GEOTHERMAL SYSTEM FEASIBILITY REPORT
K067
51 ST. EDWARDS ST.
NEW YORK, NY

NYC SCHOOL CONSTRUCTION AUTHORITY

Completed by

XYZ CONSULTING ENGINEERS
New York, NY

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1.0 Background

SCA Geothermal System Feasibility Tool analyzes the feasibility of a geothermal system for a major renovation/addition to Public Schools within New York City. The Proposed Design of XYZ Consulting Engineers is the renovation/addition of K067 which is a 5 story, 121,000 ft^2 existing school. The building includes classrooms, offices and support spaces. The geothermal system feasibility assessment is based on the 100% SD drawing set dated October 26, 2018.

2.0 Heating and Cooling System Design

The SCA standard heating system design chosen for this building is an air-source electric heat pump RTU system.

The SCA standard cooling system chosen for this building is an air-source electric heat pump RTU system.

3.0 Heating and Cooling System Capital Costing

The costing for the heating and cooling system was found to be in line with the ranges noted in the SCA Geothermal System Feasibility Tool. It is believed that the costing for the standard air-source heat pump RTU systems on this project will fall in the lower end of this range.

4.0 Geothermal Pre-feasibility Tool

The online geothermal pre-feasibility tool developed by the NYC Mayor's Office of Sustainability and NYC DDC was used to determine the geological, and to a basic extent technical feasibility of a geothermal system. The project building was located within the *NYC Geothermal Pre-feasibility Tool* (link below) by searching for the project site.

NYC Geothermal Pre-feasibility Tool: https://www.nyc.gov/assets/ddc/geothermal/geothermalTool.html

The project specific building site information (Lot Area, Building Area, Building Footprint) was entered into the screening tool under the "Building" category (see Figure 1). The screening tool determined that the building site has Geological and Technical Suitability for all geothermal systems (standing column well, closed loop, and open loop). For the project building, standing column well and closed loop geothermal systems were determined to be recommended for a Full System Feasibility Study (see Figure 1).

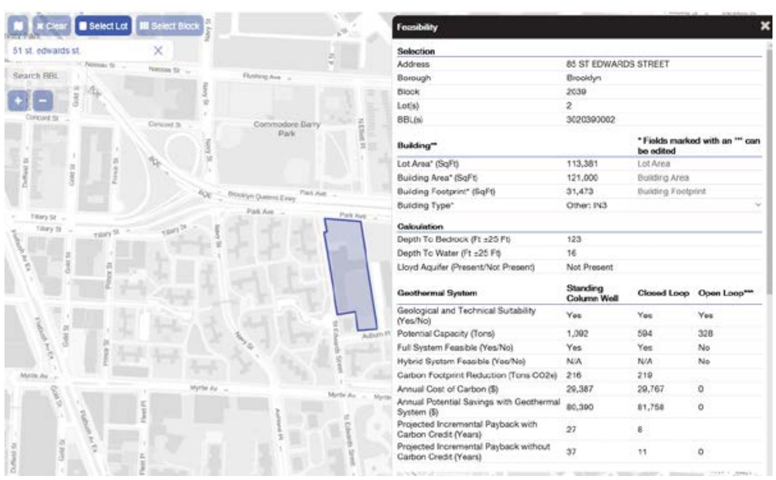

Figure 1. NYC Geo Pre-Feasibility Tool Map

Based on the results in Figure 1, the project site is recommended for a Full Feasibility study and these results were entered into the *SCA Geothermal Feasibility Tool,* as outlined in Section 5.0.

5.0 Geothermal Feasibility Tool

Since the *NYC Geothermal Pre-feasibility Tool* indicated "Yes" for standing column well and closed loop geothermal system type Full System Feasibility, these results were be entered into the *SCA Geothermal System Feasibility Tool*. The Building Site Information table (i.e. project name, project address, building area, number of floors, and lot size) was entered into Table A of the tool, shown below.

Table A: Building Site Information

Building Site Information	
Project Name	K067
Project Address	51 St. Edwards St.
Building Area (ft²)	121,000
No. of Floors	5
Lot Area (ft²)	113,381
Depth to Bedrock (ft)	123

The screening tool determined that the building site has Geological and Technical Suitability for standing column well and closed loop systems. These results were entered into Table 1 within the SCA Geothermal Feasibility Tool, shown below.

Table 1: SCA Geothermal Feasibility Tool Results

	Geothermal System	Standing Column Well	Closed Loop	Open Loop
1	Geological and Technical Suitability (Yes/No)	Yes	Yes	No
Is a Geothermal Feasibility Study Required		Yes		

For the project building, standing column well and closed loop systems were determined to be recommended for a Full System Feasibility Study. This information was entered into Table 2 within the SCA Geothermal Feasibility Tool, shown below.

Table 2: SCA Geothermal Feasibility Tool Results Continued

	Geothermal System	Standing Column Well	Closed Loop	Open Loop
1	Potential Capacity (Tons)	1092	594	328
2	Full System Feasibility (Yes/No)	Yes	Yes	No
3	Carbon Footprint Reduction (Tons CO2e)	216	219	-
4	Annual Cost of Carbon ($)	$29,387	$29,767	-

Within Table C of the tool, the Cooling Load was entered as 400 ft²/ton and the Heating Load was entered as 25 Btu/ft², per the design, shown below. These peak cooling loads and heating loads were confirmed to be input as loads prior to any equipment safety factors or redundancy requirements.

Table C: SCA Standard HVAC Baseline System

Baseline Cooling System Chiller Type	Cooling Load (ft²/ton)	Cooling Load (tons)	Baseline Heating System Type	Heating Load (Btu/ft²)	Heating Load (MBH)
SCA Standard HVAC System (Air-Source Heat Pump RTUs)	400	303	SCA Standard HVAC System (Heat Pump RTU's)	25	3,025

Once all this information was entered, the SCA Geothermal Feasibility Tool determined that a geothermal system is not required for this project under both low cost and high cost assumptions, indicated in Table 3 of the tool, shown below.

Table 3: SCA Geothermal Feasibility Study Results

Type of Systems Studied	Capital Cost Estimate (Plant)		Yearly Maintenance Cost		Electric Cost (Yearly)	Cost of Carbon (Year)	Cost of Carbon (Site Cost)	System Life Expectancy			Net Present Value		Lowest Net Present Value?	
	Low	High	Low	High							Low	High	Low	High
SCA Standard HVAC System (Air-Source Heat Pump RTUs)	$3,680,375	$7,360,750	$3,000	$5,000	$130,063	2023	$18,904	15	To	19	$6,114,538	$10,051,457	Yes	Yes
Geothermal Closed Loop	$5,300,613	$12,513,275	$1,217	$1,825	$116,459	N/A	$17,498	15	To	19	$7,432,570	$14,850,009	No	No
Geothermal Standing Column	$4,462,455	$9,937,013	$24,333	$48,666	$97,468	N/A	$8,012	15	To	19	$6,522,955	$12,609,040	No	No
Geothermal Open Loop	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	To	N/A	N/A	N/A	N/A	N/A
Is a Geothermal System Required	No	No												
	(Low)	*(High)*												

Section 7.0 provides further reference information on the calculations/assumptions for each of these tabs in the tool.

6.0 Findings and Next Steps

Based on the results in the SCA Geothermal Feasibility Tool, the air-source heat pump RTU system was determined to have the lowest net present value and therefore be favorable over that of the geothermal standing column or closed loop system types. Therefore, in proceeding into the design documents, this project will continue to be designed for an air-source heat pump RTU system type.

7.0 SCA Geothermal Feasibility Tool – References

7.01 Assumptions

The Assumptions tab within the *SCA Geothermal Feasibility Tool* lists the cooling and heating systems performance data consisting of calculations derived from operating data entered in the Baseline Systems tab which are based on NYC SCA requirements, ASHRAE 90.1, or industry standards.

7.02 Baseline Systems

The baseline systems utilized in this tool are based on 2020 NYC SCA eQuest Input Summary, NYC Green Schools Guide 2016, SCA Design Requirements Document, and ASHRAE 90.1 – 2016.

The cooling system type under the Baseline Systems tab is based on ASHRAE 90.1-2016 for air-cooled heat pumps systems greater than 240,000 Btu/h (EER = 9.3, IEER = 10.4) (Figure 10).

Cooling Systems			
Cooling Type	Size Category (Btu/h)	EER	IEER
Air-Source Heat Pump	≥240,000	9.3	10.4
Data for air-cooled heat pump based on ASHRAE 90.1-2016, Table 6.8.1-2.			

Figure 10. Cooling System Specifications

The heating system type under the Baseline Systems tab is based on a combination of ASHRAE 90.1-2016 for air-cooled heat pump systems greater than 135,000 Btu/h (COP = 3.2), (Figure 11).

Heating Systems		
Heating Type	Size Category (Btu/h)	Heating COP
Air-Source Heat Pump	≥135,000	2.9
Data for air-cooled heat pumps based on ASHRAE 90.1-2016, Table 6.8.1-2. *Effective Heating COP is an estimated value based on equipment performance data rated at approximate average NYC winter temperature.*		

Figure 11. Heating System Specifications

The geothermal systems data performance indicated in the Geothermal Systems table under the Baseline Systems tab is based on ASHRAE 90.1-2016 for closed loop and open loop / standing column well systems (Figure 12).

Geothermal Systems					
System Type	Equipment Type	Rating Condition	Minimum Efficiency	Efficiency Unit	Well Water Delta T
Closed Loop	Ground Source brine to air (cooling mode)	77°F entering water	14.1	EER	10
	Ground Source brine to air (heating mode)	32°F entering water	3.2	COP	10
	Ground Source brine to water (cooling mode)	77°F entering water	12.1	EER	10
	Ground Source brine to water (heating mode)	32°F entering water	2.5	COP	10
Open Loop/ Standing Column	Groundwater Source water to air (cooling mode)	59°F entering water	18	EER	10
	Groundwater Source water to air (heating mode)	50°F entering water	3.7	COP	10
	Groundwater Source water to water (cooling mode)	59°F entering water	16.3	EER	10
	Groundwater Source water to water (heating mode)	50°F entering water	3.1	COP	10
Data based ASHRAE 90.1-2016 Table 6.8.1-2. All equipment types assumed to be less than 135,000 Btu/h.					

Figure 12. Geothermal Systems Specifications

7.03 Energy Consumption

The Energy Consumption tab within the *SCA Geothermal Feasibility Tool* displays the Bin analysis calculations performed based on Central Park, NY weather data from the BinMaker software tool to calculate the total energy consumption of each system type studied. BIN hours were separated into average school occupied hours and average school unoccupied hours, based on an occupied schedule of an average of 4.5 days per week, 7am-6pm on full days. From this, heating and cooling load profiles were developed for both occupied and unoccupied periods.

Annual electric energy usage (kWh) are calculated for each system type based on load, hours, and equipment efficiencies. Energy usage for the heat pumps, pumps, and heat rejection systems were evaluated. The geothermal system types were calculated with the assumption that these are variable flow well water systems.

7.04 Energy Demand

The Energy Demand tab within the *SCA Geothermal Feasibility Tool* displays the monthly and annual cooling electric demand, monthly and annual heating electric demand and total plant monthly and annual electric demand calculated for each system studied based on the values inputted in the Summary tab and the Baseline Systems tab. As the new SCA standard HVAC system is all electric, the peak demand is expected to be higher than the geothermal systems.

7.05 Energy Cost

The Energy Cost tab within the *SCA Geothermal Feasibility Tool* calculates the total energy cost of each system studied based on the total energy consumption calculated in the Energy Consumption tab and the total demand calculated in the Energy Demand tab along with the utility rates entered in the Summary tab.

7.06 Capital Cost

The capital cost for each heating and cooling plant system type is variable depending on the particular system design and project bidding conditions. With the proposed design for geothermal equipment within the building being variable and assuming institutional level equipment being used the majority of the cost difference between the geothermal options and baseline systems is in the well field or well water systems. The construction cost ranges for the various geothermal options include parameters such as the amount of well casing required for the particular site-specific drilling conditions along with heat exchangers and pumping systems for standing column/ open loop systems. Well field construction costs were developed with the help of well field contractors familiar with installing various well field systems within the 5 boroughs.

An assumption was made that air handling systems within the building would meet SCA standards and have load reducing strategies such as energy recovery and demand control ventilation which is critical for reducing plant equipment and well field capacities.

The tool also assumes that SCA requirements for a perimeter radiation heating system is included in all system types in order to reduce off hours fan energy usage. Building fan energy usage is assumed to be similar for each system type and will be based on actual design.

7.07 Annual Maintenance Cost

The Annual Maintenance Cost tab indicates the incremental low and high maintenance costs for each system studied per year. The SCA standard HVAC system maintenance costs were primarily based on annual cleaning of the air-cooled condensers for each rooftop unit. The geothermal closed loop maintenance costs were based on minor water treatment required annually. The geothermal standing column system maintenance costs were based on heat exchanger and well pump maintenance costs. The geothermal open loop system maintenance costs were based on heat exchanger, water filtration, and well pump maintenance costs. The tool indicates a significant variance in maintenance costs for both standing column and open loop systems due to site specific water quality and actual system installation.

7.08 Carbon Impact

The Carbon tab within the spreadsheet tool indicates the annual carbon dioxide emissions cost per system type studied. This is determined by using Energy Star's CO2 emission rates for electricity. In addition, LL6 dollar value per metric ton of carbon dioxide equivalent per year was used to determine this cost estimate.

7.09 System Life Expectancy

The System Life Expectancy tab within the spreadsheet tool indicates the estimated low and high life expectancies of each system type studied. These values were taken from ASHRAE's Life Expectancy Chart while the life expectancy on the geothermal heat pump systems were based on industry standards. NPV analysis for all systems are currently based on 20 years in the tool per LL6, so this specific system information is not yet factored into analysis. Factoring this in would further disadvantage geothermal systems.

7.10 Net Present Value (Low)

The NPV (Low) tab within the SCA Geothermal Feasibility Tool spreadsheet indicates the low net present value analysis on each system type studied. The net present value calculations are based on the initial costs (capital costs) of each system type, the total annual costs (utility cost, maintenance cost, and carbon cost) of each system type, along with an assumed discount/interest rate of 5%.

7.11 Net Present Value (High)

The NPV (High) tab within the *SCA Geothermal Feasibility Tool* spreadsheet indicates the high net present value analysis on each system type studied. The net present value calculations are based on the initial costs (capital costs) of each system type, the total annual costs (utility cost, maintenance cost, and carbon cost) of each system type, along with an assumed discount/interest rate of 5%. The high NPV calculations were developed using risk or lack of risk between the systems studied.