

# Final Scientific Report For Grant DE-EE0003007

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Tennessee Department of Education  
Energy Efficient Schools Initiative

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10 April 2017

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Acknowledgment: "This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy under Award Number DE-EE0003007."

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## EXECUTIVE SUMMARY

The Tennessee Energy Efficient Schools Initiative (EESI) Hybrid-Water Source Heat Pump (HY-GSHP) Program sought to provide installation costs and operation costs for different Hybrid water source heat pump systems' configurations so that other State of Tennessee School Districts will have a resource for comparison purposes if considering a geothermal system. The proposed Hybrid water source heat pump (HY-GSHP) systems included –

- HY-GSHP system having either vertical bore field or horizontal trenches geothermal field, cooling tower, boiler, high efficiency water source heat pump equipment, loop pumps and reverse-return interior and exterior loop piping configuration,
- HY-GSHP system having either vertical bore field or horizontal trenches geothermal field, cooling tower, boiler, high efficiency water source heat pump equipment, loop pumps and a single pipe interior and exterior loop piping configuration,
- HY-GSHP system having either vertical bore field or horizontal trenches geothermal field, cooling tower, boiler, high efficiency water source heat pump equipment, loop pumps and a combination of reverse-return interior and exterior loop piping configuration and a single pipe interior and exterior loop piping that are installed in separate wings or floors of a school facility,
- HY-GSHP system having either vertical bore field or horizontal trenches geothermal field, cooling tower, boiler, high efficiency water source heat pump equipment, loop pumps and reverse-return interior and exterior loop piping configuration installed in a school facility that already has a conventional geothermal heat pump installation serving one wing that utilizes a properly sized vertical bore field or horizontal trenches to provide 100% of the design cooling and heating loads.

EESI secured commitments from three Tennessee school districts (Hamilton County, Hardeman County and Lawrence County) having a total of 5 projects (Brainerd High School, Bolivar High School, Middleton High School (see Task 2.3, Page 24), Lawrence Public School and South Lawrence School) with a total cooling load of 750 Tons. All projects were "shovel ready" whenever the DOE Grant monies were awarded.

	System Type	Field Type	System Size (tons)
<b>Hamilton County</b>			
Brainerd High School	HY-GSHP	Vertical Bore	425
<b>Hardeman County</b>			
Bolivar High School	GSHP*	Vertical Bore	75
Middleton High School	HY-GSHP**	Vertical Bore	150
<b>Lawrence County</b>			
Lawrence Public School	HY-GSHP	Horizontal Loop	50
South Lawrence School	HY-GSHP	Horizontal Loop	50
		<b>TOTAL</b>	<b>750</b>
* Based on the feasibility study presented to DOE, including system costs as well as safety/aesthetic considerations, a variance from the originally approved SOPO was determined to be reasonable. A formal revision to the SOPO was completed to reflect this change though a modification to the award.			
** This project was approved in the original SOPO; However, the school district was not able to obtain sufficient matching funds over and above any DOE and EESI funds that would be available for them to use and was withdrawn from the award and program.			

The EESI-Technical Advisory Committee (TAC) surveyed the various sites and chose which HY-GSHP option was best suited for each site. The various school districts agreed in principle to the EESI-TAC options for their facilities. The EESI-TAC was responsible for reviewing and approving the feasibility studies that were developed for each school district's site. Hamilton County and Lawrence County submitted their feasibility studies but Hardeman County submitted a Design Narrative directly to DOE, by-passing the EESI-TAC review process. The submitted Design Narrative was not for a HY-GSHP system but rather an extension of their existing vertical bore field. The Design Narrative was approved by the DOE Program Director.

During the 60% design review process it was discovered that the equipment being proposed for the Bolivar High School did not comply with ASHRAE Standard 90.1 performance requirements since an independent 3<sup>rd</sup> party had not certified the equipment performance. A delay was experienced until the equipment was tested and certified by an independent 3<sup>rd</sup> party.

The EESI and State of Tennessee contracted with Commissioning of Green Building Solutions (CxGBS) to be the EESI Program Administrator. The Program Administrator was to implement a technical (testing-based) commissioning program for the Design Phase, Installation Phase, Performance Verification Phase and Project Reporting and Data Collection Phase. The EESI Program Administrator was to provide monthly reports and updates to the EESI-Council and EESI-TAC on the progress, any identified problems and corresponding solutions during the term of the DOE Grant Program. The EESI Program Administrator was also to provide links to EESI-TAC for each school district's Building Automation System that was recording performance data.

After all bids were received and approved for installation, the EESI Program Administrator was to develop spreadsheets of installation costs for each type of HY-GSHP version that was being installed for the DOE Grant Program and submit to the EESI-Council for distribution purposes to any Tennessee School District interested in Hybrid water source/geothermal systems.

During the construction phases of the individual projects, the EESI Program Administrator provided field reports and photos to the EESI-Council. The EESI Program Administrator was also to observe the Performance Verification Tests (PVT) or start-up of the equipment for each type of HY-GSHP system. After the PVT, the EESI Program Administrator was to conduct Pre-Functional Tests (PFT) and Functional Performance Tests (FPT) for each HY-GSHP system and report the results to both the School District and EESI-Council/EESI-TAC.

The State contract for the EESI Program Administrator was not renewed. This action resulted in the Phase 3 Project Reporting and Data Collection activities being relegated to the individual School Districts where the HY-GSHP system are located. The EESI-TAC is working with the EESI Executive Director in developing methods and means to collect performance data and develop installation cost spreadsheets for other Tennessee Schools districts to use as resources in considering HY-GSHP systems.

The EESI HY-GSHP program was able to bring the Hybrid water source technology to Lawrence County School District and expand the use of geothermal applications to both Hardeman County and Hamilton County School Systems. All school systems were introduced to Hybrid-geothermal performance monitoring techniques and BAS/EMS performance verification protocols.

For the Lawrence County School projects, both gym facilities and the South Lawrence Training/Team Locker Rooms were upgraded from heated only to fully conditioned and properly ventilated facilities that can now be used year around. The Bolivar High School geothermal loop expansion has made the high school facility fully geothermal conditioned. The Brainerd High School project replaced an HVAC system that was well past its functional life and irreparable due to the level of asbestos in its HVAC systems' insulation with an efficient Hybrid geothermal HVAC system that increased the ventilation levels for the facility.

The financial impact of the integration of EESI funds into the economic analyses produced loan repayment periods less than five years for all school districts that participated. The repayment of the EESI funds can be made only by utility savings from the installed efficient systems as compared to the existing HVAC systems' utility consumptions.

## **EESI HYBRID GEOTHERMAL PROJECT GOALS**

### **A) OBJECTIVES**

The primary objective of this project was to develop a cost effective, innovative design for Hybrid ground source heat pump systems for K-12 school use. The use of a Hybrid system will enable the installed cost to be lowered; in addition, valuable data on installation costs, operation costs and maintenance will be collected for use in future project designs. This project will utilize financing from excess State lottery funds that have been specifically earmarked by the State Legislature for K-12 school energy conservation projects through one-time grants and a low interest loan program. A maximum of five schools were selected for participation in this Hybrid ground source heat pump project.

Many schools in Tennessee have plans for either the expansion of school facilities or the replacement of old inefficient mechanical equipment; the cost of a traditional ground source heat pump system or the lack of information on Hybrid ground source heat pump systems has hampered the widespread utilization of this type of systems in both new and existing facilities. This project would provide design and installation guidance on Hybrid systems that would become an example for K-12 school systems State-wide to consider for similar types of projects. Providing actual installed cost and operating cost information for various sizes and applications of Hybrid ground source heat pump systems will assist other school systems in their planning and project development activities for similar types of applications.

Accurate operating and maintenance costs developed from these operating systems will provide valuable data for decision makers, further enhancing the value of the Hybrid water source heat pump system installation.

### **B) SCOPE OF WORK**

The State of Tennessee Energy Efficient Schools Initiative (EESI) hired Commissioning of Green Building Solutions (CxGBS) as Project Administrator to coordinate the design, installation and performance monitoring of the Hybrid ground source heat pump projects that have been evaluated as being both technically and economically viable installations. The collaborative entity of CxGBS, EESI Council, the EESI-(TAC), CxGBS, CDH Energy, Oak Ridge National Lab (ORNL) and Kirk Mescher/CM Engineering, Inc. are designated as the EESI-Team.

## C) TASKS TO BE PERFORMED

### **PHASE 1**

EESI, the entity responsible for the disbursement and management of the excess State lottery funds, will provide alternative financing to the participating schools systems through their grant and low interest loan program. The Technical Advisory Committee (TAC) of EESI provided the initial technical review of the proposed Hybrid ground source heat pump installations and determined if the projects were technically and economically viable for implementation. TAC's membership is composed of professional engineers and architects, representatives from utilities and power distributors, and national labs. TAC made recommendations for funding and support to the EESI Council which made the final determination of the level of funding that each TAC recommended Hybrid ground source heat pump project would receive. EESI also worked with other State of Tennessee funding sources for applied energy conservation measures to determine if any additional funding levels were available for projects the EESI Council determined to be suitable for financial support.

The types of Hybrid ground source heat pump (HY-GSHP) systems that EESI promoted for consideration of participation in this innovative funding effort included the following HY-GSHP systems' options:

- GSHP, sized for a facility's base load, with cooling towers/boilers for peak loads,
- GSHP with cooling towers and innovative distribution single pipe loop system,
- GSHP with cooling towers and combinations of reverse-return and single pipe loop systems for common loops serving multiple school buildings.

The primary criteria for EESI consideration were HY-GSHP systems that can be replicated in school districts throughout the State of Tennessee in an economically viable manner.

#### **Task 1.1 – Feasibility Study**

Each school district was to prepare an engineering feasibility study for the proposed installation of the type of HY-GSHP system that was proposed to be installed. The EESI TAC evaluated the life cycle cost analysis in each schools district's engineering feasibility study in order to determine if the proposed HY-GSHP installation was technically viable and economically cost effective.

#### **Task 1.2 – Evaluate Site**

The EESI TAC evaluated each site with respect to the submitted engineering feasibility study which was to include any sample bore drill logs' information and thermal conductivity test results. If TAC requested that a site inspection be conducted, the EESI TAC Principal Investigator would either perform the site inspection or assign a TAC member in the vicinity of the proposed installation to perform the requested site inspection.

#### **Task 1.3 – Design Hybrid GSHP system**

The chosen individual school districts were to select an engineering design team to develop complete construction documents, including ground loop design, interior distribution loop design, mechanical equipment layout, DDC controls systems, pumps, specifications and other required items for a complete HY-GSHP system.

For the selected school districts, representatives of the EESI-Team worked with the designated engineering design team in the use of Cavanaugh's geothermal loop sizing program, and conducted reviews of the design of the

Hybrid systems including the bore-field sizing, fluid cooler/cooling tower sizing, heat pump sizing, and methods of control.

#### **Task 1.4 – Release Bid Documents and Project Management**

After final review by members of the EESI-Team, the school districts were released for the project to bid according to the respective school district's bidding procedures, bid evaluation process and bid award procedures.

The EESI-Team was to collaborate with the chosen school districts in the overall project management effort for all aspects of the Phase I work to select the most viable HY-GSHP system options, complete the necessary design and review phases, acquisition process of all systems' components, construction, commissioning, and acceptance of a fully functioning Hybrid ground source heat pump system.

### **PHASE 2**

Phase 2 includes the installation and commissioning of the complete Hybrid ground source heat pump system. Detailed costs for each project will be reported and an evaluation of both direct and indirect jobs created by each project will be made.

The EESI-Team was to provide regularly scheduled site inspections during each project's installation process. The EESI Program Administrator CxGBS was to conduct technical (testing-based) commissioning of the Hybrid ground source heat pump systems for each school site. The EESI-Team was to gather installation cost data for each project during each task of the HY-GSHP installation process and develop spreadsheets that could be used by other school districts who may want to consider HY-GSHP installations.

#### **Task 2.1 – Equipment Installation**

Installation was to be either a horizontal or vertical bore field, cooling tower, boiler, direct digital controls, interior loop piping and other mechanical equipment required for a complete HY-GSHP operating system. The EESI-Team was to provide technical assistance to each school district that requests it during the systems' installations.

#### **Task 2.2 – Equipment costs**

The EESI-Team was to develop detailed equipment cost reports for each school district's HY-GSHP installation. The developed reports were to break down pricing into small, easily compared components for use in developing accurate cost estimates for use by other school districts that may want to consider HY-GSHP projects. The EESI-Team was to develop a list of both direct and indirect jobs that were created by the individual school district HY-GSHP projects that were included in the EESI HY-GSHP program.

#### **Task 2.3 – Project Commissioning**

The EESI-Team's Project Administrator (CxGBS) was to work with the individual school districts in the capacity of a certified commissioning authority (CxA) for each HY-GSHP project in order to ensure that the system operated as designed and at optimum component efficiencies. For any required TAB activities, it was required that either a NEBB or TABB certified TAB contractor would conduct these activities.

## **PHASE 3**

### **Task 3.1 – Project Reporting and Data Collection**

Upon completion of each HY-GSHP systems' commissioning, the EESI-Team was to be able to download data from the building control system to assess data quality, calculate the energy use of the GSHP system and subcomponents, and to identify any problems with system operation and/or sensors..

#### **Task 3.1a: Develop detailed data collection plan**

The data collection plan, was to define all the monitored data to be collected and how it will be used to meet the project goals. The plan would define which systems will be tested in each school, what instrumentation and monitoring hardware will be used or installed, where and how it will be installed in each school, what continuous (15-minute) and one-time data readings will be collected.

#### **Task 3.1b: Install and maintain data collection equipment**

Log files were to be setup and automated processes were to be established to reliably capture the necessary data.

### **Task 3.3 – Annual Reporting**

At the end of each year, EESI-Team's Project Administrator was to prepare a report describing the performance of the GSHP system in each school during the previous year. This report was to include a detailed analysis of energy use and efficiency of the GSHP systems, and a breakdown of energy use by subcomponent. The energy use and pollutant emissions were to be compared with the energy use and pollutant emissions of similar nearby schools that use conventional equipment. The simulation model to be used was to estimate the energy use and pollutant emissions of each school if the heating and cooling been provided by conventional equipment. The report was to also analyze the performance of the bore field and fluid coolers in each school to compare their performance with the performance of conventional vertical loop ground heat exchangers.

### **Task 3.4 – Final Reporting**

EESI-Team's Project Administrator was to provide a complete dataset from the project and make it available to the National Geothermal Data System.

## COMPARISON OF PROJECT GOALS AND ACCOMPLISHMENTS

### **SUMMARY OF EESI COUNCIL & EESI-TECHNICAL ADVISORY COMMITTEE ACTIVITIES WITH ACCEPTED SCHOOL DISTRICTS FOR HYBRID-GSHP DOE GRANT PROGRAM**

- (PROPOSED HYBRID-GSHP SYSTEMS FOR SCHOOL DISTRICT'S PROJECTS)

The EESI-TAC proposed that the following HY-GSHP systems be implemented by the respective School Districts –

- Lawrence County Public School – Gym, a horizontal loop field had been installed under a previous contract and no as-built drawings or documentation were available. With the level of unknown conditions (loop field length, separation of horizontal loops, thermal conductivity tests and back-fill material for the horizontal loops, a conventional HY-GSHP with cooling tower and boiler was chosen as the preferred system. (Estimated load = 50 Tons.)
- Lawrence County South Lawrence School – Gym + Fieldhouse, another horizontal loop field had been installed under the same contract as the Lawrence County Public School and no as-built drawings or documentation were available. With the same level of unknown conditions as the Public School horizontal loop, a conventional HY-GSHP with cooling tower and boiler was chosen as the preferred system. (Estimated load = 50 Tons.)
- Hardeman County Bolivar High School - two areas were chosen by the owner to expand the existing interior loop by installing new GSHP units for seven classrooms and the hallways; Install a new HY-GSHP system using vertical bore holes, cooling tower and boiler for nine classrooms, Faculty Lounges and hall units in the remaining school wing.  
(Estimated total load = 75 Tons.)
- Hardeman County Middleton High School – Convert the existing conventional HVAC system to a HY-GSHP having a cooling tower, boiler and vertical geothermal loops. The HY-GSHP options chosen for this multiple wing building were a single pipe supply and return system for one wing and a reverse-return supply and return system for the second wing. (Total estimated load = 150 Tons.)
- Hamilton County Brainerd High School – Convert the existing inefficient HVAC system to a HY-GSHP having vertical bore holes, cooling tower and boiler. The routing of the HY-GSHP interior and exterior loop piping systems will be complicated with the presence of asbestos throughout the facility. Because of this existing condition, the EESI-TAC chose a basic HY-GSHP reverse-return piping system for this facility. (Total estimated load = 425 Tons.)

Representatives of the EESI Council and EESI-TAC met with the individual school system representatives to discuss the HY-GSHP system options chosen for their respective school facilities. The basic concern was with the design of the single pipe supply and return system. EESI had reached an agreement with the originator of the single pipe system to act as a design consultant (design services to any school district utilizing this design concept was to be paid by EESI.)

### **PHASE 1**

All of the School Districts and associated facility sites agreed in principle to the EESI-TAC HY-GSHP options chosen for the respective sites by EESI-TAC. These options would allow other Tennessee School Districts to compare options for HY-GSHP applications. The diversity of types of HY-GSHP systems design variances should also provide a good installation cost/system performance comparison for the various system options.

The various School Districts chose the engineering design consultants for their respective sites. The Hardeman County Bolivar High School, the Lawrence County Public School, South Lawrence School and Brainerd High School were designated as the initial projects for design services initiation.

The Project Administrator (Cx GBS) was selected by the State of Tennessee bid procurement process. The Executive Director of EESI conducted the initial meeting with the chosen Project Administrator and provided the EESI-TAC HY-GSHP options for the respective School District's facility sites.

### **Task 1.1 – Feasibility Study**

The engineering design consultants for Lawrence County and Hamilton County provided engineering feasibility studies for EESI-TAC review and approval. The engineering design consultant for Hardeman County developed a design narrative and submitted to the EESI Project Administrator who then submitted directly to the DOE Project Director for approval.

The preliminary Hardeman County Design Narrative for the Bolivar High School was approved by DOE. However, a modification request, which called for a more conventional heat pump system with additional capacity for peak cooling loads in summer, was submitted to DOE for consent due to owner project stipulations and safety/aesthetic considerations.

Given the results of the feasibility study presented to DOE for Bolivar High School, including system costs as well as safety/aesthetic considerations, the proposed variance from the originally approved Statement of Project Objectives (SOPO) was determined to be reasonable. A formal revision to the SOPO was completed to reflect this change through a modification to the award.

### **Task 1.2 – Evaluate Site**

A member of the EESI-Team visited all four sites included in the initial design effort. Photos were taken and interviews were conducted with School District personnel before the formal design process was initiated.

Prior to the site visit to Bolivar High School, EESI was notified of a design change request for a conventional vertical bore field, with GSHP components preferred by the owner, reverse-return supply/return piping loops and loop pumps. During the site visit of the Bolivar High School project EESI was advised that the DOE Project Director had approved their revised Design Narrative/Feasibility Study.

### **Task 1.3 – Design Hybrid GSHP system**

The engineering design consultants for Hamilton County, Hardeman County and Lawrence County were placed under contract with the respective school systems. In order for EESI to refund the various school districts for the engineering design consultants' fees, EESI-TAC mandated that 60% and 95% reviews be conducted. The EESI Project Administrator was also to conduct design reviews and develop Issues' Logs to be distributed to the respective engineering design consultants, designated school district personnel and EESI-TAC.

During the 60% review process, EESI-TAC discovered that the GSHP equipment being proposed for the Bolivar High School did not have 3<sup>rd</sup> party performance verification/certification as required by ASHRAE Standard 90.1. Even though the owner specifically required this GSHP equipment, the DOE Project Director confirmed that the 3<sup>rd</sup> party performance verification/certification was required for participation in the DOE Grant Program.

The required 3<sup>rd</sup> party performance verification/certification resulted in 4 month delay in the design activities for the Bolivar High School GSHP system. EESI-TAC required that the 3<sup>rd</sup> party report for each GSHP components

tested be sent directly to EESI Executive Director. This certification report was received and reviewed by EESI's TAC and Executive Director.

#### **Task 1.4 – Release Bid Documents and Project Management**

After all items on the Design Issues Logs were satisfactorily closed, the school districts were given the design drawings and specifications (bid documents) for inclusion in their bid package that included the school district's front end materials of bidder instructions and requirements. The EESI Project Administrator was also to conduct reviews of all performance monitoring drawings, diagrams and specifications of performance measuring components before submitting to the EESI-TAC for their review and approval.

The EESI-TAC was also made available to review the submitted bids for conformance to both the DOE HY-GSHP Grant Programs requirements and the respective design bid documents. The reviews of the submitted bids were documented and submitted to the school districts for their final approval and award.

The only difficulty experienced was with the lowest bid for the Bolivar High School project. The low bid was submitted by a mechanical contracting firm that was wholly owned by the manufacturer of the GSHP equipment (that the owner stipulated to use on their projects) but they did not have sufficient bonding capacity for the entire project. The owner wanted to exempt this requirement but the State of Tennessee Comptroller refused to allow any EESI funds be distributed for construction to a firm without sufficient bonding. This caused a delay in contract award for approximately 6 weeks until sufficient bonding was provided by the contractor.

#### **PHASE 2**

Phase 2 included the installation and technical commissioning of the complete Hybrid ground source heat pump system. Detailed costs for each project were to be reported by the EESI Program Administrator as well as an evaluation of both direct and indirect jobs created by each project.

The EESI-Team was to provide regularly scheduled site inspections during each project's installation process. The EESI Program Administrator was contracted to conduct technical (testing-based) commissioning of the Hybrid ground source heat pump systems for each school site. The EESI-Team/Program Administrator was to gather installation cost data for each project during each task of the HY-GSHP installation process and develop spreadsheets that could be used by other school districts who may want to consider HY-GSHP installations.

#### **Task 2.1 – Equipment Installation**

Install bore field (if applicable), cooling tower, boiler, direct digital controls, interior and exterior loops' piping and other mechanical equipment required for a complete HY-GSHP operating system. The EESI-Team was made available to provide technical assistance to each school district that requested it during the systems' installations.

The following are photos of the HY-GSHP Installations for Hamilton County and Lawrence County facilities that were a part of the EESI HY-GSHP Program:

**Hamilton County Brainerd High School –**



Photo 1 – Exterior Geothermal Main Distribution Loop



Photo 2 Cooling Towers for HY-GSHP System



Photo 3 Geothermal Loop Header

**Hardeman County Bolivar High School –**



Photo 4 New Loop Field Location



Photo 5 New Hall GSHP Unit



Photo 6 Classroom GSHP Unit

**Lawrence County Public School –**



Photo 7 New Cooling Tower



Photo 8 New WSHP Units for Gymnasium



Photo 9 New Fabric Duct for Gymnasium

Lawrence County South Lawrence -

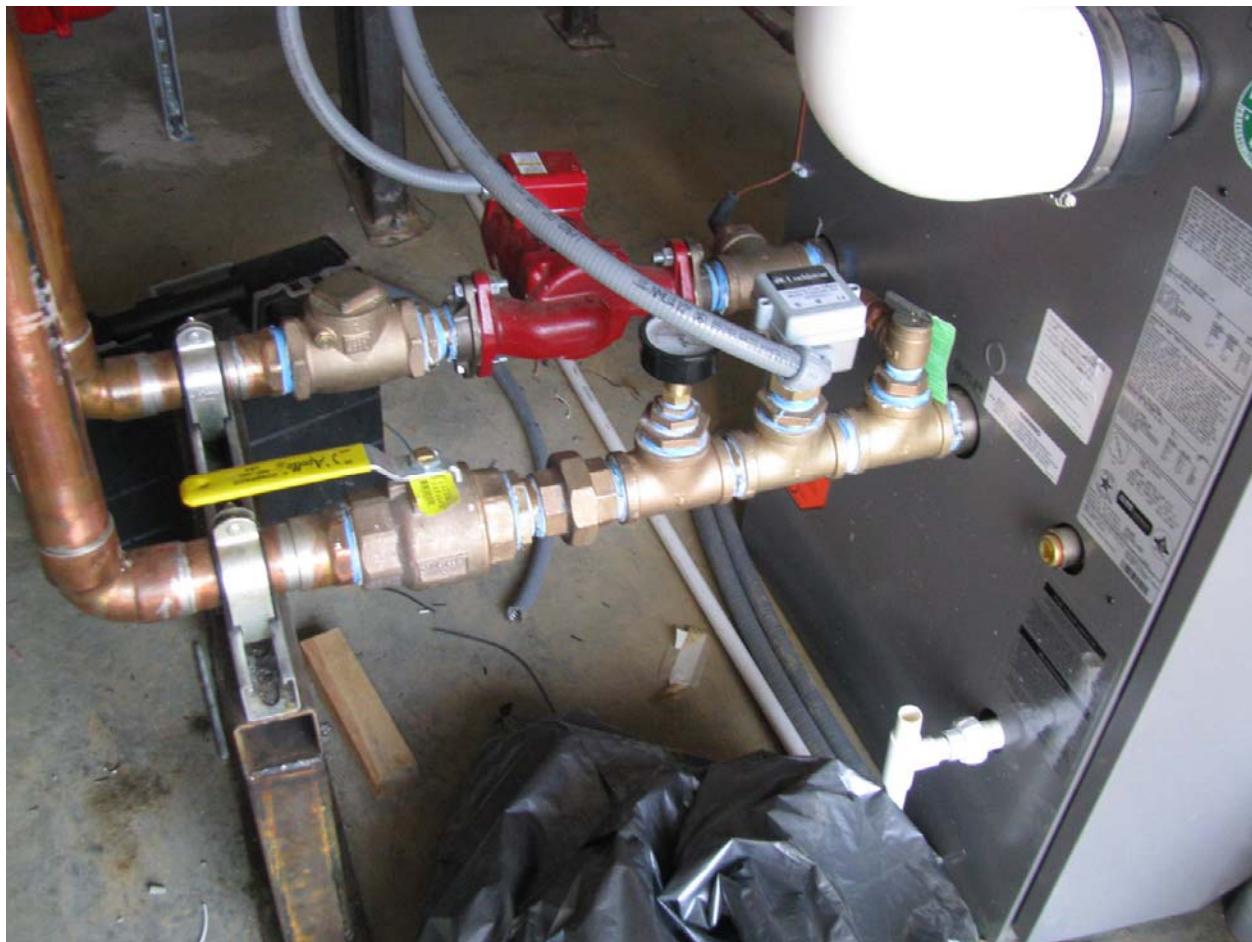


Photo 10 Typical Heat Pump Piping Connection



Photo 11 Cooling Tower for Gym & Locker Room/Weight Room



Photo 12 Ductwork for Gym

### **Task 2.2 – Equipment costs**

The EESI-Team’s Project Administrator was to develop detailed equipment cost reports for each school district’s HY-GSHP installation. The developed reports were to break down pricing into small, easily compared components for use in developing accurate cost estimates for use by other school districts that may want to consider HY-GSHP projects. The EESI-Team’s Project Administrator was to also develop a list of both direct and indirect jobs that were created by the individual school district’s HY-GSHP projects.

### **Task 2.3 – Project Commissioning**

The EESI-Team’s Project Administrator was to work with the individual school districts in the capacity of a certified commissioning authority (CxA) for each HY-GSHP project in order to ensure that the system operated as designed and at optimum component efficiencies. The scope of technical commissioning activities that were to be conducted were –

- Observe all equipment start-up activities (Performance Verification Testing (PVT)),
- Conduct Pre-Functional Tests of the geothermal systems’ components,
- Conduct Functional Performance Tests of the entire HY-GSHP system,
- Conduct point-to-point tests of all Performance Monitoring devices of the Building Automation System’s (BAS) sequences of operation,
- Assist in any trouble-shooting activities that are required to make the GSHP systems operate per design documents,
- Assist in Program Close-Out activities for the geothermal systems’ installations,
- Co-ordinate any training of the Staff and school system’s O&M personnel on the operation and maintenance of the geothermal systems,
- Assist in any trouble-shooting and corrective actions for performance-limiting items that are discovered during the performance monitoring period.

For any required TAB activities, it was required that either a NEBB or TABB certified TAB contractor would conduct these activities.

At this point in the various installation and start-up activities of the four initial sites, the Hardeman County School District informed the current Executive Director of EESI that they would not pursue the Hybrid geothermal installation at the Middleton High School site due to problems with having sufficient matching funds over and above any DOE and EESI funds that would be available for them to use.

### **PHASE 3**

Phase 3 consists of compiling and analyzing operational data collected from the BAS located at each school site. The EESI Project Administrator was responsible for providing the EESI-Team with the access information for downloading performance data from each school site.

At the beginning of the Phase 3 activities, it was the decision of the current Executive Director of EESI to not seek to renew the contract of the EESI Project Administrator because the contract had expired and could not be renewed per the Department of Education’s Financial Section.

### **Task 3.1 – Project Reporting and Data Collection**

## **INCOMPLETE AND OUTSTANDING**

### **Task 3.1a: Develop detailed data collection plan**

This task is the responsibility of each school system for their respective geothermal projects funded by the DOE HY-GSHP Grant Program.

### **Task 3.1b: Install and maintain data collection equipment**

This task is now the responsibility of the individual school systems for their respective geothermal projects funded by the DOE HY-GSHP Grant Program.

### **Task 3.3 – Annual Reporting**

This is an optional requirement for the individual school systems to provide EESI with annual reports about the operation and performance of their GSHP systems funded under the DOE HY-GSHP Grant Program.

### **Task 3.4 – Final Reporting**

This requirement is being prepared by the EESI Executive Director's office and the EESI-TAC.

## OVERALL PROJECT SUMMARY AND RECOMMENDATIONS

The Tennessee Energy Efficient Schools Initiative's (EESI) purpose for participating in the DOE Hybrid Geothermal Water Source Heat Program was to develop initial cost and operating information/utility cost savings for the various K-12 School Districts to consider and evaluate for either the renovation or the construction of new school facilities. The proposed four Hybrid-Water Source Heat Pump (HY-GSHP) configurations were to be located at Hamilton County's Brainerd High School, Hardeman County's Bolivar High School and Middleton High School, and Lawrence County's Lawrence Public School and the South Lawrence Elementary School.

The State of Tennessee decided to hire an independent Program Administrator for EESI and chose Commissioning of Green Building Solutions (CxGBS) after conducting an RFP process. The EESI Program Administrator was to work closely with the EESI Council and the EESI Technical Advisory Committee (TAC) during all phases of the DOE HY-GSHP program's phases. The following Scope of Services was integrated into the Program Administrator's contract

- Conduct Technical Commissioning approach with the design phase of each project funded with DOE HY-GSHP grant monies,
- Observe all equipment start-up activities (Performance Verification Testing (PVT)),
- Conduct Pre-Functional Tests of the geothermal systems' components,
- Conduct Functional Performance Tests of the entire HY-GSHP system,
- Conduct point-to-point tests of all Performance Monitoring devices of the Building Automation System's (BAS) sequences of operation,
- Assist in any trouble-shooting activities that are required to make the GSHP systems operate per design documents,
- Oversee Data Collection Phase of the DOE Grant Program,
- Assist in Program Close-Out activities for the geothermal systems' installations,
- Co-ordinate any training of the Staff and school system's O&M personnel on the operation and maintenance of the geothermal systems,
- Assist in any trouble-shooting and corrective actions for performance-limiting items that are discovered during the performance monitoring period,
- Provide Project Closeout activities for EESI and assist in the development of the Final Report to DOE.

The three school districts and four school facilities that were a part of the EESI HY-GSHP Program were able to get new, high efficient heat pump components and hybrid system components integrated into working HVAC systems that are saving the school districts energy consumption and operating costs each year. The school districts also have integrated performance verification programs into their respective school system's BAS/EMS master system. EESI is now working with each school system to have them upload their utility consumption information into the EPA Portfolio Manager platform for comparative and analysis purposes by EESI.

In comparison with the Original Project Goals, the majority of the Tasks defined in the EESI Program Objectives have been realized in accordance with acceptable applications of geothermal systems by the respective school systems. The participating school districts now have achieved energy consumption savings, reduced operation & maintenance costs and HVAC systems that have longer useful lives than the systems they replaced.

One of the largest benefits being realized by the participating school districts is that the facilities installing HY-GSHP systems are also complying with the ventilation and comfort requirements defined in ASHRAE Standards 55 and 62.1 as well as ASHRAE Standard 90.1, energy efficient HVAC systems. The collective effect of these compliances is an improved learning environment for the students and a better working environment for teachers and staff.

#### **RECOMMENDATIONS FOR CONSIDERATION ON FUTURE DOE GRANT PROGRAMS**

1. Any school district wanting to participate in a DOE Grant Program that requires performance verification/performance data recording and reporting must have an existing open-protocol platform Building Automation System/Energy Management System (BAS/EMS) that is capable of being updated on a regular basis.
2. Any future renewable energy-oriented grant program must be able to develop a “dashboard” for an ongoing Performance Verification program that is specifically developed for each grant program facility. This will also require a comprehensive training program, regularly scheduled follow-up and performance observation activities by the Program Administrator for each facility in the grant program.
3. If a DOE Grant Program is intended to improve the energy performance of a facility, the first grant program requirement should be the implementation of a Technical Retro-Commissioning (RCx) program for the purpose of making the existing facility as-energy-efficient-as-possible before any new energy efficient/renewable energy systems are integrated into a facility. The cost for the RCx program and systems' upgrades should be a part of the DOE Grant Program's scope and funding.