APPENDIX

Geothermal Feasibility Assessment

A technical and economic feasibility assessment of geothermal applications for the Falls Church School Campus.

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GEOTHERMAL FEASIBILITY ASSESSMENT
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BACKGROUND

In the spring of 2016, the City of Falls Church was awarded technical assistance through the US Department of Energy (US DOE) Climate Action Champions Program to conduct a Geothermal Feasibility Study at the Falls Church Campus Redevelopment site. The study included evaluating the geothermal potential of a redeveloped George Mason High School connected to an expanded Mary Ellen Henderson Middle School. This project has been conducted in partnership with Oak Ridge National Laboratory (ORNL) and the Metropolitan Washington Council of Governments (COG).

The Geothermal Feasibility Study is part of the larger assessment of redevelopment possibilities for the schools and redevelopment site, including advanced sustainability solutions. City staff and stakeholders expressed interest in exploring how the campus can serve as a sustainability learning lab for students and how a zero energy high school could help support that purpose. Geothermal is leading energy solution implemented in zero energy schools.

ZERO ENERGY SCHOOL

In 2015, the US DOE released a common definition for zero energy buildings: A zero energy building (ZEB) produces enough renewable energy to meet its own annual energy consumption requirements, thereby reducing the use of non-renewable energy in the building sector. ZEBs use all cost-effective measures to reduce energy usage through energy efficiency and include renewable energy systems that produce enough energy to meet remaining energy needs.

There are several long-term advantages of moving toward ZEBs, including lower operating and maintenance costs, lower environmental impacts, better resiliency to power outages and natural disasters, and improved energy security. Schools that incorporate energy efficiency and renewable energy technologies make a strong statement about the importance of protecting the environment. Buildings can be teaching tools that demonstrate scientific and policy best practices.

Based off the research conducted with the Geothermal Feasibility Study, there are three steps that can move George Mason High School towards zero energy (each step getting you closer to zero energy):

1. Maximize energy efficiency
2. Apply geothermal heat pump
3. Apply Solar

1. MAXIMIZE ENERGY EFFICIENCY

The first consideration of a zero-energy high school – or any high-performance building – is to maximize energy efficiency. Energy efficiency measures such as the use of lighting systems which incorporate daylighting, and high efficiency heating and cooling systems reduce operating costs, can provide an improved physical environment and better student performance.

ASHRAE's *Advanced Energy Design Guide for K-12 School Buildings* provides direction for achieving at least 50% better energy performance than conventional schools (e.g. minimum code requirements of ASHRAE/IESNA Standard 90.1-2004). The Guide includes techniques to improve the learning environment and provide teachable models of energy-efficiency principles. It also includes techniques to reduce operating costs, lower construction costs, and provide for faster payback. Building a new school to meet a goal of at least 50% energy savings does take thought and determination, but it is within reach of any school district. [1]

The Falls Church Campus Geothermal Feasibility Study analyzed the cost savings of applying these advanced energy design standards to a new high school. ORNL recommends that Falls Church apply advanced energy design standards and include these principles in the request for proposal (RFP) for a new high school.

2. GEOTHERMAL HEAT PUMP

The second consideration in striving for a net zero high school is to use geothermal heat pumps (GHPs) for heating, cooling and hot water. GHPs are recognized by the US Environmental Protection Agency (US EPA) as the most efficient and comfortable heating and cooling technology currently available. They have simple controls and equipment, are quiet, have low maintenance, and last 50+ years. There is no outdoor equipment, which means GHP systems are not exposed to the weather or affected by extreme weather events (Figure 1).

Figure 1: Geothermal Heat Pump Illustration

Metropolitan Washington's mean ground temperature is 56^{o}F year-round. GHPs use the ground as a "heat source" for heating in the winter; and as a "heat sink" for cooling in the summer. GHPs move fluids through continuous pipeline loops that are buried underground and deliver conditioned air through heat pump equipment serving the various parts of the building. GHPs are a common technology used in metropolitan Washington.

For commercial systems, geothermal loops are typically set in vertically boreholes 4-6" in diameter and 100-500 feet deep. For the Falls Church Campus Geothermal Feasibility Study, ORNL is recommending 25-foot spacing and 230' deep boreholes. More specific information on the scope and results are shown below in the Geothermal Feasibility Study section.

[1] At the time the Geothermal Feasibility Study was conducted, ASHRAE was in the process of developing a K-12 guide to achieving zero energy; however, it was not yet available to incorporate into the study.

3. SOLAR

The third consideration in striving to design a ZEB is incorporating solar technology into the building. A recent relevant example is the Alexandria Renew Administrative Building (Figure 2). The rooftop solar and solar awnings applied to this building are a good example of how Falls Church could maximize the solar potential on a new high school with a smaller footprint and a few stories high.

If it is not financially feasible to implement solar at the initial development of the new high school, it is recommended that the RFP for a new high school specify that the school is developed as "solar ready" so that solar can be later installed on the roof and awnings. The City may also want to explore use of any solar Power Purchase Agreement (PPAs) utilized in neighboring jurisdictions.

Figure 2: Alexandria Renew Enterprises

GEOTHERMAL FEASBILITY STUDY

SCOPE

Geothermal experts from ORNL led the Geothermal Feasibility Study of the new high school and the expanded middle school. Site and feasibility assessments evaluated the engineering and economic feasibility of implementing GHPs at the two schools. Design and installation of GHPs requires an evaluation of available land, underlying geology and drilling conditions, climate, building heating and cooling loads, and the thermal interactions that affect the performance of the GHP system and the indoor environment of the building.

The scope of this study included:

- Preliminary assessment as to whether the available land is large enough and suitable for installing ground heat exchangers
- Size major components of GHP systems
- Estimate the initial and operating cost of GHP systems
- Evaluate potential benefits resulting from implementing GHP systems

Phase I - High School:

- Develop a computer model for the new high school (based on ASHRAE's 50% Advanced Energy Design Guide for K-12 School Buildings)
- Conduct preliminary design of the GHP system
- Size GHP equipment and evaluate bore field designs
- Estimate GHP system's initial cost
- Evaluate costs and benefits of GHP implementation compared with a baseline

Phase II - Middle School:

- Develop a computer model for the existing middle school
- Calibrate the model with available utility bills
- Add the planned addition and model baseline performance
- Replace baseline HVAC system (i.e., the existing HVAC system) with a GHP system and model its performance
- Size GHP equipment and evaluate bore field designs
- Estimate GHP system's initial cost
- Evaluate costs and benefits of GHP implementation compared with the baseline

RESULTS

PHASE I – HIGH SCHOOL

As part of Falls Church Campus Redevelopment, a new school building is being considered to replace the aging existing George Mason High School. The RFP drafted for the Falls Church Campus Redevelopment in April 2016 identified a target building energy use intensity (EUI) of 25 kBtu/sqft for the new high school building and requested evaluation of techniques such as GHP to reach this target.

In this feasibility study, ORNL developed a series of computer models for the proposed new high school building. The first model was created assuming that the high school will be built to the minimum energy efficiency standards (i.e., ASHRAE/IESNA Standard 90.1-2004). ORNL analyzed the total building EUI, HVAC loads, HVAC EUI, and carbon emissions with the first model to establish a baseline (see Box 1 in Fig. 3).

The second model was built upon the first model by adopting the recommended measures of building envelope insulation, infiltration, thermostat setpoints, lighting power density, and efficiencies of conventional HVAC and service water heating equipment listed in ASHRAE's 50% Advanced Energy Design Guide for K-12 School Buildings at Climate Zone 4[2].

The third model was identical to the second model except that a GHP system is used instead of the recommended conventional HVAC system, which is a variable air volume system with highly efficient chiller and boiler.

ORNL used these computer models to analyze and compare the performance of the systems. Figure 3 on the following page compares the two alternative HVAC systems (Box 2 and Box 3) against the baseline (Figure 3, Box 1). A new, highly efficient high school building with a conventional HVAC system will provide a building EUI of 44 kBtu/sf-yr, which is 23% less than one built to minimum efficiency standards to (see Box 2). It will save $59K per year compared with the baseline (a 34% reduction in HVAC related energy cost).

If the building is conditioned with the GHP system, the building EUI will be reduced by 42% to 33 kBtu/sf-yr (see Box 3). Compared with the baseline, it will save $108K per year (a 63% reduction in HVAC related energy cost). However, to reach the goal of 25 kBtu/sf-yr building EUI, more aggressive measures, such as solar, would need to be integrated.[3]

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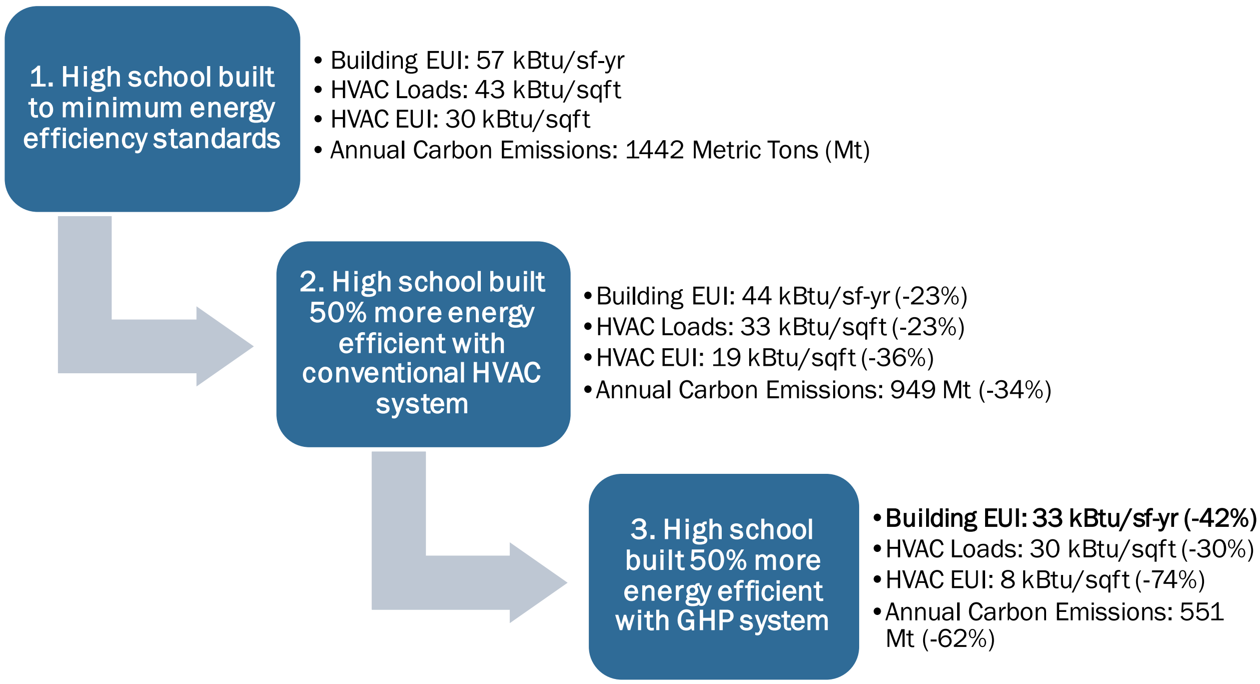
[2] Other recommended measures related to daylighting, exterior lighting, non-HVAC equipment choices and controls were not modeled due to limited information about the design of the proposed new high school.

[3] Energy use intensity (EUI): EUI is a building's annual energy use per unit area. EUI is useful for comparing performance of buildings across sizes, types, and locations. EUI can be used to set energy targets for a building's design. The British [3]

Figure 3: Options Toward a More Efficient New High School



While the GHP system results in $49K/year more energy cost savings than the conventional HVAC system, it costs more to be implemented. Table 1 on the following page summarizes the cost premium and savings of a new energy efficient high school building that uses a GHP system instead of a conventional HVAC system (e.g. costs and savings from Box 2 to Box 3).

Table 1 provides a range for the costs and payback of implementing a GHP system based on different estimates for the cost of vertical borehole ground heat exchangers (VBGHX) to be transparent regarding the range of estimates Falls Church could receive from a GHP design and installation firm.

ORNL estimates the average installed cost of VBGHX in the eastern US region is $16 per linear foot of the vertical bore and the high end of the cost range is about $19 per linear foot. The payback, considering both energy and potential operations and maintenance (O&M) cost savings, would be from 3 to 5 years depending on the cost of VBGHX.

Energy use intensity (EUI): EUI is a building's annual energy use per unit area. EUI is useful for comparing performance of buildings across sizes, types, and locations. EUI can be used to set energy targets for a building's design. The British thermal unit (Btu or BTU) is a traditional unit of heat; it is defined as the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit.

Table 1: Summary of Costs and Savings from Implementing a GHP System for the New George Mason High School

VBGHX cost	$16/ft	$19/ft
GHP system capacity	821 tons	
Estimated cost premium of GHP system	$375K	$720K
Energy cost savings	$49K per year (43% savings)	
O&M cost savings	$108K per year (73% savings)	
Payback without O&M cost savings	8 years	15 years
Payback with O&M cost savings	3 years	5 years

The study results for the high school could slightly shift depending on the final architectural design of the building, the level of energy efficiency measures incorporated into the design, and the effective ground thermal conductivity value at the site. It is recommended that Falls Church conduct an on-site ground thermal conductivity test prior to further developing the design of the GHP system.

PHASE II - MIDDLE SCHOOL

The Mary Ellen Henderson Middle School building is approximately ten years old and is not being considered for replacement as part of the Falls Church Campus Redevelopment. An addition to accommodate future students is being considered. ORNL developed a model of the existing middle school with the proposed addition to analyze the geothermal feasibility for the middle school.

The recommendation from ORNL is for the middle school and high school to have separate GHP systems. Since the middle school is a retrofit and the high school is a new building, different controls will be needed in each building. Separate bore fields are needed due to space limitations and what's known about onsite soil conditions.

ORNL recommends that the middle school upgrade to a GHP system when the existing HVAC system needs to be replaced. Table 2 reflects the cost premium, savings, and payback of a GHP system for the middle school when the existing system needs replacement. The payback, considering energy and potential O&M savings, would be from 3 to 6 years.

If the system is upgraded before the existing HVAC system needs replacement, the payback for the middle school's GHP could be up to 29 years. Implementation of the GHP system for the middle school can be staged. It can be done by constructing the bore field in several stages and expanding the hydronic piping and adding more heat pumps correspondingly in each stage.

Table 2 provides a range for the costs and payback of the GHP system depending on the estimated cost of VBGHX (as discussed above for the high school).

Table 2: Summary of Geothermal Cost and Savings for Mary Ellen Henderson Middle School

VBGHX cost	$16/ft	$19/ft
GSHP system capacity	556 tons	
Estimated cost premium of GHP system	$370K	$603K
Energy cost savings	$61K per year (56% savings)	
O&M cost savings	$52.5K per year (73% savings)	
Payback without O&M cost savings	6 years	10 years
Payback with O&M cost savings	3 years	6 years

ORNL estimates the current annual HVAC related carbon emissions of the middle school to be 981 metric tons (Mt). Replacing the middle school's existing HVAC system with a new GHP system would reduce annual carbon emissions to 455 Mt, a 54% reduction.

CONCLUSIONS AND NEXT STEPS

The Falls Church Campus Redevelopment Geothermal Feasibility Study was selected and awarded technical assistance through the US DOE Climate Action Champions Program as it could have a direct and immediate impact on the design and implementation of this site, which has the potential to serve as a national model for climate and economic resilience. This study was also conducted to build the capacity of local governments to implement GHPs across metropolitan Washington.

A summary of recommendations from this study are as follows:

High School:

- Incorporate in the building design the recommended energy efficiency measures listed in ASHRAE's 50% Advanced Energy Design Guide for K-12 School Buildings.
- Implement a GHP system to serve the full heating and cooling loads of the new high school.
- Develop the new high school as "solar ready" if it is not financially feasible to implement solar during initial development of the new high school.

Middle School:

- Upgrade the middle school to a GHP system when the existing system needs to be replaced. It is recommended to have a GHP system and bore field that is separated from the high school.

The next steps to implement this study’s recommendations include:

1. Perform an on-site ground thermal conductivity test.
    - The test provides the site-specific information needed for verifying the bore field design, including spacing and depth of boreholes.

2. Determine the preferred approach for financing.
    - GHP can be incorporated into the overall financing for the project or through potential energy financing opportunities such as Qualified Energy Conservation Block Grants (QECBs).
    - There are also firms that are willing to develop, own and operate the GHP system, thus eliminating the cost premium for implementing the GHP system from the capital expenditures for the new school. The firm would charge a fee based on energy delivered to the building to pay for the construction and operation of the GHP system.

3. Incorporate specific language for energy efficiency in the RFP for the new high school.
    - This could include a zero-energy goal or the 50% advanced energy design standard. This should also include specific language for utilizing the GHP system and solar-ready features.