PGW 35588
Geothermal Feasibility Study

Primary Site:
John F. McCloskey Elementary School & Dorothy Emanuel Rec Center

8500 Pickering Ave.
Philadelphia, PA 19150

Prepared for:

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1 - EXECUTIVE SUMMARY

Alderson Engineering (AE) has prepared this Geothermal Feasibility Study for Philadelphia Gas Works (PGW). The purpose of this effort is to determine the technical and economic viability of implementing a shared geothermal heating and cooling system at the site serving John F. McCloskey Elementary School and Dorothy Emanuel Recreation Center in Philadelphia, PA.

PGW provides natural gas service to approximately 502,000 active accounts within the city of Philadelphia, using 6,000 miles of gas mains and services. PGW is the only utility currently distributing natural gas within the city of Philadelphia. Its mission is to enhance the quality of life for all by delivering safe, reliable, and affordable energy in an environmentally responsible way.

General

John F. McCloskey Elementary School is an 57,000 square foot elementary school operated by the School District of Philadelphia (SDP) at 8500 Pickering Ave. It was built in the 1950's and predominantly has the original HVAC systems (steam, heating and ventilation only) and electrical infrastructure.

The land is shared by the Dorothy Emanuel Recreation Center operated by Philadelphia Parks and Recreation (PPR) and the City of Philadelphia (COP). This is a 20,000 square foot neighborhood recreation center with gymnasium, 4 classrooms, and other supporting spaces. It was built in the early 2000's and has the original HVAC systems (2 DX cooling, Gas heating RTUs).

Site

The site of the two buildings is a single parcel owned by the SDP, spanning approximately 5.7 acres, generally the entire block between Pickering Ave & Provident St and E Gowen Ave & Roumfort Rd.

PPR operates an additional building onsite used for food donation and distribution. The most Northwest portion of the site is generally fenced in and has a baseball field with backstop. The site has had a playscape improvement completed in 2026.

The geological conditions of the site are the Bryn Mawr Formation on top of the Wissahickon Formation. The Wissahickon Formation is composed of primarily a hard bedrock (schist) that is favorable for vertical borehole drilling. Local thermal conductivity tests indicate moderately above average thermal conductivity, which is an important parameter in geothermal system performance.

The drilled vertical closed-loop borehole system will fit on the project site.

Environmental

An environmental study was performed regarding the site. The study included RCRA Exposure, NEPA Exposure, and PNDI review. Research of the current and historic uses of the property, environmental databases, and the results of interviews indicate that no recognized environmental conditions, historical recognized environmental conditions, or controlled recognized environmental conditions could be found for the subject property or adjacent sites.

Systems

John F McCloskey Elementary School (MES)

The existing equipment at this school does not provide cooling, has exceeded its expected lifetime, and is recommended to be replaced.

At this feasibility study level, a few system configurations were reviewed for the replacement option, since there a several configurations that suit the HVAC retrofit for this school. Those configurations are:

(1) Geothermal Option 1 – Distributed WSHP

(2) Geothermal Option 2 – Water-to-Water Heat Pump Plant w/ 4-pipe Fan Coil Units

These systems are compared to an Air-Source Heat Pump replacement system so that a comparison between similarly featured equipment can be made, and the operational comparison has the inclusion of cooling in the baseline, like the geothermal options provide.

A "replace in kind" version of the system was also evaluated.

Dorothy Emanuel Recreation Center (DER)

The existing equipment at this recreation center is original to the building and approximately 24 years old, which is nearing the end of its expected service life. The HVAC replacement configuration for this facility is:

(1) Geothermal Option – Distributed WSHP [Roof Top Units]

This system was compared to an Air-Source Heat Pumps with Gas-fired backup solution, which is nearly a replace in kind. Energy codes have progressed to include air-to-air energy recovery requirements since the construction of this building, so the solutions include that energy saving feature.

Geothermal Utility

The planned borehole system, related delivery pump systems, and enclosures would be placed on the grass area next to the playing field area of the site. A new prefabricated building would be required to house and provide utility connections for the pumping infrastructure. The geothermal utility would deliver fluid to a heat exchanger system in each of the connected buildings. A reduced cost alternate to the new prefabricated structure would be to house the utility pumping infrastructure in the school's basement.

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Costs

The studied primary geothermal solution for the combined project is expected to cost near $19M. Projected potential incentives, primarily through the Investment Tax Credit (ITC), could reduce that total cost by about $7.6M. The net total cost is estimated to be nearly $11.4M.

A secondary solution alternative studied, that moves the compressors out of the classrooms, is expected to cost near $25M. Projected potential incentives, primarily through the ITC, could reduce that total cost by about $10M. The net total cost is estimated to be nearly $15M.

Currently, commercial geothermal heating and cooling systems are eligible for an Investment Tax Credit (ITC) through the Inflation Reduction Act (IRA) of 2022. The credit available to the project would be 40%, through compliance with the Prevailing Wage and Apprenticeship requirements and meeting Domestic Content requirements. The project is not in an Energy Community and does not qualify for an additional 10% credit. The current regulations of the ITC make the credit applicable if both the borehole system and the building systems are owned by the same entity, but not if they are owned separately.

Additionally, this project may be eligible for funding support from local entities such as PECO through product rebate (water-cooled equipment and VFDs) and other grant programs. If the ownership of the system is by a business, Modified Accelerated Cost-Recovery System (MACRS) depreciation could be applied.

The operating and expected maintenance costs have been estimated and incorporated into Life Cycle Cost Analyses. By way of capturing the ITC, <u>the whole project costs for the geothermal solution are expected to be lower than a comparable traditional system option.</u> Operational and maintenance cost estimates yield additional annual savings over the non-geothermal baseline options. The replacement interval of the geothermal equipment is expected to be longer than traditional options, further enhancing the long-term savings.

The geothermal system uses less energy than the comparable alternatives and therefore will result in reduced equivalent carbon dioxide emissions when compared at the source-level. Social Cost of Carbon (SCC) estimates yield reduced impact over the non-geothermal baseline options.

When the scope is limited to replacing existing heating equipment, natural gas remains the lowest-cost option from both a capital and operating-cost perspective. John F. McCloskey Elementary School currently uses an oil-fired heating system and lacks central air conditioning. However, when compared with a natural-gas-fired heating retrofit that also includes a new central cooling system, and assuming the full projected Investment Tax Credit can be captured, the primary geothermal solution is the lowest-cost option evaluated. This is fully dependent on the Investment Tax Credit offsetting approximately 40% of the geothermal project cost.

Scalability & Repeatability

This study primarily focuses on the application to suit the two subject buildings. Alternate configurations for the geothermal distribution system are discussed that would enable/simplify expansion of the system to incorporate properties nearby. The alternate configuration (single-pipe) has more upfront cost to implement.

When the system is planned in this alternate configuration, the order and location of customer connections is important to the performance of each customer, whereas the primary application delivers the same temperature profiles to both buildings. The alternate configuration would need to be planned with speculative customer loading and would have a finite limit to the number that could be connected.

The nearby properties are predominantly residential homes. The lot density offers a noteworthy potential customer base opportunity, and the load profile of the homes compliments the school and recreation center's profile offering some diversity. The load requirements of the school and recreation center do not fully utilize the school's lot, so there may be opportunity to modestly increase the geothermal system to serve a limited number of homes.

Repeatability will rely on the future development of company standards for materials, construction methods, contracting, and in-house design capabilities.

Next Steps

1. This study has reviewed multiple options for system types as the configuration for McCloskey Elementary School. The School District of Philadelphia should review these options with their goals for the HVAC replacement at the school to determine which to pursue for further design development.
2. PGW, SDP, & PPR will need to determine possible ownership strategies and funding sources.
3. Energy cost rate structures will need to be evaluated.
4. PGW will need to review with the PA Public Utility Commission (PUC).
5. Perform an on-site geothermal thermal conductivity test.
6. Proceed with Design Development of the selected options.

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2 - GENERAL

INTRODUCTION

This geothermal feasibility study evaluates the scope of work to provide a utility-style energy service to two buildings on the same site. The scope is broken into several distinct parts to align with each stakeholder in the project:

- Philadelphia Gas Works (PGW)
- The School District of Philadelphia (SDP)
- Philadelphia Parks and Recreation (PPR)

The delivery of thermal energy contained in the form of an aqueous fluid to a customer heat exchanger to absorb heat from or reject heat to condition the operating fluid temperature of a water-source heat pump HVAC system shall be provided by PGW. This shall be accomplished by constructing a geoexchange system that is operated and maintained by PGW.

The School District of Philadelphia and Philadelphia Parks and Recreation shall each retrofit their facilities and equipment to geothermal water-source heat pump systems. They shall operate and maintain all building HVAC equipment.

For the purposes of this study, the heat exchangers that interface the utility system to the building systems shall be attributed to the utility portion of the network system.

The networked buildings are comprised of the following:

Description	Occupancy Type	Total Area (S.F.)
John F. McCloskey Elementary School	Educational	
Basement – Original Building		4,500
Ground Floor – Original Building		27,200
Ground Floor – Temporary Wing		7,700
Ground Floor – Library/Computer Addition		2,100
Second Floor - Original Building		15,500
Dorothy Emanuel Recreation Center	Assembly	20,000
Total	------	77,000

FEASIBILITY CRITERIA AND DOCUMENTATION

Available Land Area

The required land area must be available for the system type and size. This has been reviewed in in this study, see 3 - SITE section. There is enough land on this site to serve the buildings with a geothermal borehole system.

Subsurface Conditions

The project geology must support the selected system type. This has been reviewed in in this study, see GEOLOGY section. The geology is generally acceptable for this system application.

Environmental Impacts

The provision of the system must not create immediate environmental harm. This has been reviewed in in this study, see 4 - ENVIRONMENTAL section. The

Life Cycle Cost Analysis

The project must meet each stakeholder's lifecycle cost and payback requirements. An evaluation has been prepared in the LIFE CYCLE COST ANALYSIS section.

Upfront Capital Costs

The project must meet each stakeholder's funding capabilities. Costs estimates have been prepared in 6 - COSTS section.

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Documentation

Supporting Documents

The study includes several supporting documents that have been included as 9 - APPENDICES. See the list of appendices at the end on this study on page 51.

[redacted]

Reports

- McCloskey - FCA Report 2022
- McCloskey - AHERA - 3-Year Report 10-2024
- McCloskey - Utility Report - 36 months (01-2022 - 12-2024)
- Dorothy Emanuel Rec Center – Utility Report - 36 months (07-2022-06-2025)

New Records

We have transcribed the pertinent information from the existing record plans (from scans) to approximations within a Building Information Model (BIM) using Autodesk Revit for the McCloskey. This model is considered an Instrument of Service, not a deliverable.

The BIM was used to prepare the 30% design documents.

GEOTHERMAL SYSTEM TYPES

Geothermal systems are a type of heating and cooling system that uses thermal exchange with the ground as a source or sink of energy. Most commonly the application of geothermal systems for building heating and cooling systems uses water-source heat pumps to exchange energy with fluid circulated through or from the ground. There are two primary types of geothermal fluid systems: closed loop and open loop.

Some geothermal heating and cooling systems use more types of energy sources than just geoexchange. Those type of systems are called hybrid systems.

Closed Loop

Closed loop geothermal systems are systems where the piped heat exchange fluid is in a completely closed system. The fluid only circulates through the piping and equipment and therefore fluid quality can be controlled. Closed loop geoexchange systems rely on the heat transfer through the pipe wall of the pipe buried in the ground or submerged in water. The control of the fluid promotes longer equipment lifetimes and less overall maintenance.

Closed loop geothermal systems can be come in several general configurations that can be used to meet specific project needs.

Vertical Borehole

Vertical borehole systems are the most commonly applied to commercial buildings because they typically have the best land to load requirement. Drilling deep boreholes, commonly 300-500 feet, and sometimes deeper, requires less real estate than other closed loop options.

Horizontal

Horizontal systems are usually planned in two forms:

Straight

Straight horizontal systems are similar to vertical boreholes, except they are installed in long horizontal trenches (or directional drilled). These are typically installed about 3-8 feet below the ground and can be used when there is plenty of available land and deep drilling is cost prohibitive.

Slinky

Slinky horizontal systems are installed by trench excavating wide trenches and stretching out a coil of pipe so that the rings of the coil overlap to a degree. These are used when lans is less available than for straight horizontal systems, or less trenching is desired and directional drilling is not preferred.

Inclined Boreholes

Inclined borehole systems are directionally drilled at an angle between vertical and horizontal, usually closer to vertical. This technique is used to drill boreholes under on grade constraints or when limited setup areas are available. Some installations are planned to create a “cone” of boreholes. This installation method requires specialized drilling equipment and techniques that many drilling contractors do not have.

Body of Water

Some geothermal piping systems are installed in bodies of water (ponds, lakes, rivers, etc.) Often tight coils of piping are weighted and submerged into the water body. The pipes must be installed deep enough that they do not experience freezing conditions and that the water flows or circulates adequately year-round to meet the system capacity. Careful attention needs to be paid to the potential disruption to the environment.

Open Loop

Open loop systems differ from closed loop system because they draw groundwater into the pipe system and discharge it out. This type of system is subject to the water quality from the groundwater, which often contains particulate and dissolved minerals. These foreign materials create accelerated wear and tear and surface contamination that is detrimental to the service life of the pumps, heat exchanges, and/or heat pump equipment. Mineral buildup will also diminish the heat transfer over time.

These systems predominantly rely directly on the groundwater temperature, which is even more moderate than typical closed loop systems' fluid temperatures. This allows the heat pumps to operate at even higher efficiency. In exchange for that increase heat pump efficiency is commonly additional pumping power required to lift the groundwater up to the surface.

The significant increase in maintenance and replacement equipment costs often makes this system type less preferred than a closed loop option.

Another challenge for this type of geoexchange system is that it is dependent on the available groundwater flow at the site. Geotechnical investigation for this type of system is often riskier and more expensive to perform than thermal conductivity testing on closed boreholes. The well yield is important to the overall capacity of the system.

Supply / Return

This configuration of an open system extract groundwater from a supply well and discharges it to one or more diffusion (return) wells.

Standing Column

This configuration draws the ground water from the borehole and then returns the groundwater to the same well through a concentric pipe and pump arrangement. This type of configuration is similar a closed loop system, in that the conductivity of the geology plays a part in the total capacity of the system.

Body of Water

This type of configuration draw water directly from a body of water and usually returns it to the same source. This type of system has significant filtering requirements and the highest frequency of needed maintenance to ensure particulate does not inhibit the system operation. Careful attention needs to be paid to the potential disruption to the environment.

Hybrid

A hybrid geothermal system is not related to open or closed but instead implies that a second heat exchange method is used to supplement the geoexchange system. Hybrid systems are used in various types of scenarios. Reasons hybrid system are planned include: limited site resources for full geothermal capacity, energy optimization techniques, funding constraints, or additional resiliency. System sizing techniques vary and include peak shaving, thermal storage, or true backup.

Heating

Heating hybrid systems typically include boilers to support minimum entering fluid conditions to the system equipment.

Cooling

Cooling hybrid systems usually include dry coolers or cooling towers to limit the maximum entering fluid temperatures to the equipment.

Cooling hybridization equipment operation can be optimized by controlling the operation to non-peak load times of the day and year.

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3 - SITE

GENERAL

The site of the subject buildings is owned by the School District of Philadelphia. It consists of 5.7 acres, generally the entire block between Pickering Ave & Provident St and E Gowen Ave & Roumfort Rd, in NW Philadelphia, PA.

Figure 1 - Site Boundary **Figure 2 - Birds Eye of Site from Google Streetview**

The SE portion of the lot is utilized by the existing elementary school and courtyard play areas.

The recreation center is sited along the SW side of the property.

Along the NE side of the site are two fenced basketball courts and a food pantry building, that was previously used a recreation center prior to the Dorothy Emanuel Recreation Center being built.

The spaces between the three buildings onsite are generally covered in hardscape (asphalt, concrete and other paving). Play structures were installed in 2025/2026 between the food pantry and the recreation center.

The grass-covered and playing field area of the NW portion of the site is approximately 77,000 SF (1.7 acres). The site is crossed by a few small site lighting power conduits installed relatively shallow below grade. A few large trees are growing around the perimeter of the field. This perimeter of the site has tall chain link fencing.

This grass-covered and playing field area of the site could accommodate approximately ±180 boreholes (20' on center). It would be recommended to limit the installation of any boreholes to limit significant impact to existing fencing. This is more than adequate to support the two project buildings. See APPENDIX D - 30% Design Drawings, Sheet GEO-A.

HISTORICAL USE OF THE SITE

Up until 1952 the property remained primarily undeveloped except for a singular road running through the site boundaries. Holy Sepulcher Cemetery and Ivy Hill Cemetery lie to the north and south of the site respectively. The Cedarbrook Country Club is marked to the east of the site.

The John F McCloskey Elementary School was built in 1954. The school had two additions built prior to 1990; a six classroom expansion wing and a library/computer room.

The Food Pantry building was built prior to 1988.

The Dorothy Emanuel Recreation Center was built in 2004.

BUILDINGS ON SITE

John F McCloskey Elementary School

The existing 2 story school consists of approximately 26 instructional spaces, a combination gym/cafeteria, an auditorium, offices and other supporting spaces. The approximate building gross square footage is 57,000 SF.

The original 19 classroom building has a 6 classroom addition (Blue below) and another single classroom space addition (yellow below). The entire original building has a substantial basement and crawlspace below the ground floor.

See also APPENDIX H.1 - Existing Building Plans: John F. McCloskey Elementary School.

Cooling loads for school buildings often fall between 150-350 SF/Ton. Because this school is older, it is on the lower end of that, at about 185 SF/Ton.

[redacted]

Dorothy Emanuel Recreation Center

The existing single story recreation center is built on a slab on grade. The approximate building gross square footage is 20,000 SF.

See also APPENDIX H.2 - Existing Building Plans: Dorothy Emanuel Rec Center.

Cooling loads for recreation centers often fall between 90-400 SF/Ton. This facility is about 180 SF/Ton.

Food Pantry

The existing single food pantry center is built on a slab on grade. The approximate building gross square footage is 1,700 SF. This building is not being considered at this time as part of the geothermal feasibility study.

[redacted]

GEOLOGY

The local geology of the area was researched using the Commonwealth of Pennsylvania Department of Environmental Resources, Bureau of Topographical and Geologic Survey Geologic Map of Pennsylvania.

The site is underlain by the Bryn Mawr Formation (Tbm), a gravelly sand formation common throughout the Southeastern Pennsylvania region. This formation is relatively shallow. These soils have generally been altered by leveling and filling operations associated with urban development and therefore surficial soils can vary considerably in soil type, color and density. Soils natural to the area consist of silt, sand, and gravel derived from weathered schist and gneiss associated with local bedrock formations.

The surficial soils of the area are underlain by the Wissahickon Formation (Xw) of Lower Paleozoic Age. The Wissahickon Formation consists of oligolclase-mica schist and includes some hornblende gneiss, some augen gneiss, and some quartz-rich and feldspar-rich members due to various degrees of granitization.

This type of geological formation typically results in reliable drilling experiences and is suitable for geothermal vertical boreholes.

Figure 5 - USGS boundaries for geological units, on and near site.

Well Drilling Logs

Brightcore reviewed publicly available well drilling logs within one mile of the school obtained from the Pennsylvania Department of Conservation and Natural Resources. Because geology can change significantly within a short distance, utilizing well logs in close proximity to the school is crucial for selecting relevant data. A summary of relevant well log data can be found in the table below.

Well Address	Distance From Site (mi)	Well Depth (ft)	Depth to Bedrock (ft)	Overburden	Bedrock	Water Production
3200 W Cheltenham Avenue	0.17	41	7	Fill	Schist	N/A
1413 Firethorne Lane	0.47	95	23	N/A	N/A	25 GPM @ 19ft
1501 Firethorne Lane	0.48	110	23	N/A	N/A	30 GPM @ 19ft
8111 Woolston Ave	0.66	52	32	N/A	Schist	N/A
1044 E Sedgwick Street	0.80	47	27	N/A	Schist	N/A
1044 E Sedgwick Street	0.80	42	30	N/A	Schist	N/A
813 Gilbert Avenue	0.87	325	20	Dirt	Grey Rock	N/A
8110 Flourtown Avenue	0.89	150	35	N/A	N/A	25 GPM @ 12ft
300 Longfellow Road	0.97	500	50	Sand	Shale	N/A

Table 1 - Local Well Drilling Logs

The referenced well logs indicate a shallow overburden with a depth to bedrock ranging from 20-35 feet below the surface. This is a favorable depth to bedrock for geothermal drilling, as a minimal amount of steel casing is required to maintain borehole integrity in the overburden before more stable bedrock is reached.

Water Table

Some of the well logs reviewed provide information on the static water level encountered during drilling, which we used to estimate the groundwater depth at the school. Based on these logs, the groundwater depth appears to be relatively close to the surface, with depths ranging from 10 to 20 feet below the surface with 25 to 30 GPM of water production. This shallow water level and low production means that normal levels of water production can be expected during drilling, which can be managed with an effective water management system. Drillers will need to implement standard water management procedures at all of their drilling locations that would effectively be able to manage the expected production levels at this site.

THERMAL CONDUCTIVITY ESTIMATES

Historically Recorded Thermal Conductivity Data of the Region

Below is a table of nearby thermal conductivity borehole test data that are within our records.

Project Site	City, State	Dist	k	α	Temp	Driller's Rock Description
		mi	BTU/hr-ft-°F	ft2/day	°F	
McCloskey Elementary	*Philadelphia, PA*	*0*	*Reference Project Site*			
Arcadia University	Glenside, PA	1	2.25	1.36	55.4	Gray Schist
Germantown Friends School	Philadelphia, PA	3.3				
Office	Ambler, PA	5.5	1.89	1.46	56	Shale
Library	Lower Merion, PA	6.4	1.41	0.87	56.5	Schist, Gneiss, & Granite
Unknown	Hatboro, PA	7.3	1.71	1.32	57	Shale
Kensington HS (CAPA)	Philadelphia, PA	7.5	2.03	1.23	57.5	Schist
Philadelphia Zoo	Philadelphia, PA	7.5				
Rec Center	Haverford, PA	8.6	1.67	1.27	57	Limestone
Police Training Facility	Philadelphia, PA	9.4				
Society Hill	Philadelphia, PA	9.4	1.38	0.87	59	
Corporate HQ	Warminster, PA	9.5	2.02	1.04	53.6	Shale
Broad Street #1	Philadelphia, PA	9.8	1.81	1.12	59.5	Schist
Broad Street #2	Philadelphia, PA	9.8	1.66	1.01	59.4	Schist
Montgomery Rec Ctr	Montgomeryville, PA	10.2	<1.05	Low	54.5	Argillite
Bartram Gardens	Philadelphia, PA	10.5				
Barry Playground	Philadelphia, PA	11.5	No Test Well Performed			
Nursing Home	Doylestown, PA	13.2	1.03	0.79	--	Shale
Arboretum	Berwyn, PA	13.8	1.55	1.00	57	Gneiss
High School #1	Bensalem, PA	14	1.98	1.00	54.8	Schist and Sandstone
High School #2	Bensalem, PA	14	2.05	0.99	55	Schist and Sandstone
High School #3	Bensalem, PA	14	2.09	0.92	--	Schist and Sandstone
Retirement Community	Newtown, PA	15.7	1.99	1.34	54.5	Sandstone & Shale
Fire Dept	Paoli, PA	16.4	1.29	0.88	57	Limestone
Schools	Woodbury, NJ	16.5	1.69	1.09	58	Silt, Gravel, Sand, Clay
Cheyney	Cheyney, PA	21.2	1.45	0.95	55.5	Gneiss
West Chester	West Chester, PA	23.4	1.52	1.05	57	Granite & Quartz
West Chester	West Chester, PA	24.4	1.73	1.17	--	Granite & Quartz

Table 2 - Nearby Thermal Conductivity Test Borehole Data

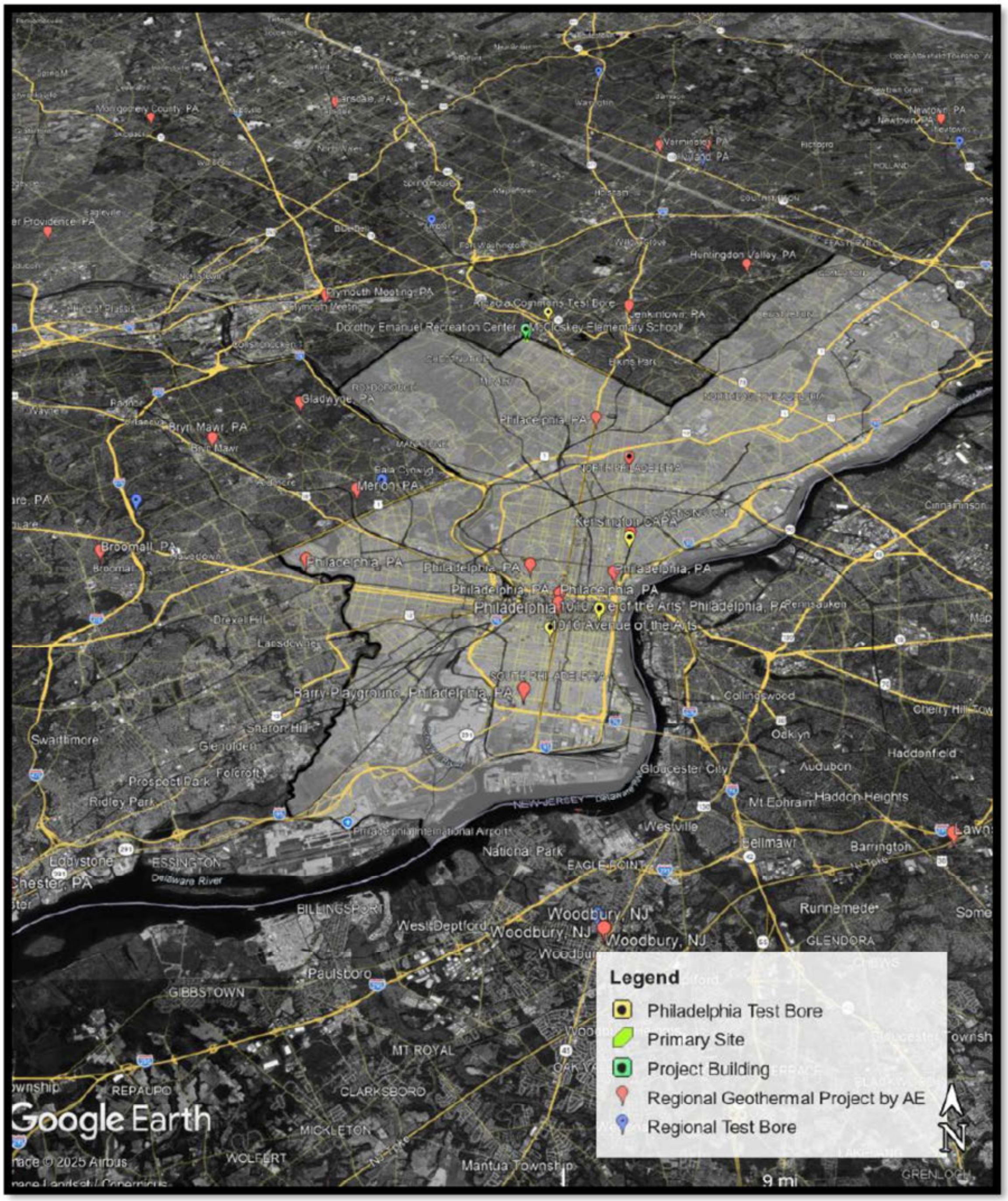

Figure 6 - Nearby Thermal Conductivity Test Borehole and Project Map

The closest thermal conductivity test information we have direct access to is 1 mile from the project site. It is located NE of the site on Arcadia University's Campus, and was prepared in conjunction with a 2009 project. The borehole was completed to 400' and experienced a gray schist (consistent with the expectations from this geological formation). During the drilling procedures, up to 10 GPM of groundwater were produced. The borehole drilling was performed by Geothermal Services, Inc. and the conductivity test report was prepared by Geothermal Resource Technologies, Inc. (GRTI).

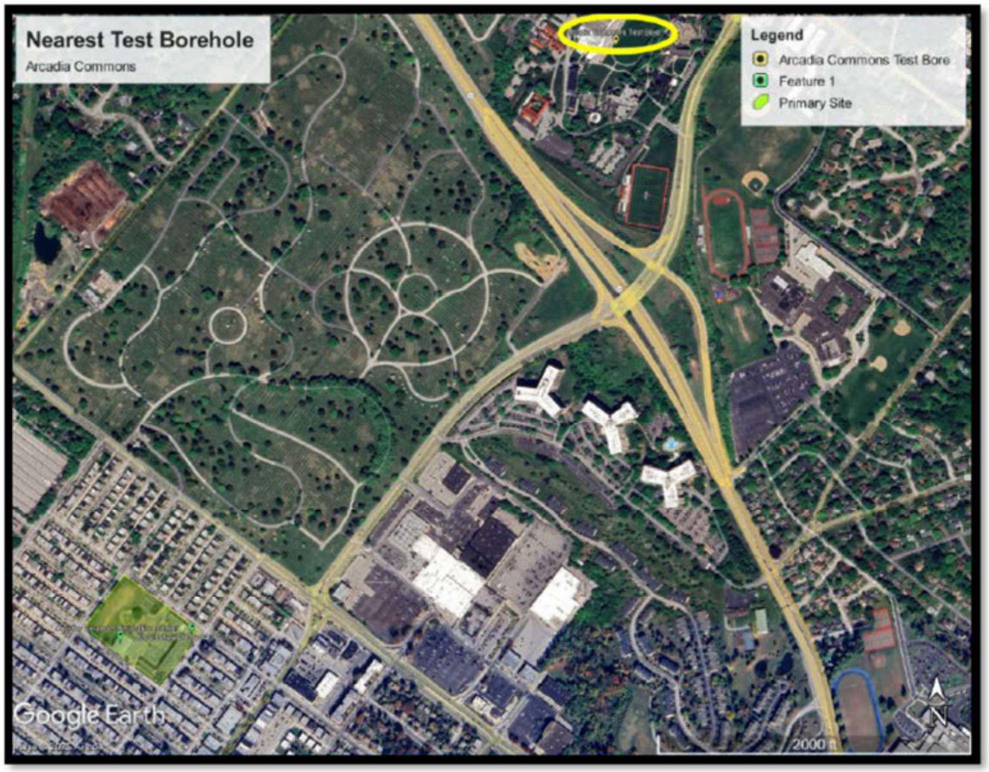

Figure 7 - Nearest Thermal Conductivity Test Borehole Map

Formation Thermal Conductivity = 2.25 $^{\mathrm{BTU}}/_{\mathrm{hr\text{-}ft\text{-}°F}}$

Formation Thermal Diffusivity ≈ 1.36 $^{\mathrm{ft2}}/_{\mathrm{day}}$

Undisturbed Formation Temperature ≈ 54.8-56°F

Recommendations for Future Test Boreholes

The ground conditions can vary over this or even smaller distances. An onsite thermal conductivity test is recommended in the next phase of the project's development.

We also recommend connecting with local well drillers, universities, and businesses to acquire additional Philadelphia regional information about the drilling conditions and available data.

4 - ENVIRONMENTAL

GENERAL

We retained Sci-Tek Consultants, Inc. (Sci-Tek) to perform an Initial Environmental Feasibility Study (IEFS) for the property of the John F. McCloskey School and Dorothy Emanuel Recreation Center located at 8500 Pickering Avenue and 8500 Provident Road, in Philadelphia, PA 19150, respectively. The Initial Environmental Feasibility Study was requested as part of this Geothermal Feasibility Study for Philadelphia Gas Works (PGW).

FINDINGS AND OPINOINS

The property is not within a 100 or 500-year flood zone.

No wetlands are mapped on site.

The average radon level for the 19150 zip code is reported on average as 2.3 picocuries per liter. This concentration is below the EPA action level of 4.0 picocuries per liter.

The PNDI Environmental Review Tool returned no potential conflicts with known species or resources of concern.

RCRAInfo returned some nearby sites that may generate, transport, store, treat and/or dispose of hazardous waste as defined by the Resource Conservation and Recovery Act (RCRA) of 1976 and the Hazardous and Solid Waste Amendments (HSWA) of 1984. Each is downgradient of the project site and is unlikely to pose an environmental risk.

National Environmental Policy Act (NEPA) only applies to federal facilities; therefore there are no NEPA related issues.

Research of the current and historic uses of the property, environmental databases, and the results of interviews indicate that no recognized environmental conditions, historical recognized environmental conditions, or controlled recognized environmental conditions could be found for the subject property or adjacent sites.

The assessment has revealed evidence of Business Environmental Risks (BERs) in connection with the subject property. The underground heating fuel storage tank onsite should be tested for integrity. Drainage is reportedly slow in some parts of the school site.

> These Business Environmental Risks would not affect the installation of a geothermal system.

No notable data gaps have been found in the study.

For more information refer to: APPENDIX B - Initial Environmental Feasibility Study

5 - SYSTEMS

Overall Systems

The primary stakeholders have discussed that the building systems and the geothermal system should be interfaced at plate and frame heat exchangers. The conceptual arrangement follows the general diagram below. Blue lines represent the geothermal utility piping. Green represents the building-side system.

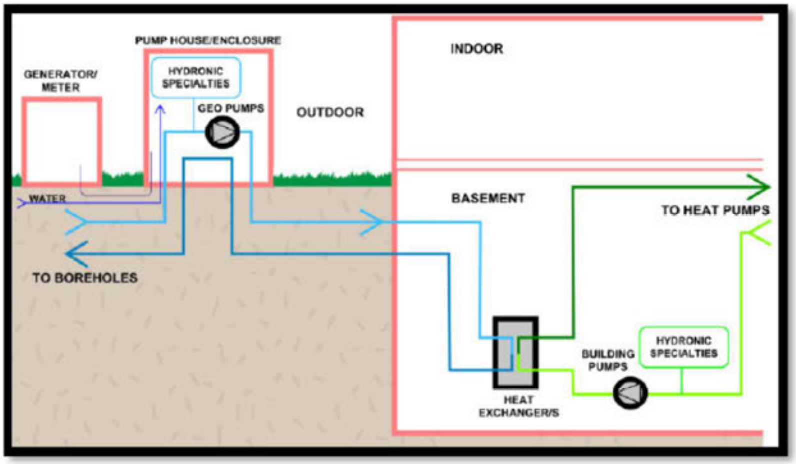

Figure 8 - Concept Geothermal Flow Diagram

The below site plan shows the conceptual arrangement of the borehole field, the pipe mains of geothermal loop, the initial location of the prefabricated pumphouse building.

This layout has been optimized to serve the two building in this study. It minimizes the geothermal loop piping, but routes it in a way that future expansion would be more challenging and costly.

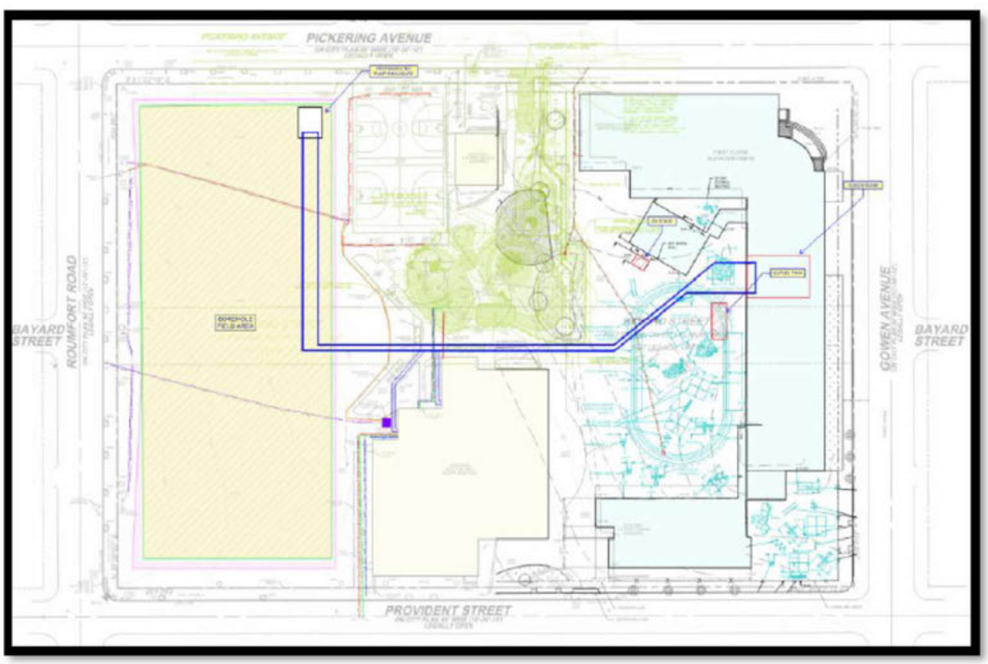

Figure 9 – Conceptual Geothermal Site Plan

The primary geothermal solution in this study uses the general configuration of the conceptual flow diagram below, where building-side central pumping flows through the heat exchanger and then delivers the fluid to distributed GWSHP through the building through a two-pipe distribution system. In this arrangement, individual GWSHP can independently operating in heating or cooling modes from the two-pipe system.

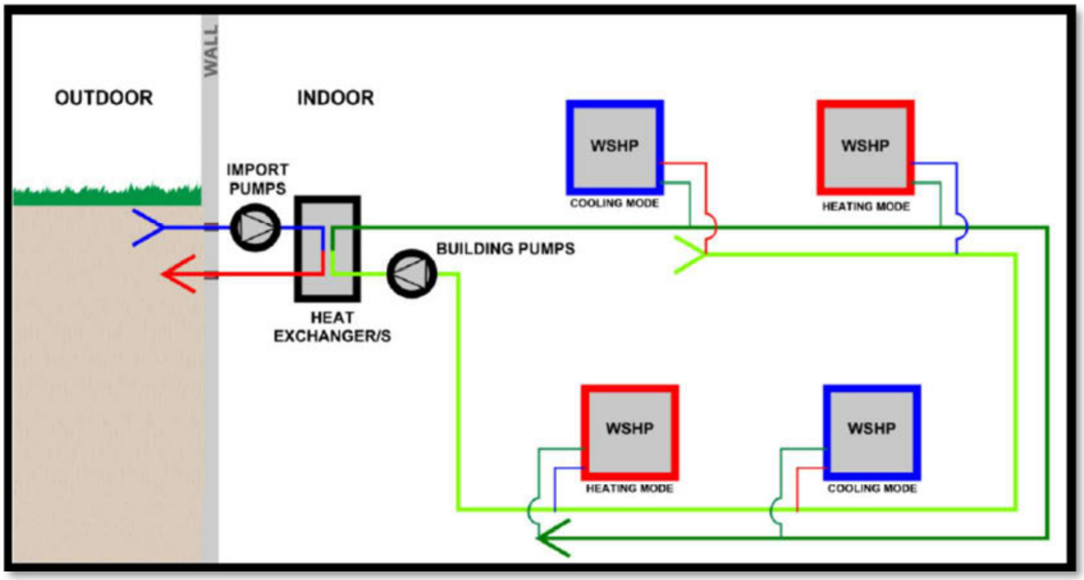

Figure 10 - Building-side Concept Flow Diagram

30% Design Documents

In APPENDIX C - 30% Design Narrative and APPENDIX D - 30% Design Drawings, several design options are explored. The primary options are summarized in this report.

In the 30% documents, two system options for typical geothermal solutions for schools are presented, one with distributed compressors, the other with centralized compressors. For each of these geothermal options a corollary non-geothermal solution was developed, so that they would be comparable.

We also outlined a replace-in-kind option, that represents a no enhancement replacement of the equipment that is past its expected life. This is for reference, so that the total cost of the project has a full perspective.

For the recreation center only one geothermal replacement option was studied. A non-geothermal replacement option was also developed for comparison. This non-geothermal replacement options is nearly a replace-in-kind option, so an independent version was not also created.

John F McCloskey Elementary School (MES)

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Predominantly, the school does not have air conditioning. A few classrooms and offices throughout the school have window air conditioners. One space has a mini-split air conditioner.

[redacted]

[redacted]

The table below summarizes industry recommendations for expected electrical equipment service life. All significant electrical equipment in the facility is beyond its expected service life and should be planned to be replaced.

Equipment Type	Expected Useful Life Period (years)[1]
Transformers	25 to 30
Circuit Breakers	15 to 20[2]
Switchboards/Switchgear	30 to 40
MCC / Motor Starters	20 to 30
Panelboards	30
Motors	18 to 25
Generators	5 to 20
UPS	10
Luminaire	20
Capacitors (Power Factor Correction)	17
VFDs	20
Cable/Wire	30 to 40
[1]Life expectancy info collected from ABB, CDA, CDM, IEEE Gold Book, and Siemens.	
[2]By year 10, 50% of Circuit breakers don't function properly per specs. By years 20, 90% don't function properly.	

Table 5 - Electrical Equipment Service Life

Recommended Electrical System Modifications

The existing electrical service does not have the capacity or the voltage characteristics to serve any of the various planned HVAC modernization options.

- The existing electrical service feeders, service disconnecting means and related equipment shall be demolished and replaced with new.
- The new electrical service shall be rated for 3000A at 208/120V, 3Ø, 4W. It is anticipated that the new electrical service will be fed from a new padmount transformer located on site. The final location of the transformer shall be coordinated with PECO.
- Feeders shall be extended to new panelboards throughout to serve new HVAC equipment.
- [redacted]
- All panels and feeders to remain shall be tested in accordance with the latest published NETA standards and specifications. Testing shall be completed by licensed electrical testing agency.

Mechanical System Options

For the purposes of the feasibility study several system options are being considered. They are outlined as follows:

Geothermal Option 1 – Distributed WSHP

This option is the base geothermal case.

The Building HVAC system shall consist of distributed GWSHP units. The units are served by an insulated Condenser Water Supply and Return piping network.

The thermal energy is transferred from the Pair of Utility Heat Exchangers located in the boiler room.

For more information refer to: 235700 HEAT EXCHANGERS FOR HVAC

(These types of references throughout this study refer to sections within the 30% Design Narrative [Appendix C])

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The system will have a pair of condenser water pumps to supply flow. They are controlled and sized using a lead/lag configuration, which provides full backup in the event of a single pump being inoperable.

The System will use a pair of Motor Operated Valves to modulate the required flow through the pair of parallel Heat Exchangers. It will also include a main bypass of the heat exchangers.

The condenser water system will be charged with 25% propylene glycol with corrosion inhibitors. This allows the WSHP equipment to operate at lower temperatures, which helps to optimize the geoexchange size requirements.

Hydronic specialty devices shall be provided to maintain the operational excellence of the fluid systems.

For more information refer to: 232100 HYDRONIC PIPING, PUMPS AND ACCESSORIES

Figure 12 - MES-1A Unit Ventilator Concept

Unit Ventilators in the classrooms shall be replaced with Daikin (GRQ) GWSHP. The new units are longer than the existing unit ventilators. The adjacent piece of casework in the base building classrooms will need to be demolished. Provide a new custom shelving unit to match the existing and fill in any gap. The existing outside air sleeves be reused. The existing louvers will be reused in the original building and replaced in the temporary wing. This is referred to as MES-1a in the 30% documents.

For more information refer to: 238149.1a GWSHP Horizontal Unit Ventilators for MES-1a

<u>[Optional Enhancement, MES-1B]</u> *Unit Ventilators in the classrooms shall be replaced with Enhanced Vertical Airdale SchoolMate SMG GWSHP. The new units are narrower than the existing unit ventilators. An adapter back plenum and filler endcap will be required to align the unit with the existing window unit. Provide a new custom shelving unit to match the existing and fill in any gap. The existing outside air sleeves/louvers and operable sash of the window will be reused in the original building. The existing louver and sleeve in the temporary wing will be removed, infilled, and sealed. This is referred to as MES-1b in the 30% documents.*

Figure 13 - MES-1B Unit Ventilator Concept

For more information refer to: 238149.1b GWSHP Vertical, Enhanced Unit Ventilators for MES-1b

New console GWSHP shall replace convectors in offices, lounges, bathrooms, etc. Provisions for these units shall include cutting sleeves through the existing block and brick wall, providing galvanized steel lintels in the brick, louvers, and applying moisture barrier.

For more information refer to: 238149.2 GWSHP Console Heat Pumps for MES-1

New console GWSHP shall replace heaters in the hallways.

For more information refer to: 238149.2 GWSHP Console Heat Pumps for MES-1

New rooftop mounted packaged GWSHP shall be retrofitted to serve the recreation room and the auditorium. These units shall be mounted on the roof above the bathrooms and locker room areas adjacent to the upper fan room. Duct modifications will be necessary to increase the duct sizes to suit higher flow rates required for cooling air distribution. Condenser water connections will be routed to these locations. Additional Structural Support will be required.

For more information refer to 238149.3 GWSHP Rooftop Units with ERV for MES-1

New condensate disposal piping shall be installed from each unit. The piping shall collect through the crawlspace and discharge to a drain in the boiler room.

All new and remaining HVAC equipment shall be controlled with a new DDC BACNET building management system (BMS). The BMS shall include a local workstation and report all data to a web-enabled access.

Geothermal Option 2 – Water-to-Water Heat Pump Plant with 4-pipe Fan Coil Terminal Units

This option is an alternate geothermal case. This case offers two key benefits:

(1) the compressors are located in the boiler room, not the occupied spaces and

(2) when cooling and heating are simultaneously required, only one compressor transfers the energy instead of two.

Locating the compressor in the basement moves a regular source of noise from the units in the spaces (including classrooms) to the basement and centralizes the maintenance on that type of system component. There will be a fewer total number of (larger) compressors as well.

The Building HVAC system shall consist of a centralized plant of GWSHP modular units. The units will condition 4-pipe, chilled water / hot water distribution systems. The 4-pipe systems shall be piped to 4-pipe fan coils throughout the building. All three piping systems (condenser water, chilled water, and heating water) shall be insulated.

The thermal energy is transferred from the Pair of Utility Heat Exchangers located in the boiler room.

For more information refer to: 235700 HEAT EXCHANGERS FOR HVAC

Each of the three systems will have a pair of pumps to supply flow. Each pair is controlled and sized using a lead/lag configuration, which provides full backup in the event of a single pump being inoperable.

The condenser water system will use a pair of Motor Operated Valves to modulate the required flow through the pair of parallel Heat Exchangers. It will also include a main bypass of the heat exchangers.

The water-to-water GWSHP equipment will have a 6-pipe header configuration allowing the units to operate in any of three modes: Cooling, heating, or heat recovery.

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The systems will be charged with 25% propylene glycol with corrosion inhibitors. This allows the WSHP equipment to operate at lower temperatures on both the condenser water and chilled water systems, which helps to optimize the geoexchange size requirements. The water is comingled with the heating water system because of the way the equipment is valved, so equal concentration of antifreeze is required. This also provides some degree of freeze protection for coils that serve outside air.

Hydronic specialty devices shall be provided to maintain the operational excellence of the fluid systems.

For more information refer to: 232100 HYDRONIC PIPING, PUMPS AND ACCESSORIES

Unit Ventilators in the classrooms shall be replaced with Daikin or Nesbitt 4-pipe fan coil options. The new units are longer than the existing unit ventilators. The adjacent piece of casework in the base building classrooms will need to be demolished. Provide a new custom shelving unit to match the existing and fill in any gap. The existing outside air sleeves be reused. The existing louvers will be reused in the original building and replaced in the temporary wing.

For more information refer to: 238219.0 4-Pipe Horizontal Unit Ventilator Fan Coil Units for MES-2

New console units shall replace convectors in offices, lounges, bathrooms, etc. Provisions for these units shall include cutting sleeves through the existing block and brick wall, providing galvanized steel lintels in the brick, louvers, and applying moisture barrier.

For more information refer to: 238219.1 4-Pipe Fan Coil Console Units for MES-2

New console shall replace heaters in the hallways.

For more information refer to: 238219.1 4-Pipe Fan Coil Console Units for MES-2

New rooftop mounted 4-pipe fan coil units shall be retrofitted to serve the recreation room and the auditorium. These units shall be mounted on the roof above the bathrooms and locker room areas adjacent to the upper fan room. Duct modifications will be necessary to increase the duct sizes to suit higher flow rates required for cooling air distribution. Condenser water connections will be routed to these locations. Additional Structural Support will be required.

For more information refer to 238219.2 4-Pipe Rooftop Units with ERV for MES-2

New condensate disposal piping shall be installed from each unit. The piping shall collect through the crawlspace and discharge to a drain in the boiler room.

All new and remaining HVAC equipment shall be controlled with a new DDC BACNET building management system (BMS). The BMS shall include a local workstation and report all data to a web-enabled access.

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Dorothy Emanuel Recreation Center (DER)

Existing Conditions

<u>*Heating and Cooling*</u>

Two existing rooftop mounted DX/Gas-heat rooftop units serve the gymnasium and other spaces. These units are located on the roof. The existing equipment is enclosed by a louver wall and upper screen (enclosure). The upper screen must be disassembled to allow demolition of the existing units.

The compressors on these two rooftop units were replaced recently.

[redacted]

Figure 14 - Existing Rooftop Unit Layout (DER)


Existing Classroom

[redacted]

[redacted]

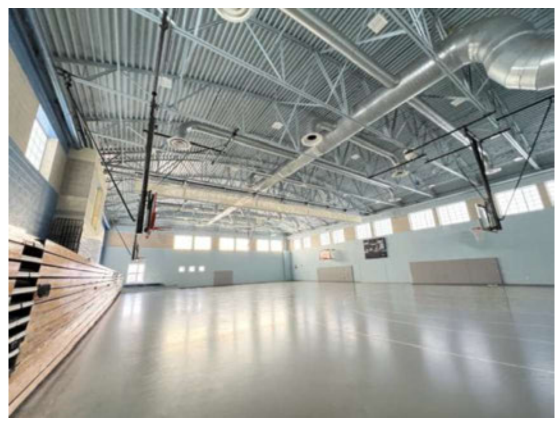
Existing Gymnasium

Table 6 - Existing Mechanical Equipment Survey Photographs (DER)

Electrical

[redacted]

[redacted]

[redacted]

[redacted]

Recommended Electrical System Modifications

The existing electrical service is expected to have the capacity to serve any of the various planned HVAC modernization options. No service upgrades are planned at this time.

Mechanical System Options

<u>*Geothermal Option – Distributed GWSHP [RTU's]*</u>

This option is the geothermal case.

The Building HVAC system shall consist of distributed GWSHP units. The units are served by an insulated Condenser Water Supply and Return piping system.

The thermal energy is transferred from the Pair of Utility Heat Exchangers located on the back wall of the Mechanical Room. A rated wall with doors shall be constructed so that the fire pump is separated from other equipment in this space, including the new HX and pumping equipment.

For more information refer to: 235700 HEAT EXCHANGERS FOR HVAC

The system will have a pair of condenser water pumps to supply flow located in the mechanical room. They are controlled and sized using a lead/lag configuration, which provides full backup in the event of a single pump being inoperable.

The System will use a pair of Motor Operated Valves to modulate the required flow through the pair of parallel Heat Exchangers. It will also include a main bypass of the heat exchangers.

The condenser water system will be charged with 25% propylene glycol with corrosion inhibitors. This allows the WSHP equipment to operate at lower temperatures, which helps to optimize the geoexchange size requirements.

Hydronic specialty devices shall be provided to maintain the operational excellence of the fluid systems.

For more information refer to: 232100 HYDRONIC PIPING, PUMPS AND ACCESSORIES

New rooftop mounted packaged GWSHP shall be retrofitted to serve the gymnasium and other spaces. These units shall be mounted on the roof on adapter curbs in the locations of the existing equipment. [redacted]

[redacted]

[redacted]

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6 - COSTS

Construction

Refer to APPENDIX F.1 & F.2 for detailed information about construction and project costs.

Incentive Estimates, Operating Costs, Maintenance Costs, Carbon Emissions SCC are estimated in further sections.

The cost estimates were prepared assuming no proprietary equipment is required for the project. While a basis-of design was selected for each equipment type, there are more than one viable equipment option when procuring the equipment. If proprietary equipment suppliers are required, costs for those portions of the work are expected to increase.

All this cost information is put into LCCA at the end of the costs section.

Geothermal Utility

Below is a summary of the construction costs for the various system options of this study.

Scope of Work		GEO-A (UB-A)	GEO-B (UB-A)
CONSTRUCION BUDGET:		$4,887,167	$6,081,320
DESIGN FEE ESTIMATE:	6%	$293,230	$364,879
PERMIT ESTIMATE:	0%	$0	$0
CONTINGENCY ESTIMATE:	20%	$977,433	$1,216,264
PROJECT COST SUBTOTAL:		**$6,157,830**	**$7,662,463**

Table 7 - Geothermal Utility Construction Cost

As reflected in the cost data above, the incremental added cost to provide the single-pipe network layout (GEO-B), in lieu of the optimized layout (GEO-A) is estimated near $1.5M.

An alternate configuration where the geothermal utility pumping infrastructure is placed in the basement of the elementary school instead of a new prefabricated utility structure has the potential to save about $416,000 (UB-B vs UB-A).

Geothermal Utility option costs must be added to each of the geothermal configurations below to determine total project costs, but not included in non-geothermal options.

For the purposes of the life cycle cost analyses, the optimized (GEO-A) layout was used.

John F McCloskey Elementary School (MES)

Below is a summary of the construction costs for the various system options of this study.

Scope of Work		MES-RIK	MES-0	MES-0B	MES-1A	MES-1B	MES-2
CONSTRUCION BUDGET:		$4,154,998	$8,687,282	$10,096,401	$8,370,412	$9,548,714	$13,096,513
DESIGN FEE ESTIMATE:	6%	$249,300	$521,237	$605,784	$502,225	$572,923	$785,791
PERMIT ESTIMATE:	0%	$0	$0	$0	$0	$0	$0
CONTINGENCY ESTIMATE:	20%	$831,000	$1,737,456	$2,019,280	$1,674,082	$1,909,743	$2,619,303
PROJECT COST SUBTOTAL:		**$5,235,297**	**$10,945,975**	**$12,721,465**	**$10,546,719**	**$12,031,380**	**$16,501,606**

Table 8 - MES Construction Cost

Dorothy Emanuel Recreation Center (DER)

Below is a summary of the construction costs for the various system options of this study.

Scope of Work		DER-0	DER-1
CONSTRUCION BUDGET:		$1,429,756	$1,813,786
DESIGN FEE ESTIMATE:	6%	$85,785	$108,827
PERMIT ESTIMATE:	0%	$0	$0
CONTINGENCY ESTIMATE:	20%	$285,951	$362,757
PROJECT COST SUBTOTAL:		**$1,801,493**	**$2,285,370**

Table 9 - DER Construction Cost

Incentives

Investment Tax Credit (ITC)

<u>Basics</u>

The Inflation Reduction Act (IRA) of 2022 restored and expanded ITC opportunities for geothermal projects. The credit is eligible for Direct Pay including tax-exempt entities. The base incentive for qualifying project costs is 6%. This base rate, like the Domestic Content and Energy Community bonuses, are multiplied by 5 when prevailing wage and apprenticeship (PWA) requirements are met for the project. The credit is realized during the tax year in which the eligible energy property is officially placed in service. This would typically be claimed 6-18 months after the project is completed.

The scope covered by the ITC % calculation would be based on the entire geothermal system. All its contributing components, including mechanical equipment, interior piping, insulations, electrical equipment, wiring, and new and modified general building components would be included. Allocated Indirect Costs are also eligible to be used in the % calculation.

An important characteristic of the credit, and related bonuses, is the five-year recapture period, during which the credit vests at 20% annually. If ownership changes or the facility ceases operations prematurely, the IRS may recapture the unvested portion.

<u>Domestic Content</u>

There is a +2% base rate bonus if the products used for the project meet US Domestic Source Content requirements.

Projects installed after 2026 will be required to meet 55% domestic content.

Each component provided for the project must be inventoried and have a domestic content % determination. The % determination is generally based on the material cost value of the individual components. The projects total aggregate percentage is used for qualification. This allows some products to not meet required thresholds, while other can make up for the short fall.

Generally, the products required for this project would be able to be sourced to comply with the needed domestic content. Confirming the appropriate products are procured to meet this requirement is an important effort that requires monitoring throughout the projects duration.

Domestic content success is often determined during design, specification, and procurement — not after installation. Requirements should be put in specification language and contracts.

This process typically requires domestic content affidavits from the companies providing the main equipment, so that they don't have to reveal proprietary information, but can demonstrate compliance.

Energy Communities

Like the Domestic Content bonus, there is a +2% base rate bonus to the ITC base rate for projects located in federally designated communities. These are Brownfield communities, Coal communities, and where employment in fuel related fields met specific criteria.

We have reviewed the US DOE Energy Community Tax Credit Bonus mapping tool provided with the National Energy Technology Laboratory. There are no designated energy communities in Philadelphia, so the project will not be eligible for this bonus.

Prevailing Wage and Apprenticeship (PWA) Requirements

To achieve a 5 times multiplier to the base rates of the ITC, projects must ensure that all tradespeople employed in the construction, alteration, or repair work are paid not less than applicable prevailing wage rates and to employ apprentices from registered apprenticeship programs for a certain number of hours. This is typically readily achievable in the Philadelphia labor markets.

These prevailing wage rates are found in general wage determinations on sam.gov/content/wage-determinations and are regionally and trade specific.

It is recommended to engage a consultant to review, monitor, and help administrate the process of diligence for compliance with the intricacies of the PWA requirements, as it lowers the risk of invalidating the 5 time multiplier for the ITC. Fees for this type of consultant are typically a very small percent (~1%) of the wages monitored in the prevailing wage base, and a fee based component for support of the domestic content monitoring and other administrative needs.

Any small premium cost that might result from the PWA and it's monitoring efforts will be offset many times over due to the 5 times multiplier.

Sample ITC

Category	Amount
Qualifying Direct Costs	$14,100,000
Allocated Indirect Costs	$705,000
Total Qualifying Costs	**$14,805,000**
Base ITC - 6%	$888,300
2% Domestic Content Bonus	$296,100
2% Energy Community Bonus	Not Qualified
Total Base ITC	$1,184,400
PWA Multiplier	X 5
Total ITC Achieved	**$5,922,000**

Table 10 - Sample ITC Calculation

Other Tax-related Incentives

Bonus Modified Accelerated Cost-Recovery System (MACRS) [Federal]

Section 168 of the internal revenue code contains a Modified Accelerated Cost Recovery System (MACRS) by which businesses can recover investments in solar, wind, and geothermal property through depreciation deductions. The MACRS establishes the time over which various types of property may be depreciated (3-50 years).

The allowance for bonus depreciation has since been extended and modified several times since the original enactment. Bonus depreciation is generally a faster depreciate period than otherwise allowed by the standard property type.

The One Big Beautiful Bill (OBBB) repealed the ability for "energy property" to qualify for the previous 5-year Modified Accelerated Cost-Recovery System (MACRS). Instead, the OBBB permanently restored 100% bonus depreciation in year one.

This is not available to non-profit organizations.

Tax deduction for energy-efficient commercial buildings

The federal Energy Policy Act of 2005 established a tax deduction for energy-efficient commercial buildings applicable to qualifying systems and buildings placed in service from January 1, 2006, through December 31, 2007. This deduction was subsequently extended several times, and up until recently was permanent.

$0.50 per square foot for a building with 25% energy savings,

Plus $0.02 per SF for each percentage point above 25%,

Up to a maximum of $1.00 per SF for a building with 50% energy savings.

Like the ITC, this incentive is granted a 5 times multiplier if PWA requirements are met.

Section 70507 of The One Big Beautiful Bill (OBBB) repealed this tax credit for property the construction of which begins after June 30, 2026. This project will not be able to receive this expiring tax deduction.

Note: Any tax related information herein is not tax advice. Stakeholders must review all tax-related matters with their tax professionals. Tax law is subject to continual change, at times on a retroactive basis and may result in incremental taxes, interest or penalties.

Energy Company Incentives

PECO Incentives

PECO Incentives are subject to availability and change from time to time. A plan administrator change is anticipated soon. At this time the incentives generally include the following:

Equipment Incentives

PECO offers equipment incentives for various types of equipment replacement. The program offers a per unit incentive for equipment types used on the project.

Equipment type	Size	Value	Unit
Water Cooled Heat Pump	<1.4 tons	$150	Unit
Water Cooled Heat Pump	1.4–5.4 tons	$250	Unit
Air Cooled Air Conditioner	<5.4 tons	$40	Ton
Air Cooled Air Conditioner	≥5.4 and <11.25 tons	$50	Ton
Air Cooled Air Conditioner	≥11.25 and <20 tons	$60	Ton
Air Cooled Air Conditioner	≥20 and <63.33 tons	$1,400	Unit
Air Cooled Air Conditioner	≥63.33 tons	$1,600	Unit
Air Cooled Heat Pumps	<5.4 tons	$75	Ton
Air Cooled Heat Pumps	≥5.4 and <11.25 tons	$85	Ton
Air Cooled Heat Pumps	≥11.25 and <20 tons	$85	Ton
Air Cooled Heat Pumps	≥20 tons	$1,800	Unit
Ductless Mini-Split Heat Pump		$50	Ton
Packaged Terminal Systems	<0.66 tons	$45	Ton
Packaged Terminal Systems	≥0.66 and <0.875 tons	$48	Ton
Packaged Terminal Systems	≥0.875 tons	$50	Ton
Air Cooled Chiller	<75 Tons, HVAC	$1,550	Unit
Air Cooled Chiller	75–150 Tons, HVAC	$3,100	Unit
Water Cooled Centrifugal Chiller	≥150 tons and greater	$20	Ton
Water Cooled Positive Displacement or Recip. Chiller	≥75 tons and greater	$20	Ton
VFD on Heating Hot Water Pumps	≤10 HP	$500	Unit
VFD on Heating Hot Water Pumps (PROCESS)	11–20 HP (≤10 HP)	$1,000	Unit
VFD on Heating Hot Water Pumps	21–30 HP	$1,250	Unit
VFD on Heating Hot Water Pumps	31–40 HP	$1,500	Unit
VFD on Heating Hot Water Pumps (PROCESS)	41–50 HP (11-20 HP)	$2,000	Unit
VFD on Heating Hot Water Pumps	> 50 HP	$2,520	Unit
VFD on PROCESS Motors	21–30 HP	$3,000	Unit
VFD on PROCESS Motors	31–40 HP	$3,500	Unit
VFD on PROCESS Motors	41–50 HP	$4,000	Unit
VFD on PROCESS Motors	> 50 HP	$5,799	Unit

Table 11 - PECO Incentives/Rebates

Whole Building Energy Savings

PECO has whole building incentive programs. These are typically reserved for new construction projects.

See APPENDIX I - PECO Commercial & Industrial Retrofit and New Construction Application, Instructions and Guidelines.

PGW Incentives

Commercial Equipment Rebates – EnergySense

Commercial Boilers used in the non-geothermal solution would be potentially eligible for rebates.

Commercial Boiler Equipment Rebates		
Equipment Size (kBtu/h)	Efficiency	Rebate
300-499	≥92% Et	$2,700
500-799	≥92% Et	$4,400
800-1,199	≥92% Et	$6,300
1,200-1,599	≥92% Et	$8,400
1,600+	≥92% Et	$9,000

Table 12 - PGW Rebates

Loan and Grant Opportunities

There are number of Loan and Grant opportunities that may apply to this type of project. More preliminary information about each can be found at https://programs.dsireusa.org/system/program/pa.

Wind and Geothermal Incentives Program: Department of Community and Economic Development

Loans for geothermal systems: $3 per square foot of space served up to $5 million

Grants for feasibility studies: 50% of cost up to $175,000

The Green Energy Loan Fund (GELF): US DOE, Commonwealth of Pennsylvania, Pennsylvania Department of Environmental Protection

Loans for 3rd Party Building Commissioning, Energy Audit or Modeling, Other Energy Soft Costs, ENERGY STAR office equipment, Cooling Equipment, HVAC Distribution, Ventilation Equipment, Heating Equipment

Municipal Opportunities for Retrofits and Energy Efficiency (MORE) Program: National Energy Improvement Fund

Loans for Energy efficiency upgrades (type not specified), building retrofits

Geothermal Renewable Energy Credits (GREC)

Ground-source heat pump installations in Pennsylvania qualify as Tier II alternative energy systems under the Pennsylvania Alternative Energy Portfolio Standard (AEPS). The AEPS requires electric distribution companies (EDCs) and electric generation suppliers (EGSs) to source 18% of electricity supply from alternative sources, including 8% from Tier I resources and 10% from Tier II resources, the category that includes geothermal heat pump systems.

To meet these requirements, utilities procure Alternative Energy Credits (AECs), where each AEC represents one megawatt-hour (1,000 kWh) of qualified energy generation or savings. The BTU's from the ground source heat pump are converted into equivalent MWh. Pricing for AECs is variable, however, based on Pennsylvania AEPS program data and PUC compliance reports, Tier II AECs have recently averaged approximately $26–$27 per credit with prices capped at $45/credit.

Private industry also participates in GREC purchasing for their own corporate needs. Through GREC aggregators, these credit could be valued at about >$500/ton or equipment.

When GREC's are sold, the rights to "claim" the energy savings are transferred and may present technical issues for various stakeholders on this project.

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Operating Costs

As part of the study and through the support of Lorax Partnerships, we have estimated the energy use of the systems on a typical annual basis. Below is a summary of the operating energy costs of the primary comparison solutions for each of the school and the recreation center.

	MES-0		MES-1A		DER-0		DER-1		GEO
	Electricity $	Gas $	Electricity $	Gas $	Electricity $	Gas $	Electricity $	Gas $	Electricity $
Jan	$13,730	$0	$5,790	$0	$2,210	$40	$1,090	$0	$706
Feb	$9,890	$0	$4,640	$0	$1,660	$20	$890	$0	$639
Mar	$5,180	$0	$2,960	$0	$1,080	$0	$750	$0	$639
Apr	$2,730	$0	$1,660	$0	$850	$0	$780	$0	$639
May	$2,140	$0	$1,300	$0	$1,120	$0	$1,080	$0	$639
Jun	$2,040	$0	$1,170	$0	$1,800	$0	$1,490	$0	$706
Jul	$3,090	$0	$1,680	$0	$2,410	$0	$1,800	$0	$639
Aug	$3,040	$0	$1,710	$0	$2,230	$0	$1,730	$0	$639
Sep	$2,850	$0	$1,520	$0	$1,590	$0	$1,370	$0	$639
Oct	$2,410	$0	$1,510	$0	$870	$0	$830	$0	$639
Nov	$4,210	$0	$2,270	$0	$1,070	$0	$750	$0	$639
Dec	$7,200	$0	$3,740	$0	$1,410	$0	$830	$0	$639
Total	$58,510	$0	$29,950	$0	$18,300	$60	$13,390	$0	$7,804

Table 13 - Operating Cost Estimate

The schools is expected to realize substantial savings with a geothermal solution.

Refer to APPENDIX E.1 - Energy Analysis Reports: John F. McCloskey Elementary School, APPENDIX E.2 - Energy Analysis Reports: Dorothy Emanuel Rec Center, and APPENDIX E.3 - Energy Analysis: Geothermal Pumping for more detailed information.

Note: The School does not currently have full air conditioning throughout. When air conditioning, by any solution, is added to the building, the energy use and utility cost will go up. This is a reason why it is it necessary to develop comparable replacement options with non-geothermal solutions for the life cycle cost analysis. We cannot make comparisons between the existing energy consumption and the geothermal solutions without a broader context.

Maintenance Costs

Accurate maintenance costs are difficult to predict. Generally, it is expected that geothermal WSHP equipment will experience less extreme operating conditions and fluid temperatures and therefore experience relatively lower maintenance expenses.

Building industry recommendations for ongoing maintenance costs are commonly in the 2-3% of the asset value per year. Half of that value may be attributed to accruing replacement costs, leaving about 1-1.5% true maintenance costs per year.

Geothermal borehole systems typically have a near zero maintenance cost, due to their longevity of material, no moving parts, and isolation from extreme above-ground weather.

For use in the LCCA we have assumed the following:

System Type	Annual Maintenance % (of asset value)
Air-Source (HP, Chillers, Boilers)	1.5
GWSHP	1.0
Pumps	1.5
Geothermal Loops	0.25

Table 14 - Maintenance Cost

Carbon Offsets

Many organizations now consider the social cost of carbon (SC-CO_2 or SCC) in overall decision making. It is a monetary value used to estimate the impact of increases in emissions which allows it to be used in overall cost evaluation for systems like these. The dollar value can be considered the value of reduced impact for the energy related emissions reduction of the geothermal system when compared to a conventional system.

Energy consumption creates emissions, whether in the form of natural gas use or electricity use. As part of the study and through the support of Lorax Partnerships, we have estimated the energy use of the systems on a typical annual basis.

	MES-0		MES-1A		DER-0		DER-1		GEO
	Electricity CO_2 eq.	Gas CO2 eq.	Electricity CO2 eq.	Gas CO2 eq.	Electricity CO2 eq.	Gas CO2 eq.	Electricity CO2 eq.	Gas CO2 eq.	Electricity CO2 eq.
Jan	37.2	-	15.7	-	6.0	0.4	3.0	-	1.9
Feb	26.8	-	12.6	-	4.5	0.2	2.4	-	1.7
Mar	14.1	-	8.0	-	2.9	-	2.0	-	1.7
Apr	7.4	-	4.5	-	2.3	-	2.1	-	1.7
May	5.8	-	3.5	-	3.0	-	2.9	-	1.7
Jun	5.5	-	3.2	-	4.9	-	4.0	-	1.9
Jul	8.4	-	4.6	-	6.5	-	4.9	-	1.7
Aug	8.2	-	4.6	-	6.1	-	4.7	-	1.7
Sep	7.7	-	4.1	-	4.3	0.0	3.7	-	1.7
Oct	6.5	-	4.1	-	2.4	-	2.3	-	1.7
Nov	11.4	-	6.2	-	2.9	0.0	2.0	-	1.7
Dec	19.5	-	10.2	-	3.8	0.0	2.3	-	1.7
Total	158.7	-	81.2	-	49.6	0.6	36.3	-	21.2

Table 15 - Carbon Emission Estimate

Refer to APPENDIX E.1 - Energy Analysis Reports: John F. McCloskey Elementary School, APPENDIX E.2 - Energy Analysis Reports: Dorothy Emanuel Rec Center, and APPENDIX E.3 - Energy Analysis: Geothermal Pumping for more detailed information.

The carbon offset impact of the drilling or other installation efforts is not specifically addressed in this study. It is generally expected that the operational savings related to the geothermal project will payback in a short time (< 5 years) compared to the carbon impact of continuing to operate the existing savings.

The value of the SCC is ever evolving as the models used to estimate its value continue to be developed and refined. Through discussion with PGW, it was determined to use \$143/metric ton of CO_2 equivalent for the purpose of this study.

	MES-0	MES-1A	DER-0	DER-1	GEO
	CO_2 eq. \$	CO_2 eq. \$	CO_2 eq. \$	CO_2 eq. \$	CO_2 eq. \$
Jan	\$6,220	\$2,240	\$910	\$420	\$270
Feb	\$5,070	\$1,800	\$670	\$350	\$250
Mar	\$3,470	\$1,150	\$420	\$290	\$250
Apr	\$1,770	\$640	\$330	\$300	\$250
May	\$720	\$500	\$430	\$420	\$250
Jun	\$330	\$460	\$700	\$580	\$270
Jul	\$410	\$650	\$930	\$700	\$250
Aug	\$400	\$660	\$870	\$670	\$250
Sep	\$460	\$590	\$620	\$530	\$250
Oct	\$1,500	\$580	\$340	\$320	\$250
Nov	\$2,730	\$880	\$420	\$290	\$250
Dec	\$4,400	\$1,450	\$550	\$320	\$250
Total	\$27,480	\$11,600	\$7,190	\$5,190	\$3,040

Table 16 - Social Cost of Carbon Emission Estimates

LIFE CYCLE COST ANALYSIS

Life cycle cost analyses (LCCA) are necessary and used for planning decision making. They allow stakeholders to compare viable solution's total system costs over a long term time perspective, so that individual cost information, like construction cost, is not the exclusive parameter available for decision making. Key components evaluated for inclusion in these LCCA include estimates of: Design Costs, Construction Costs, Energy Operating Costs, Maintenance Costs, and Replacement Costs. We have also included information about estimates of the Social Cost of Carbon Dioxide equivalent emission related to energy use of the systems.

For the purposes of this feasibility study, we determined it necessary to develop comparable replacement options with non-geothermal solutions. The non-geothermal replacement systems include similar system typologies and similar heating and cooling features for each space.

Scope Of Work	MES-1A DER-1 GEO-A (UB-A)	MES-0 DER-0 -
CONSTRUCTION BUDGET:		
John F McCloskey Elementary School:	$10,546,719	$10,945,975
	($4,235,288)	($19,763)
Dorothy Emanuel Recreation Center:	$2,285,370	$1,801,493
	($914,148)	($3,600)
Geothermal Utility:	$6,157,830	$0
	($2,474,730)	$0
PROJECT COST SUBTOTAL:	**$11,365,754**	**$12,724,105**
Annual Operating Costs: John F McCloskey Elementary School:	$29,950	$58,510
Dorothy Emanuel Recreation Center:	$13,390	$18,360
Geothermal Utility:	$7,810	$ -
OPERATING COST TOTAL:	**$51,150**	**$76,870**
Annual Maintenance Costs: John F McCloskey Elementary School:	$83,704	$130,309
Dorothy Emanuel Recreation Center:	$18,138	$21,446
Geothermal Utility:	$33,308	$ -
MAINTENANCE COST TOTAL:	**$135,149**	**$151,756**
Annual SCC Estimate: John F McCloskey Elementary School:	$11,600	$27,480
Dorothy Emanuel Recreation Center:	$5,190	$7,190
Geothermal Utility:	$3,040	$ -
SCC ESTIMATE TOTAL:	**$19,830**	**$34,670**

Table 17 - Cost Summary for LCCA

See APPENDIX F.3 - LCCA for Net Present Value Analysis following FEMP methods.

Heating Only

John F. McCloskey Elementary School currently uses an oil-fired heating system and lacks central air conditioning. When the scope is limited to only replacing existing heating equipment, natural gas remains the lowest-cost option from both a capital and operating-cost perspective.

However, when compared with a natural-gas-fired heating retrofit that also includes a new central cooling system, and assuming the full projected Investment Tax Credit can be captured, the primary geothermal solution is the lowest-cost option evaluated. This is fully dependent on the Investment Tax Credit offsetting approximately 40% of the geothermal project cost.

7 - SCALABILITY & REPEATABILITY

General

The focus of this study is serving the two subject buildings with a geothermal system.

This section of the report is the beginning of further exploration into aspects that would make a geothermal system solution repeatable and/or scalable to additional site/projects and users.

Load profile diversity is helpful but not critical to planning network or district systems. The diversity offers some potential for reducing the total thermal asset required for the average load. This is the result of occupants and internal loads not occurring at maximum values simultaneously. Schools and homes offer a good amount of diversity, since schools are occupied during the day and residences are more occupied during mornings and evenings.

Typical Customers

Schools (SDP)

Philadelphia has a large property base of many schools and support buildings throughout its city. The School District of Philadelphia currently manages 249 District & Alternative Schools, not including the 81 charter schools, serving nearly 200,000 students each year.

This large group of similar buildings are in a wide range of age and many may prove potentials for similar systems to those studied for the primary site. Continuing development work and standards with a single organization with the same region would likely be efficient and would create a measure of reliability in repeated outcomes.

SDP does operate one other school with a geothermal WSHP system, Kensington High School for Creative and Performing Arts (CAPA). This system has been operating successfully since the new construction facility was built in 2011. The building achieved a LEED Platinum rating from the US Green Building Council (USGBC).

City of Philadelphia (COP)

Much like the SDP, the City of Philadelphia has a large property base, with the same territorial boundaries as PGW, and could operate as a single partner stakeholder in systems like this. The types of buildings operated by the COP are more diverse than the SDP; therefore, more unique analysis would be required for each potential opportunity.

Examples of facility types would include: Police, Fire Houses, Recreation Centers, Libraries, and Wastewater treatment plants. Wastewater treatment plants have a high availability of thermal assets in the treated effluent.

The city does operate another recreation center with a geothermal WSHP system, Barry Playground Recreation Center. This system has been operating successfully since the retrofit and renovation of the facility in 2016. The building achieved a LEED GOLD rating from the US Green Building Council (USGBC).

The City also operates the Police Tactical Training Facility, which is also certified LEED GOLD, and utilizes a geothermal HVAC system.

Commercial

Shopping centers and museums offer larger opportunities to develop large base loads from these bigger properties. Complimenting these base loads with residential load profiles can result in effective systems. Commercial building are more likely to be significantly cooling dominant, so they would send more heat into the system than other building types, which can make then more difficult to balance annual heating anc cooling loads.

Nursing Homes would follow residential load profiles, but don't have much reduction in occupancy during the daytime, so they do not have as much diversity with other loads.

Residential

The surrounding area around the project site largely consists of residential duplexes along streets off of Pickering Ave, and rowhomes along the other three streets and their side streets. These are a common building type that could be considered for future inclusion on networked geothermal systems.

The housing stock for many of these are very similar and could be evaluated in more detail. Based on our knowledge of the surrounding homes, the row homes were generally built with forced hot air systems and the duplexes were built with steam boilers with radiators. The rowhomes offer a simpler conversion, where the new GWSHP would replace (or potentially supplement) the duct furnace and use the existing ductwork to distribute heating and cooling.

The rowhomes (purple below) are approximately 1100-1300 SF, 2 story, 3 bedroom homes, on 1,500 SF lots, built in the 1950's. Some have finished basements. They often have central air conditioning. Cooling systems for these homes would be sized between 1.5-3 tons.

There are 34 rowhomes along Provident St. Similar lot densities exist in the surrounding blocks.

Along Pickering Ave. to the NE (cyan Below) there are blocks of twin duplexes, often each side is 1300-1500 sf and has a 2 bedroom upstairs and a 1 bedroom apartment downstairs + basement. There are 16 duplexes per block. Each apartment would need its own GWSHP (2 per duplex). Each would be 1-1.5 tons of cooling. Some may have cooling. Load profiles between upper and lower apartments will be different.

Most of these homes are PGW gas customers.

Table 18 - Residential Customers

See APPENDIX E.4 - Energy Analysis: Residential Customer for more information.

In the context of the ITC rules regarding single ownership of the geothermal and supported equipment, lease-to-own strategies should be explored. This would help capitalize on the investment tax credit, other incentives, and PGW's economy of scale to construct.

Some conversions to GWSHP may require electrical service upgrades to facilitate the new electrical equipment. Many conversions would be from gas furnaces or boilers and may not have existing air conditioning. With the service upgrade being part of the GWSHP conversion, the cost may be partially covered by the ITC.

With the size of individual residential customers total conversion projects being relatively small, alternate billing structures would need to evaluated, so that expensive BTU meters are not required for every residential customer.

Residential customers may have different shutoff for non-payment evaluations than commercial customers.

Networked Geothermal Systems

There are several possibilities for networked geothermal system layouts. One of the more promising option for sites like this is the single-pipe, or one-pipe loop. This is in comparison to two-pipe networks that use a dedicated supply and a dedicated return pipe. The single-pipe network has the advantage of about half the major distribution piping and the single sizing of most of the loop. This provides a robust delivery mechanism to customers. Each connect draws fluid out, exchanges the thermal energy, and then return the fluid downstream of the intake point. This results in a temperature impact on the downstream flow. Depending on the size of the connection, the temperature change can be small or large. Because of this downstream impact on temperature, distributing the geothermal assets around the loop is important in planning and operation. The total distance and configuration of the single-pipe may cause multiple pumping and power stations to be required.

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[redacted]

Figure 15 - Single-pipe Geothermal Network Conceptual Diagram

In contrast, a two-pipe distribution network has a dedicated supply system that is not impacted by the preceding connection, because the return water is sent to a dedicated return pipe. This configuration advantages central geothermal assets to tie in a single central location. This approach also allows centralization of pumping and power infrastructure. This configuration requires less complicated thermal modeling during planning. Its major compromise is that it requires more total pipe installed and that pipe size planning is required to be planned well in advance.

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8 - RECOMMENDATIONS

CONSIDERATIONS

- The ITC requires the ownership of the boreholes and the building system equipment by the same owner for at least the first 5 year to claim the tax credit. An acceptable ownership and operating agreement will be required amongst the stakeholders to successfully claim the 40% Investment Tax Credit.
- The SCC will need to be updated periodically to align with stakeholder methods.
- This study looked at two geothermal options for the school's system, and had an additional partial variation to the base geothermal option. These variations should be evaluated by the school district to determine which options are preferred.
- The School District has Design Guidelines. The guidelines do not address the GWSHP types of equipment in this study (nor the ASHP alternatives). SDP will need to evaluate these new equipment types for inclusion in their product standard requirements.
- Philadelphia enacted Bill Number 080025 in December 2009. The bill requires all new construction or major renovations to achieve LEED Silver certification if more than 50% of the design and construction costs are funded by the city. "Major renovations" are defined as "major HVAC renovation, significant building envelope modification and major interior rehabilitation that in total directly affect more than 50% of the gross floor area of an enclosed and conditioned building space." This requirement became effective on January 1, 2010.
- The elementary school exceeds the current limitations for Type IIB construction while not having fire sprinkler protections, which would require the building to be evaluated as Type IIA. Type IIA construction required that the exterior walls maintain a 1-hour fire rating. Either providing a fire sprinkler system or maintaining a 1-hour rating for the exterior envelope is recommended in any HVAC retrofit project.
- SDP may want to consider other building improvements, including envelope upgrades, in the larger context of this project. Envelope improvements will lower operating costs and increase occupant comfort.
- Heat exchangers used to separate the geothermal system from the building systems are generally preferred with system of multiple stakeholders, so that each has direct control and responsibility over their owned side of the system. These heat exchangers introduce operational inefficiencies. There is pumping power to flow through each side of the system. There is maintenance of these heat exchangers. The design temperatures and performance of the geothermal system must be several degrees better than without the heat exchanger resulting in slightly larger geoexchange systems required. In specific and small networked systems, it would be worth considering removal of the heat exchangers. This may be most meaningful for small residential customers.
- The geothermal pumping station includes a gas generator for backup. Providing only a connection for temporary generators may be viable and should be considered, if cost reductions are preferred.
- Metering equipment will be an important part of customer connections. Further determination of specific products for this application should be considered.
- The COP and SDP have independent requirements and goals for connecting their buildings automation controls to their own central management systems.
- The replacement project at the school needs to occur so that work occurs in such way as the existing systems remain available until each space's conversion occurs, and only a limited number of spaces can be impacted simultaneously, so that the student population can be served by limited swing spaces.

NEXT STEPS

1. This study has reviewed multiple options for system types as the configuration for McCloskey Elementary School. The School District of Philadelphia should review these options with their goals for the HVAC replacement at the school to determine which to pursue for further design development.
2. PGW, SDP, & PPR will need to determine possible ownership strategies and funding sources.
3. Reach out to potential partners and customers to continue to develop and refine potential customer profiles and interest in this type of energy utility.
4. Energy cost rate structures will need to be evaluated.
5. PGW will need to review with the PA Public Utility Commission (PUC).
6. If a decision is made to move forward, a test well should be drilled to validate the expected conditions presented and confirm thermal conductivity before proceeding to full design.
7. Proceed with Design Development of the selected options.

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9 - APPENDICES

	TITLE	PREPARED BY	DATE
APPENDIX A	Geology & Incentive Overview	Brightcore BUILDING ENERGY PERFORMANCE	December 2, 2025 Rev. May 15, 2026
APPENDIX B	Initial Environmental Feasibility Study	SciTek Consultants, Inc.	February 5, 2026, Rev. March 11, 2026
APPENDIX C	30% Design Narrative	alderson engineering	March 23, 2026 Rev. April 6, 2026
APPENDIX D	30% Design Drawings	alderson engineering	April 4, 2026
APPENDIX E.1 **APPENDIX E.2**	<u>Energy Analysis Reports</u> John F. McCloskey Elementary School Dorothy Emanuel Rec Center	lorax	December 17, 2026 Rev April 13, 2026 Rev. May 6, 2026 Rev. May 21, 2026 Rev. July 14, 2026
APPENDIX E.3 **APPENDIX E.4**	<u>Energy Analysis:</u> Geothermal Pumping Residential Customer	alderson engineering	July 15, 2026
APPENDIX F.1	Construction Cost Estimates	BSI CONSTRUCTION, LLC.	May 4, 2026 Rev. May 16, 2026 Rev. May 20, 2026
APPENDIX F.2	Project Cost Estimates	alderson engineering	May 22, 2026
APPENDIX F.3	LCCA	alderson engineering	May 22, 2026
APPENDIX G.1 **APPENDIX G.2**	<u>Building Code Summary</u> John F. McCloskey Elementary School Dorothy Emanuel Rec Center	JACOBS WYPER ARCHITECTS	April 24, 2026 May 12, 2026
APPENDIX H.1 **APPENDIX H.2**	<u>Existing Building Plans</u> John F. McCloskey Elementary School Dorothy Emanuel Rec Center		
APPENDIX I	PECO Commercial & Industrial Retrofit and New Construction Application, Instructions and Guidelines		
APPENDIX J	PGW Commercial Heating Equipment Rebate Application		

Building Modeling (BIM) support was provided by ADVENSER