



New York Police Academy College Point, New York



John M. Scavelli

Mechanical Option

Senior Thesis 2010-2011

The Pennsylvania State University; Department of Architectural Engineering

Master/Bachelor of Architectural Engineering Student

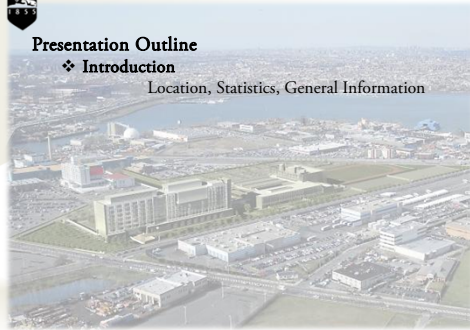
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Presentation Outline

❖ **Introduction**

Location, Statistics, General Information



Introduction

Presentation Plan

New York Police Academy
College Point, New York



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The Pennsylvania State University
Architectural Engineering
Mechanical Option
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Thesis Advisor: Dr. William Bahnfleth

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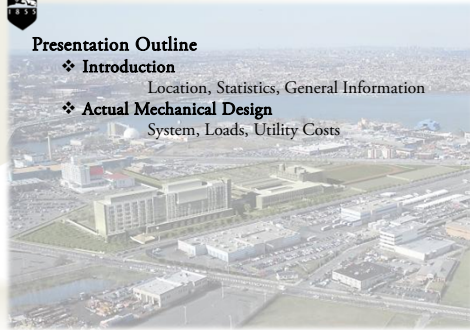
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Presentation Outline

- ❖ **Introduction**
Location, Statistics, General Information
- ❖ **Actual Mechanical Design**
System, Loads, Utility Costs



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Mechanical Depth: GSHP
Electrical Breadth: PV Array
Construction Breadth: Cost Analysis



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Building Location



Location

College Point, New York

North Eastern Part of the United States of America





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Building Location



Location

College Point, New York

Close Proximity to Manhattan, NY



Presentation Outline

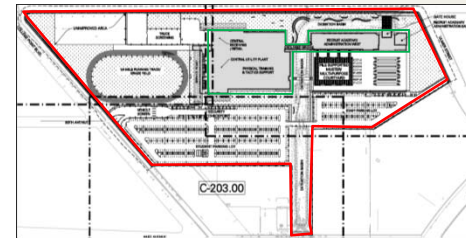
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Building Location



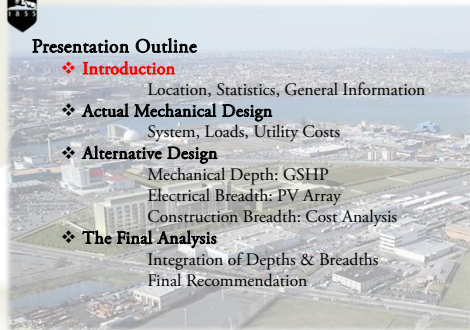
Location College Point, New York





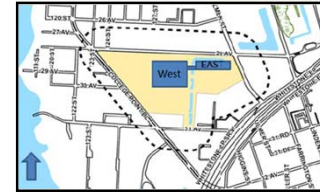
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Building Statistics

- ❖ **Occupant:** New York Police Department
- ❖ **Architect:** Perkins + Will
- ❖ **Site Size:** 2,400,000 SF
- ❖ **Building Size:** 840,400 SF
- ❖ **Overall Cost:** \$656,000,000



- ❖ **East Campus:** Academic/Office Space
❖ 375,405 SF
- ❖ **West Campus:** Physical Fitness/ Central Plant
❖ 465,000 SF
- ❖ **Architecture:** Modern w/ Strong Geometric Forms





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General Information

General Construction Information

- ❖ 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.

General Structural Information

- ❖ Structural Engineers : Robert Silman Associates
- ❖ Steel Super Structure

General Electrical Information

- ❖ Electrical Engineers: WSP Flack + Kurtz
- ❖ 460/265V 3-Phase High Voltage system stepped down to 120/208 V 3-Phase Low Voltage System

General Mechanical Information

- ❖ Mechanical Engineers: WSP Flack + Kurtz
- ❖ Centralized Heating and Cooling Plant System



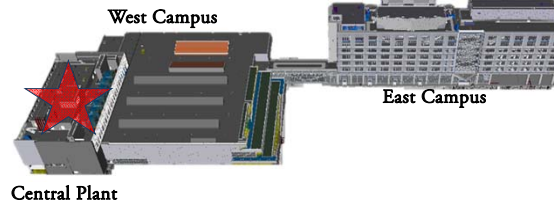


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Mechanical Systems Overview



❖ **Ventilation Needs**

- ❖ 63 Air Handling Units-3,000-30,000 CFM
- ❖ 18-Central Plant
- ❖ 26-West Campus
- ❖ 19-East Campus

❖ **Central Plant-Heating and Cooling**

- ❖ 6- 1350 Ton Electric Centrifugal Chillers
 - ❖ 2 Installed for future expansion
- ❖ 6- Induced Draft Cooling Towers
 - ❖ 3 Installed for future expansion
- ❖ 5-25110 MBH Natural Gas Water Tube Boilers
 - ❖ 2 Installed for Future expansion



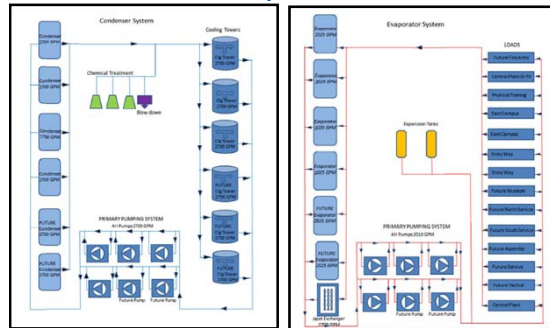


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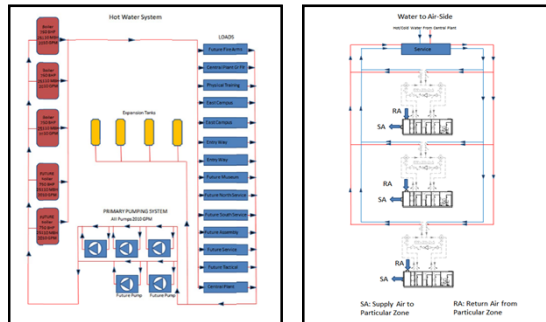


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East Campus Building Loads

Station	Latitude	Longitude	Elevation	Heating DB (99.6%)	Cooling DB (84.6%)	Cooling MCWB (84.6%)	Evaporation WB (84.6%)	Evaporation MCDB (84.6%)	Dehumid. DP (84.6%)	Dehumid. HR (84.6%)	Dehumid. MCDB (84.6%)
New York, LaGuardia Intl	40.78N	73.88W	30	12.6	92.2	74.4	77.2	87.2	74.3	185.5	81.0

	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

- ❖ The East Campus was chosen as the specific building of study.
 - ❖ East and West Campus essentially two separate buildings
 - ❖ 375,405 SF
- ❖ TRANE Trace 700 Used
 - ❖ Location: LaGuardia Airport (1.6 miles from NYPA)
 - ❖ Block Load Analysis
 - ❖ 52 Zones





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East Campus Energy 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

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

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East Campus Energy Utility Costs

Energy Cost	Energy Consumption	Building Size (East Campus Only)	Utility Price/ ft ² •yr
\$0.1611 /kWh	5,634,061 kWh/yr	375,405 ft ²	\$2.507 / ft ² • yr
\$11.858/1000 ft ² NG	5,530,679 kBtu/yr	375,405 ft ²	\$0.1699/ ft ² • yr
Total Utility Cost:			\$2.677/ ft²• yr
Annual Cost:			\$1,004,921/yr

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Alternative Design Proposal

Mechanical Depth:
East Campus
Ground Source Heat Pump System

Electrical Breadth:
Photovoltaic System

Construction Management Breadth:
GSHP Cost, Labor, Schedule Impact



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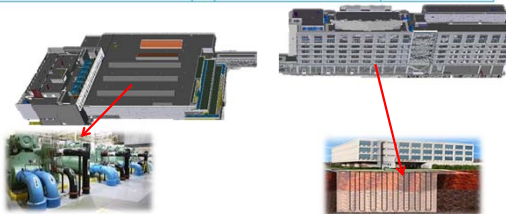
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Mechanical Depth Proposal

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	



GSHP Major Discussion Topics

- ❖ Justification
- ❖ System Schematics
- ❖ Ground Source Heat Pump Loop Sizing
- ❖ Energy Modeling
- ❖ Utility Cost Comparison





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GSHP System Justification

- ❖ Reduce Size of Central Plant yet keep ability for future expansion for West Campus.
 - ❖ East Campus will not be expanded upon.
- ❖ High Electricity Costs in New York
 - ❖ Reduce Energy Consumption
 - ❖ Therefore, reduce utility costs and emissions
- ❖ New Construction Project
- ❖ Large enough site for well field

GSHP Major Discussion Topics

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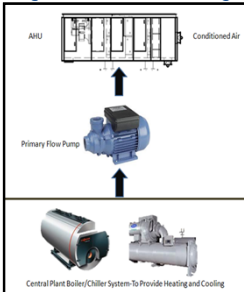
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GSHP System Schematics

Original Central Plant Design



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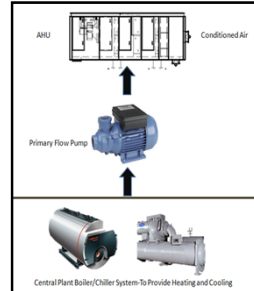
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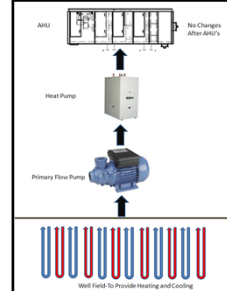


GSHP System Schematics

Original Central Plant Design



GSHP Design



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GSHP Loop Sizing

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

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

- ❖ Calculated using ASHRAE's Handbook: HVAC Applications (Chapter 32)
- ❖ Largest length required would be for cooling: 299,183 ft.
- ❖ Cost Optimization of Loop Size (will be discussed under CM Breadth)

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Energy Modeling

GSHP Design

System	Yearly Electricity Consumption [kWh]		
	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

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

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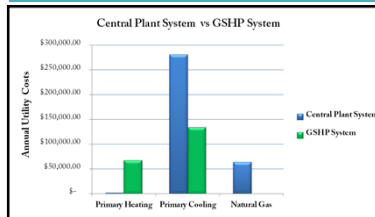
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Utility Cost Comparison

GSHP Design

Energy Cost	Energy Consumption		Utility Price/ ft ² *yr	
	CP	GSHP	CP	GSHP
\$1.6411 /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	\$1,699/ 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



- ❖ 17% Annual Utility Savings
- ❖ Electricity + Natural Gas
- ❖ Annual Savings: \$171,147

❖ Life Cycle Analysis will be evaluated after construction (first) costs are established

GSHP Major Discussion Topics

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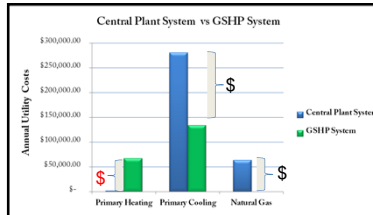
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Alternative Design Proposal

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East Campus
Ground Source Heat Pump System**

**Electrical Breadth:
Photovoltaic System**

**Construction Management Breadth:
GSHP Cost, Labor, Schedule Impact**

Photovoltaic System Discussion Topics

- ❖ Array Size
- ❖ Panel Chosen, Mounting System Chosen
- ❖ Electrical Characteristics
 - ❖ Strings, Inverter, Switchgear
- ❖ Economic Analysis





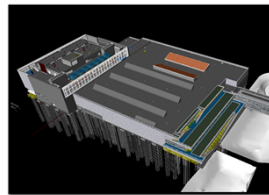
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Electrical Breadth Proposal

Photovoltaic Array on West Campus Roof



Prior to PV Array

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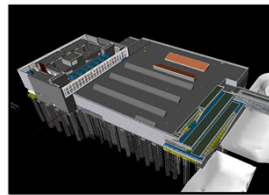
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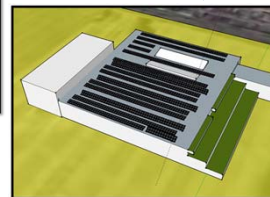
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Photovoltaic Array on West Campus Roof



Prior to PV Array

W/ PV Array



Photovoltaic System Discussion Topics



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- ❖ Economic Analysis

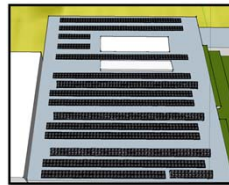


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Construction Breadth: Cost Analysis
- ❖ **The Final Analysis**
Integration of Depths & Breadths
Final Recommendation



Array Size



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

Photovoltaic System Discussion Topics



- ❖ Array Size
- ❖ Panel Chosen, Mounting System Chosen
- ❖ Electrical Characteristics
 - ❖ Strings, Inverter, Switchgear
- ❖ Economic Analysis

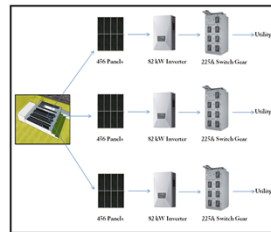


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Electrical Characteristics



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

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

Photovoltaic System Discussion Topics



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- ❖ Economic Analysis

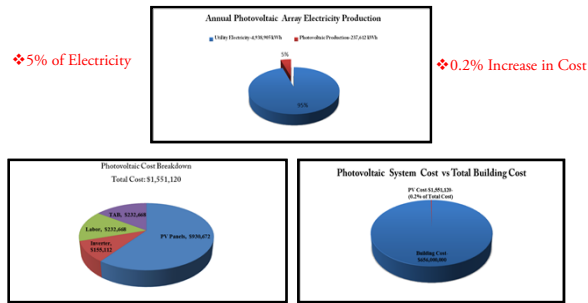


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Economic Analysis



Photovoltaic System Discussion Topics

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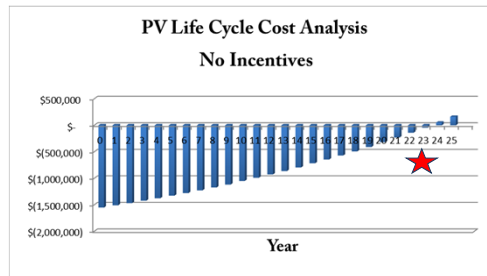


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Photovoltaic System Discussion Topics



- ❖ Array Placement
- ❖ Array Size
- ❖ Panel Chosen, Mounting System Chosen
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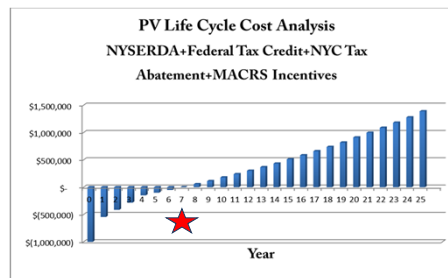


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Photovoltaic System Discussion Topics



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Alternative Design Proposal

**Mechanical Depth:
East Campus
Ground Source Heat Pump System**

**Electrical Breadth:
Photovoltaic System**

**Construction Management Breadth:
GSHP Cost, Labor, Schedule Impact**

Construction Discussion Topics

- ❖ Length Optimization
- ❖ Construction Cost
- ❖ Life Cycle Cost Analysis



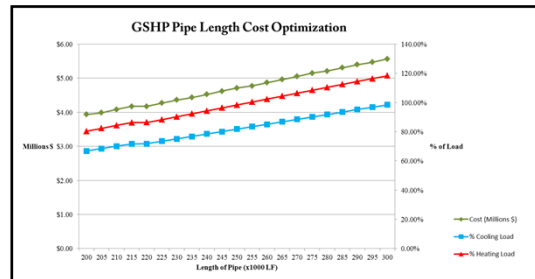


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Length Optimization



Construction Discussion Topics

- ❖ Length Optimization
- ❖ Construction Cost
- ❖ Life Cycle Cost Analysis



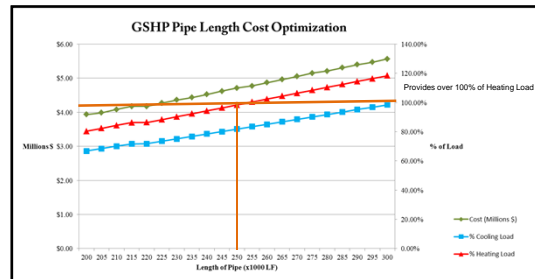


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Length Optimization



Construction Discussion Topics

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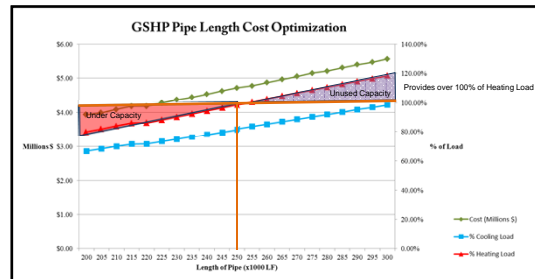


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Construction Discussion Topics



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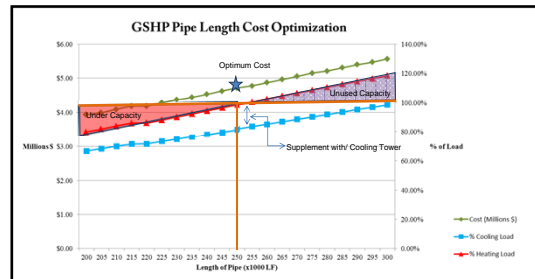


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Construction Cost

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_br	\$-170,200
Total Cost of System	Cost total	\$4,789,325

Variables			
Length of GSHP	L_gshp	249,047	units [ft]
Water Circulation	Q	22563	[gallons]
GSHP Cooling	Q	1009	[tons]
CT Supplementary Cooling		203	[tons]
% of Cooling		83.2%	[%]
% of Heating		100.0%	[%]

Construction Discussion Topics



- ❖ Length Optimization
- ❖ Construction Cost
- ❖ Life Cycle Cost Analysis

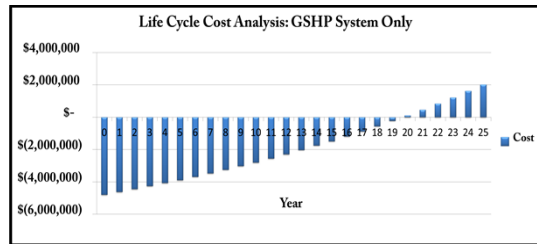


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GSHP Life Cycle Cost Analysis



Construction Discussion Topics

- ❖ Length Optimization
- ❖ Construction Cost
- ❖ Life Cycle Cost Analysis





The Final Analysis

**Mechanical Depth:
East Campus
Ground Source Heat Pump System**

**Electrical Breadth:
Photovoltaic System**

**Construction Management Breadth:
GSHP Cost, Labor, Schedule Impact**

Final Analysis

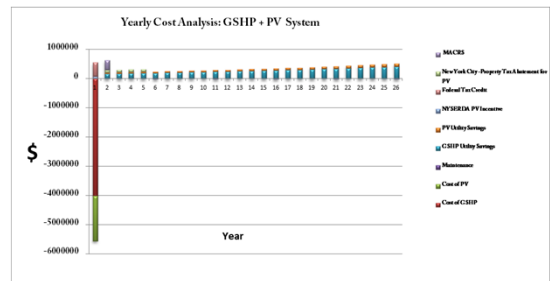
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- ❖ Final Recommendations



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Yearly Cost Analysis: GSHP + PV System



Final Analysis

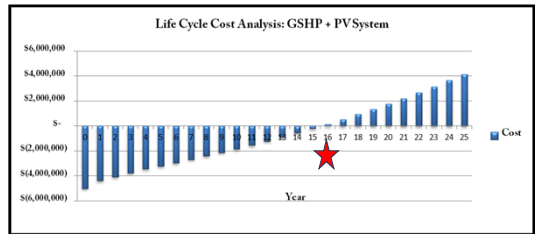
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Life Cycle Cost Analysis



Final Analysis

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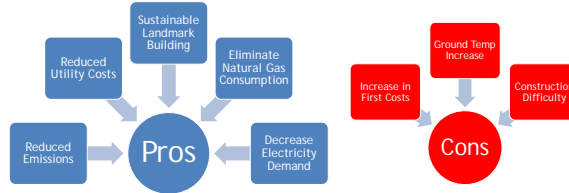


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Pros vs. Cons



- ❖ Final Recommendations
 - ❖ GSHP Implementation: **Affirmative**
 - ❖ Photovoltaic Implementation: **Affirmative**

Final Analysis



- ❖ Yearly Cost Analysis: GSHP + PV System
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- ❖ Final Recommendations



Thank You for Listening

Special Thanks to:

Turner Construction Company

**Penn State Architectural Engineering Faculty,
Staff, and Students**



John M. Scavelli

Mechanical Option

Senior Thesis 2010-2011

The Pennsylvania State University; Department of Architectural Engineering

Master/Bachelor of Architectural Engineering Student



New York Police Academy College Point, New York

Questions?



John M. Scavelli

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New York Police Academy

College Point, New York

Appendix



John M. Scavelli

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Master/Bachelor of Architectural Engineering Student



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Well Field Layout

GSHP Design



GSHP Major Discussion Topics

- ❖ Justification
- ❖ System Schematics
- ❖ Ground Source Heat Pump Loop Sizing
- ❖ Well Field Layout
- ❖ Energy Modeling
- ❖ Utility Cost Comparison



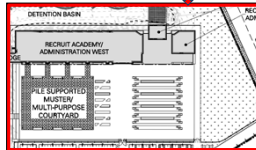


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Well Field Layout GSHP Design



GSHP Major Discussion Topics

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- ❖ System Schematics
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- ❖ Well Field Layout
- ❖ Energy Modeling
- ❖ Utility Cost Comparison



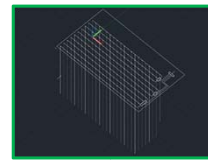
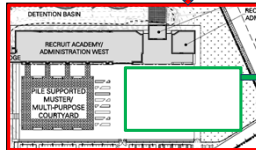


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Well Field Layout GSHP Design



- ❖ 214 Wells
- ❖ Depth 350'
- ❖ Two Loops per well

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%





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Array Placement



Photovoltaic System Discussion Topics



- ❖ Array Placement
- ❖ Array Size
- ❖ Panel Chosen, Mounting System Chosen
- ❖ Electrical Characteristics
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- ❖ Economic Analysis

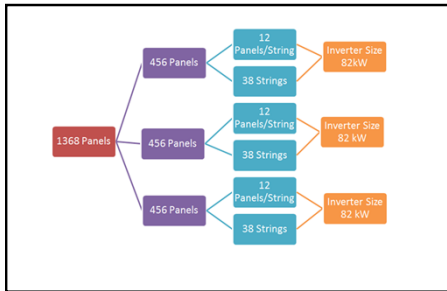


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Electrical Schematic



Photovoltaic System Discussion Topics



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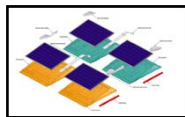
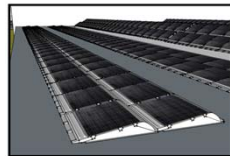


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Panel and Mounting System



- ❖ Sharp NU Series 185 W Panels
- ❖ Solion SunMount System

Photovoltaic System Discussion Topics

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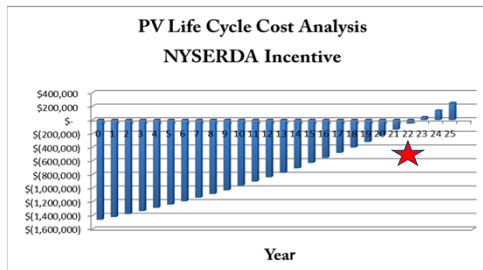
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Economic Analysis

**PV Life Cycle Cost Analysis
NYSERDA Incentive**



Photovoltaic System Discussion Topics



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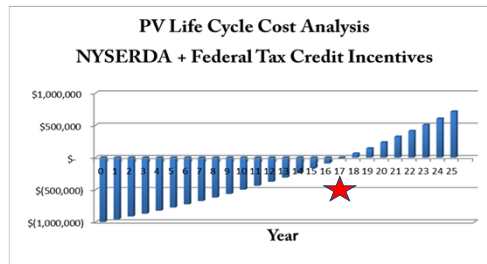


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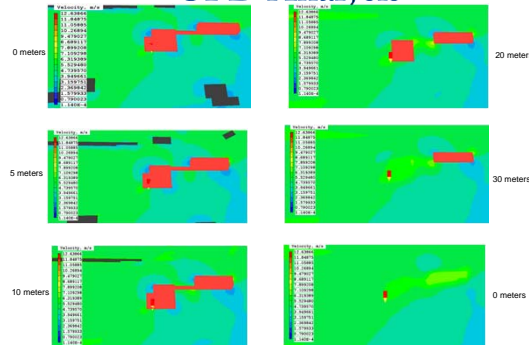


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CFD Analysis



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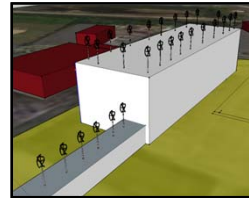
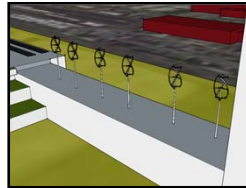


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CFD Analysis



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