site will be reduced by 25% and the collected storm water will be used for irrigation of the native vegetation throughout the site. Sustainable water management will also be reflected in the plumbing fixtures used throughout the building

Overall, the New York Police Academy is continuing the goal of DDC in building sustainable buildings. The New York Police Department is an integral part of New York City and their Academy will set a good example for other New York City institutional buildings.

(For a full LEED assessment of the NYPA please see appendix)

Structure

The predominant architectural shape of the New York Police Academy is a rectangle. Both the East Campus and the West Campus have a typical rectangular shape that allows for structural steel to be arranged in square bays. The bays are typically structured with wide flange beams spaced at 10 feet and girders spaced at 30 feet. The foundation of the academy begins with steel piles that each have a 100 ton capacity and are 16in diameter. There may be anywhere from two to eleven of these steel piles for each concrete pad on the ground floor. The slab on grade is 14 inches thick while all other floors are 4concrete slabs on metal decking.

Structural bracing can be found running diagonally across the vertical bays that provide structural stiffening. This technique is also used to support the main atrium of the building and it provides a pleasant architectural aesthetic.

Electrical/Lighting

The total electrical load in the building is 8644kW. Eighteen percent of the load (1542kW) is attributed to the lighting needs, nineteen percent (1668 kW) is attributed to the power needs, and the final sixty three percent (5434 kW) is needed for the HVAC needs. Also the generators provide 1219kW of emergency power and 3361kW of standby power for a total of 4580kW of emergency power potential.

The electrical system will run off a high voltage and low voltage design. There will be 460/265V 3-phase high voltage power delivered to certain points of the building, then this high voltage will be stepped down to 120/208V-(3 phase) low voltage further down the electrical system. The transformers will range in size from 3KVA to 2500 KVA. 2.5MW/3.12MVA 460V diesel generators will be placed in the central plant to provide reliable power in the event of a utility power failure.

There will be a variety of lighting fixtures used throughout the building. Also 90% of individual work areas (offices and open plan workstations) will include task lighting incorporated in the workstation areas. There will be easy control-ability of lights so that spaces can easily be lit one section at a time. This will limit the use of lights in areas where people do not reside. Natural day lighting is prevalent along the perimeter of the entire academic building with a repeating window pattern that lines the building. There is also large central atrium that provides natural day light that can penetrate deep into the building.

Mechanical Systems Overview

The air conditioning needs of the building will be met by 63 chilled water Air Handling Units (AHUs). The capacity of the AHUs range from 3,000 CFM to 30,000 CFM. The 63 Air Handling Units will be housed in different sections of the campus. 18 AHUs will reside in the Central Plant, 26 AHUs will reside in the West Campus, the final 19 AHUs will be located in the East Campus. Indoor air quality needs will also be addressed with precautions such as a no smoking policy, indoor CO_2 sensors, and appropriate placement of air intakes that will limit outdoor contaminants entering the building.

There are five water tube boilers that are located in the central plant that will be responsible for introducing the hot water for the entire campus. Along with the boilers there will be six 1350 ton chillers that will supply all the cold water needs of the Academy. The central plant serves both the East and West Campus. The capacity of the central plant has been oversized both for redundancy and the intent for future expansion of the New York Police Academy.

Mechanical System Schematics

Hot Water System Schematic

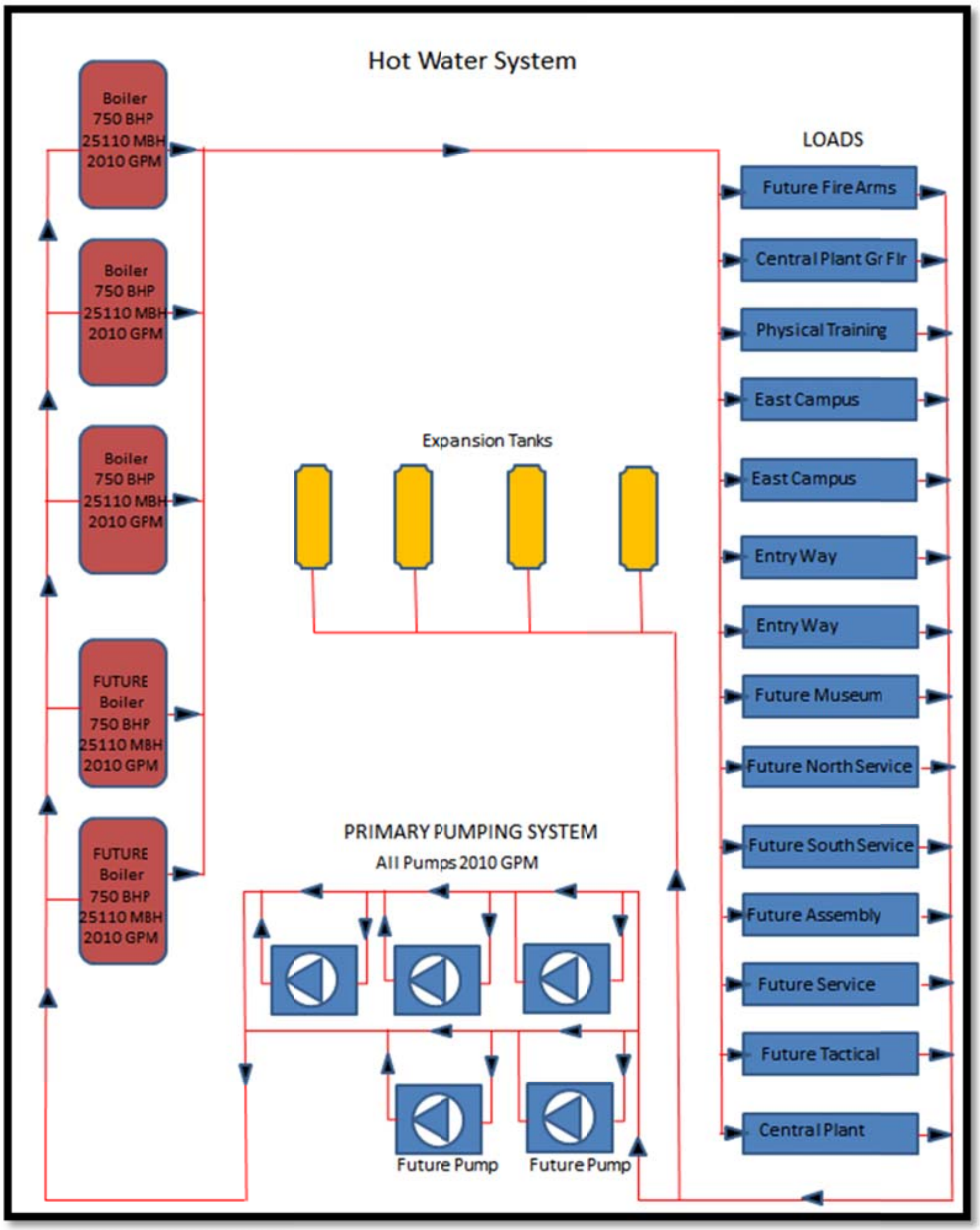

Figure 3: Hot Water System Schematic

Evaporator System Schematic

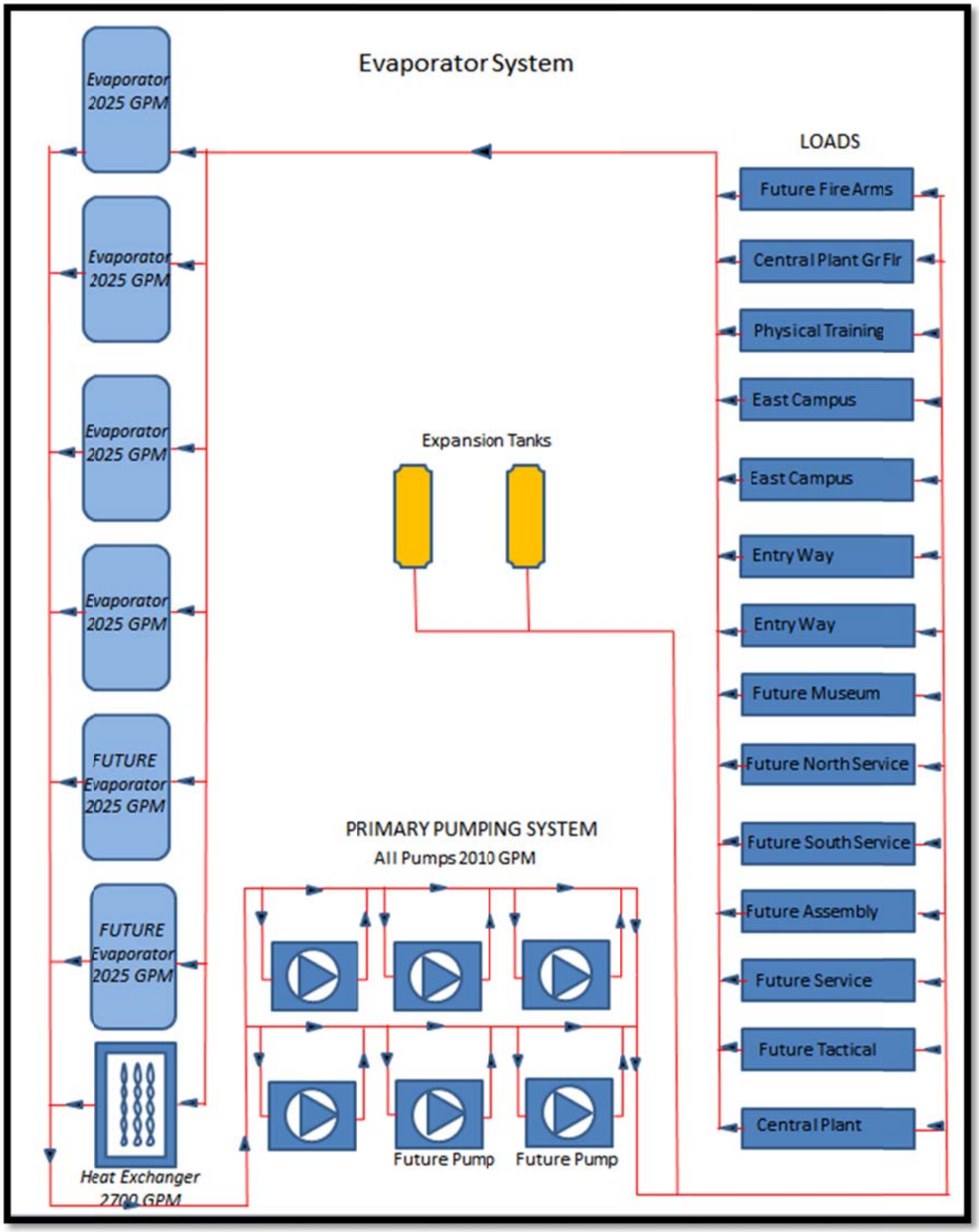

Figure 4: Evaporator System Schematic

Condenser System Schematic

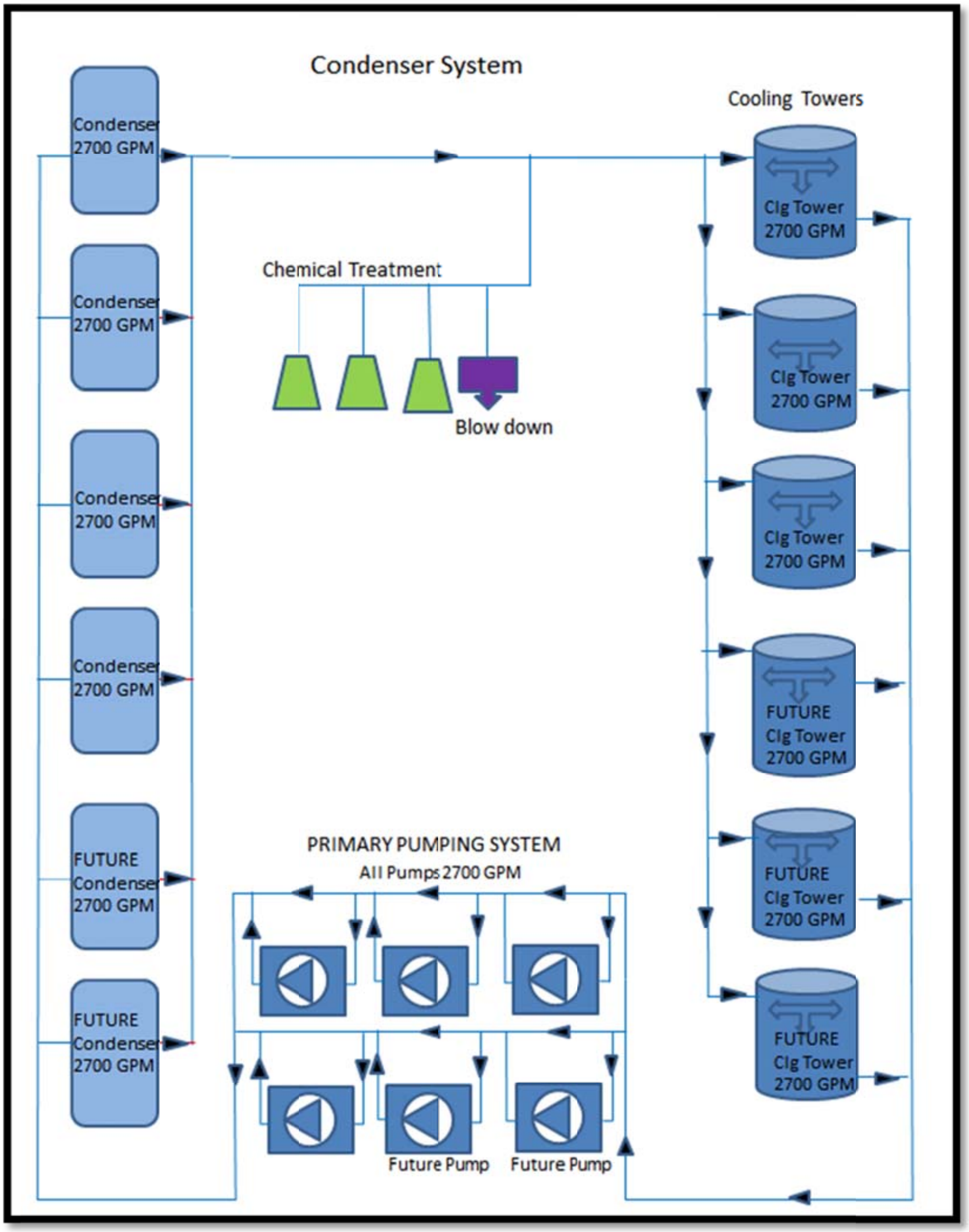

Figure 5: Condenser System Schematic

Water to Air Side System Schematic

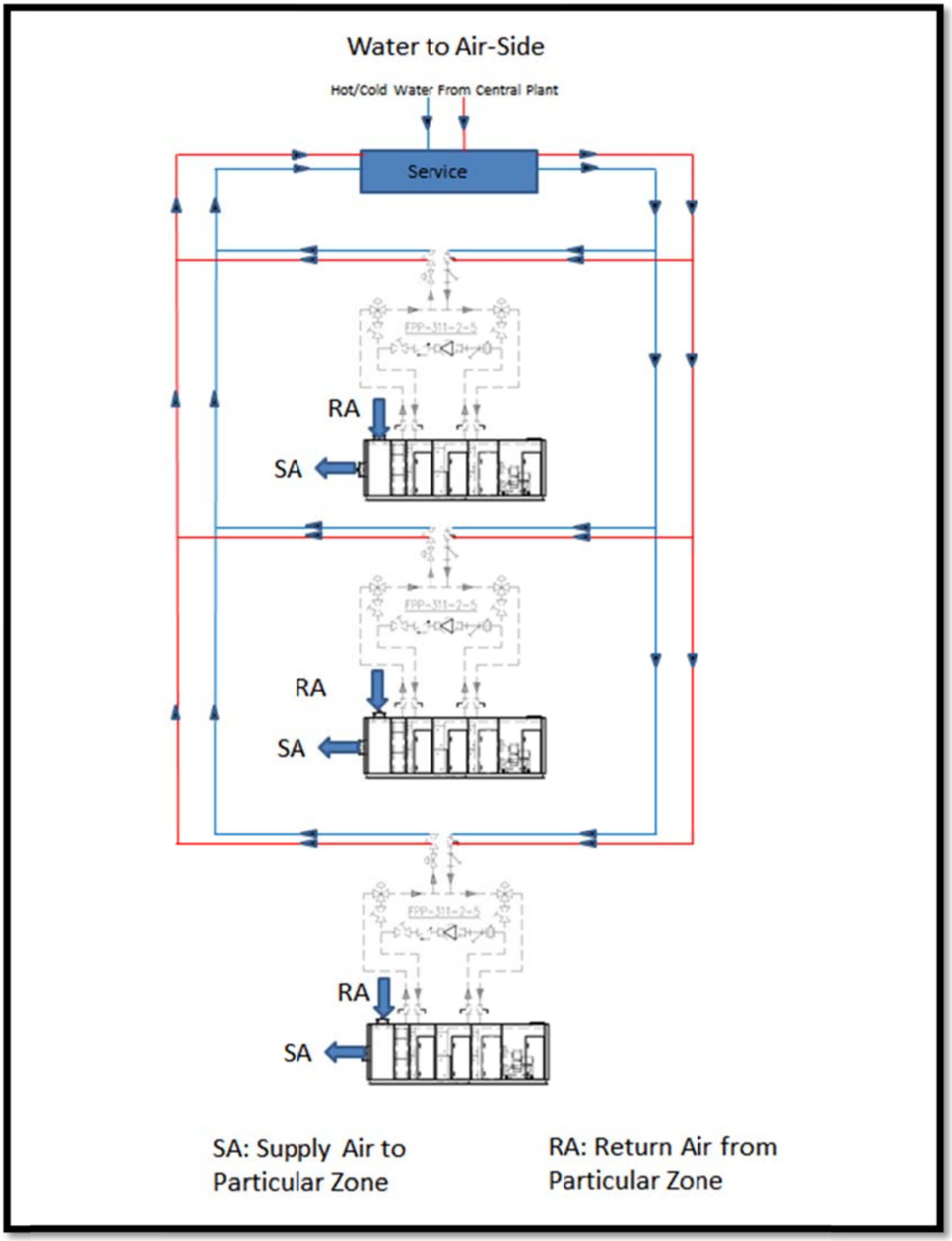

Figure 6: Water to Air Side System Schematic

Major Equipment Schedules

Detailed information about major HVAC equipment can be found in the appendix.

System Operation

The New York Police Academy's mechanical system operates around a central heating and cooling plant located in the West Campus Building. Boilers, chillers, and cooling towers provide the necessary hot and cold water needs for the campus. The central plant operates on a variable primary flow pumping system. The primary pumps are located in the central plant and they distribute water to the cooling towers and air handling units located throughout the entire campus. The primary pumping systems can be seen in the Hot Water System Schematic, Evaporator System Schematic, and the Condenser System Schematic. These pumping system help to distribute the hot/cold water to and from the particular loads. The loads include sixty three air handling units of various sizes throughout the campus. The air handling units are supplied with hot/cold water from the central plant which allows for hot and cold air to be distributed to the intended zones (see *Mechanical System Schematics*). An example of this water to air system can be seen in the *Water to Air Side System Schematic.*

The central plant contains five 25110 MBH hot water boilers (two of which are for future use), six 1350 ton electric water chillers (two of which are for future use), one 2700 GPM heat exchanger, and the roof of the central plant house six 2700 GPM cooling towers (three of which are for future use). The central plant also houses seventeen water pumps: six for chilled water, six for condenser water, and five for hot water (six of these pumps are for future use). For a more detailed description of the equipment see the previous *Major Equipment Schedule Section.*

The chillers and boilers will vary on and off based on the load demand. Below is a summary of what chiller/boiler will be switched on/off in reference to the load demand.

THE CHILLERS SHOULD BE STAGED ON IN ACCORDANCE WITH THE FOLLOWING TABLE:

STEP	LOAD PERCENT	CH-1	CH-2	CH-3	CH-4	CH-5	CH-6
1.	0%-90%	ON	OFF	OFF	OFF	OFF	OFF
2.	40%-90%	ON	ON	OFF	OFF	OFF	OFF
3.	50%-90%	ON	ON	ON	OFF	OFF	OFF
4.	60%-90%	ON	ON	ON	ON	OFF	OFF
5.	70%-90%	ON	ON	ON	ON	ON	OFF
6.	75%-90%	ON	ON	ON	ON	ON	ON

THE CHILLERS SHOULD BE STAGED OFF IN ACCORDANCE WITH THE FOLLOWING TABLE:

STEP	LOAD PERCENT	CH-1	CH-2	CH-3	CH-4	CH-5	CH-6
1.	90%-70%	ON	ON	ON	ON	ON	ON
2.	90%-65%	OFF	ON	ON	ON	ON	ON
3.	90%-55%	OFF	OFF	ON	ON	ON	ON
4.	90%-45%	OFF	OFF	OFF	ON	ON	ON
5.	90%-35%	OFF	OFF	OFF	OFF	ON	ON
6.	90%-0%	OFF	OFF	OFF	OFF	OFF	ON

Figure7: Chiller Operation Schedule

THE BOILERS SHOULD BE STAGED ON IN ACCORDANCE WITH THE FOLLOWING TABLE:

STEP	LOAD PERCENT	B-1	B-2	B-3	B-4	B-5
1.	0%-90%	ON	OFF	OFF	OFF	OFF
2.	45%-90%	ON	ON	OFF	OFF	OFF
3.	55%-90%	ON	ON	ON	OFF	OFF
4.	60%-90%	ON	ON	ON	ON	OFF
5.	70%-90%	ON	ON	ON	ON	ON

THE BOILERS SHOULD BE STAGED OFF IN ACCORDANCE WITH THE FOLLOWING TABLE:

STEP	LOAD PERCENT	B-1	B-2	B-3	B-4	B-5
1.	90%-65%	ON	ON	ON	ON	ON
2.	90%-60%	OFF	ON	ON	ON	ON
3.	90%-50%	OFF	OFF	ON	ON	ON
4.	90%-40%	OFF	OFF	OFF	ON	ON
5.	90%-0%	OFF	OFF	OFF	OFF	ON

Figure 8: Boiler Operation Schedule

The chillers and boilers vary the amount of hot water and cold water to each Air Handling Unit. As stated above, there are sixty three AHU's located in this academy. This report is not intended to describe the system operation of each individual AHU. However, this report is intended to provide a concise summary of the entire mechanical system of the academy. Generally, each AHU is fitted with variable speed supply and return fans. The variable speed fans are intended to provide the proper amount of air for ventilation and thermal comfort requirements. Some AHU's serve several zones, where this is applicable variable air volume boxes are strategically placed to vary the volume of air flow to meet each particular zones needs. The AHU's that serve a single zone are not outfitted with VAV boxes.

The basic premise of the operation of this mechanical system stems from a central plant that serves AHU's located throughout the building. These AHU then provide the air conditioning needs and ventilation needs of the occupied spaces.

Design Factors

Outdoor Design Considerations

Location Information

The New York Police Academy will be constructed in College Point, Queens. Its location is 1.5 miles East of LaGuardia airport. Thus, the weather information provided for New York's LaGuardia airport will be used and should provide a high level of accuracy to the actual weather conditions of the NYPA.

Table 1: Location Information: College Point, Queens

ASHRAE Handbook of Fundamentals

Station	Latitude	Longitude	Elevation	Heating DB (99.6%)	Cooling DB 0.4%	Cooling MCWB 0.4%	Evaporation WB 0.4%	Evaporation MCDB 0.4%	Dehumid. DP 0.4%	Dehumid HR 0.4%	Dehumid MCDB 0.4%
New York, LaGuardia Aprt	40.78N	73.88W	30	12.6	92.2	74.4	77.2	87.2	74.3	185.5	81.0

Information	Input
Air Density	0.0760 lb/ft^3
Air Specific Heat	0.244 Btu/lb •°F
Density-Specific Heat Product	1.1147 Btu/h •cfm °•F
Latent Heat Factor	4906.9 Btu •min/h• ft^3
Enthalpy Factor	4.5604 lb•min/hr • ft^3
Summer Design Dry Bulb	89°F
Summer Design Wet Bulb	73°F
Winter Design Dry Bulb	15°F
Summer/Winter Clearness Number	0.85°F
Summer/Winter Ground Reflectance	0.20°F
Carbon Dioxide Level	400 ppm

Indoor Design Considerations

There are several different types of spaces and the indoor design temperatures will slightly vary depending on occupancy and room usage. However, typical spaces in the academy have an indoor design temperature set point 72 °F.

Miscellaneous Internal Loads

All equipment and lighting loads were modeled on a watts per square foot (w/sf) basis. Lighting fixtures and office equipment schedules have not yet been released for this project at this time. Therefore, it was determined to input each space with a typical equipment and lighting load based on the occupancy. Below is a summary of the modeled equipment loads, lighting loads and occupant loads.

Table 2: Internal Load Densities

Space	Lighting Load	Equipment Load	Occupant Load	Sensible Load	Latent Load
Classroom	1.0 w/sf	0.22 w/sf	20 ft^2/occ	250 Btu/hr	200 Btu/hr
Office	1.0 w/sf	0.5 w/sf	143 ft^2/occ	250 Btu/hr	200 Btu/hr
Mechanical Room	0.8 w/sf	2.0 w/sf	400 ft^2/occ	275 Btu/hr	200 Btu/hr
Lobby Corridor	0.8 w/sf	0.25 w/sf	50 ft^2/occ	250 Btu/hr	200 Btu/hr

Energy Analysis

Block Load Analysis

A block load analysis was performed for the energy analysis of NYPA's East Campus. The East Campus consists of eight floors. Each floor was divided into zones based on orientation and occupancy use. In total, the building was designated into 52 different zones. A room by room analysis for this size project was deemed unnecessary for this report because of the size of this building. By grouping similar spaces into larger zones it will allow for easier analysis and provide a similar level of accuracy.

Below is a summary of some useful information that was gathered and imported into TRACE 700 for the analysis. It summarizes information such as weather input, zone designation, power loads, and construction types.

As stated previously, in order to effectively analyze the building it was unnecessary to model each room in TRACE 700. Therefore, each floor was divided into smaller zones based on proximity, occupancy and orientation. In total the eight stories of the East Campus building was designated into 52 different zones, each floor ranging from five to seven zones. The East Campus consists of four different types of spaces which include classroom spaces, office spaces, mechanical rooms, and lobby/corridors. These different spaces were used as a templates to model each zone.

Below is an example of how Level 3 was designated into separate zones for analysis. All other zones can be found in Technical Report 2.

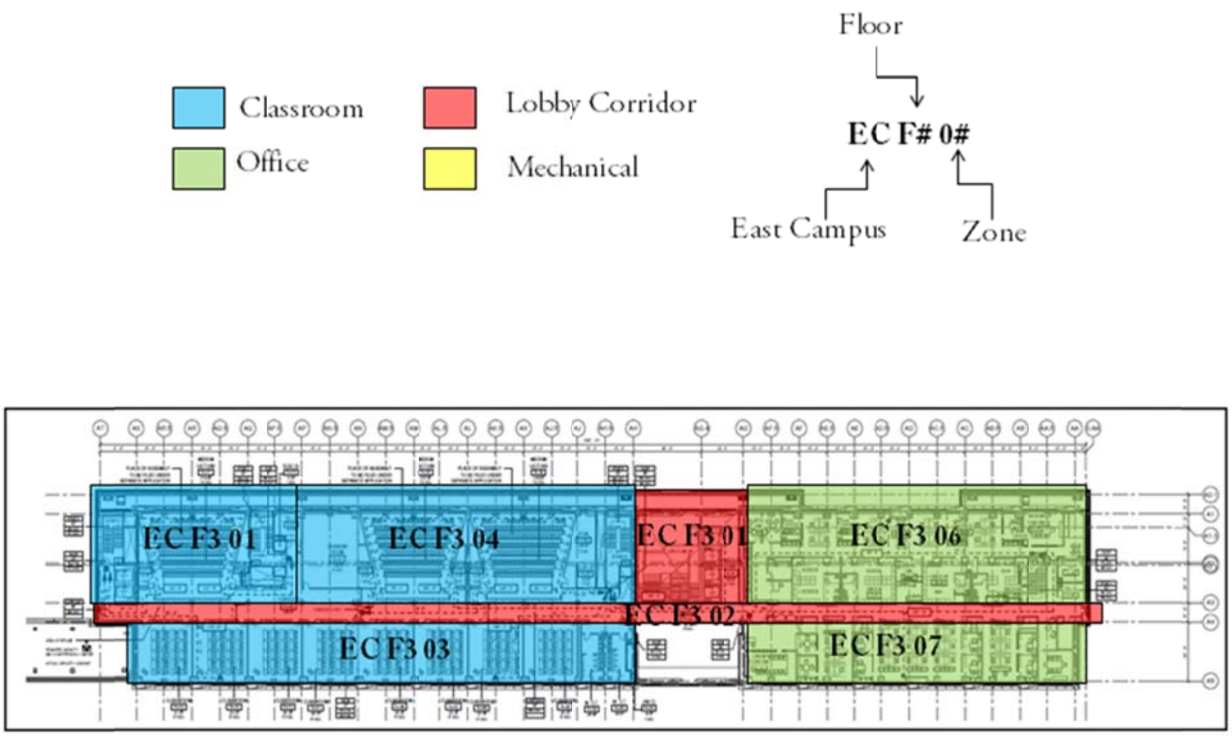

Figure 9: New York Police Academy Energy Simulation Zones (Floor 3)

Building Loads

Table 3: East Campus Electricity Consumption

Source	Electricity Consumption [kWh]
Primary Heating	10,945 (does not include gas consumption)
Primary Cooling	1,745,320
Auxiliary	103,668
Lighting	2,986,304
Receptacle	839,635
Totals	5,685,782

Table 4: East Campus Natural Gas Consumption

Primary Heating	Natural Gas Consumption[kBtu]
Natural Gas Boilers	5,530,679

Table 5: East Campus Water Consumption

Primary Cooling	Water Consumption (1000 gallons)
Cooling Equipment	7,233

Table 6: East Campus Heating and Cooling Load

	Tons	ft^2/ton	MBh	Btu/hr ft^2
Cooling Load	1235.5	303.84	14826.4	39.49
Heating Load	-	-	-10,104.2	-26.92

Table 7: East Campus Ventilation Results

	[cfm]	**[cfm/ft^2]**
Outside Airflow	98,265	0.26
Cooling Airflow	234,422	.62
Heating Airflow	73,890	.20
Return Airflow	270,912	.72
Exhaust Airflow	134,754	.36

Annual Energy Costs

Table 8: Electric Utility Costs

Source	Energy Cost	Electricity Consumption [kWh/yr]	Utility Price [$ /yr]	Utility Price [$/ ft^2 • yr]
Primary Heating	$.1611 /kWh	10,945	$1763	$.005/ ft^2 • yr
Primary Cooling	$.1611 /kWh	1,745,320	$281,171	$.769/ ft^2 • yr
Auxiliary	$.1611 /kWh	103,668	$16,701	$.046/ ft^2 • yr
Lighting	$.1611 /kWh	2,986,304	$481,094	$1.317/ ft^2 • yr
Receptacle	$.1611 /kWh	839,635	$135,265	$0.37/ ft^2 • yr
Totals	$.1611 /kWh	5,685,782	$915,979	$2.507/ ft^2 • yr

Table 9: NYPA East Campus Total Utility Costs

Energy Cost	Energy Consumption	Building Size (East Campus Only)	Utility Price/ ft^2 • yr
$.1611 /kWh	5,634,061 kWh/yr	375,405 ft^2	$2.507 / ft^2 • yr
$11.858/1000 ft^3 NG	5,530,679 kBtu/yr	375,405 ft^2	$.1699/ ft^2 • yr
		Total Utility Cost:	**$2.677/ ft^2 • yr**
		Annual Cost:	**$1,004,921/yr**

*High Heating Value for Natural Gas was used 1ft^3=1028 Btu in accordance with specification of boiler.

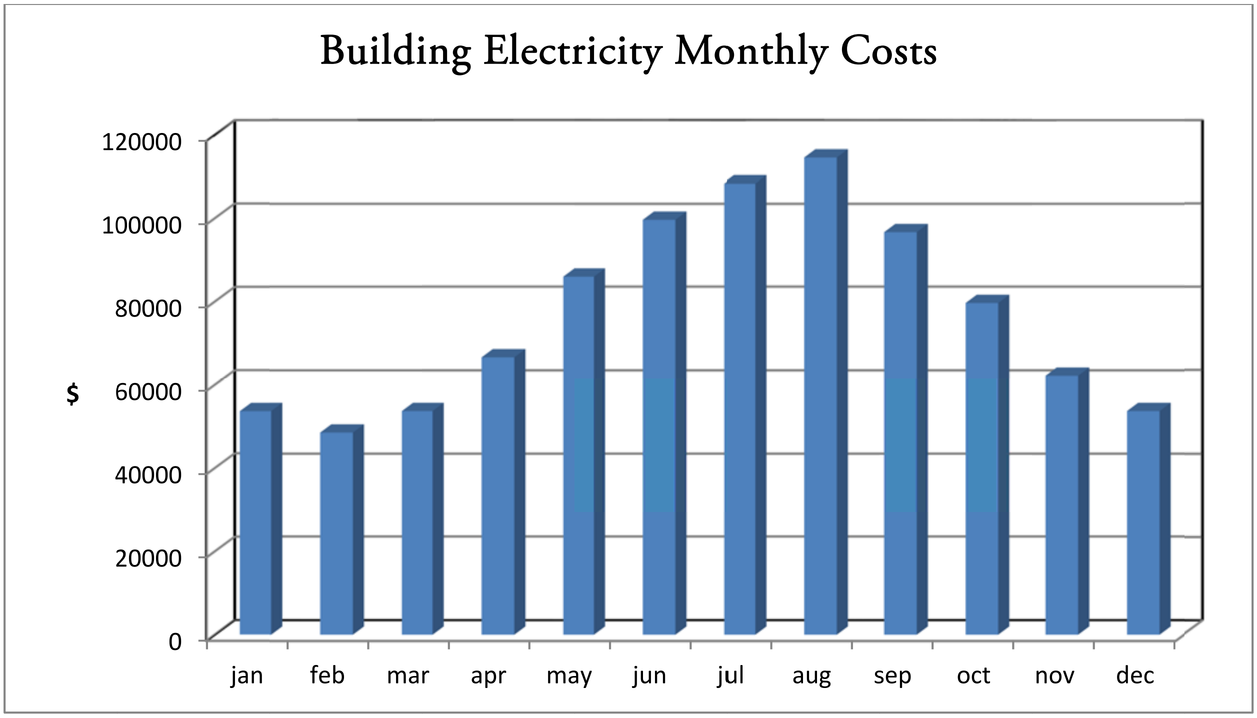

Figure 10: East Campus Monthly Electricity Costs

Alternative System Design Proposal

East Campus Ground Source Heat Pump System

The actual plan for the NYPA is to have a central plant located in the West Campus that will serve the entire academy as well as future buildings. The major alternative design that will be proposed for the New York Police Academy will be to incorporate a ground source heat pump system (GSHP) for the East Campus building of the NYPA. The GSHP is not intended to replace the central heating and cooling plant. The central plant will be necessary for the heating and cooling needs of the West Campus as well as for future buildings. The GSHP system will allow the central plant to be greatly reduced in size, and the cooling and heating will come from a more energy efficient source.

There are several reasons that make a GSHP system a feasible mechanical system for the NYPA. First and foremost is the energy savings and emissions reduction of the system. An analysis of both the electrical savings of the GSHP and the emissions reduction will be studied. Also the East Campus building will not be expanded, thus developing a mechanical system that is appropriately sized will be a much more efficient design than the current grossly oversized mechanical system serving the building. However, the central plant will remain in the West Campus. The plant will now only serve the west campus as well as future buildings.

Below are a few diagrams representing the intended design for the East Campus GSHP system. A vertical loop system will be designed to serve the building. The loops will provide hot/cold water to heat pumps located throughout the East Campus. The heat pump system will be integrated with a ventilation system to provide the thermal and ventilation needs for the entire building. The focus of study for this proposed design will be to establish the energy savings of the GSHP system compared to the actual central plant design.

Table 10: Original vs. Proposed Mechanical Systems Service

Original Mechanical Design		**Proposed Mechanical Design**	
Central Plant Service		**Central Plant Service**	**GSHP Service**
East Campus		---------->	**East Campus**
West Campus		**West Campus**	
Future Expansions		**Future Expansion**	

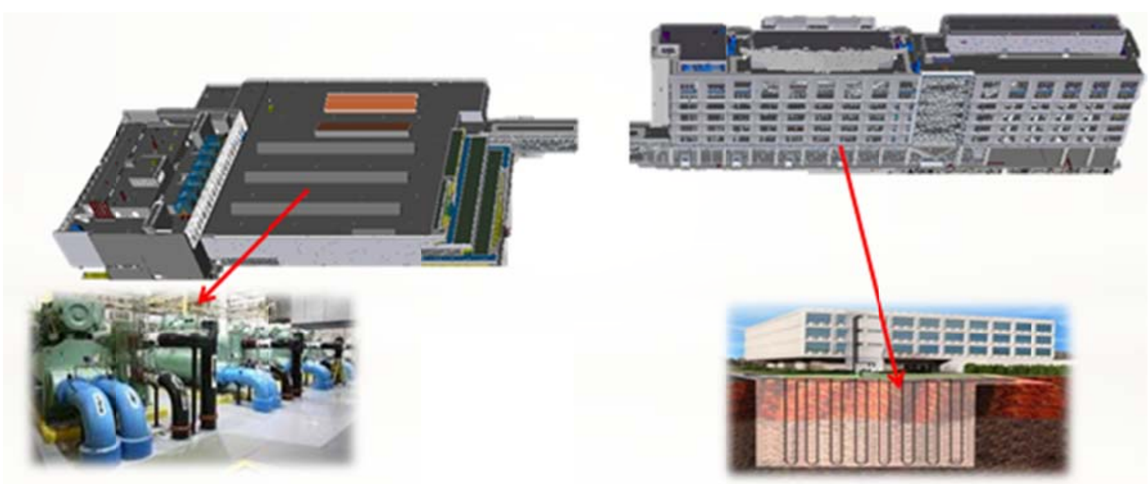

Figure 11: Proposed Mechanical Service to Particular Buildings

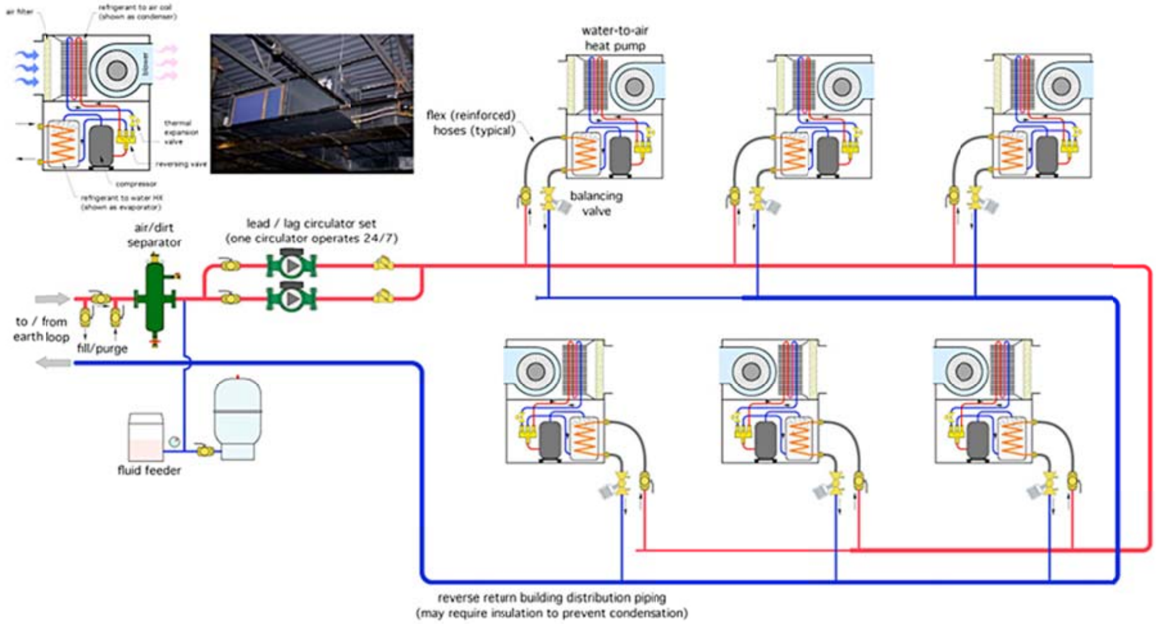

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Figure 12: Ground Source Heat Pump Distribution Schematic

Breadth Topics

Construction Management

The feasibility of the GSHP system will be evaluated from a constructability standpoint. The construction and placement of the vertical boreholes will be evaluated. The NYPA is in the infancy stages of construction. Obviously, it will be assumed that a GSHP system would have been implemented as an original system in the project. A GSHP for this size of building would not be feasible if the building has already been constructed. Therefore, the construction of GSHP will be treated as if the building has not yet been constructed. Also the reduction in equipment needed for the central plant will be evaluated against the cost of the system.

A construction management evaluation will take into account many different factors. First the layout of the boreholes will be evaluated and the optimum placement/layout of the holes will be determined. There are several hundred structural piles that will be implemented into the NYPA construction site. It will be proposed to also dig the GSHP bore holes in coordination with the structural piles. During this period, the site would already be properly prepped for digging the bore holes. Also there will be a schedule impact because there is a considerable amount of time that will need to be designated for the installation of the bore holes. Thus, schedule coordination and added cost will be evaluated from a construction standpoint.

Electrical

The New York Police Academy is a very large facility, which offers a tremendous amount of rooftop space. Much of the roof top of the New York Police Academy is not being used, and it offers a unique opportunity to explore a large photovoltaic array. The proposed area for the photovoltaic array would be on the West Campus above the Athletic Facilities (see figures below). There are also several long sky-lights that run the length of the roof that could potentially offer valuable space for an array, a schematic section view is shown below. These sky lights offer a tilted axis as well as direct southern exposure, which both would benefit the electrical output of the photovoltaic array.

An electrical analysis will be done to calculate the amount of electricity produced by such a system. Also an economic feasibility analysis will be done to determine if this system could potentially produce enough electricity to have a payback period that is worthwhile.

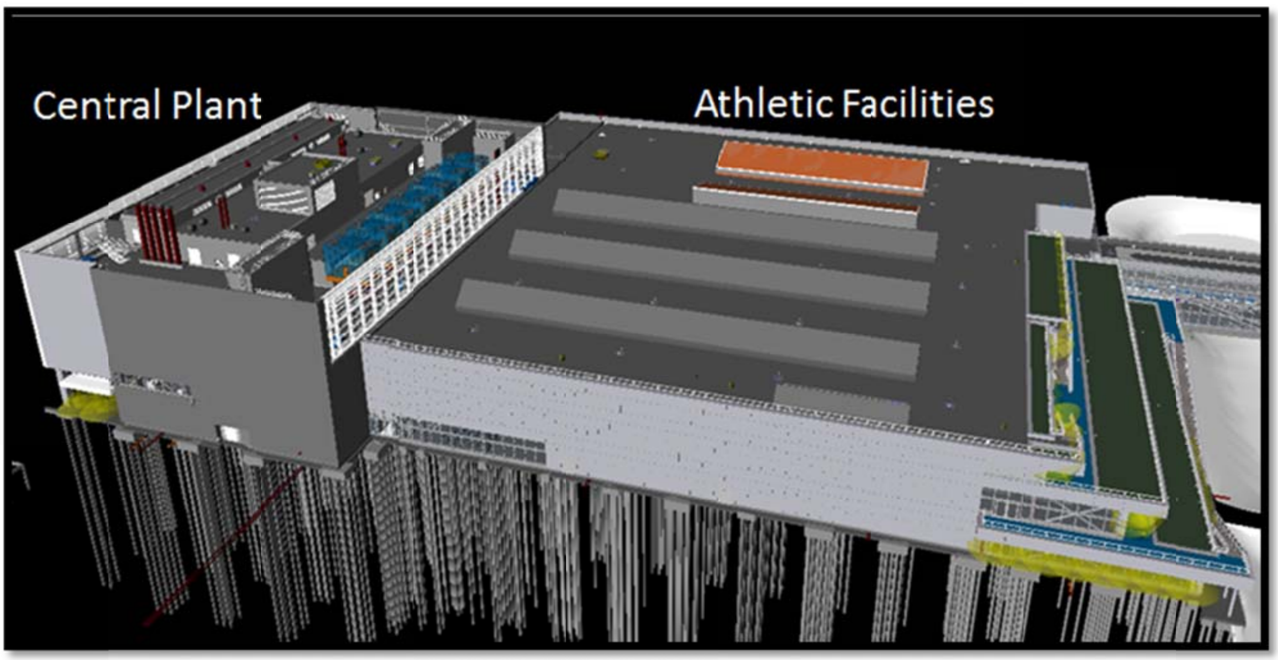


Figure 13: West Campus Roof Top

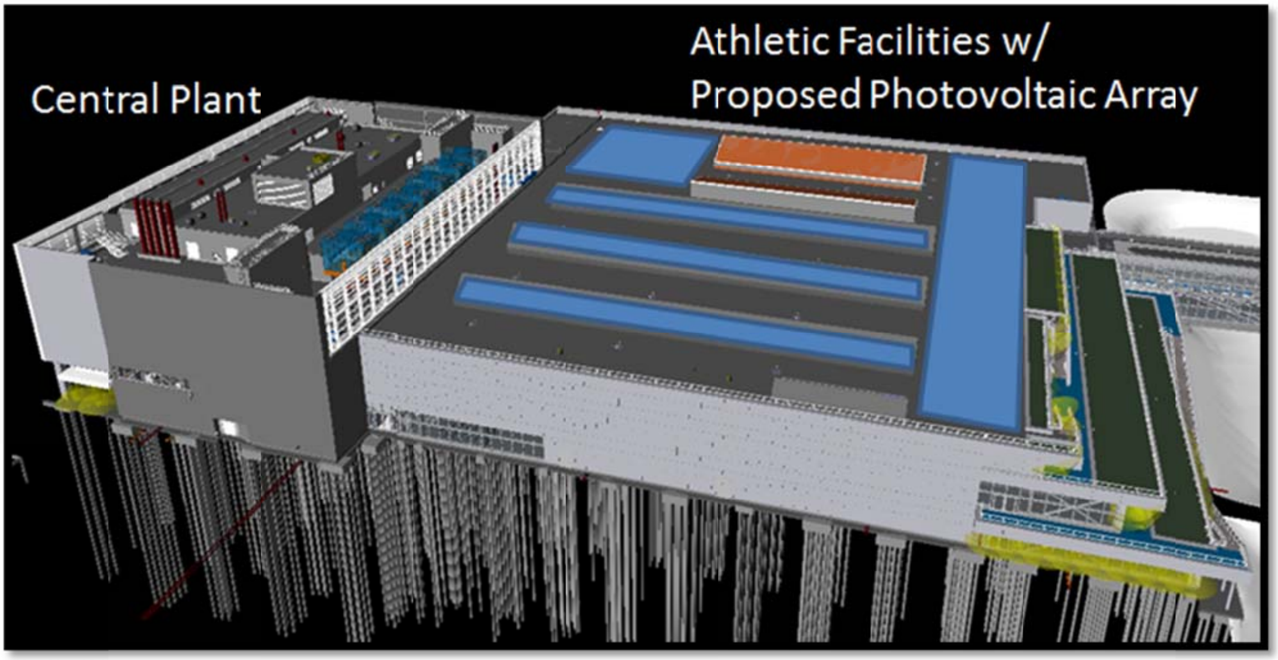


Figure 14: West Campus Roof Top with Proposed Photovoltaic Panels

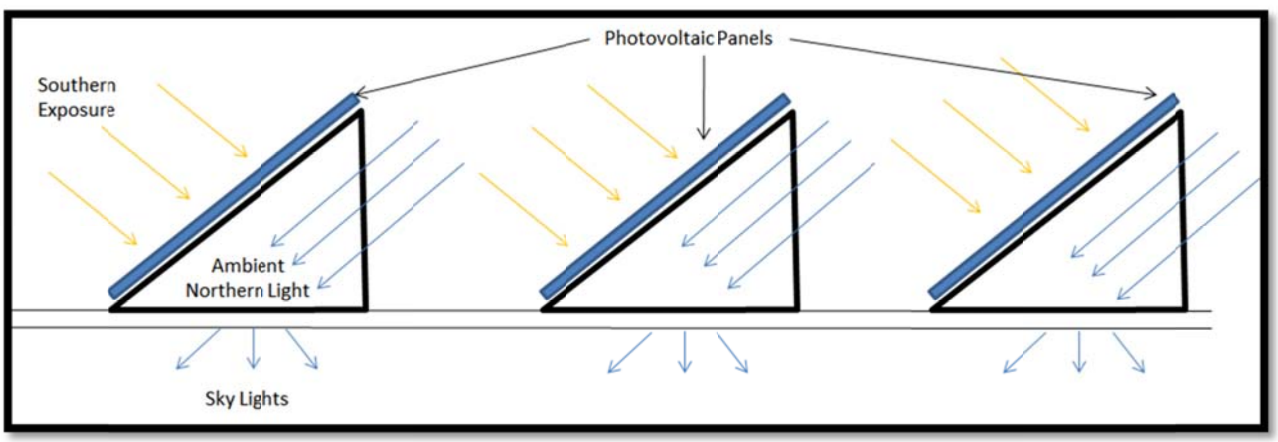


Figure 15: Section View of Proposed Photovoltaic Panels Mounted to Sky Lights

Justification of Proposed Re-Design

As stated above under the discussion of the GSHP system, the academy has been designed with a grossly oversized central plant. Establishing a GSHP system to a section of the academy that will be not be expanded, allows for the central plant to be reduced in size and it allows for a chance to optimize the mechanical system for the East Campus building. Designing an optimum mechanical system for a building that will not have any future expansion is more feasible than designing a mechanical system for potential growth. The idea of a hybrid central plant and GSHP system allows for both expansion and optimization. The East Campus building can be optimized with a GSHP system. The East Campus is nearly 400,000 square feet. The opportunity to optimize the mechanical system of such a large building should greatly reduce the central plant size, but it will still leave the ability for future expansion. Optimization of systems is the basis of justification for the re-design of the mechanical system of the New York Police Academy.

Ground Source Heat Pump System

Ground Source Heat Pump Loop Sizing

Overview

The vertical loop for the ground source heat pump (GSHP) system was designed using ASHRAE's 2007 Handbook: HVAC Applications. Chapter 32 of this handout walks through the procedure of sizing a vertical loop system for a GSHP. In order to properly size the vertical loop system, the following formulas were used:

Formulas

Cooling Length

$$L_C = \frac{q_c R_a + (q_{lc} - 3.41W_c)(R_b + PLF_m R_m + R_{gm} + R_{gd} F_{sc}}{t_g - \frac{t_{wi} - t_{wo}}{2} - t_p}$$

Heating Length

$$L_h = \frac{q_c R_a + (q_{l_h} - 3.41 W_h)(R_b + PLF_m R_m + R_{gm} + R_{gd} F_{sc}}{t_g - \frac{t_{wi} - t_{wo}}{2} - t_p}$$

Variables

Below is a summary of the variables that were used in the above equations and the units attached to each variable. (If units are omitted, this means the variable is dimensionless).
Fsc= Short circuit heat loss factor

Lc=Required Bore Length for cooling [ft]

Lh=Required Bore Length for heating [ft]

PLFm=Part load factor during the design month

qa=Net annual average heat transfer to the ground [Btu/hr]

qlc=Building design cooling block load [Btu/hr]

qlh=Building design heating block load [Btu/h]

Rga=Effective thermal resistance of the ground (annual pulse) [h ·ft° F/Btu]

Rgd=Effective thermal resistance of the ground (daily pulse) [h ·ft° F/Btu]

Rgm=Effective thermal resistance of the ground (monthly pulse) [h ·ft° F/Btu]

Rb= Thermal Resistance of the pipe [h ·ft° F/Btu]

Tg=Undisturbed ground temperature [° F]

Tp=Temperature penalty for interference of the adjacent bore [° F]

Twi=Liquid temperature at heat pump inlet [° F]

Two=Liquid Temperature at heat pump outlet [° F]

Wc= Power input at the design cooling load [W]

Wh=Power input at the design heat load [w]

Table 11: Loop Sizing Variables

Variable	Value
Fsc	1.01
Lc	299,183
Lh	214,818
PLF	1
Qa	4467000
Qlc	14556000
Qlh	10089000
Rga	0.2903
Rgd	0.4000
Rgm	0.3100
Rb	0.1
tg	52
tp	3.9
twi	85
two	75
Wc	90304
Wh	62638

After developing a spreadsheet using Microsoft Excel, it was determined that the largest length of pipe needed to serve all loads would be 299,183 LF. The cooling load length dictated a larger pipe length than the heating coil. However, for cost justification reasons it would be more economical to size the system based on first cost. This analysis is located in the construction management breadth, "Cost Optimization of Pipe Length". The first costs of a ground source heat pump system are significant and therefore a proper cost/construction analysis was needed to be done.

Well Field Layout

In the previous section, it was outlined how the ground source heat pump system was sized and the buried pipe length needed was determined to service the East Campus of the New York Police Academy. After the length of the system was determined the layout of the well field needed to be designed to both provided the proper pipe length underground and fit in the appropriate area.

The area chosen for the well field is a large 200' x 350' field located directly in front of the East Campus Building (see below). A fifteen foot radius between each well is needed to provide the proper thermal environment for each well. Typical depths for vertical ground source heat pump system can reach hundreds of feet deep. A depth of 350' for each well was chosen because this is also the depth of the structural steel piles that are being used to support the structure of the building. By using the same depth as the structural piles, the soil properties will be well established and the boring equipment can be used directly after the structural piles have been placed. With 350' wells, each having two loops per well, there was a total need for 214 bored wells spaced at a 15' radius. The final design for the well field was 20 columns of 10 wells with 2 columns of 7 wells.

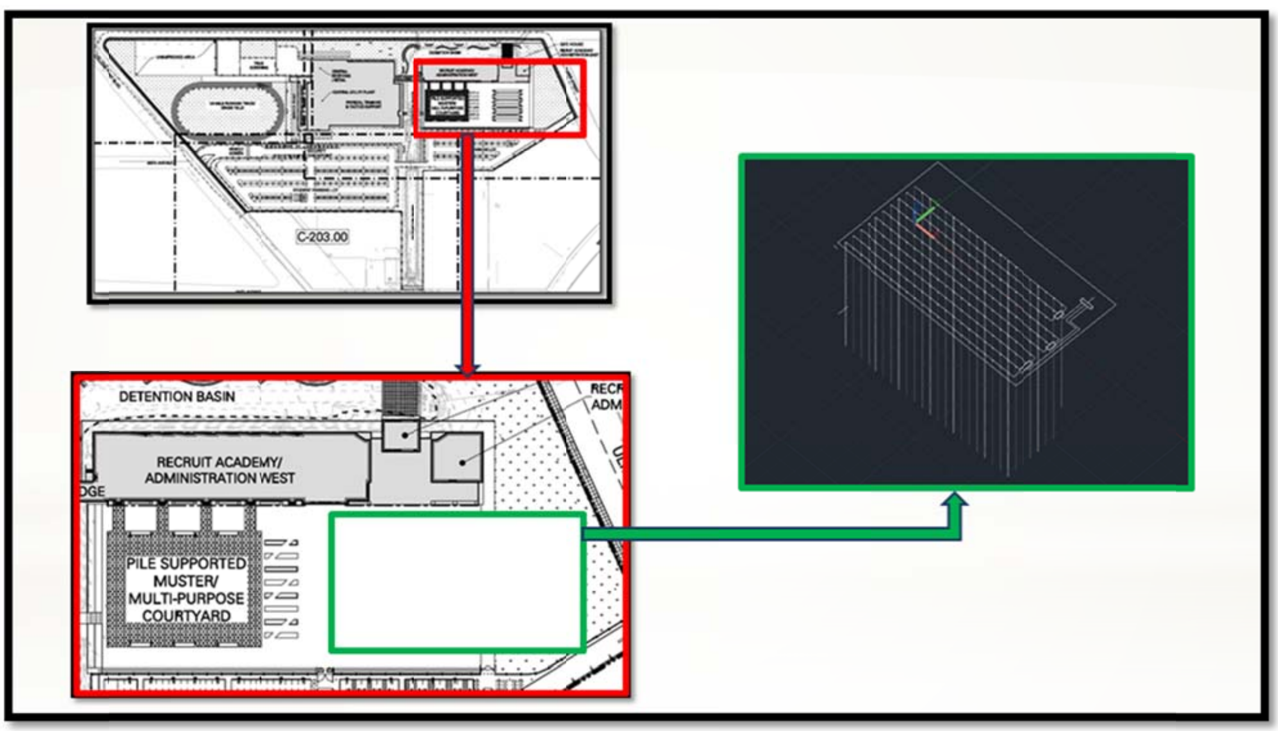


Figure 16: Site Placement of Well Field

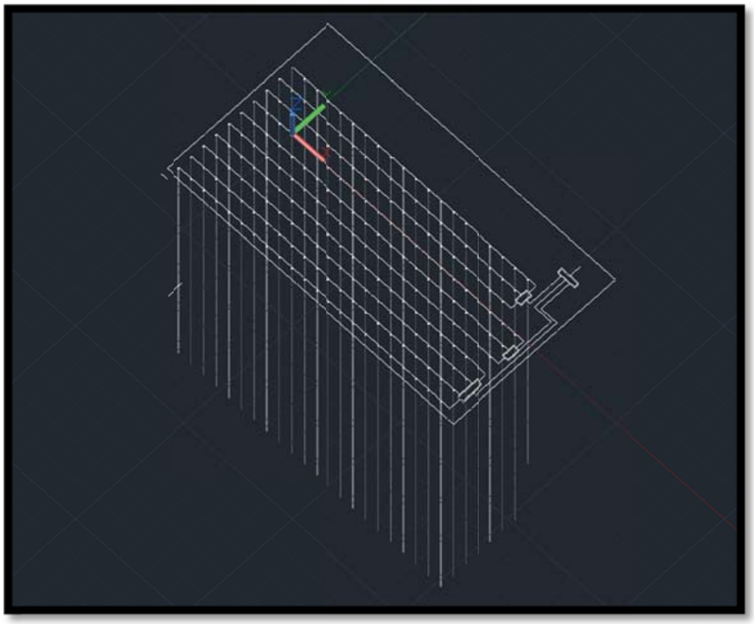


Figure 17: 3-D Well Field Layout

It is typical to have a well field split into different section with manifolds that allow control valves to open or close an individual well field. The well field has been designed to be split into three separate sections (rows 1-3, rows 4-6, rows, 7-10).

Table 12:Well Field Layout

Well Field Layout		
Row	# of Wells	Capacity
1	20	9.3%
2	20	9.3%
3	20	9.3%
Manifold 1 Total:	60	28%
4	22	10.3%
5	22	10.3%
6	22	10.3%
Manifold 2 Total:	66	31%
7	22	10.3%
8	22	10.3%
9	22	10.3%
10	22	10.3%
Manifold 3 Total:	88	41%

Heat Pump Selection

The East Campus of the New York Police Academy has its heating ventilating and air conditioning needs met by 19 air handling units that are currently served by the central heating and cooling plant. The new ground source heat pump system will replace the central plant service to the AHU's with 38 heat pumps. Two heat pumps will serve each air handling unit. The decision to have two heat pumps serve each air handling unit was decided because typical heat pumps are not easily manufactured for the heating and cooling capacity needed. Also with having two heat pumps serve each AHU. There will be more controllability for the system.

The heat pumps that have been chosen to use for the GSHP system are from McQuay International. The specific model is the McQuay WRA 420 High Efficiency Water to Water Source 35 ton Heat Pump. Below are some of the design features outlined by McQuay for this specific model of heat pump.

-Bi-flow Thermal Expansion Valve (TXV) for precise metering of refrigerant flow under all expected operating conditions.

-High efficiency coaxial water-to-refrigerant coils, fully insulated with polyurethane foam to maximize performance while helping to prevent condensate build-up in unit base pan.

-Fully insulated refrigerant and water lines to help prevent condensation from collecting in the unit base.

-High efficiency scroll compressors

-Temperature Control System– Controls return water temperature and has a separate setpoint for heating and cooling (1–2 stages). Requires a field supplied signal for heat/cool changeover.

-Adjustable Freezestat for geothermal and boiler tower applications. Senses leaving water on the source side and will shut down the unit if below setpoint.

-R-410A Refrigerant – No Ozone Depletion Potential with no phase out date.

After evaluating the ground conditions and matching the conditions needed to serve the existing AHU's the specifications of the WRA heat pump are as follows:

System Comparison

Central Plant System vs. GSHP System

Table 13: Electricity Consumption

	Electricity Consumption [kWh]		Total Building Electricity	
System	CP	GSHP	CP	GSHP
Primary Heating	10,945*	**421,204**	0.2%	8%
Primary Cooling	1,745,320	**833,324**	30.7%	16%
Auxiliary	103,668	**96,049**	1.8%	2%
Lighting	2,986,304	**2,986,304**	52.5%	58%
Receptacle	839,635	**839,635**	14.8%	16%
Totals	5,685,782	**5,176,517**	100.0%	100%

*Heating is primarily natural gas

Table 14: Yearly Electricity Distribution

	Yearly Electricity Consumption [kWh]		
System	CP	GSHP	**Δ**
Primary Heating	10,945*	421,204	**-410,259**
Primary Cooling	1,745,320	833,324	**911,996**
Auxiliary	103,668	96,049	**7,619**
Lighting	2,986,304	2,986,304	**0**
Receptacle	839,635	839,635	**0**
Totals	5,685,782	5,176,517	**509,265**

Table 15: Natural Gas Consumption

	Natural Gas Consumption [kBtu] GSHP System		
Primary Heating	Central Plant	GSHP System	Δ
Natural Gas Boilers	5,530,679	0	5,530,679

Table 16: Electric Utility Costs

	Energy Cost	Electricity Consumption [kWh/yr]		Utility Price [$ /yr]		Utility Price [$/ ft^2 • yr]	
System	Both	CP	GSHP	CP	GSHP	CP	GSHP
Primary Heating	$.1611 /kWh	10,945	**421,204**	$ 1,763	**$ 67,856**	$0.005/ ft^2 • yr	**$0.181/ ft^2 • yr**
Primary Cooling	$.1611 /kWh	1,745,320	**833,324**	$ 281,171	**$ 134,248**	$0.769/ ft^2 • yr	**$0.358/ ft^2 • yr**
Auxiliary	$.1611 /kWh	103,668	**96,049**	$ 16,701	**$ 15,473**	$0.046/ ft^2 • yr	**$0.041/ ft^2 • yr**
Lighting	$.1611 /kWh	2,986,304	**2,986,304**	$ 481,094	**$ 481,094**	$1.317/ ft^2 • yr	**$1.282/ ft^2 • yr**
Receptacle	$.1611 /kWh	839,635	**839,635**	$ 135,265	**$ 135,265**	$0.370/ ft^2 • yr	**$0.360/ ft^2 • yr**
Totals	$.1611 /kWh	5,685,782	**5,176,517**	$ 915,979	**$ 833,937**	$2.507/ ft^2 • yr	**$2.221/ ft^2 • yr**

Table 17: Total Utility Costs

Energy Cost	Energy Consumption		Utility Price/ ft^2 • yr	
	CP	GSHP	CP	GSHP
$.1611 /kWh	5,685,782 kWh/yr	5,176,517 kWh/yr	$2.507 / ft^2 • yr	**$2.221/ ft^2 • yr**
$11.858/1000 ft^3 NG	5,530,679 kBtu/yr	0	$.1699/ ft^2 • yr	**0**
		Total Utility Cost:	$2.677/ ft^2 • yr	**$2.221/ ft^2 • yr**
		Annual Cost:	$1,004,921/yr	**$833,774**
			Savings	**$171,147 (17%)**

*High Heating Value for Natural Gas was used 1ft^3=1028 Btu in accordance with specification of boiler.

Utility Cost Comparisons

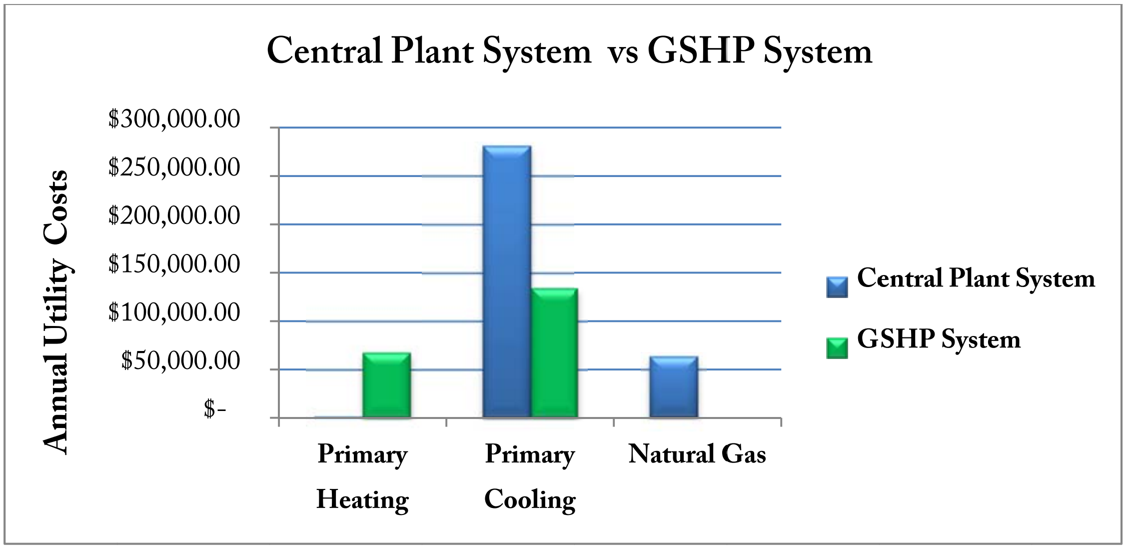


Figure 18: Annual Utility Cost Comparison Bar Graph

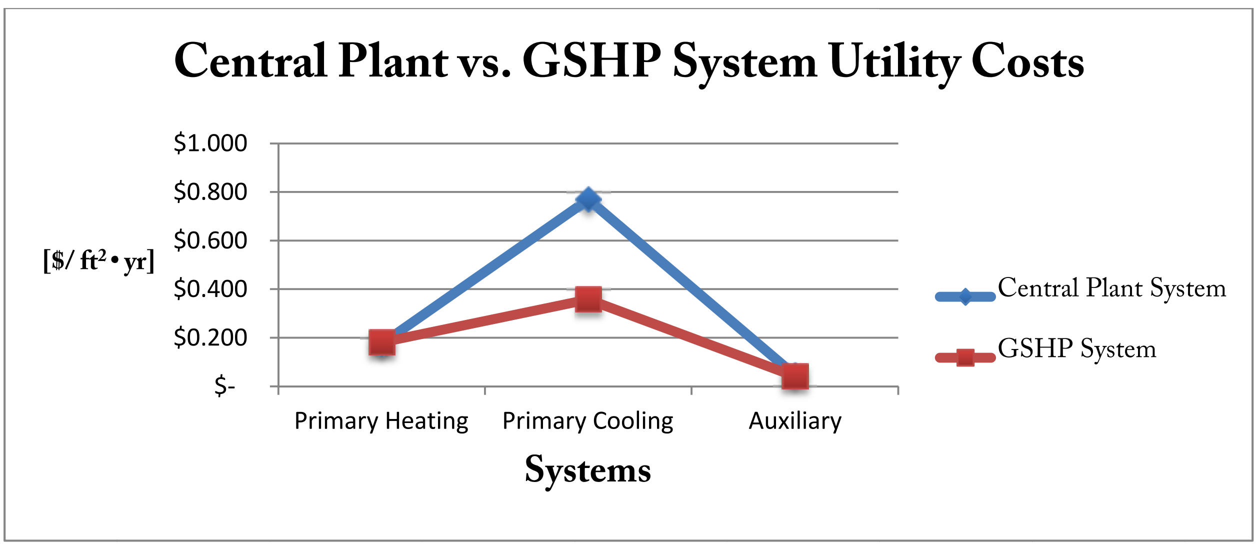


Figure 19: [$/ ft2 • yr] Comparison Line Graph

Economic Analysis

From a utility savings standpoint it has been found that the GSHP will reduce the annual utility costs by 17% which is equal to $171,147 . The utility savings is predominantly attributed to the savings in electricity from cooling and reducing all natural gas consumption.

A more specific cost analysis can be found further in the report in the final analysis section. Construction costs (first costs) needed to be established before an economic analysis has been made. Thus, when reviewing this report it is important to study the construction section before the final GSHP economic analysis. The construction costs are first established then the final GSHP economic analysis is analyzed and this is found in the Final Analysis Section.

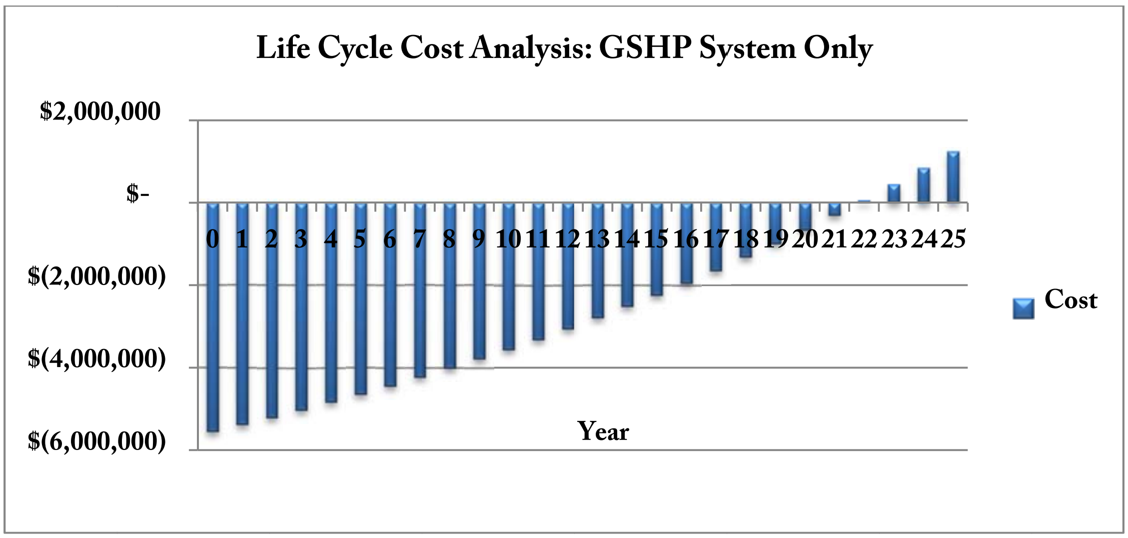


Figure 20: Life Cycle Cost Analysis GSHP Only

Summary

There are several key discoveries that have been made about the GSHP system that allow for it to be feasible. First and foremost, by calculating the necessary length of pipe needed for the heating and cooling load it was discovered that the site is large enough to support a well field. Also through developing and studying and energy model of the GSHP system, it was discovered that energy use could be reduced by 17% and this includes eliminating all natural gas being burned for heating of the East Campus.

A more specific cost analysis can be found further in the report in the final analysis section. Construction costs (first costs) needed to be established before an economic analysis has been made. Thus, when reviewing this report the construction costs are first established then the final GSHP economic analysis is analyzed. To understand the feasibility of the GSHP system it must be evaluated from both a mechanical standpoint as well as a constructability/cost standpoint.

Electrical Breadth

Overview

The New York Police Academy is a very large facility, which offers a tremendous amount of rooftop space. Much of the roof top of the New York Police Academy is not being used, and it offers a unique opportunity to explore a large photovoltaic array. The proposed area for the photovoltaic array would be on the West Campus above the Athletic Facilities (see figures below). There are also several long sky-lights that run the length of the roof that could potentially offer valuable space for an array, a schematic section view is shown below. These sky lights offer a tilted axis as well as direct southern exposure, which both would benefit the electrical output of the photovoltaic array .An electrical analysis will be done to calculate the amount of electricity produced by such a system. Also an economic feasibility analysis will be done to determine if this system could potentially produce enough electricity to have a payback period that is worthwhile.

Photovoltaic Analysis

In order to perform an electrical photovoltaic analysis, there are several important logistical decisions that need to be made. The location and site of the NYPA along with the architectural design of the building are indicative of the size of the array, positioning of the array, and thus the power output of the array. The NYPA will be located in College Point New York and the array will be located on the roof of the West Campus building. The orientation of the West Campus is directly south which is vital for photovoltaic power output. The solar radiation for a panel facing South at the latitude of this location is 4.6kwh/m^2/day.

Location

New York, New York

Figure 21: Site of the New York Police Academy without Photovoltaic Array

Figure 22: Site of the New York Police Academy with Photovoltaic Array

The yellow area (above) represents the site boundaries of the NYPA while the white blocks represent NYPA. The red blocks represent large surrounding buildings. It can be seen that the there are no buildings that will pose shading to the West Campus Building. The black area on the West Campus Building is the photovoltaic array. This view of the site shows that a shading analysis does not need to be performed for any specific obstructions.

Photovoltaic Panel

The array sizing and placement is completely dictated by the layout of the NYPA. A major assumption for this analysis is the photovoltaic array will not be a "building integrated photovoltaic array (BIPV). Rather, it is assumed that this array is being installed as an addition to the NYPA. Thus, in order to affectively design the array a photovoltaic panel and mounting system needs to be chosen to match the needs of the NYPA existing conditions. Thus, the panel and mounting systems chosen is specifically designed for use in large arrays. Below is information that details the specifications for the panel and mounting system chosen.

Sharp NU Series 185W Monocrystalline Silicon Photovoltaic Module

Product Features (Sharp NU Series Catalog)

-High performance photovoltaic modules made of mono crystalline (155.55 mm2) silicon solar cells with module efficiency of up to 14.1%.
- Bypass diodes to minimize power loss with shading.
- Textured cell surface for especially high current yields.
- Black Surface Field (BSF) structure for optimizing cell efficiency.
- Use of annealed glass, EVA plastic and weather-protection foil, as well as an anodized aluminum frame with water drainage holes for prolonged use.
- Output: connection cable with water-protected plug connector.
- The NU Sharp series of photovoltaic modules are designed for applications with a high power requirement. These mono crystalline quality modules produce a sustained, reliable yield even under demanding deployment conditions.

Please see appendix for further specification and characteristics of the Sharp NU Series 185W Monocrystalline Silicon Photovoltaic Module.

Mounting System: Solion SunMount ® MK3

Product Features (Solion SunMount® Features and Specifications)

- -Designed specifically for flat roof buildings
- -Requires no roof penetration and ballast is optional (12,24,48kg).
- -Light-weight roof loading: 2.3 PSF (Includes PV Panel, excludes a ballast weight)
- -Mounting system designed to reduce wind uplift and drag forces.
- -Modular interlocking design for easy installation
- -Connection and disconnection is easily accessible

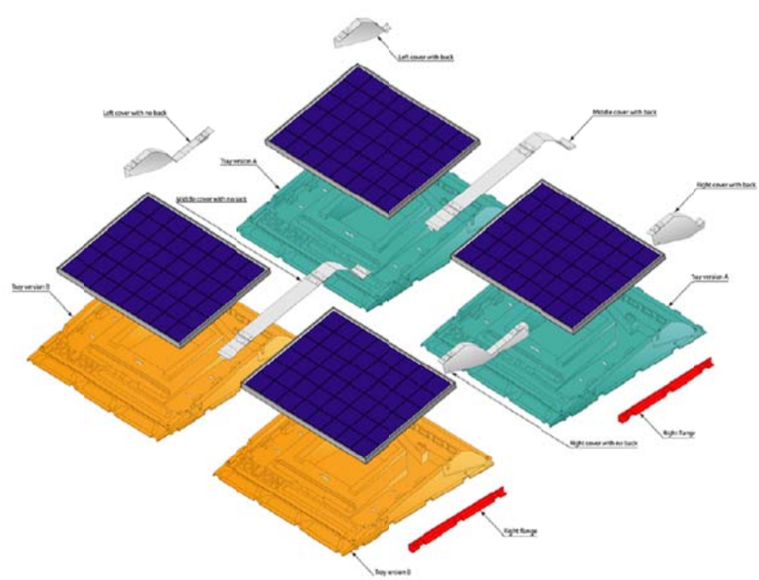


Figure 23: Soloin Sunmount Diagram

The Sharp NU Series panel along with the Solion Sunmount® system has been chosen because it is specifically designed for large arrays that will be installed on flat roofs. The NYPA's West Campus roof provides a large flat area that can easily be used for a photovoltaic array.

Designing the Array

In order to design the array a three dimensional model of the New York Police Academy was constructed using Google Sketchup. By developing a three dimensional model of the academy the positioning and size of the array can be determined by evaluating where exactly the array will be placed and the size of the array. The size of the array was dictated by the allowable space on the West Campus building. The array was <u>not</u> initially designed to provide a certain amount of electricity. Conversely, the array was designed to provide the maximum amount of electricity possible within the given roof space. Below are graphical representations of the analysis performed to determine the array size.

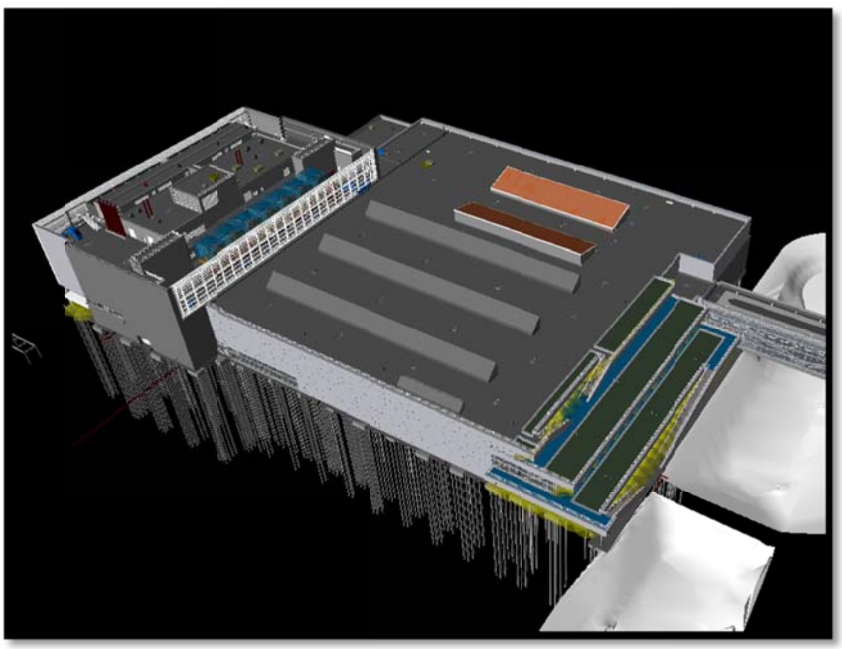


Figure 24: West Campus Roof without Photovoltaic Array

The West Campus roof being analyzed is approximately 86,000 SF. This does not include the roof area above the central plant or the green roof area on the South East corner of the West Campus. The 86, 000 SF is the area that is usable for the photovoltaic array,

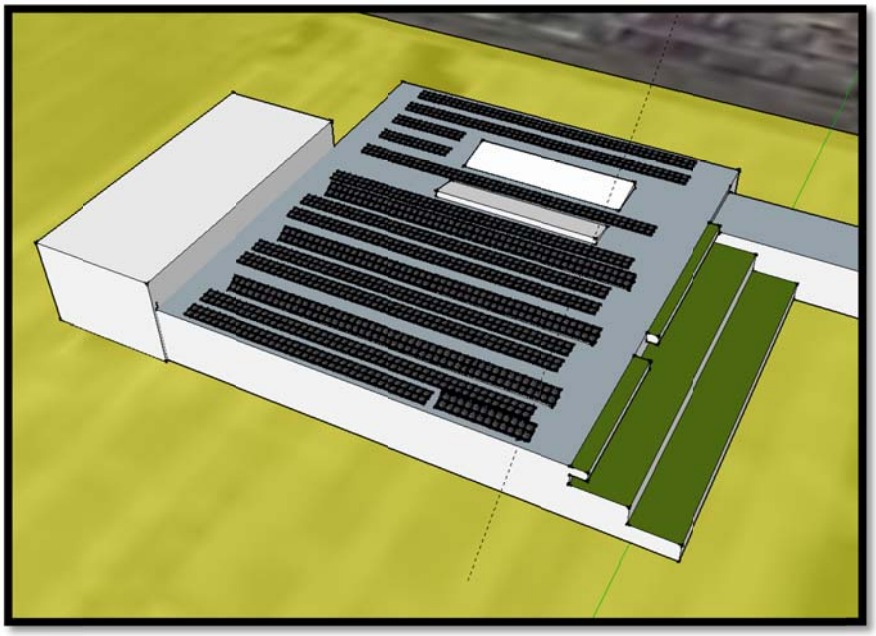


Figure 25: West Campus Roof With Photovoltaic Array I

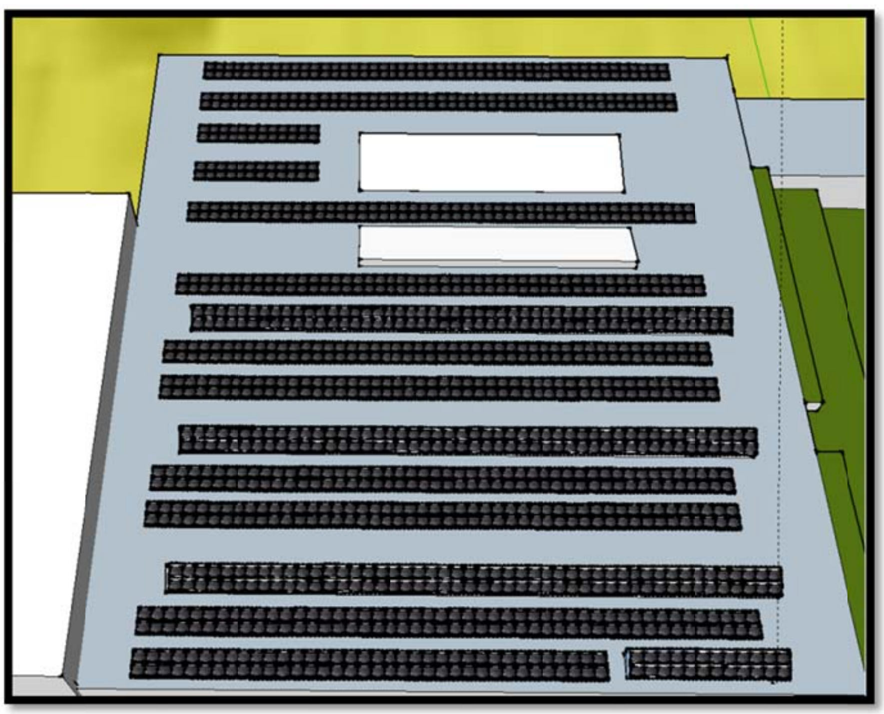


Figure 26: West Campus Roof with Photovoltaic Array II

Figure 27: Actual Installation of Sharp NU Series panels with Solion SunMount® system

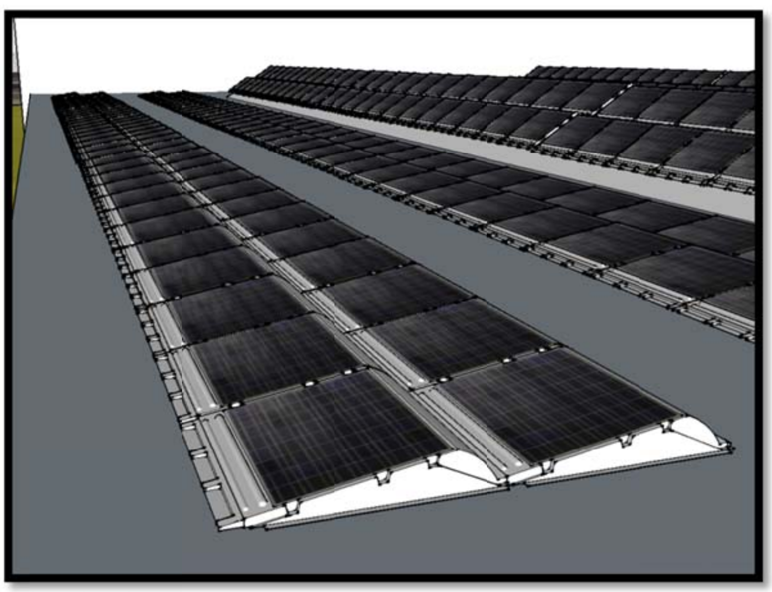


Figure 28: Zoomed View of Google Sketch up Model Panels

The photovoltaic array needed to be designed in a logical manor that would provide the most effective use of the West Campus Roof. Photovoltaic arrays need to be laid out with paths in between the array for easy maintenance. The manufacturer suggests that an array be no more than four panels deep. However, I decided that arrays would be two panels deep to allow for each individual panel to be easily accessed for any type of maintenance. Also the arrays needed to align around roof drains that are designed into the system. The roof drains fit safely within the utility paths outlined in this array design.

Table 18: Array Information

Basic Array Information	
Total Number of Panels	1368 Panels
Total SF of Photovoltaics	19,290Ft^2

Inverter Sizing

In sizing the inverter for a photovoltaic system there are several variables in which need to be accounted for. A vital part of a photovoltaic system is the inverter system because photovoltaic panels produce DC electricity however nearly all building loads run on AC electricity. Thus, in order to use the electricity produced by the photovoltaic array inverters needed to be connected to the system. Inverter sizing is based on the panel specifications as well as the layout of the array. Below is schematic diagram of how the 1368 photovoltaic panels will be stringed together. This layout has dictated the sizing of the inverters as well the connectivity of the array.

String Layout

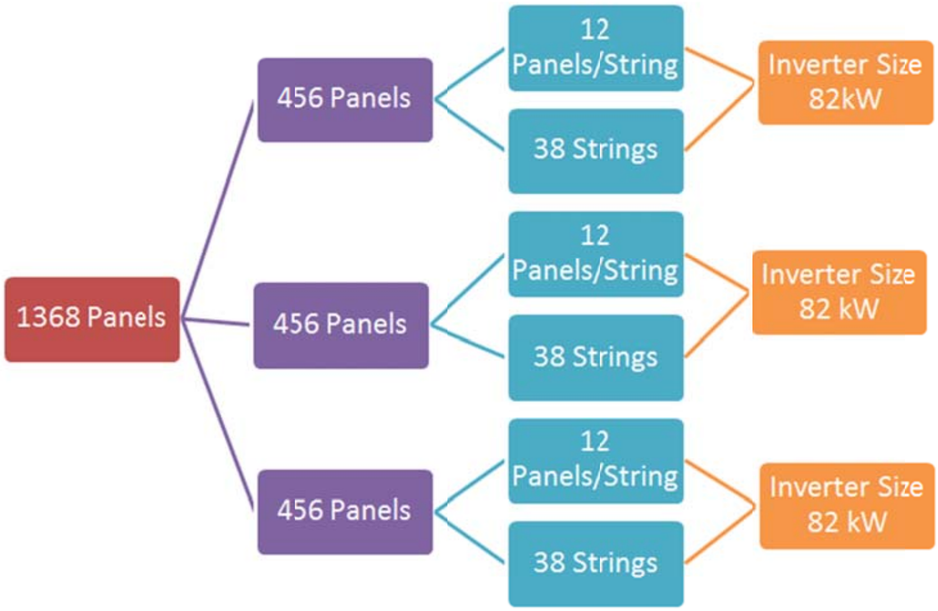


Figure 29: String Layout Diagram

Module Manufacturer	Sharp				
Module Model	NT-185UI (24V module)	Power @ MPP	185.0 W		
Voltage @ MPP (STC)	36.2 VDC	PTC Power Rating	163.5 W		
Current @ MPP (STC)	5.11 ADC	Temp Coeff of Vmpp	0.144 V/degC	(Vmpp)	
Current, short circuit	5.75 ADC	Temp Coeff of Vocv	0.144 V/degC	(Vocv)	
OCV @ 25 deg C cells	44.9 VDC	NOCT(nom. cell temp)	47.5 deg C		117.5 deg F

For Vmpp @ max amb temp and OCV @ coldest temperature, green is OK, red is not OK
orange is acceptable but should be avoided where possible (inverter will hold at 330VDC)
purple is OK but indicates inverter will limit to 95 kW AC continuous output
pink is acceptable but should be avoided where possible (inverter will not run above 600VDC)
(note that NEC 690 prohibits system voltage to exceed 600VDC)

Modules total in array	330	352	396	440	484	528	561	583	605
Modules per string	11	11	11	11	11	11	11	11	11
Strings in Parallel	30	32	36	40	44	48	51	53	55
Voltage @ MPP (STC)	398.2	398.2	398.2	398.2	398.2	398.2	398.2	398.2	398.2
Vmpp @ max amb temp (30C, 86F amb)	346.7	346.7	346.7	346.7	346.7	346.7	346.7	346.7	346.7
Vmpp @ max amb temp (35C, 95F amb)	338.8	338.8	338.8	338.8	338.8	338.8	338.8	338.8	338.8
Vmpp @ max amb temp (40C, 104F amb)	330.9	330.9	330.9	330.9	330.9	330.9	330.9	330.9	330.9
Vmpp @ max amb temp (45C, 113F amb)	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0	323.0
Vmpp @ max amb temp (50C, 122F amb)	315.0	315.0	315.0	315.0	315.0	315.0	315.0	315.0	315.0
OCV @ 25 deg C cells	493.9	493.9	493.9	493.9	493.9	493.9	493.9	493.9	493.9
OCV @ coldest temp (-40C, -40F amb)	596.9	596.9	596.9	596.9	596.9	596.9	596.9	596.9	596.9
OCV @ coldest temp (-30C, -22F amb)	581.0	581.0	581.0	581.0	581.0	581.0	581.0	581.0	581.0
OCV @ coldest temp (-20C, -4F amb)	565.2	565.2	565.2	565.2	565.2	565.2	565.2	565.2	565.2
OCV @ coldest temp (-10C, 14F amb)	549.3	549.3	549.3	549.3	549.3	549.3	549.3	549.3	549.3
OCV @ coldest temp (0C, 32F amb)	533.5	533.5	533.5	533.5	533.5	533.5	533.5	533.5	533.5
Power @ MPP (STC)	61050	65120	73260	81400	89540	97680	103785	107855	111925
PTC AC system power rating	51527	54962	61832	68703	75573	82443	87596	91031	94466
Suggested Inverter	PVI 60KW	PVI 60KW	PVI 60KW	PVI 82KW	PVI 82KW	PVI 82KW	PVI 95KW	PVI 95KW	PVI 95KW

Modules total in array	300	360	384	432	480	528	552	576	600
Modules per string	12	12	12	12	12	12	12	12	12
Strings in Parallel	25	30	32	36	40	44	46	48	50
Voltage @ MPP (STC)	434.4	434.4	434.4	434.4	434.4	434.4	434.4	434.4	434.4
Vmpp @ max amb temp (30C, 86F amb)	378.2	378.2	378.2	378.2	378.2	378.2	378.2	378.2	378.2
Vmpp @ max amb temp (35C, 95F amb)	369.6	369.6	369.6	369.6	369.6	369.6	369.6	369.6	369.6
Vmpp @ max amb temp (40C, 104F amb)	361.0	361.0	361.0	361.0	361.0	361.0	361.0	361.0	361.0
Vmpp @ max amb temp (45C, 113F amb)	352.3	352.3	352.3	352.3	352.3	352.3	352.3	352.3	352.3
Vmpp @ max amb temp (50C, 122F amb)	343.7	343.7	343.7	343.7	343.7	343.7	343.7	343.7	343.7
OCV @ 25 deg C cells	538.8	538.8	538.8	538.8	538.8	538.8	538.8	538.8	538.8
OCV @ coldest temp (-40C, -40F amb)	651.1	651.1	651.1	651.1	651.1	651.1	651.1	651.1	651.1
OCV @ coldest temp (-30C, -22F amb)	633.8	633.8	633.8	633.8	633.8	633.8	633.8	633.8	633.8
OCV @ coldest temp (-20C, -4F amb)	616.6	616.6	616.6	616.6	616.6	616.6	616.6	616.6	616.6
OCV @ coldest temp (-10C, 14F amb)	599.3	599.3	599.3	599.3	599.3	599.3	599.3	599.3	599.3
OCV @ coldest temp (0C, 32F amb)	582.0	582.0	582.0	582.0	582.0	582.0	582.0	582.0	582.0
Power @ MPP (STC)	55500	66600	71040	79920	88800	97680	102120	106560	111000
PTC AC system power rating	46843	56211	59959	67454	74948	82443	86191	89908	93686
Suggested Inverter	PVI 60KW	PVI 60KW	PVI 60KW	PVI 82KW	PVI 82KW	PVI 82KW	PVI 95KW	PVI 95KW	PVI 95KW

Modules total in array	432	480
Modules per string	12	12
Strings in Parallel	36	40
Voltage @ MPP (STC)	434.4	434.4
Vmpp @ max amb temp (30C, 86F amb)	378.2	378.2
Vmpp @ max amb temp (35C, 95F amb)	369.6	369.6
Vmpp @ max amb temp (40C, 104F amb)	361.0	361.0
Vmpp @ max amb temp (45C, 113F amb)	352.3	352.3
Vmpp @ max amb temp (50C, 122F amb)	343.7	343.7
OCV @ 25 deg C cells	538.8	538.8
OCV @ coldest temp (-40C, -40F amb)	651.1	651.1
OCV @ coldest temp (-30C, -22F amb)	633.8	633.8
OCV @ coldest temp (-20C, -4F amb)	616.6	616.6
OCV @ coldest temp (-10C, 14F amb)	599.3	599.3
OCV @ coldest temp (0C, 32F amb)	582.0	582.0
Power @ MPP (STC)	79920	88800
PTC AC system power rating	67454	74948
Suggested Inverter	PVI 82KW	PVI 82KW

Figure 30: Sharp Manufacturer Inverter Recommendation Chart

Switchgear Sizing

Table 19: Electrical Information

System Characteristics	Each of the Arrays (456 Panels)
Voltage [Volts]	434
Current [amps]	194.4
Power [kW]	84.36

Photovoltaic System Schematic

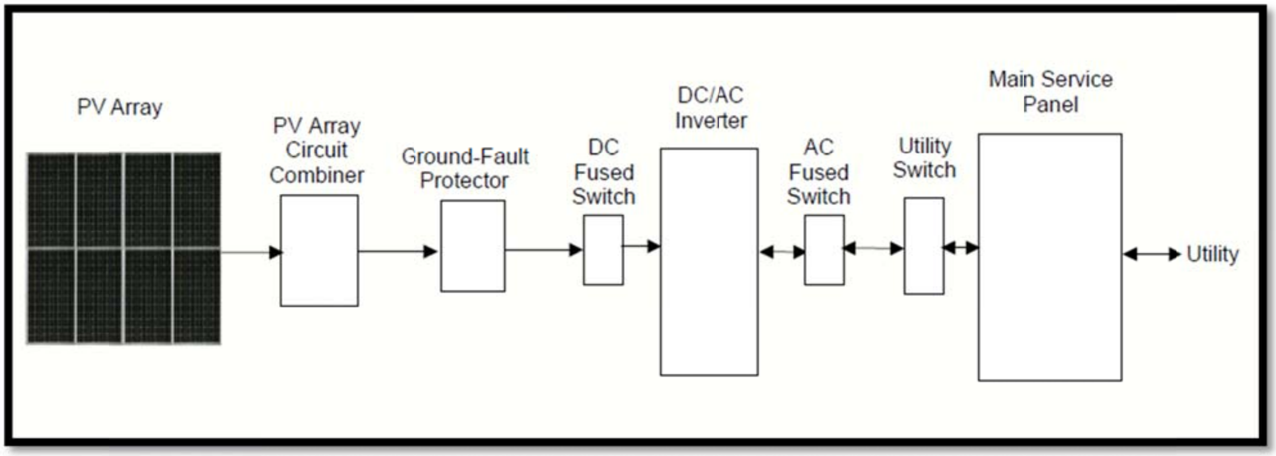


Figure 31: Basic Photovoltaic Schematic (California Energy Commission)

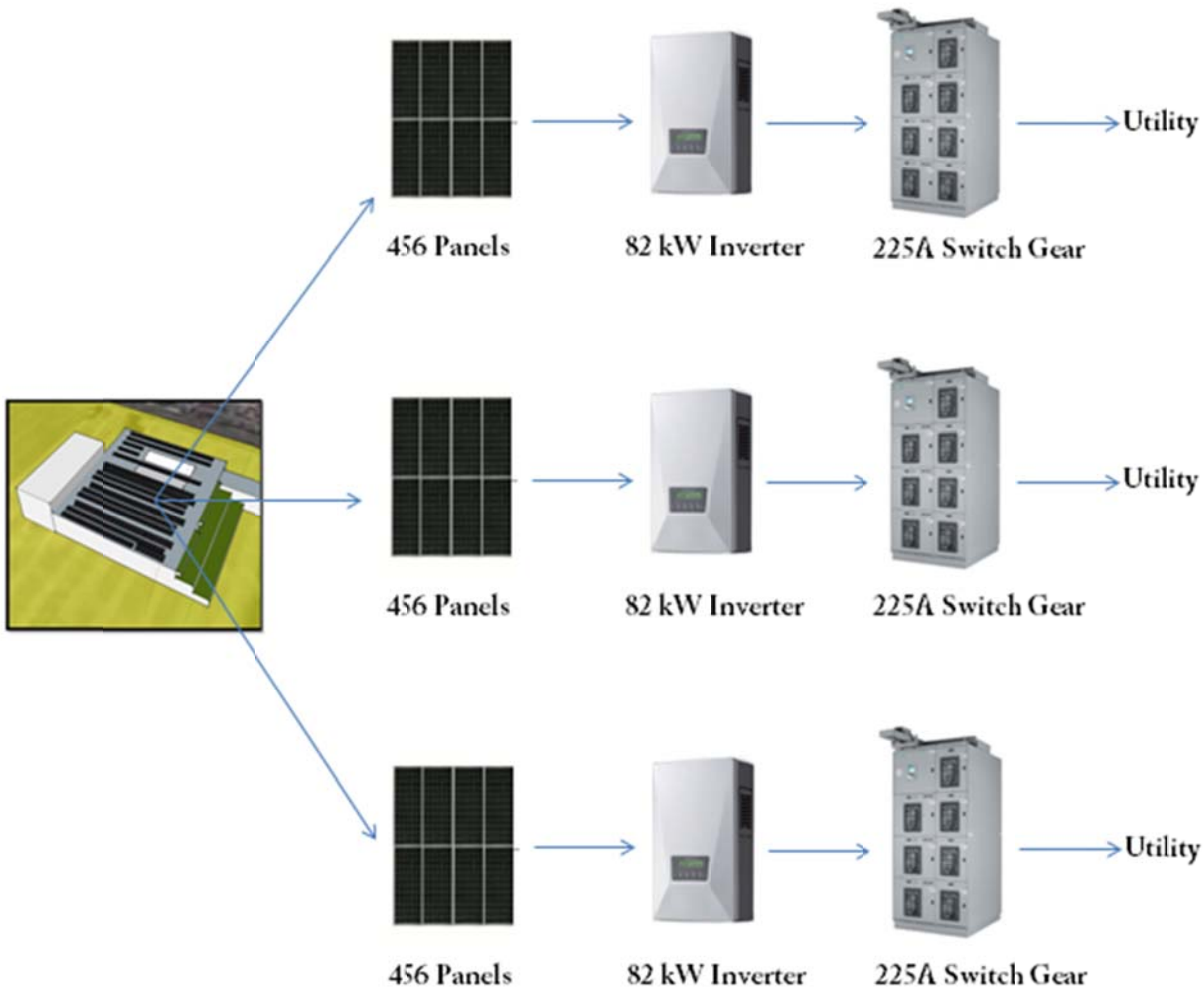


Figure 32: Graphic System Schematic

Photovoltaic Economic Analysis

In order to effectively evaluate the feasibility of a photovoltaic array an economic analysis needs to be performed to evaluate the economic impact of the system. Information that is pertinent to the economic analysis of the photovoltaic array would be the energy production of the array, the total cost of the array, as well as a life cycle analysis of the array. Below are figures and tables that represent the economic analysis of the photovoltaic array. For a breakdown of the tables and calculations performed for the economic analysis please see the electrical Appendix.

Table 20: Photovoltaic Energy Production

Energy Production Information	
Solar System Capacity	193.89kW
Annual Electrical Production	237,612 kWh

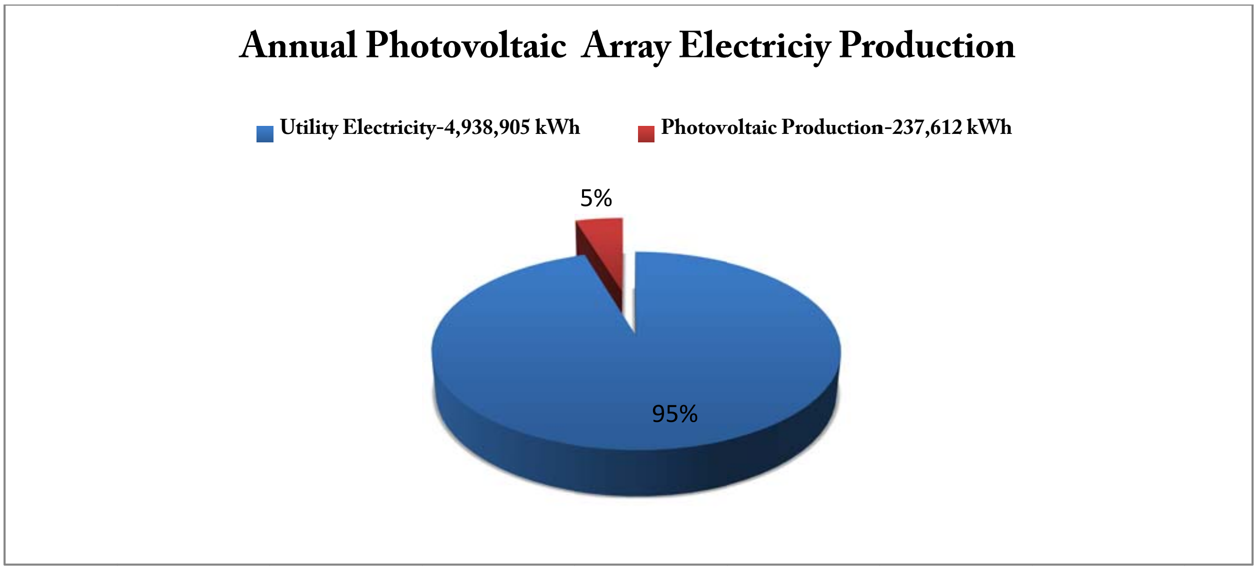


Figure 33: Annual Electricity Production

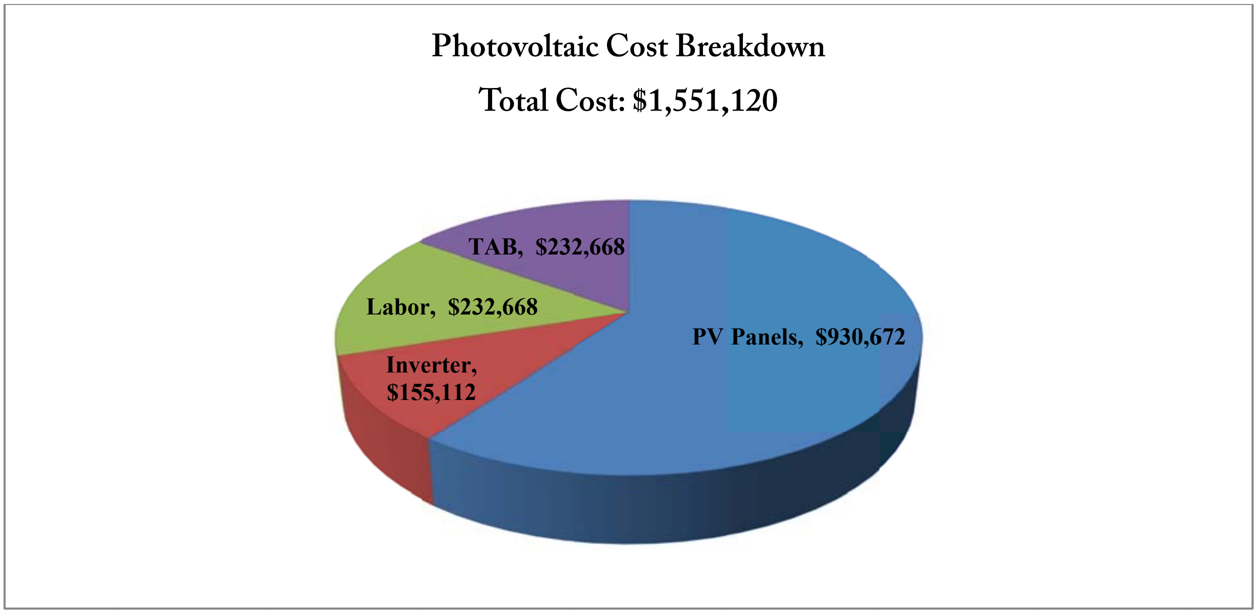


Figure 34: Photovoltaic System Cost

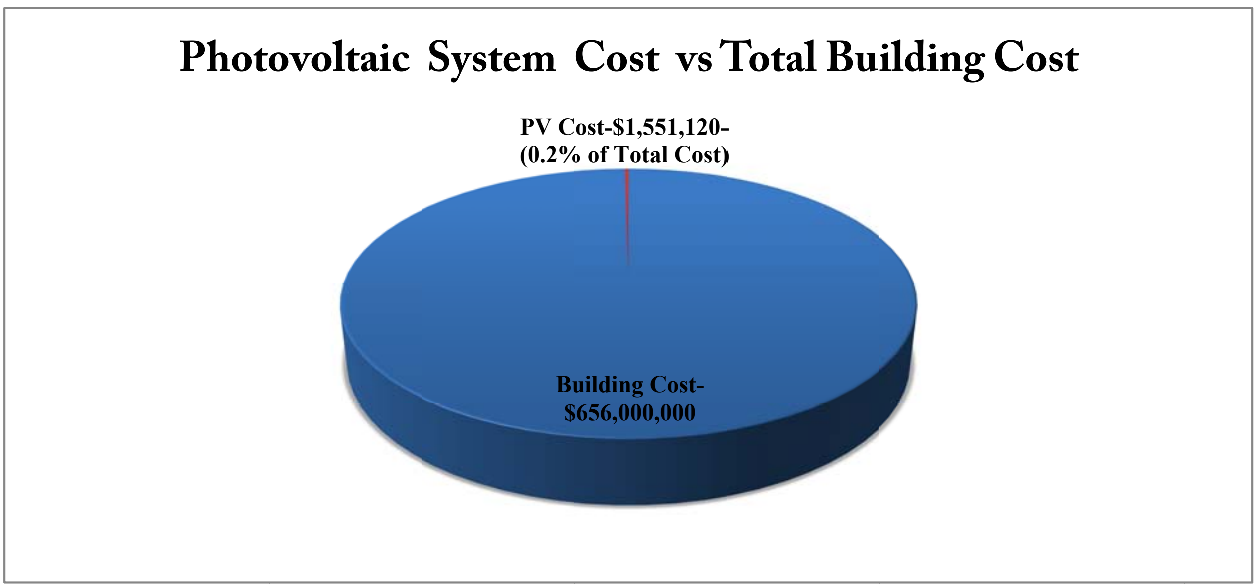


Figure 35: Photovoltaic System Cost vs Total Building Cost

Life Cycle Cost Analysis

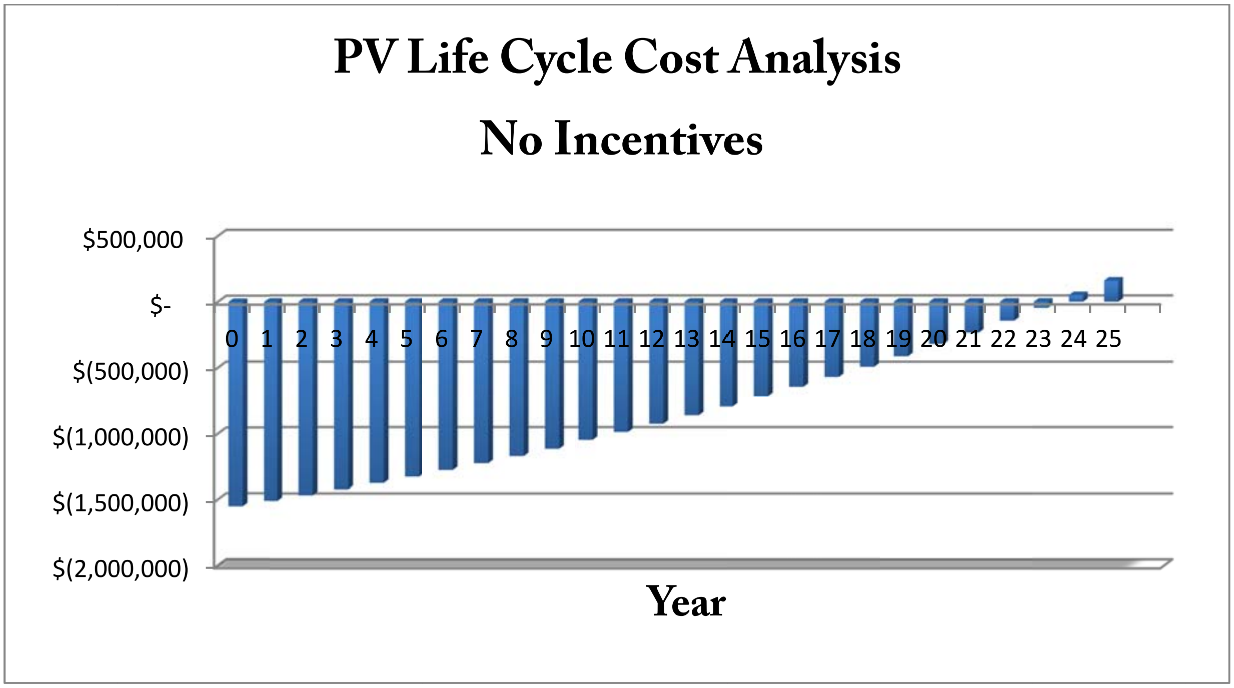
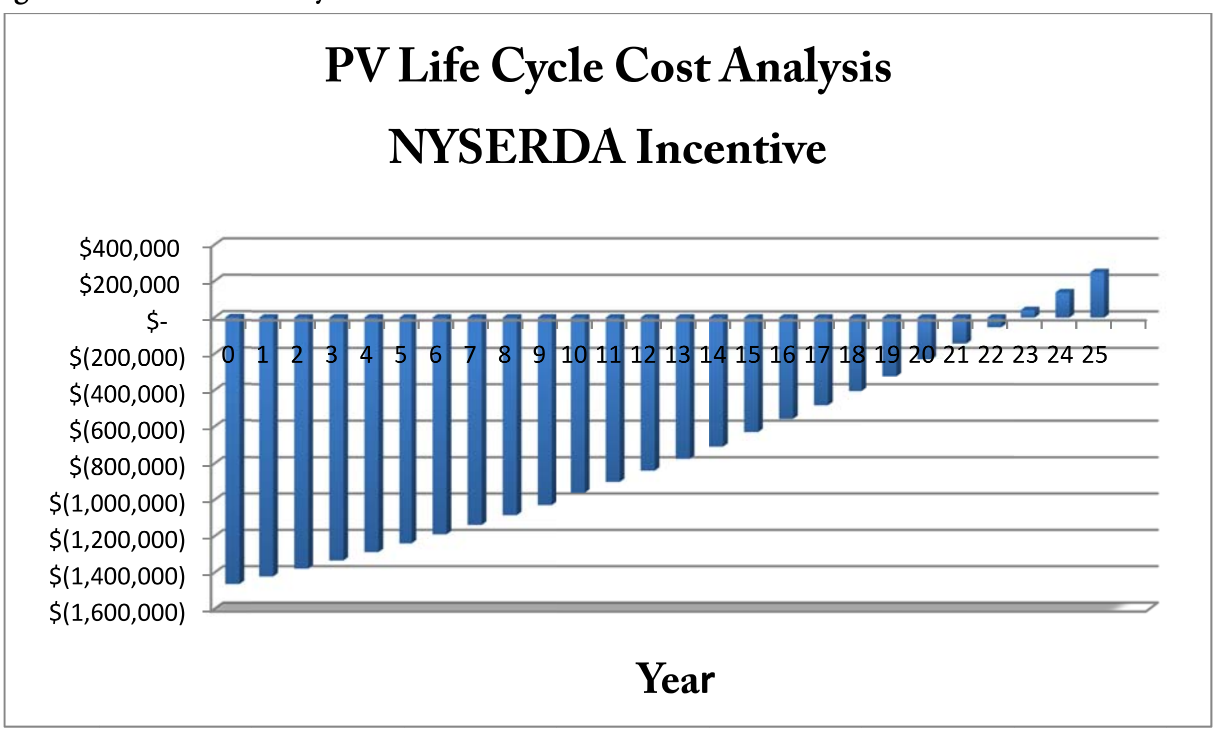


Figure 36: PV LCC Analysis-No Incentives



*NYSERDA: New York State Energy Research and Development Authority

Figure 37: PV LCC Analysis-NYSERDA Incentive

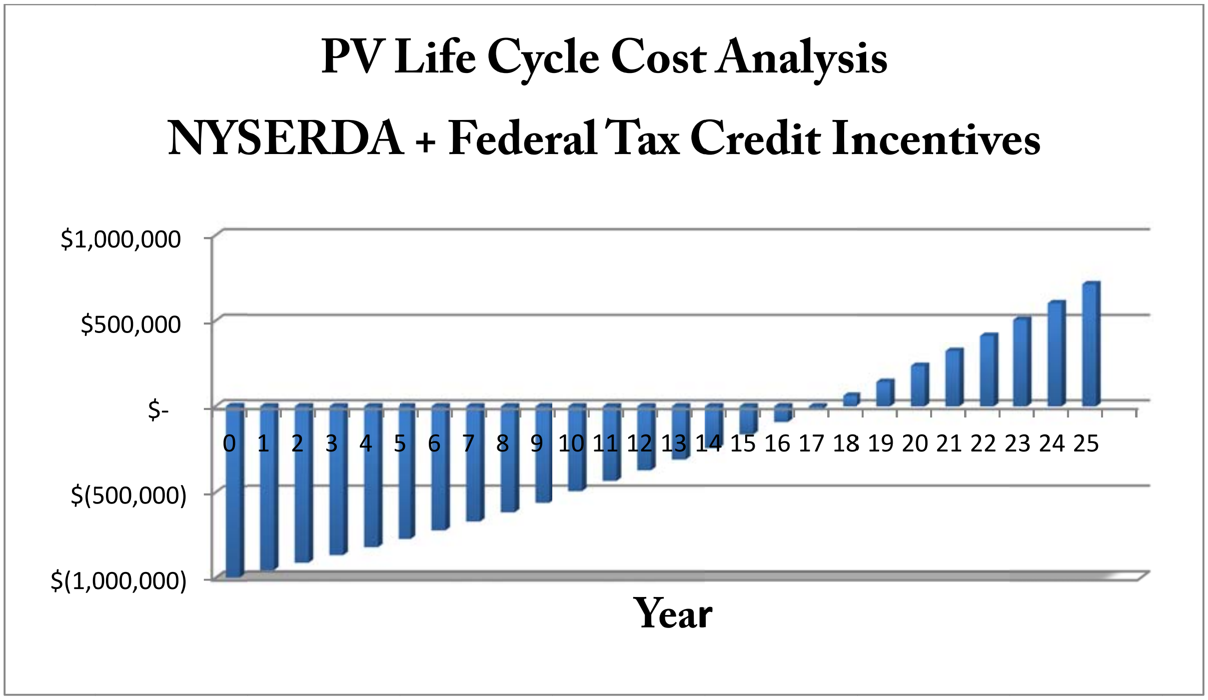


Figure 38: PV LCC Analysis-NYSERDA + Federal Tax Credit Incentives

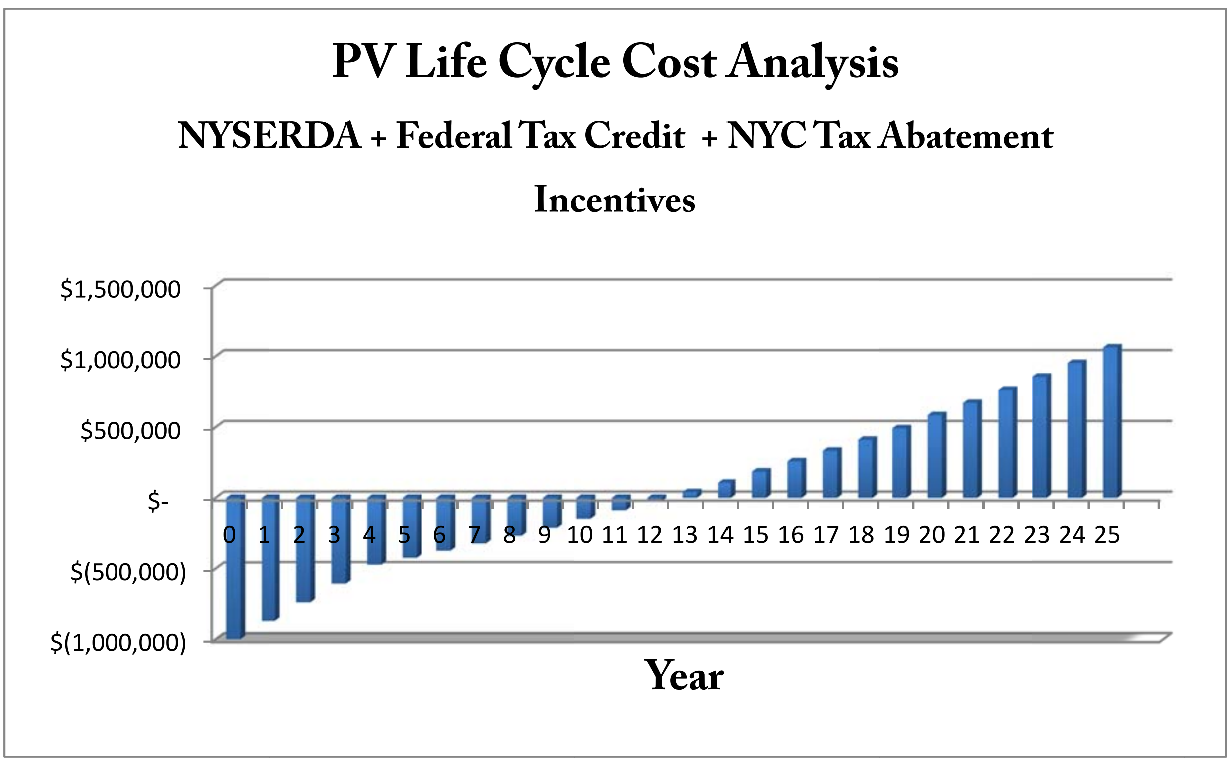
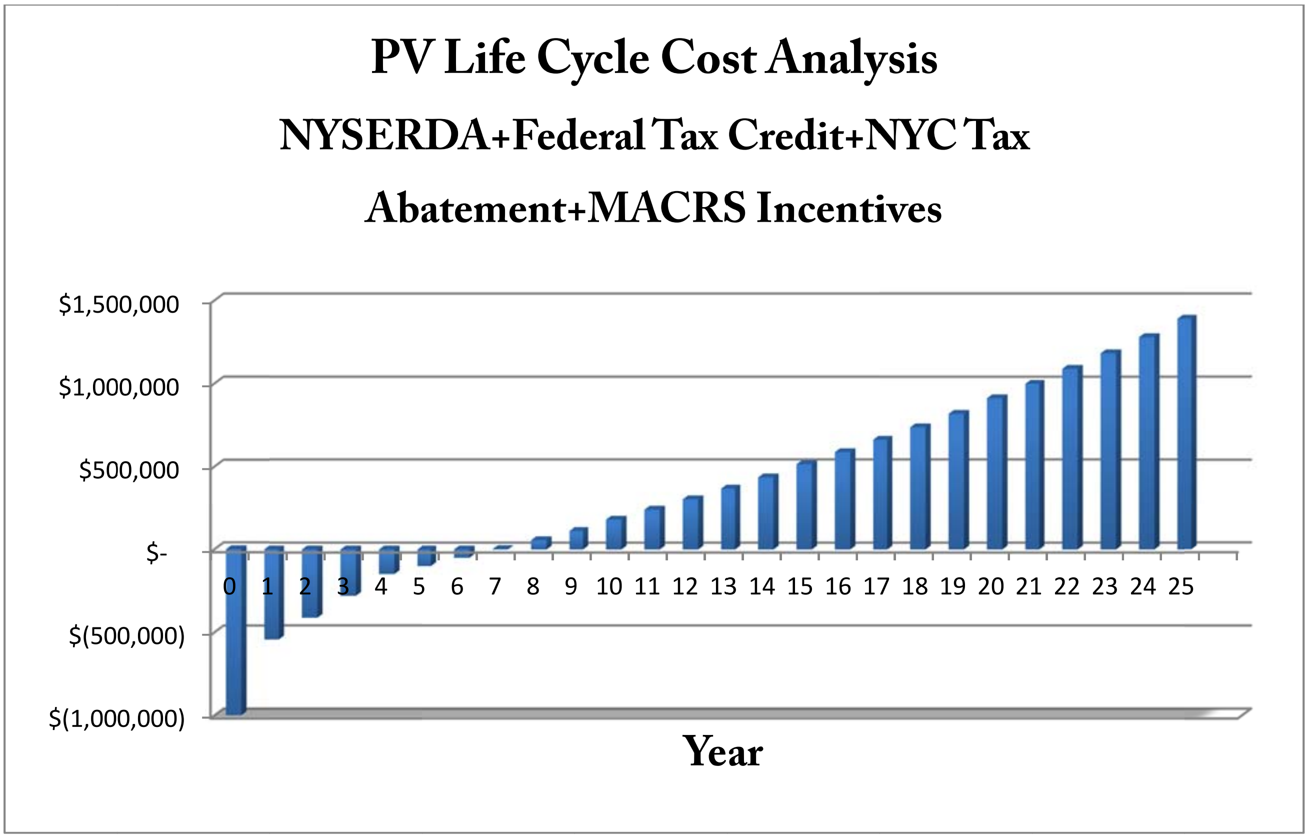


Figure 39: PV LCC Analysis-NYSERDA+ Federal Tax Credit+ NYC Tax Abatement Incentives



*MACRS: Modified Accelerated Cost Recovery System

Figure 40: PV LCC Analysis-NYSERDA+ Federal Tax Credit+ NYC Tax Abatement + MACRS Incentives

Summary

After analyzing the design and implementation of the photovoltaic array there are several conclusions that can be made about implementing a photovoltaic system for the NYPA. First and foremost it was discovered that there is not nearly enough roof space on the West Campus building to provide a significant portion of electricity for the campus. The photovoltaic array would only provide 5% of the total electricity needs for the campus. This in itself would seem to discourage the idea of the implementing an array for the academy. However, upon further economic analysis there are several strong arguments for implementing the system. The first would be the total cost of the system would only be a 0.2% cost increase for the construction of the buildings. Spending 0.2% more on the upfront costs of the Academy to provide 5% of the electricity for the building is a compelling argument for installing the array. This fact coupled with the idea that there would be a seven year pay pack period for this system with all incentives included is the second compelling argument for installing the system. The payback period is reduced from 24 years to seven years with several incentives. This means that after seven years the array would have paid for itself and then provides clean "free" energy for the remainder of the arrays life.

The NYPA will be a building used for many years and it will be an iconic building for the City of New York and specifically College point, Queens. By implementing such a system it will show that New York City Department of Design and Construction is strongly encouraging sustainable building techniques in an economically conscious way.

Construction Management Breadth

Overview

In order to implement a ground source heat pump system to service such a large building, there will need to be a considerable amount of attention attributed to the construction of the system. Installing 214 wells for the GSHP system will develop unique construction related issues that need to be addressed. Specifically, there will be an increased first cost along with impacting the coordination and scheduling of activities. An analysis has been performed to evaluate the construction impacts that will need to be addressed to implement the proposed ground source heat pump system.

GSHP Length Optimization

The largest cost associated with a GSHP system is the first cost of the system. GSHP systems can save energy usage over the course of its lifetime as compared with other systems. However analyzing the first cost of the system is vital in understanding the economic sense of implementing the system.

An analysis was done to understand what the most optimized size of the GSHP system would be from a first cost standpoint. As mentioned earlier in the report the cooling load dictated a larger GSHP pipe length than the heating load. Thus, the system was designed to provide for the cooling load. However, this also means that that the system would be oversized for the heating load. Thus, there is an opportunity to find the most optimized pipe length for the system.

In order to perform this analysis there are several factors that need to be considered. First and foremost is the total cost of the system which needs to be minimized. Next is providing a system that safely meets both the heating and cooling loads. A spreadsheet was developed to perform this analysis. The spreadsheet took into account the different variables that will affect the system cost. The determining factor in the cost is the length of the GSHP system because this affects the construction costs as well as all associated equipment costs. Specific costs include: cost of construction, cost of heat pumps, costs of cooling towers, savings on chillers, and savings on boilers. Below are screen shots of the excel spread sheet developed

Variables			
			units
Length of GSHP	L_gshp	**249,047**	[ft]
Water Circulation	G	22663	[gallons]
GSHP Cooling	Q	1009	[tons]
CT Supplementary Cooling		203	[tons]
% of Cooling		83.2%	[%]
% of Heating		100.0%	[%]

Figure 41: Input Variables Pipe Length Cost Optimization

Costs		
Cost Digging,Piping, Grouting, Install	Cost_wells	$3,937,433
Cost of Cooling Towers	Cost_ct	$40,700
Cost of Heat Pumps	Cost_hp	$1,008,000
Savings on Chillers	Saving_chlr	$-278,208
Savings on Boilers	Saving_blr	$-170,200
Total Cost of System	**Cost_total**	**$4,789,325**

Figure 42: Cost Calculations for Pipe Length Cost Optimizations

Results						
	Length	Cost	GSHP Cooling	CT Cooling	% of Cooling	% of Heating
Run 1	200,000	$3,935,190	810	402	66.80%	80.30%
Run 2	205,000	$3,987,395	830	382	68.40%	82.30%
Run 3	210,000	$4,080,925	851	362	70.10%	84.30%
Run 4	214,818	$4,171,578	870	342	71.70%	86.20%
Run 4	215,000	$4,174,455	871	341	71.80%	86.30%
Run 5	220,000	$4,268,709	891	321	73.50%	88.30%
Run 6	225,000	$4,362,239	911	301	75.10%	90.30%
Run 7	230,000	$4,432,444	932	281	76.80%	92.30%
Run 8	235,000	$4,525,974	952	260	78.50%	94.30%
Run 9	240,000	$4,620,228	972	240	80.10%	96.30%
Run 10	245,000	$4,713,758	992	220	81.80%	98.30%
Run 11	250,000	$4,773,538	1013	200	83.50%	100.40%
Run 12	255,000	$4,867,068	1033	179	85.10%	102.40%
Run 13	260,000	$4,961,322	1053	159	86.80%	104.40%
Run 14	265,000	$5,054,852	1073	139	88.50%	106.40%
Run 15	270,000	$5,148,382	1094	119	90.10%	108.40%
Run 16	275,000	$5,209,962	1114	98	91.80%	110.40%
Run 17	280,000	$5,304,216	1134	78	93.50%	112.40%
Run 18	285,000	$5,397,746	1154	58	95.20%	114.40%
Run 19	290,000	$5,471,461	1175	$37	96.80%	116.40%
Run 20	295,000	$5,564,991	1195	$17	98.50%	118.40%
Run 21	299,183	$5,606,847	1212	$0	100.00%	120.10%

Figure 43: Results for Cost and Heating/Cooling Capacity for Cost Optimization

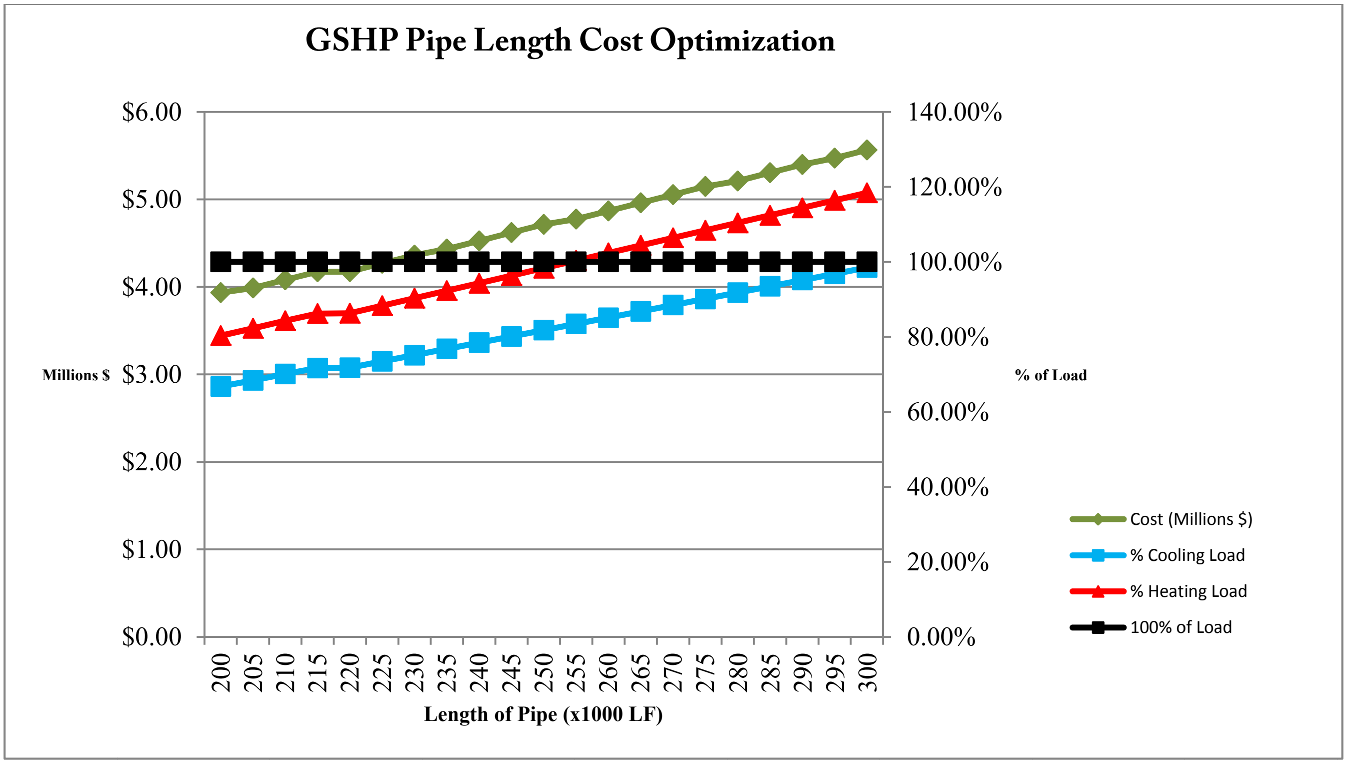


Figure 44: GSHP Pipe Length Cost Optimization Graphical Analysis

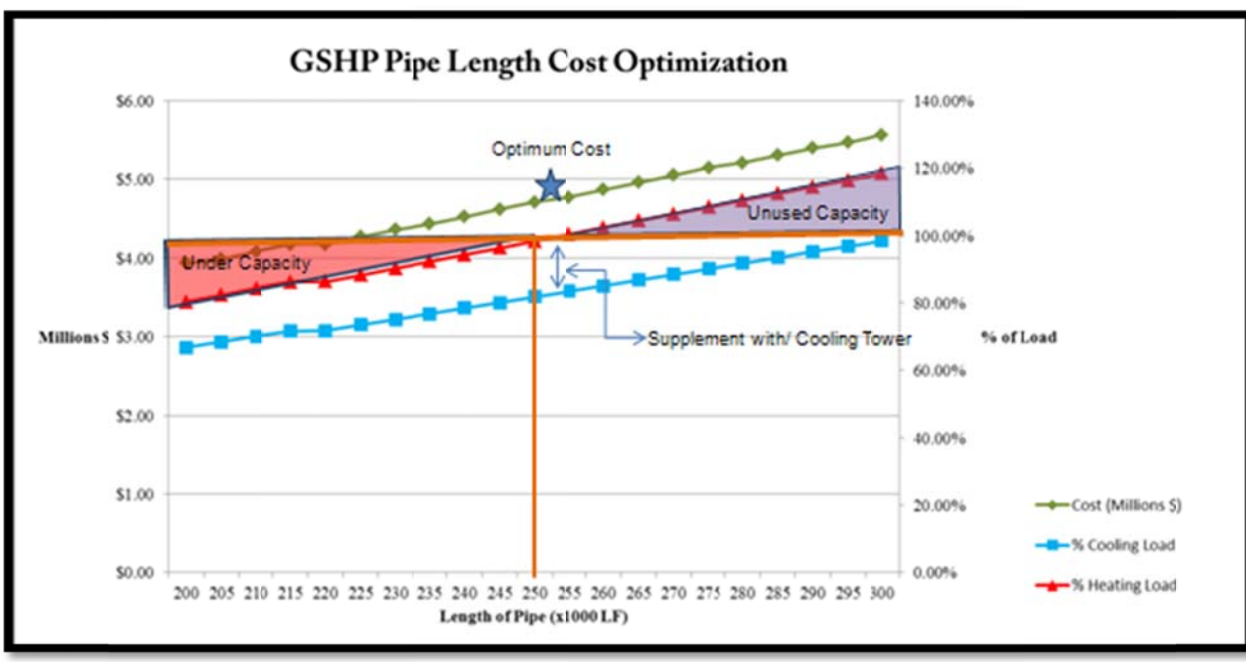


Figure 45: GSHP Pipe Length Cost Optimization Graphical Analysis w/ notes

Labor and Cost Information

In order to evaluate the construction impacts of the GSHP and thorough analysis of the additional costs was needed to be performed. Below is a summary of the additional material, equipment, and labor needed for the GSHP system. The information was obtained using RS Means and the prices were adjusted for New York.

Table 21: Construction Cost Evaluation

	Description	Unit	Material	Labor	Eqmnt	Total	Total Incl O&P	Location Adjustment NY	Unit Multplier	Total Cost
Geo technical Investigation	Drawings showing boring details	Day Total	0	$690	$70	$760	$1,125	$1,496	1	$1,496
	Reports and recommendations from P.E.	Day Total	0	$300	$0	$300	$375	$499	1	$499
Directional Drilling	Medium Unit Mobilization to Site	Day Total	0	$204	$231	$435	$565	$751	1	$751
Medium Equipment	Medium Unit setup per drill	EA		$450	$610	$1,060	$1,350	$1,796	1	$1,796
	Minimum Charge gravel, sand & silt up to 12"	EA		$225	$305	$530	$675	$898	1	$898
	gravel, sand & silt up to 12" diameter	EA		$2,281	$380	$670	$855	$1,137	1	$1,137
Water Supply Polyethylene Pipe, C901	1-1/2" Diameter	LF	0.06	$3	$3	$6	$8	$10	249,047	$2,583,614
Water Supply HDPE	6" Diameter	LF	1.09	$1		$2	$3	$4	249,047	$990,385
		LF	10.7	$4	$2	$17	$20	$27	10,000	$265,335
Grout	GSHP betonite,sand, water grout Grout Price Calculator Work Book						$125,183	$166,493	1	$166,493
									Total Cost	$4,012,404

Table 22: Labor Review Evaluation

	Description	Crew	Daily Output	Labor Hours	Unit	Crew Needed	NYPA Unit Multplier	Work Days
Geo technical Investigation	Boring, initial field stake out & determination of elevations	A-6	1	16	Day Total	1	1	1.0
	Drawings showing boring details	A-6	1	16	Day Total	1	1	1.0
	Reports and recommendations from P.E.	A-6	1	16	Day Total	1	1	1.0
Directional Drilling	Medium Unit Mobilization to Site	B-82B	2	12	EA	1	1	0.5
Medium Equipment	Medium Unit setup per drill	B-82B	4	6	EA	1	1	0.3
	Minimum Charge gravel, sand & silt up to 12"	B-82B	3.2	7.5	EA	1	1	0.3
	gravel, sand & silt up to 12" diameter	B-82B	350	0.069	LF	15	249047	47.4
Water Supply Polyethylene Pipe, C901	1-1/2" Diameter	Q-1A	525	19	LF	15	249047	31.6
Water Supply HDPE	6" Diameter	B-22A	380	0.105	LF	8	10000	3.3
							1	
Grout	GSHP betonite, sand, water grout	Grout Price Calculator Work Book						24.0
							Total Days	86.4

Schedule Impact

The construction duration for the GSHP system totaled to 86 work days. The best time for constructing this system would be during the construction of the structural piles. Structural piles that are 300' deep and 6" in diameter are being installed as the structural foundation. The construction techniques and equipment used overlap between the structural piles and the ground source heat pump wells. Thus, it would make the most sense to have the activities at similar times. Below are representations of how the schedule would be changed.

Table 23: GSHP Well Field Construction Duration Statistics

GSHP Well Field Construction Duration	**86 Days**
Early Start Date	31 JANUARY 2011
Early Finish Date	13 MAY 2011

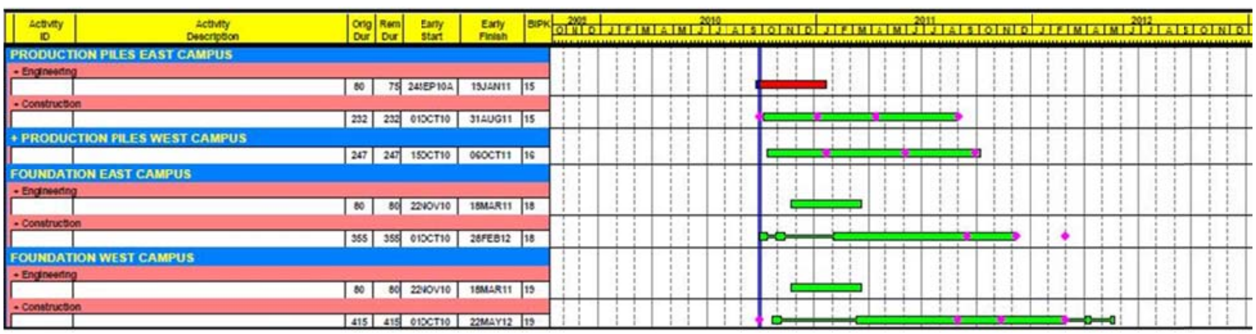


Figure 46: Schedule before GSHP Well Field Construction

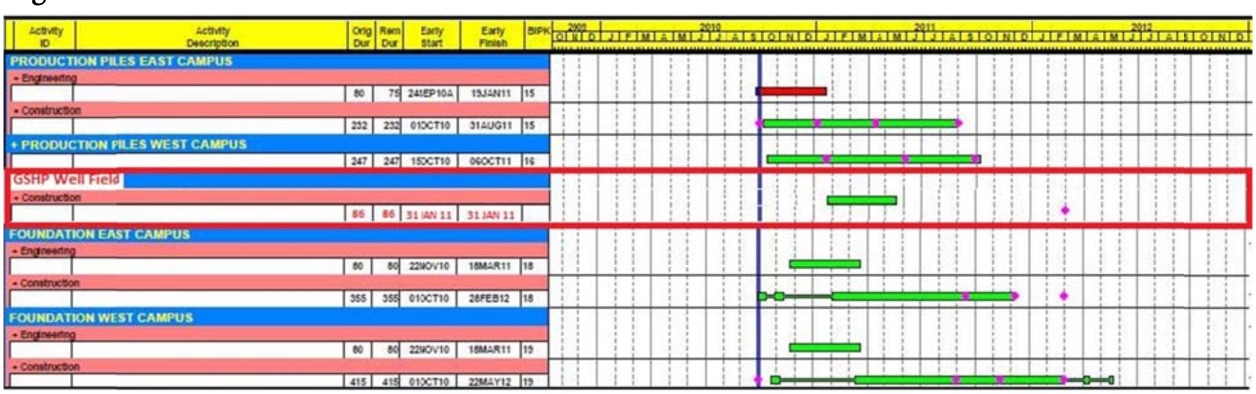


Figure 47: Schedule with GSHP Well Field Construction

Summary

There are several factors that will affect the construction of the New York Police Academy if a GSHP system was to be implemented. Most notably is the additional construction cost as well as the schedule impact. The construction cost for the system is quite substantial totaling to $4,012,404. However, that is only 0.6% increase in the total construction cost. Also the length of time for construction was calculated to be 86 days. It was decided that the best opportunity for constructing the GSHP system would be during the time of the structural piles construction. There are no significant changes that would need to be made to the schedule if this system was installed. Simply, there would be an increase in man power during the time of the well field construction. Overall, implementing a GSHP system could feasible be constructed for the New York Police Academy.

The Final Analysis

Emissions Reduction

Table 24: Central Plant Emissions

Pollutant	lb/kWh	kWh/yr	lbs of Pollutant/yr
CO2e	1.03	5,685,782	5,856,355.46
CO2	0.961	5,685,782	5,464,036.50
CH4	0.00259	5,685,782	14,726.18
N20	0.00000168	5,685,782	9.55
N0x	0.00172	5,685,782	9,779.55
S0x	0.00623	5,685,782	35,422.42
CO	0.00175	5,685,782	9,950.12
TNMOC	0.0000638	5,685,782	362.75
Lead	5.59E-08	5,685,782	0.32
Mercury	3.99E-08	5,685,782	0.23
PM10	0.0000687	5,685,782	390.61
Solid Waste	0.0618	5,685,782	351,381.33

Table 25: Ground Source Heat Pump Emissions

Pollutant	lb/kWh	kWh/yr	lbs of Pollutant/yr
CO2e	1.03	5,176,517	5,331,812.51
CO2	0.961	5,176,517	4,974,632.84
CH4	0.00259	5,176,517	13,407.18
N20	0.00000168	5,176,517	8.70
N0x	0.00172	5,176,517	8,903.61
S0x	0.00623	5,176,517	32,249.70
CO	0.00175	5,176,517	9,058.90
TNMOC	0.0000638	5,176,517	330.26
Lead	5.59E-08	5,176,517	0.29
Mercury	3.99E-08	5,176,517	0.21
PM10	0.0000687	5,176,517	355.63
Solid Waste	0.0618	5,176,517	319,908.75

Table 26: Emissions Comparison Central Plant vs GSHP

	Central Plant	GSHP	Emissions Reduction
Pollutant	lbs of Pollutant/yr	lbs of Pollutant/yr	lbs of Pollutant/yr
CO2e	5,856,355	5,331,813	524,543
CO2	5,464,037	4,974,633	489,404
CH4	14,726	13,407	1,319
N20	10	9	1
N0x	9,780	8,904	876
S0x	35,422	32,250	3,173
CO	9,950	9,059	891
TNMOC	363	330	32
Lead	0	0	0
Mercury	0	0	0
PM10	391	356	35
Solid Waste	351,381	319,909	31,473

Financial Analysis

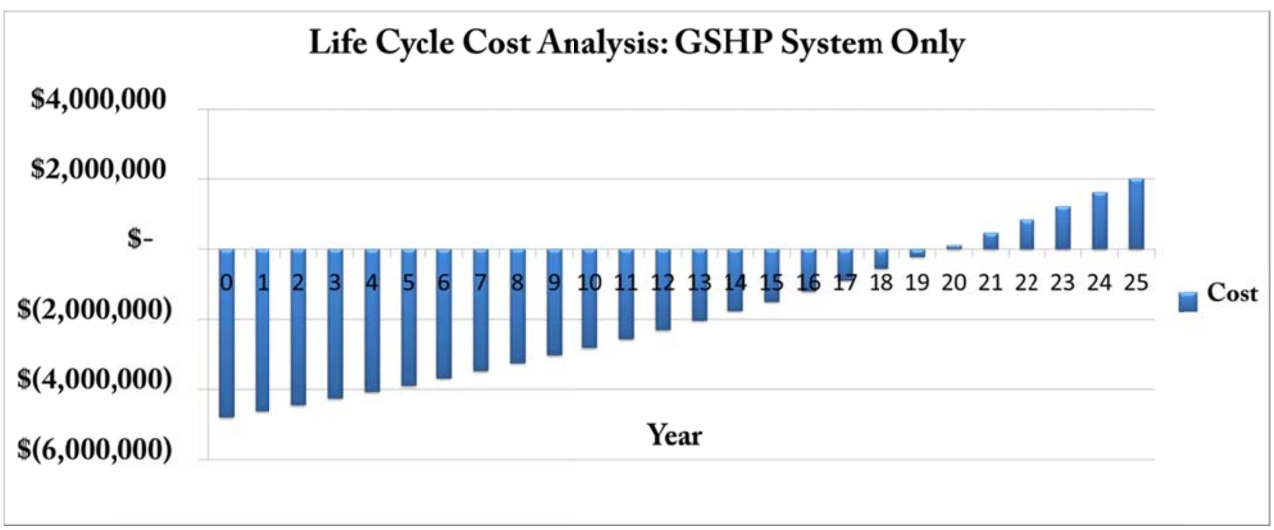


Figure 48: Life Cycle Cost Analysis GSHP System Only

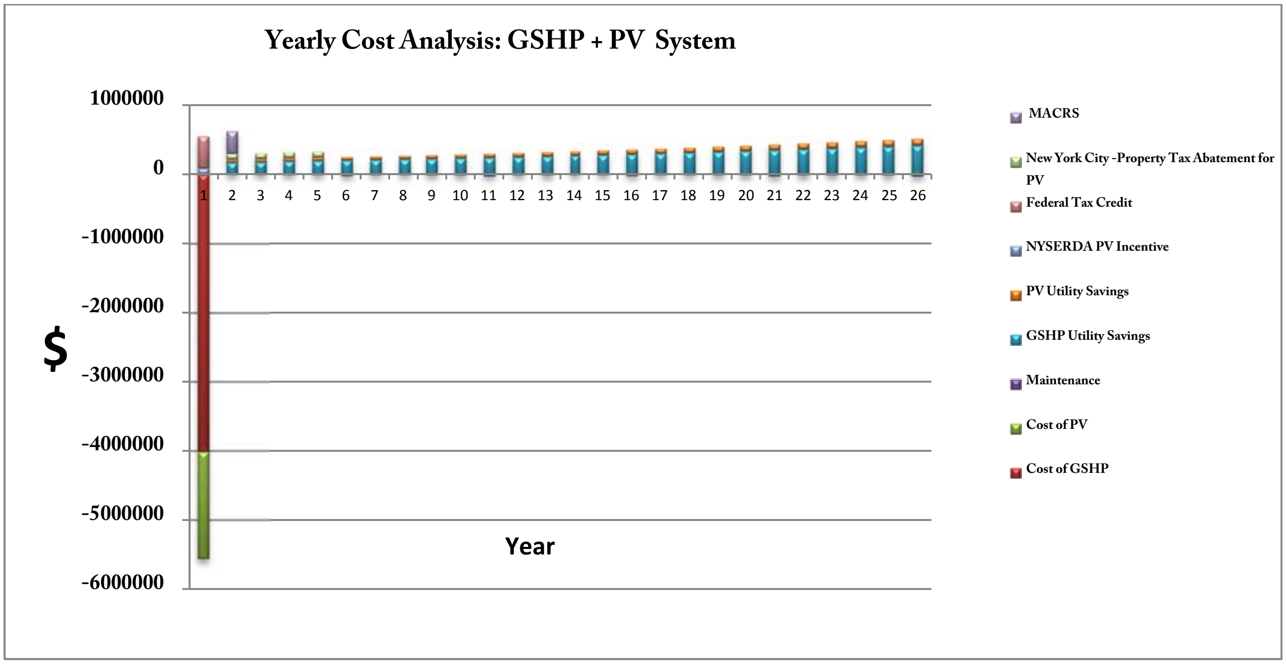


Figure 49: Yearly Cost Analysis GSHP + PV System

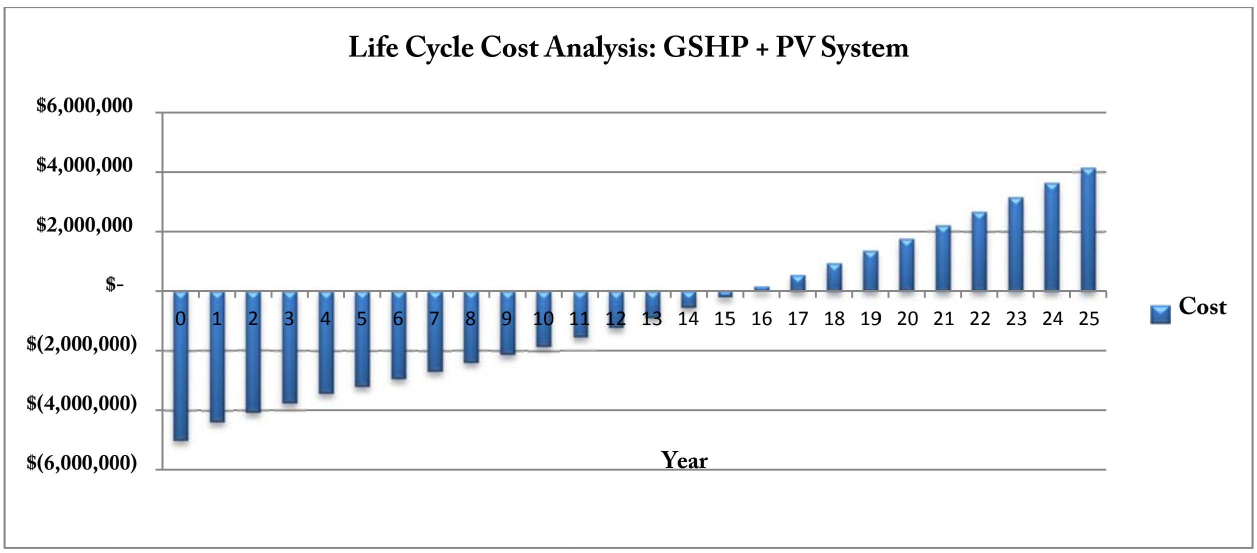


Figure 50: Life Cycle Cost Analysis: GSHP + PV System

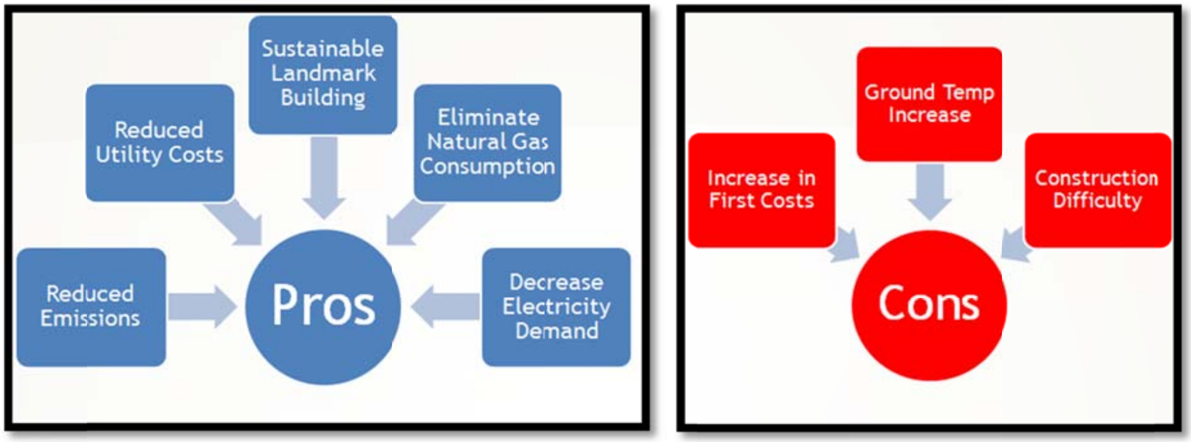


Figure 51: Pros vs. Cons Graphic

Final Recommendations

The purpose of this report was to evaluate a new mechanical design for the New York Police Academy. A ground source heat pump system was chosen to serve the East Campus of the academy along with a photovoltaic array on the West Campus roof. Before the analysis, the hope for the ground source heat pump system and the photovoltaic array was to make an impact on the energy use of the building. Decreasing the energy use would also effectively decrease the utility costs and the emissions produced by the academy.

It was determined that the GSHP system could reduce the energy use of the academy by 17% as compared to the central plant system. Also it was determined that the photovoltaic array on the West Campus roof could provide a 5% of the buildings electricity needs. Upon this analysis, the costs and lifecycle of these systems were also analyzed. The total costs of these two systems topped out at $6,340,445. The payback period of the GSHP system was calculated to be 20 Years while the photovoltaic array was calculated to be 7 years (with incentives). Evaluating these two system together, the final payback period was calculated to be 16 years. This payback period is a very reasonably number considering the life of the NYPA should far outreach this number.

First and foremost, I would recommend the GSHP system and photovoltaic array based on economics. Both the GSHP system and photovoltaic array will save the NYPA and ultimately the city of New York money over the lifespan of the system. Secondly, these two systems are more friendly to the environment by cutting energy use and emission productions. Finally, the New York Police Academy will be a landmark building in College Point, New York and by establishing the building as a sustainable one will set a great example for the City of New York and the New York Police Department. Overall, I would recommend all engineers to consider alternative mechanical systems and onsite energy production systems because it can be economically feasible and also reduce the impact buildings have on the environment.

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I would like to thank my family and friends for their support through my college career. I would also like to thank The Pennsylvania State University and specifically there Architectural Engineering department for providing me with a wonderful education that will allow me to become a successful professional engineer. There are many individuals that have made my time at Penn State a great experience and I have a very deep gratitude for all of them.

In reference to this report, I would like to thank Turner Construction Company for allowing me to study the New York Police Academy and providing me with all the necessary documentation for analysis.

Master of Architectural Engineering Course Related Study

As part of the integrated Master of Architectural Engineering and Bachelor of Architectural Engineering program information from graduate level classes must be integrated into the thesis analysis. AE 557 Central Cooling Systems and AE 558 Central Heating Systems are classes that provide information directly related to central heating and cooling plants. The NYPA is equipped with a central plant. The information that has been learned from AE 557 and AE 558 were integral in understanding the central plant system. Also life cycle analysis is a very important engineering tool and AE 557 and AE 558 were helpful in teaching how to evaluate the life cycle costs of the mechanical systems.

Also AE 559 Computational Fluid Dynamics, is a class focused on developing the skills to perform CFD analysis. A wind feasibility study was performed for the NYPA to test if wind turbines could be sustained on the site of the NYPA. However, a full economic analysis was not performed due to time constraints. The appendix includes specific information about the wind study.

Appendix:

LEED Assessment New Construction Version 2.2

The New York Police Academy has a minimum project requirement of LEED Silver as mandated by the New York City Department of Design and Construction. The project will be following the criteria of LEED New Construction Version 2.2. Perkins + Will, the lead architecture firm, has developed a plan to target 35 LEED points with a possibility of up to 44 points. LEED Silver certification is 33 points and LEED goal certification is 39 points. The NYPA should safely reach their goal of LEED Silver certification and could potential be LEED Gold.

Below is a summary of the achievable points from the Water Efficiency, Energy and Atmosphere, and Indoor Environmental Quality sections of LEED NC v2.2 that are directly related to the mechanical systems of the New York Police Academy.

Water Efficiency

WE-C1.1 Water Efficiency Landscaping-Reduce by 50%

Credit Requirements: Reduce potable water consumption for irrigation by 50% from calculated mid-summer baseline case. Reductions shall be attributed to any combination of the following items:

-Plant Species Factor
-Irrigation Efficiency
-Use of captured rainwater
-Use of recycled wastewater
-Use of water treated & conveyed by a public agency specifically for non-potable uses

The NYPA will be able to achieve this credit by specifying native or adaptive vegetation for the local landscaping. Also collected storm water will be harvested and redistributed for irrigation purposes.

WE-C.2 Innovative Wastewater Technologies- Reduce 50% or Treat 50% on Site

Option 1
Reduce potable water use for building sewage conveyance by 50% through the use of water conserving fixtures (water closets, urinals) or non-potable water (captured rainwater, recycled greywater, and on-site or municipally treated waste water).

Option 2
Treat 50% of waste water on-site to tertiary standards. Treated water must be infiltrated or used on-site.

The NYPA will achieve this credit because storm water will be collected for toilet flushing use in the Physical Training Building of the West Campus.

WE-C.3 Water Use Reduction-20%/30% Reduction

Employ strategies that in aggregate use 20% (or 30% for two points) less water than the water use baseline calculated for the building (not including irrigation) after meeting the Energy Policy Act of 1992 fixture performance requirements.

The NYPA aims to receive two points for this credit by reducing water by 30% by installing low-flow plumbing fixtures that include:

-Dual flush toilets (1.6 GPF/1.1 GPF)
-Low flow lavatories with electronic controls (0.5 GPM)
-Low flow showerheads (1.5 GPM)
-Collected Stormwater
- Collected stormwater will be used to flush toilets in PT building.
- Additional Innovation credit is achievable for Exemplary Performance (40% reduction).
- Additional Innovation credit is achievable for using collected stormwater for cooling tower make-up (equivalent to 10% reduction in Process water).

In summary, collecting and reusing stormwater on the site is related to 7 LEED points:
- WE-c1 - No potable water for irrigation (2 pts.)
- WE-c2 - 50% reduction potable water for sewage conveyance (1 pt.)
- WE-c3 - 30% reduction potable water for plumbing fixtures (2 pts.)
- ID credit - 40% reduction potable water for plumbing fixtures (1 pt.)
- ID credit - 10% reduction potable water for cooling towers (process water) (1 pt.)

Energy and Atmosphere

EA-p1Fundamental Commissioning (Cx) of the Building Energy Systems

The following Cx process activities shall be completed by the Cx Team, in accordance with LEED-NC 2.2 Reference Guide.

(1) Designate an individual as the Cx Authority (CxA) to lead, review and oversee the completion of the Cx process activities.

a) The CxA shall have documented commissioning authority experience in at least two building projects.

b) The individual serving as the CxA shall be independent of the project's design and construction mgt., though they may be employees of the firms providing those services. The CxA may be a qualified employee or consultant of the Owner.

c) The CxA shall report results, findings and recommendations directly to the Owner.

d) For projects smaller than 50,000 gross sq. ft., the CxA may include qualified persons on the design or construction teams who have the required experience.

(2) The Owner shall document the Owner's Project Requirements (OPR). The design team shall develop the basis of Design (BOD). The CxA shall review these documents for clarity and completeness. The Owner and design team shall be responsible for updates to their respective documents.

(3) Develop and incorporate Cx requirements into the construction documents.

(4) Develop and implement a Cx Plan.

(5) Verify the installation and performance of the systems to be commissioned.

(6) Complete a summary Cx Report.

EA-p2 Minimum Energy Performance

Design the building project to comply with both —

- Mandatory provisions (Sections 5.4, 6.4, 7.4, 8.4, 9.4 and 10.4) of ASHRAE/IESNA Std, 90.1-2004 (without amendments); AND

-Prescriptive requirements (Sections 5.5, 6.5, 7.5 and 9.5) or performance requirements (Section 11) of ASHRAE/IESNA Std. 90.1-2004 (without amendments).

EA-p3 Fundamental Refrigerant Management

Zero use of CFC-based refrigerants in new base building HVAC&R systems. When reusing existing base building HVAC equipment, complete a comprehensive CFC phaseout conversion prior to project completion.

Phase-out plans extending beyond the project completion date will be considered on their merits.

These prerequisites must be completed for LEED certification, thus the NYPA is planning on completing these prerequisites.

EA-c1.1 Optimize Energy Performance

- Mandatory 14% energy cost reduction (2 points)

- Flack + Kurtz (MEP Engineers) is performing energy simulation, which will quantify impact of energy efficiency measures (EEM's)relating to building envelope, mech. systems, lighting and controls, etc. Separate energy models will be done for LEED and Local Law 86 compliance.

Proposed Energy Efficiency Measures include:

- High performance envelope/ glazing
- High SRI roof surfaces
-Variable speed chillers, equipment, pumps in CUP
-Free cooling
-CO2 sensor control for ventilation
-Displacement ventilation in atrium
-Reduced lighting power densities
- Daylight and occupancy controls for interior lighting
-Potential for cogeneration microturbines (currently being evaluated; seeking outside funding)
- Process energy default: 25% of total energy cost for baseline building, unless documented otherwise.
Process energy same in baseline and proposed design models unless Exceptional Calc. Method is performed.
- Process energy includes equipment & computer plug loads, elevators, kitchen cooking & refrigeration, laundry washing/drying, non-regulated lighting.
- 30% energy cost reduction required for 2030 Challenge compliance (6 LEED pts.)

EA-C4 Enhanced Refrigerant Management

OPTION 1
Do not use refrigerants.
OR
OPTION 2
Select refrigerants and HVAC&R that minimize or eliminate the emission of compounds that contribute to ozone depletion and global warming. The base building HVAC&R equipment shall comply with the following formula, which sets a maximum threshold for the combined contributions to ozone depletion and global warming potential.

- Flack + Kurtz (MEP Engineers) has confirmed that all refrigerants will comply with LEED criteria
- Flack + Kurtz (MEP Engineers) has confirmed that fire suppression systems will comply with LEED criteria
- This credit typically covers major base-building refrigeration equipment. Small non-base building mech. equipment (e.g., CRAC units) typically do not need to comply.

EA-C6 Green Power

Provide at least 35% of the building's electricity from renewable sources by engaging in at least a two-year renewable energy contract. Renewable sources are as defined by the Center for Resource Solutions (CRS) Green-e products certification requirements.

New York City purchases wind credits for city projects, which qualify for LEED green power credits. Our understanding is that the City will purchase Renewable Energy Certificates (REC's) to achieve this credit and possible Innovation credits.

Indoor Environmental Quality

EQ-p1 Minimum IAQ Performance

Meet the minimum requirements of Sections 4 through 7 of ASHRAE 62.1-2004, Ventilation for Acceptable Indoor Air Quality. Mechanical ventilation systems shall be designed using the "Ventilation Rate Procedure" or the applicable local code, whichever is more stringent. Naturally ventilated buildings shall comply with ASHRAE 62.1-2004, paragraph 5.1.

EQ-p2 Environmental Tobacco Smoke (ETS) Control

-Prohibit smoking in the building.
-Locate any exterior designated smoking areas at least 25 ft. away from entries, outdoor air intakes and operable windows.

These prerequisites must be completed for LEED certification, thus the NYPA is planning on completing these prerequisites.

EQ-c1 Outdoor Air Delivery Monitoring

Install permanent monitoring systems that provide feedback on ventilation system performance to ensure that ventilation systems maintain design min. ventilation requirements. Configure all monitoring equipment to generate an alarm when the conditions vary by 10% or more from setpoint, via either a building automation system alarm building operator or via a visual or audible alert to the building occupants.

- Flack + Kurtz (MEP Engineers) confirmed that project will include CO2 sensors to meet LEED criteria for O.A. Delivery Monitoring
-For all densely occupied spaces (25 people / 1,000 sq.ft.) - CO2 sensors required
- For all non-densely occupied spaces - outdoor airflow measurement devices required
-CO2 sensors to be connected to Building Automation System (BAS)

EQ-c3.1 Construction IAQ Management Plan: During Construction

Develop and implement an Indoor Air Quality (IAQ) Management Plan for the construction and pre-occupancy phases of the building as follows:

- During construction meet or exceed the recommended Control Measures of the Sheet Metal & Air Conditioning National Contractors Association (SMACNA) IAQ Guidelines for Occupied Buildings under Construction, 1995, Chapter 3.
-Protect stored on-site or installed absorptive materials from moisture damage.
-If permanently installed air handlers are used during construction, filtration media with a Minimum Efficiency Reporting Value (MERV) of 8 shall be used at each return air grille, as determined by ASHRAE 52.2-1999. Replace all filtration media immediately prior to occupancy.

These Credit requirements will be included in project specifications (Division 1).

EQ-c7.1 Thermal Comfort: Design

Design HVAC systems and the building envelope to meet the requirements of ASHRAE Standard 55-2004, Thermal Comfort Conditions for Human Occupancy. Demonstrate design compliance in accordance with the Section 6.1.1 Documentation.

- Flack + Kurtz (MEP Engineers) confirmed that mech. design will comply with referenced ASHRAE standard.
- Winter humidification is not required in 2004 version of the ASHRAE standard.

Major Equipment Schedules

Boiler Schedule

Hot Water Boiler												
Designation	Service	Location	Boiler H.P.	Pass Arrangement	Design Pressure (PSIG)	Min. Efficiency at Load (%)	Entering Temp. (°F)	Leaving Temp (°F)	Gas Type	Volts/Phase	Motor H.P.	Starter Type
B-311-3-1	Hot Water	Central Plant	750	5	250	84	165	190	NG	460/3	30	VFD
B-311-3-2	Hot Water	Central Plant	750	5	250	84	165	190	NG	460/3	30	VFD
B-311-3-3	Hot Water	Central Plant	750	5	250	84	165	190	NG	460/3	30	VFD
B-311-3-4	Hot Water	Central Plant	750	5	250	84	165	190	NG	460/3	30	VFD
B-311-3-5	Hot Water	Central Plant	750	5	250	84	165	190	NG	460/3	30	VFD

Chiller Schedule

Electric Water Chiller				Evaporator Information				Condenser Information				Compressor Information			
Designation	Service	Location	Nominal Tons	Chilled Water (GPM)	Entering Water (°F)	Leaving Water (°F)	Press. Drop (Ft)	Cond. Water (GPM)	Entering Water (°F)	Leaving Water (°F)	Cond. Press Drop (Ft)	KW (Each Motor)	KW/ Ton	FLA (Each Motor)	Volts/ Phase
CH-311-3-1	Chilled Water	Central Plant	1350	2025	58	42	14	2700	85	100	12	826	0.612	1152	480/3
CH-311-3-2	Chilled Water	Central Plant	1350	2025	58	42	14	2700	85	100	12	826	0.612	1152	480/3
CH-311-3-3	Chilled Water	Central Plant	1350	2025	58	42	14	2700	85	100	12	826	0.612	1152	480/3
CH-311-3-4	Chilled Water	Central Plant	1350	2025	58	42	14	2700	85	100	12	826	0.612	1152	480/3
CH-311-3-5	Chilled Water	Central Plant	1350	2025	58	42	14	2700	85	100	12	826	0.612	1152	480/3
CH-311-3-6	Chilled Water	Central Plant	1350	2025	58	42	14	2700	85	100	12	826	0.612	1152	480/3
CH-311-3-7	Chilled Water	Central Plant	1350	2025	58	42	14	2700	85	100	12	826	0.612	1152	480/3

Cooling Tower Schedule

Cooling Tower									
Designation	Location	Type	Total Flow (GPM)	Ent. Water Temp (°F)	Lvg. Water Temp (°F)	Amb. Air Temp (°F W.B.)	Fan RPM	Volts/Phase	Starter
CT-311-R-1	Roof Level	Induced Draft Counter Flow	2700	100	85	78	1800	460/3	VFD
CT-311-R-1	Roof Level	Induced Draft Counter Flow	2700	100	85	78	1800	460/3	VFD
CT-311-R-1	Roof Level	Induced Draft Counter Flow	2700	100	85	78	1800	460/3	VFD
CT-311-R-1	Roof Level	Induced Draft Counter Flow	2700	100	85	78	1800	460/3	VFD
CT-311-R-1	Roof Level	Induced Draft Counter Flow	2700	100	85	78	1800	460/3	VFD
CT-311-R-1	Roof Level	Induced Draft Counter Flow	2700	100	85	78	1800	460/3	VFD
CT-311-R-1	Roof Level	Induced Draft Counter Flow	2700	100	85	78	1800	460/3	VFD

Pump Schedule

Pumps													
Designation	Service	Location	Flow Rate (GPM)	Pump Head (FT)	Suct. Press (PSIG)	Disch. Press. (PSIG)	Casing Press. (PSIG)	Brake H.P.	Max H.P.	RPM	Volts/Phase	Pump Type	Starter Type
PCHW-311-3-1	Chilled Water	Central Plant	2025	200	125	125	150	119.9	200	1800	460/3	Horz. Split Case	VFD
PCHW-311-3-2	Chilled Water	Central Plant	2025	200	125	125	150	119.9	200	1800	460/3	Horz. Split Case	VFD
PCHW-311-3-3	Chilled Water	Central Plant	2025	200	125	125	150	119.9	200	1800	460/3	Horz. Split Case	VFD
PCHW-311-3-4	Chilled Water	Central Plant	2025	200	125	125	150	119.9	200	1800	460/3	Horz. Split Case	VFD
PCHW-311-3-5	Chilled Water	Central Plant	2025	200	125	125	150	119.9	200	1800	460/3	Horz. Split Case	VFD
PCHW-311-3-6	Chilled Water	Central Plant	2025	200	125	125	150	119.9	200	1800	460/3	Horz. Split Case	VFD
PCW-311-3-1	Condenser Water	Central Plant	2700	130	125	125	150	110.3	150	1800	460/3	Horz. Split Case	VFD
PCW-311-3-2	Condenser Water	Central Plant	2700	130	125	125	150	110.3	150	1800	460/3	Horz. Split Case	VFD
PCW-311-3-3	Condenser Water	Central Plant	2700	130	125	125	150	110.3	150	1800	460/3	Horz. Split Case	VFD
PCW-311-3-4	Condenser Water	Central Plant	2700	130	125	125	150	110.3	150	1800	460/3	Horz. Split Case	VFD
PCW-311-3-5	Condenser Water	Central Plant	2700	130	125	125	150	110.3	150	1800	460/3	Horz. Split Case	VFD
PCW-311-3-5	Condenser Water	Central Plant	2700	130	125	125	150	110.3	150	1800	460/3	Horz. Split Case	VFD
PHW-311-3-1	Hot Water	Central Plant	2010	200	125	125	150	119.2	200	1800	460/3	Horz. Split	VFD

												Case	
PHW-311-3-2	Hot Water	Central Plant	2010	200	125	125	150	119.2	200	1800	460/3	Horz. Split Case	VFD
PHW-311-3-3	Hot Water	Central Plant	2010	200	125	125	150	119.2	200	1800	460/3	Horz. Split Case	VFD
PHW-311-3-4	Hot Water	Central Plant	2010	200	125	125	150	119.2	200	1800	460/3	Horz. Split Case	VFD
PHW-311-3-5	Hot Water	Central Plant	2010	200	125	125	150	119.2	200	1800	460/3	Horz. Split Case	VFD
GWP-211-G-1	Loading Dock	Loading Dock	50	50	125	125	150	1.19	2	1800	208/3	Vert. Inline	DOL
GWP-211-G-2	Loading Dock	Loading Dock	50	50	125	125	150	1.19	2	1800	208/3	Vert. Inline	DOL
GWP-311-G-1	Grounds Equipment	Grounds Equip.	50	50	125	125	150	1.19	2	1800	208/3	Vert. Inline	DOL
GWP-311-G-2	Grounds Equipment	Grounds Equip.	50	50	125	125	150	1.19	2	1800	208/3	Vert. Inline	DOL

Air Handling Unit Schedule

Designation	Service	Location	Total Air Quantity (cfm)	Outside Air Quantity (cfm)	OA (%)
AHU-111-8-1	2nd Floor Office	8th Floor MER	15000	2550	17%
AHU-111-8-2	7th Floor Admin Office	8th Floor MER	7500	1300	17%
AHU-111-8-3	Pedestrian Walkway	8th Floor MER	29500	5000	17%
AHU-111-8-4	Lockers	8th Floor MER	15000	2550	17%
AHU-111-8-5	Classroom	8th Floor MER	30000	10800	36%
AHU-111-8-6	Classroom	8th Floor MER	30000	10800	36%
AHU-111-PH-1	Corridor	West Penthouse MER	30000	5100	17%
AHU-111-PH-2	Classroom	West Penthouse MER	30000	12000	40%
AHU-111-PH-3	Classroom	West Penthouse MER	30000	12000	40%
AHU-111-PH-4	Auditorium	West Penthouse MER	15000	4800	32%
AHU-111-PH-5	Auditorium	West Penthouse MER	15000	4800	32%
AHU-111-PH-6	Atrium	West Penthouse MER	25000	6400	26%
AHU-131-PH-1	Atrium	East Penthouse MER	25000	6400	26%
AHU-131-PH-2	Admin Office	East Penthouse MER	25000	6400	26%
AHU-131-PH-3	Admin Office	East Penthouse MER	25000	6400	26%
AHU-131-PH-4	Admin Office	East Penthouse MER	25000	6400	26%
AHU-131-PH-5	Admin Office	East Penthouse MER	25000	6400	26%
AHU-131-PH-6	Library	East Penthouse MER	16000	6000	38%
AHU-131-PH-7	Library	East Penthouse MER	16000	6000	38%
AHU-211-2-1	Central Receiving Retail	Physical Training West Mech. 2nd Floor	10000	2500	25%
AHU-211-2-2	Central Receiving Misc.	Physical Training West Mech. 2nd Floor	10000	2500	25%
AHU-211-2-3	1st Floor Dining	Physical Training West Mech. 2nd Floor	29000	14500	50%
AHU-211-2-4	Administration	Physical Training West Mech. 2nd Floor	29000	7300	25%
AHU-211-2-5	East Pedestrian Walkway	Physical Training East Mech. 2nd Floor	29000	7300	25%
AHU-211-2-6	NE Calisthenics Gym	Physical Training East Mech. 2nd Floor	29000	14500	50%
AHU-211-2-7	E Calisthenics Gym	Physical Training East Mech. 2nd Floor	29000	14500	50%
AHU-211-2-8	SE Calisthenics Gym	Physical Training East Mech. 2nd Floor	29000	14500	50%
AHU-211-2-9	North Defib Training	Physical Training East Mech. 2nd Floor	7500	7500	100%
AHU-211-2-10	Fitness Training	Physical Training East Mech. 2nd Floor	15000	4500	30%
AHU-211-2-11	Tactical Training	Physical Training East Mech. 2nd Floor	15000	4500	30%
AHU-211-2-12	South Defib Training	Physical Training East Mech. 2nd Floor	1500	7500	50%

AHU-311-2-1	Tactical Training	Central Plant 2nd Floor	10000	3000	30%
AHU-311-2-2	W Pedestrian Walkway	Central Plant 2nd Floor	29000	7300	25%
AHU-311-2-3	NW Calisthenics Gym	Central Plant 2nd Floor	29000	14500	50%
AHU-311-2-4	1st Floor Baton Training Room	Central Plant 2nd Floor	20000	6000	30%
AHU-311-2-5	W Calisthenics Gym	Central Plant 2nd Floor	29000	14500	50%
AHU-311-2-6	Tactical Training	Central Plant 2nd Floor	10000	3000	30%
AHU-311-2-7	Tactical Training	Central Plant 2nd Floor	10000	3000	30%
AHU-311-2-8	SW Calisthenics Gym	Central Plant 2nd Floor	29000	14500	50%
AHU-311-2-9	South Corridor	Central Plant 2nd Floor	29000	7300	25%
AHU-311-2-18	Lobby	Central Plant 5th Floor	4000	2000	50%
AHU-311-5-1	Chiller Room	Central Plant 5th Floor	29000	29000	100%
AHU-311-5-3	Admin Office	Central Plant 5th Floor	3000	750	25%
AHU-311-5-5	Corridor	Central Plant 5th Floor	15000	3750	25%
AHU-311-5-6	Not Used	Not Applicable	0	0	0%
AHU-311-5-7	Not Used	Not Applicable	0	0	0%
AHU-311-G-2	Bulk Storage	Central Plant Ground Floor	1500	1500	100%
AHU-311-G-3	Equipment Storage	Central Plant Ground Floor	4600	4600	100%
AHU-311-G-4	Inventory Storage	Central Plant Ground Floor	7800	7800	100%
AHU-311-G-5	Ground Equipment	Central Plant 5th Floor	7500	7500	100%
AHU-311-2-14	HVAC Shop	Central Plant 2nd Floor	3100	3100	100%
AHU-311-2-15	Paint Shop	Central Plant 2nd Floor	2900	2900	100%
AHU-311-2-16	Carpentry Shop	Central Plant 2nd Floor	4300	4300	100%
AHU-311-2-17	Thermostat Shop	Central Plant 2nd Floor	2250	2250	100%

GSHP Length Calculation

	F_{sc}	
Bores per Loop	**2 gpm/ton**	**3 gpm/ton**
1	1.06	1.04
2	1.03	1.02
3	1.02	1.01

Appendix 4 – Equivalent Full Load Hours[25]

City	State	EFLH[1] School Occupancy		EFLH[2] Office Occupancy		EFLH[3] Retail Occupancy		EFLH[4] Hospital Occupancy	
		Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling
New York City	NY	440 - 350	360 - 550	870 - 790	540 - 1,040	760 - 630	720 - 1,480	590 - 330	1,160 - 2,440

Table 5 Thermal Properties of Selected Soils, Rocks, and Bore Grouts/Fills

	Dry Density, lb/ft^3	Conductivity, Btu/h·ft·°F	Diffusivity, ft^2/day
Soils			
Heavy clay, 15% water	120	0.8 to 1.1	0.45 to 0.65
5% water	120	0.6 to 0.8	0.5 to 0.65
Light clay, 15% water	80	0.4 to 0.6	0.35 to 0.5
5% water	80	0.3 to 0.5	0.35 to 0.6
Heavy sand, 15% water	120	1.6 to 2.2	0.9 to 1.2
5% water	120	1.2 to 1.9	1.0 to 1.5
Light sand, 15% water	80	0.6 to 1.2	0.5 to 1.0
5% water	80	0.5 to 1.1	0.6 to 1.3
Grouts/Backfills			
Bentonite (20 to 30% solids)		0.42 to 0.43	
Neat cement (not recommended)		0.40 to 0.45	
20% bentonite/80% SiO_2 sand		0.85 to 0.95	
15% bentonite/85% SiO_2 sand		1.00 to 1.10	
10% bentonite/90% SiO_2 sand		1.20 to 1.40	
30% concrete/70% SiO_2 sand, s. plasticizer		1.20 to 1.40	

Source: Kavanaugh and Rafferty (1997).

Electrical

Solar Radiation Information

New York City, New York

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	1.9	2.7	3.8	4.9	5.7	6.1	6.0	5.4	4.3	3.2	2.0	1.6	4.0
	Min/Max	1.7/2.2	2.3/3.3	3.3/4.4	4.3/5.5	4.8/6.5	5.0/6.8	5.3/6.6	4.8/5.9	3.9/4.9	2.9/3.8	1.7/2.4	1.4/1.8	3.7/4.2
Latitude -15	Average	2.9	3.7	4.6	5.3	5.8	6.0	6.0	5.7	5.0	4.1	2.9	2.4	4.5
	Min/Max	2.3/3.5	3.0/4.6	3.8/5.5	4.6/6.1	4.8/6.5	4.9/6.7	5.2/6.6	5.1/6.3	4.3/5.7	3.6/5.1	2.2/3.6	1.8/3.0	4.3/4.8
Latitude	Average	3.2	4.0	4.8	5.2	5.4	5.5	5.6	5.5	5.0	4.4	3.2	2.8	4.6
	Min/Max	2.5/4.0	3.2/5.2	3.9/5.7	4.4/6.0	4.5/6.1	4.5/6.2	4.8/6.1	4.9/6.1	4.3/5.8	3.7/5.6	2.4/4.1	1.9/3.4	4.3/4.8
Latitude +15	Average	3.4	4.1	4.6	4.8	4.8	4.8	4.9	5.0	4.8	4.4	3.3	3.0	4.3
	Min/Max	2.7/4.3	3.3/5.4	3.7/5.6	4.1/5.6	4.0/5.4	4.0/5.3	4.2/5.3	4.4/5.5	4.0/5.5	3.7/5.6	2.4/4.3	2.0/3.7	4.0/4.6
90	Average	3.2	3.6	3.5	3.1	2.7	2.6	2.7	3.0	3.4	3.6	3.0	2.7	3.1
	Min/Max	2.4/4.2	2.8/4.9	2.8/4.3	2.7/3.7	2.4/3.1	2.3/2.8	2.4/2.9	2.8/3.3	2.8/3.9	3.0/4.6	2.1/3.8	1.7/3.5	2.9/3.4

Sharp NU Series Mechanical Data

Mechanical data

Cell	Monocrystalline (155.55 mm)^2 Sharp silicon solar cells
Number and connection of cells	48 in series
Dimensions	1.318 x 994 x 46 mm (1.31 m²)
Weight	16 kg
Connection type	Cable with plug connector (MC-3)

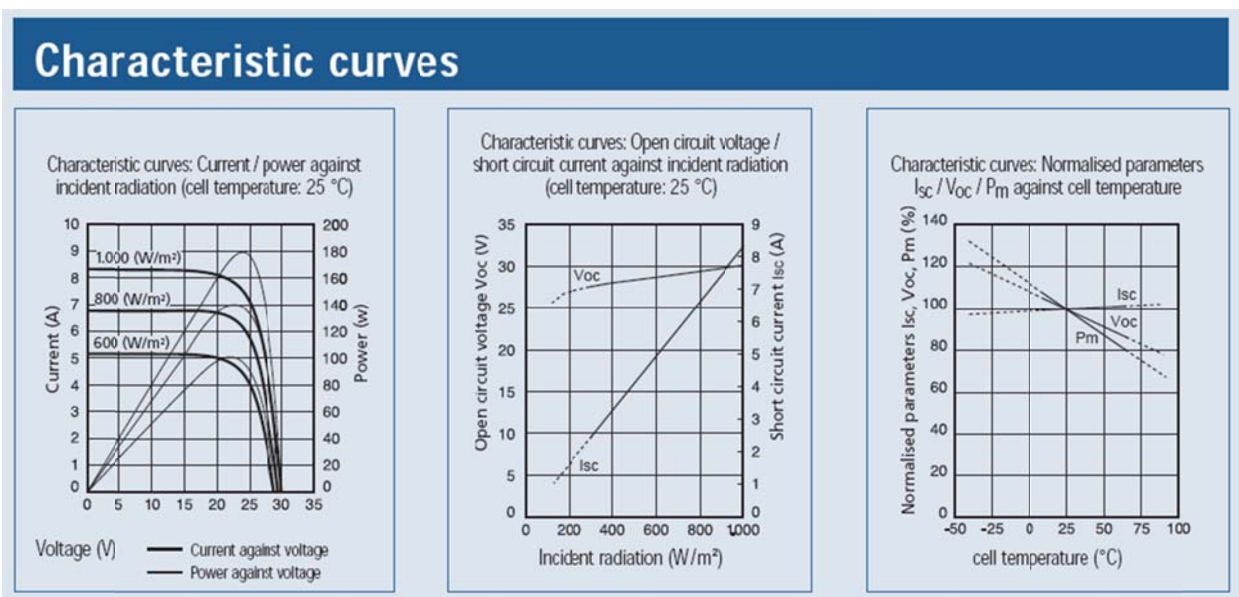
Sharp NU Series Electrical Data

Electrical data

Module production in the EU		NU-185 (E1)	NU-180 (E1)				
Module production in Japan		NU-S5 (E3E)	NU-S0 (E3E)	NU-S0 (E3Z)	NU-R5 (E3Z)	NU-R0 (E3E)	
Rated power		185 W_p	180 W_p	180 W_p	175 W_p	170 W_p	
Open circuit voltage	V_{oc}	30.2	30.0	30.0	29.8	29.4	V
Short circuit current	I_{sc}	8.54	8.37	8.23	8.29	8.37	A
Voltage at maximum power	V_{pm}	24.0	23.7	23.7	23.2	22.4	V
Current at maximum power	I_{pm}	7.71	7.6	7.6	7.55	7.60	A
Module efficiency	η_m	14.1	13.7	13.7	13.4	13.0	%
Temperature coefficient - open circuit voltage	αV_{oc}	-104	-104	-104	-104	-104	mV / °C
Temperature coefficient - short circuit current	αI_{sc}	+0.053	+0.053	+0.053	+0.053	+0.053	% / °C
Temperature coefficient – power	αP_m	-0.485	-0.485	-0.485	-0.485	-0.485	% / °C

The electrical data apply under standard testing conditions (STC): Incident radiation 1.000 W/m² nit Lichtspektrum AM 1.5 with AM 1.5 light spectrum at a cell temperature of 25 °C. The power output is subject to a manufacturing tolerance of – 5 % and + 10 %. The modules manufactured in Europe and Japan are identical.

Sharp NU Series Characteristics Curve



Life Cycle Cost Analysis Tables

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

Census Region 1 (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont)

Projected April 1 Fuel Price Indices (April 1, 2010 = 1.00)

COMMERCIAL

	Electricity				Distillate Oil				Residual Oil				Natural Gas				Coal			
	Inflation Rate				Inflation Rate				Inflation Rate				Inflation Rate				Inflation Rate			
Year	2 %	3 %	4 %	5 %	2 %	3 %	4 %	5 %	2 %	3 %	4 %	5 %	2 %	3 %	4 %	5 %	2 %	3 %	4 %	5 %
2011	0.92	0.92	0.93	0.94	1.03	1.04	1.05	1.06	1.02	1.03	1.04	1.05	1.09	1.10	1.11	1.12	1.00	1.01	1.02	1.03
2012	0.96	0.98	0.99	1.01	1.11	1.14	1.16	1.18	1.15	1.17	1.19	1.21	1.17	1.20	1.22	1.24	1.02	1.04	1.06	1.08
2013	1.00	1.03	1.06	1.09	1.21	1.24	1.28	1.32	1.30	1.34	1.38	1.42	1.20	1.23	1.27	1.31	1.04	1.07	1.10	1.13
2014	1.00	1.04	1.08	1.12	1.29	1.34	1.39	1.45	1.43	1.49	1.55	1.61	1.20	1.25	1.30	1.35	1.06	1.10	1.15	1.19
2015	1.02	1.07	1.12	1.18	1.36	1.43	1.50	1.57	1.52	1.59	1.67	1.75	1.23	1.29	1.35	1.42	1.08	1.13	1.19	1.25
2016	1.05	1.11	1.18	1.25	1.45	1.53	1.63	1.72	1.61	1.71	1.81	1.92	1.26	1.34	1.42	1.50	1.09	1.16	1.23	1.30
2017	1.09	1.16	1.24	1.33	1.53	1.64	1.75	1.87	1.71	1.83	1.96	2.09	1.28	1.37	1.47	1.57	1.11	1.19	1.27	1.36
2018	1.12	1.21	1.31	1.41	1.61	1.74	1.88	2.03	1.81	1.95	2.11	2.28	1.31	1.42	1.53	1.65	1.13	1.22	1.32	1.42
2019	1.14	1.25	1.36	1.49	1.68	1.83	2.00	2.18	1.92	2.09	2.28	2.49	1.34	1.47	1.60	1.74	1.14	1.24	1.36	1.48
2020	1.18	1.30	1.43	1.58	1.74	1.92	2.12	2.33	2.00	2.20	2.42	2.67	1.38	1.52	1.67	1.84	1.16	1.28	1.41	1.55
2021	1.22	1.36	1.51	1.67	1.79	2.00	2.22	2.47	2.06	2.30	2.56	2.84	1.42	1.58	1.76	1.95	1.17	1.30	1.45	1.61
2022	1.25	1.41	1.58	1.77	1.85	2.08	2.34	2.62	2.13	2.40	2.70	3.02	1.47	1.65	1.85	2.08	1.20	1.35	1.51	1.70
2023	1.30	1.47	1.67	1.89	1.91	2.17	2.46	2.78	2.21	2.51	2.84	3.22	1.51	1.72	1.95	2.21	1.23	1.39	1.58	1.79
2024	1.33	1.53	1.75	2.00	1.96	2.25	2.57	2.94	2.28	2.62	3.00	3.43	1.55	1.77	2.03	2.32	1.26	1.44	1.65	1.89
2025	1.35	1.57	1.81	2.09	2.02	2.34	2.71	3.13	2.36	2.73	3.16	3.65	1.58	1.83	2.12	2.45	1.28	1.48	1.71	1.97
2026	1.39	1.62	1.89	2.20	2.09	2.44	2.85	3.32	2.42	2.83	3.31	3.85	1.63	1.91	2.23	2.60	1.31	1.53	1.79	2.08
2027	1.42	1.68	1.98	2.33	2.15	2.54	2.99	3.52	2.50	2.95	3.48	4.09	1.69	1.99	2.34	2.76	1.33	1.57	1.85	2.18
2028	1.47	1.75	2.08	2.47	2.22	2.65	3.15	3.74	2.58	3.08	3.66	4.35	1.75	2.08	2.48	2.95	1.36	1.62	1.93	2.30
2029	1.53	1.84	2.21	2.65	2.30	2.77	3.33	3.99	2.67	3.21	3.86	4.63	1.82	2.19	2.63	3.16	1.39	1.68	2.02	2.42
2030	1.58	1.92	2.33	2.82	2.37	2.88	3.49	4.23	2.76	3.36	4.07	4.93	1.90	2.30	2.80	3.39	1.43	1.74	2.11	2.56
2031	1.64	2.02	2.47	3.02	2.45	3.01	3.69	4.51	2.87	3.52	4.32	5.28	1.98	2.43	2.98	3.64	1.46	1.80	2.20	2.69
2032	1.71	2.11	2.61	3.23	2.54	3.15	3.90	4.81	2.97	3.68	4.55	5.62	2.05	2.54	3.14	3.88	1.49	1.85	2.29	2.82
2033	1.76	2.20	2.75	3.43	2.63	3.29	4.11	5.13	3.05	3.82	4.77	5.95	2.10	2.63	3.29	4.10	1.53	1.91	2.39	2.98
2034	1.81	2.29	2.89	3.64	2.73	3.44	4.34	5.46	3.18	4.02	5.07	6.37	2.17	2.75	3.46	4.36	1.56	1.98	2.49	3.14
2035	1.87	2.38	3.04	3.86	2.82	3.60	4.59	5.83	3.28	4.19	5.33	6.77	2.24	2.86	3.64	4.62	1.60	2.05	2.60	3.31
2036	1.92	2.47	3.18	4.08	2.92	3.76	4.83	6.20	3.40	4.38	5.63	7.22	2.31	2.97	3.82	4.90	1.64	2.11	2.72	3.49
2037	1.97	2.56	3.33	4.31	3.01	3.92	5.09	6.59	3.52	4.58	5.95	7.71	2.38	3.10	4.02	5.21	1.68	2.19	2.84	3.68
2038	2.02	2.65	3.48	4.55	3.11	4.09	5.35	7.00	3.66	4.80	6.30	8.23	2.46	3.23	4.23	5.53	1.71	2.25	2.95	3.86
2039	2.07	2.75	3.64	4.80	3.21	4.26	5.64	7.44	3.79	5.03	6.66	8.79	2.54	3.37	4.45	5.88	1.76	2.33	3.08	4.07
2040	2.13	2.85	3.81	5.07	3.31	4.44	5.93	7.91	3.94	5.27	7.05	9.39	2.62	3.51	4.69	6.24	1.80	2.41	3.22	4.29

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No Incentives

Year	Gross Cost	Utility Savings	Annual Cash Flow	Cumulative Cash flow
0	$ (1,551,120)		$ (1,551,120)	$ (1,551,120)
1		$ 41,415	$ 41,415	$ (1,509,705)
2		$ 42,976	$ 42,976	$ (1,466,729)
3		$ 44,597	$ 44,597	$ (1,422,132)
4		$ 46,278	$ 46,278	$ (1,375,854)
5		$ 48,023	$ 48,023	$ (1,327,832)
6		$ 49,833	$ 49,833	$ (1,277,999)
7		$ 51,712	$ 51,712	$ (1,226,287)
8		$ 53,661	$ 53,661	$ (1,172,626)
9		$ 55,684	$ 55,684	$ (1,116,942)
10	$ 10,000	$ 57,784	$ 67,784	$ (1,049,158)
11		$ 59,962	$ 59,962	$ (989,196)
12		$ 62,223	$ 62,223	$ (926,974)
13		$ 64,568	$ 64,568	$ (862,405)
14		$ 67,003	$ 67,003	$ (795,403)
15	$ 10,000	$ 69,529	$ 79,529	$ (715,874)
16		$ 72,150	$ 72,150	$ (643,724)

17		$ 74,870	$ 74,870	$ (568,855)
18		$ 77,692	$ 77,692	$ (491,162)
19		$ 80,621	$ 80,621	$ (410,541)
20	$ 10,000	$ 83,661	$ 93,661	$ (316,880)
21		$ 86,815	$ 86,815	$ (230,065)
22		$ 90,088	$ 90,088	$ (139,977)
23		$ 93,484	$ 93,484	$ (46,493)
24		$ 97,008	$ 97,008	$ 50,515
25	$ 10,000	$ 100,666	$ 110,666	$ 161,181

NYSERDA Incentive

Year	Gross Cost	NYSERDA PV Incentive	Utility Savings	Annual Cash Flow	Cumulative Cashflow
0	$ (1,551,120)	$ 87,500		$ (1,463,620)	$ (1,463,620)
1			$ 41,415	$ 41,415	$ (1,422,205)
2			$ 42,976	$ 42,976	$ (1,379,229)
3			$ 44,597	$ 44,597	$ (1,334,632)
4			$ 46,278	$ 46,278	$ (1,288,354)
5			$ 48,023	$ 48,023	$ (1,240,332)
6			$ 49,833	$ 49,833	$ (1,190,499)
7			$ 51,712	$ 51,712	$ (1,138,787)
8			$ 53,661	$ 53,661	$ (1,085,126)
9			$ 55,684	$ 55,684	$ (1,029,442)
10	$ 10,000		$ 57,784	$ 67,784	$ (961,658)
11			$ 59,962	$ 59,962	$ (901,696)
12			$ 62,223	$ 62,223	$ (839,474)
13			$ 64,568	$ 64,568	$ (774,905)
14			$ 67,003	$ 67,003	$ (707,903)
15	$ 10,000		$ 69,529	$ 79,529	$ (628,374)
16			$ 72,150	$ 72,150	$ (556,224)
17			$ 74,870	$ 74,870	$ (481,355)
18			$ 77,692	$ 77,692	$ (403,662)
19			$ 80,621	$ 80,621	$ (323,041)
20	$ 10,000		$ 83,661	$ 93,661	$ (229,380)
21			$ 86,815	$ 86,815	$ (142,565)
22			$ 90,088	$ 90,088	$ (52,477)
23			$ 93,484	$ 93,484	$ 41,007
24			$ 97,008	$ 97,008	$ 138,015
25	$ 10,000		$ 100,666	$ 110,666	$ 248,681

NYSERDA+Federal Tax Credit Incentives

Year	Gross Cost	NYSERDA PV Incentive	Federal Tax Credit (30% of Gross Cost at Installation)	Utility Savings	Annual Cash Flow	Cumulative Cashflow
0	$ (1,551,120)	$ 87,500	$ 465,336		$ (998,284)	$ (998,284)
1				$ 41,415	$ 41,415	$ (956,869)
2				$ 42,976	$ 42,976	$ (913,893)
3				$ 44,597	$ 44,597	$ (869,296)
4				$ 46,278	$ 46,278	$ (823,018)
5				$ 48,023	$ 48,023	$ (774,996)
6				$ 49,833	$ 49,833	$ (725,163)
7				$ 51,712	$ 51,712	$ (673,451)
8				$ 53,661	$ 53,661	$ (619,790)

9				$ 55,684	$ 55,684	$ (564,106)
10	$ 10,000			$ 57,784	$ 67,784	$ (496,322)
11				$ 59,962	$ 59,962	$ (436,360)
12				$ 62,223	$ 62,223	$ (374,138)
13				$ 64,568	$ 64,568	$ (309,569)
14				$ 67,003	$ 67,003	$ (242,567)
15	$ 10,000			$ 69,529	$ 79,529	$ (163,038)
16				$ 72,150	$ 72,150	$ (90,888)
17				$ 74,870	$ 74,870	$ (16,019)
18				$ 77,692	$ 77,692	$ 61,674
19				$ 80,621	$ 80,621	$ 142,295
20	$ 10,000			$ 83,661	$ 93,661	$ 235,956
21				$ 86,815	$ 86,815	$ 322,771
22				$ 90,088	$ 90,088	$ 412,859
23				$ 93,484	$ 93,484	$ 506,343
24				$ 97,008	$ 97,008	$ 603,351
25	$ 10,000			$ 100,666	$ 110,666	$ 714,017

NYSERDA+ Federal Tax Credit Incentives+ NYC Tax Abatement Incentives

Year	Gross Cost	NYSERDA PV Incentive	Federal Tax Credit	New York City - Property Tax Abatement for PV	Tax Savings from MACRS Depreciation	Utility Savings	Annual Cash Flow
0	$ (1,551,120)	$ 87,500	$ 465,336				$ (998,284)
1				$ 87,350		$ 41,415	$ 128,765
2				$ 87,350		$ 42,976	$ 130,326
3				$ 87,350		$ 44,597	$ 131,947
4				$ 87,350		$ 46,278	$ 133,628
5						$ 48,023	$ 48,023
6						$ 49,833	$ 49,833
7						$ 51,712	$ 51,712
8						$ 53,661	$ 53,661
9						$ 55,684	$ 55,684
10	$ 10,000					$ 57,784	$ 67,784
11						$ 59,962	$ 59,962
12						$ 62,223	$ 62,223
13						$ 64,568	$ 64,568
14						$ 67,003	$ 67,003
15	$ 10,000					$ 69,529	$ 79,529
16						$ 72,150	$ 72,150
17						$ 74,870	$ 74,870
18						$ 77,692	$ 77,692
19						$ 80,621	$ 80,621
20	$ 10,000					$ 83,661	$ 93,661
21						$ 86,815	$ 86,815
22						$ 90,088	$ 90,088
23						$ 93,484	$ 93,484
24						$ 97,008	$ 97,008
25	$ 10,000					$ 100,666	$ 110,666

NYSERDA+ Federal Tax Credit Incentives+ NYC Tax Abatement+ MACRS Incentives

Year	Gross Cost	NYSERDA PV Incentive	Federal Tax Credit	New York City - Property Tax Abatement for PV	Tax Savings from MACRS Depreciation	Utility Savings	Annual Cash Flow

0	$ (1,551,120)	$ 87,500	$ 465,336				$ (998,284)
1				$ 87,350	$ 326,175	$ 41,415	$ 454,940
2				$ 87,350		$ 42,976	$ 130,326
3				$ 87,350		$ 44,597	$ 131,947
4				$ 87,350		$ 46,278	$ 133,628
5						$ 48,023	$ 48,023
6						$ 49,833	$ 49,833
7						$ 51,712	$ 51,712
8						$ 53,661	$ 53,661
9						$ 55,684	$ 55,684
10	$ 10,000					$ 57,784	$ 67,784
11						$ 59,962	$ 59,962
12						$ 62,223	$ 62,223
13						$ 64,568	$ 64,568
14						$ 67,003	$ 67,003
15	$ 10,000					$ 69,529	$ 79,529
16						$ 72,150	$ 72,150
17						$ 74,870	$ 74,870
18						$ 77,692	$ 77,692
19						$ 80,621	$ 80,621
20	$ 10,000					$ 83,661	$ 93,661
21						$ 86,815	$ 86,815
22						$ 90,088	$ 90,088
23						$ 93,484	$ 93,484
24						$ 97,008	$ 97,008
25	$ 10,000					$ 100,666	$ 110,666

GSHP Life Cycle Cost Statistics

Year	Cost of GSHP	Cost of PV	Maintenance	GSHP Utility Savings	Total
0	$ (4,789,325.00)				$ (4,789,325)
1				$ 171,147.00	$ (4,618,178)
2				$ 177,599.24	$ (4,440,579)
3				$ 184,294.73	$ (4,256,284)
4				$ 191,242.64	$ (4,065,041)
5			$ (20,000)	$ 198,452.49	$ (3,886,589)
6				$ 205,934.15	$ (3,680,655)
7				$ 213,697.87	$ (3,466,957)
8				$ 221,754.28	$ (3,245,203)
9				$ 230,114.41	$ (3,015,088)
10			$ (20,000)	$ 238,789.73	$ (2,796,298)
11				$ 247,792.10	$ (2,548,506)
12				$ 257,133.86	$ (2,291,372)
13				$ 266,827.81	$ (2,024,545)
14				$ 276,887.22	$ (1,747,657)
15			$ (20,000)	$ 287,325.87	$ (1,480,332)
16				$ 298,158.05	$ (1,182,174)
17				$ 309,398.61	$ (872,775)
18				$ 321,062.94	$ (551,712)
19				$ 333,167.01	$ (218,545)
20			$ (20,000)	$ 345,727.41	$ 107,182
21				$ 358,761.33	$ 465,944
22				$ 372,286.63	$ 838,230
23				$ 386,321.84	$ 1,224,552
24				$ 400,886.17	$ 1,625,438
25			$ (20,000)	$ 415,999.58	$ 2,021,438

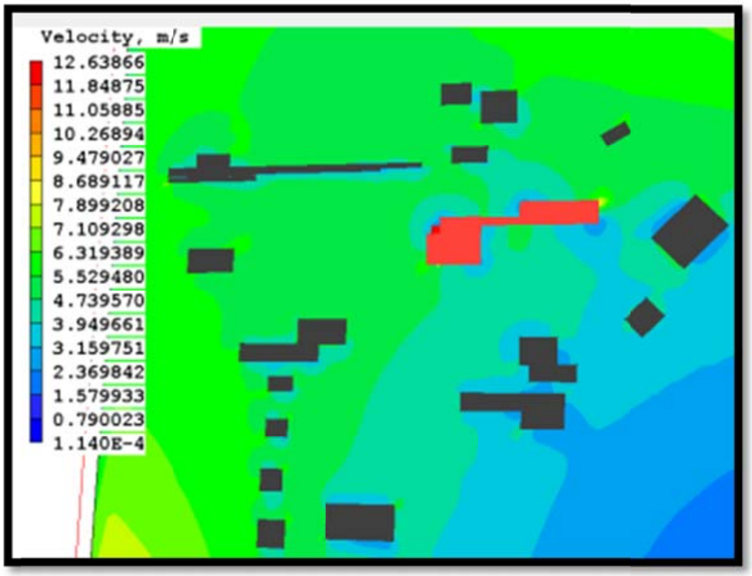
GSHP + PV System Life Cycle Cost Statistics

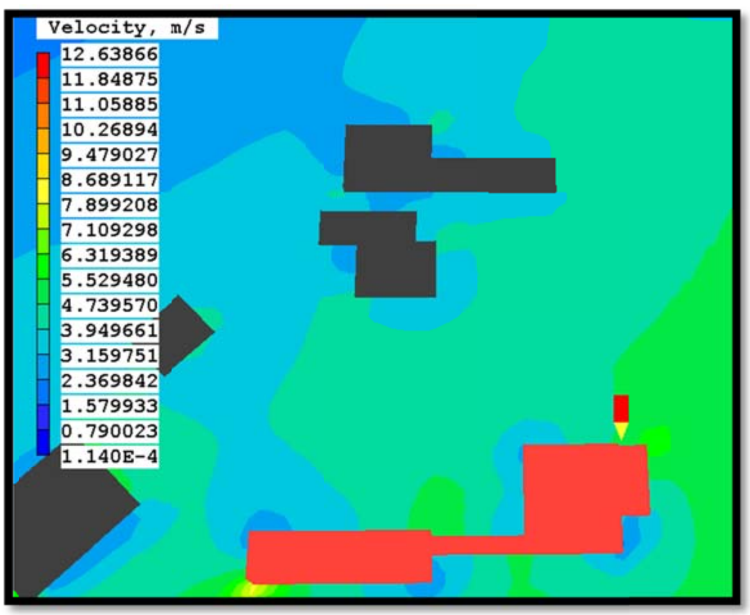
Year	Cost of GSHP	Cost of PV	Maintenance	GSHP Utility Savings	PV Utility Savings	NYSERDA PV Incentive	Federal Tax Credit	New York City - Property Tax Abatement for PV	MACRS		Total
0	$ (4,789,325.00)	$ (1,551,120)									$ (6,340,445)
1				$ 169,435.53	$ 41,000.85	$ 87,500	$ 465,336	$ 87,350	$ 326,175		$ (5,163,648)
2				$ 181,415.82	$ 43,899.90			$ 87,350			$ (4,850,982)
3				$ 184,838.76	$ 44,728.20			$ 87,350			$ (4,534,065)
4				$ 191,684.64	$ 46,384.80			$ 87,350			$ (4,208,646)
5			$ (20,000)	$ 201,953.46	$ 48,869.70						$ (3,977,822)
6				$ 212,222.28	$ 51,354.60						$ (3,714,245)
7				$ 224,202.57	$ 54,253.65						$ (3,435,789)
8				$ 232,759.92	$ 56,324.40						$ (3,146,705)
9				$ 244,740.21	$ 59,223.45						$ (2,842,741)
10			$ (20,000)	$ 258,431.97	$ 62,536.65						$ (2,541,773)
11				$ 270,412.26	$ 65,435.70						$ (2,205,925)
12				$ 285,815.49	$ 69,163.05						$ (1,850,946)
13				$ 299,507.25	$ 72,476.25						$ (1,478,963)
14				$ 309,776.07	$ 74,961.15						$ (1,094,225)
15			$ (20,000)	$ 323,467.83	$ 78,274.35						$ (712,483)
16				$ 338,871.06	$ 82,001.70						$ (291,610)
17				$ 355,985.76	$ 86,143.20						$ 150,518
18				$ 378,234.87	$ 91,527.15						$ 620,281
19				$ 398,772.51	$ 96,496.95						$ 1,115,550
20			$ (20,000)	$ 422,733.09	$ 102,295.05						$ 1,620,578
21				$ 395,349.57	$ 95,668.65						$ 2,111,596
22				$ 470,654.25	$ 113,891.25						$ 2,696,142
23				$ 494,614.83	$ 119,689.35						$ 3,310,446
24				$ 520,286.88	$ 125,901.60						$ 3,956,634
25			$ (20,000)	$ 544,247.46	$ 131,699.70						$ 4,612,582

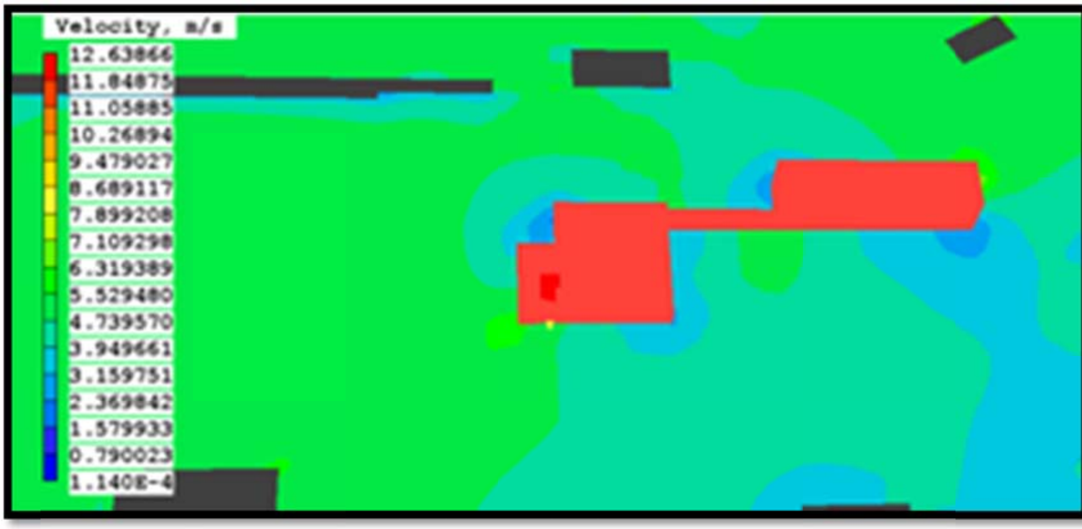
Wind Analysis

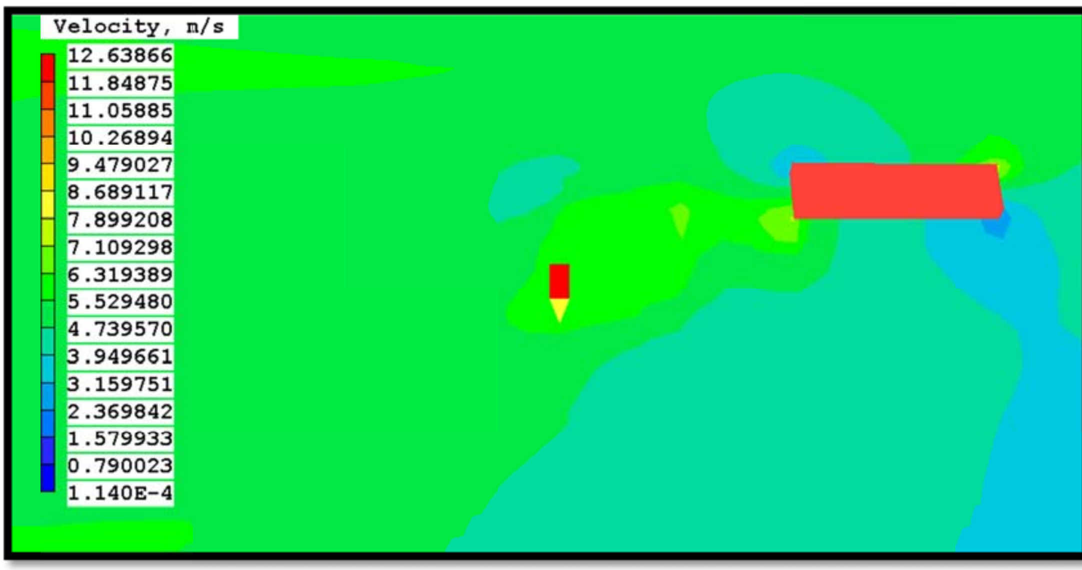
NYPA highlighted in Red

Phoenics VR Figures for NYPA Wind Analysis






Velocity, m/s
12.63866
11.84875
11.05885
10.26894
9.479027
8.689117
7.899208
7.109298
6.319389
5.529480
4.739570
3.949661
3.159751
2.369842
1.579933
0.790023
1.140E-4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12.63866
11.84875
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7.899208
7.109298
6.319389
5.529480
4.739570
3.949661
3.159751
2.369842
1.579933
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1.140E-4

Potential Location for Wind Turbines based on Calculated Wind Speeds