FINAL SCIENTIFIC/TECHNICAL REPORT

Project Information

DOE Award Number:	DE-EE0002817
Name of Recipient:	Furman University
Project Title:	North Village Ground Source Heat Pumps Demonstration Project
Project Period:	September 30, 2010 thru September 30, 2014
Project Director:	Jeff Redderson, P.E.
Total Project Cost:	$4,915,482
DOE Award:	$2,457,741

Executive Summary

Furman University successfully completed the North Village Ground Source Heat Pump Demonstration Project which included the installation of ground source heat pump systems in 10 on campus student housing buildings. The housing consists of apartment style units with 4 students in each apartment and a total of 96 students in each building. Each building is now served by a dedicated Ground Source system consisting of twenty, 500 foot nominally deep vertical wells and a pumping system for the 24 indoor heat pumps. The systems are operating very well and meeting all the operational goals established for this project. As a regional and national leader in sustainability, Furman used this grant as a teaching tool and model for its students and other universities in the Southeast. This innovative project demonstrated the economic feasibility of retrofitting ground source heat pumps in existing residence halls in an academic setting. The Shi Center for Sustainability will continue to conduct data gathering and analysis of the project's effectiveness in reducing energy consumption and greenhouse gases. This information will help tell the story of how nearly 40% of Furman's campus student housing was transformed into a living laboratory on the effectiveness of using this renewable energy technology.

<u>Provide a comparison of the actual accomplishments with the goals and objectives of the project.</u>

Project Goals and Objectives

A. PROJECT OBJECTIVES

Furman University proposed to install ground source heat pumps in tenbuildings of student housing on campus, housing 1,020 students in 255 apartments. As a regional and national leader in the sustainability movement, Furman planned to use this grant as a teaching tool, catalyst and model for its students, other universities and the Southeast. The outcome of this innovative project demonstrated the economic feasibility of ground source heat pumps in academic and commercial real estate settings. Many benefits wererealized from the installation of these systems including the replacement of aging existing equipment, signficantly lower energy consumption and annual expenses, enhanced exterior environment (reduced noise and improved aesthetics), and signficicant progress toward Furman's carbon neutrality goals. The Shi Center for Sustainability conducted data gathering and analysis of the project's effectiveness in reducing greenhouse gases which transformed almost 40% of campus student housing into a living laboratory on the effectiveness of this renewable energy technology. As a private institution with a very public mission, Furman used its participation in the Department of Energy's Ground Source Heat Pump funding opportunity not only to improve our already robust campus climate change initiatives, but also to disseminate technical advice, "best practices", innovations and information to the other fifteen colleges that comprise the Associated Colleges of the South (ACS) and to the broader community in the Southeast.

B. *PROJECT SCOPE*

Furman University's Ground source heat pump project demonstrated the feasibility of retrofitting a traditional and aging heating and air conditioning heat pump system with innovative ground source heat pumps. Construction consisted of the installation of approximately 264 wells (350 feet deep each) to supply originally planned 11 buildings. The data generated from the new system analyzed by students participating in Furman's Shi Center for Sustainability and compared to comparable data from when the apartment-style dormitory buildings were heated and cooled by older heat pumps. A sophisticated tracking system installed to showcase how much energy is being used at the apartment unit level; this can be easily compared to data from older units and thus give real-time information to the students inhabiting the apartments as well as form the basis for analysis of system performance and benefits. The buildings accommodate 1,020 residents in 220 private and 35 shared bedroom apartments.

C. PERFORMED TASKS

<u>PHASE 1 Feasibility Study and Design</u>

Task 1.0 Preliminary Feasibility Study

Description: A preliminary feasibility study was completed to determine whether the installation of a GHP system in the North Village Apartments would be economically and technically possible. The study identified the project's preliminary assumptions and the scope of the project. The required performance data were identified, the equipment and materials needed for the project were listed and quotes solicited from vendors. The preliminary design, construction and labor plans were also established. A tentative project budget and cost estimate was completed and grants, rebates and incentives were identified. The site map was reviewed and a preliminary layout of the geothermal wells developed. Finally, an analysis of energy savings of the proposed project was completed.

Task 2.0 Feasibility Study
Description: A feasibility study was completed that produced the project's final scope and confirmed the performance data. Test wells were drilled and the final list of equipment and materials was completed. The exact steps of the design, construction and labor plans were completed as well as the final project budget and cost estimate. The preliminary labor and site drawings were reviewed and an analysis of energy savings and the cost model was completed.

Task 3.0 Design
Description: A complete project design will be undertaken, beginning with a review of the existing heat pump system, which is at the end of its projected life. Load verification tests will be conducted. New equipment diversity factors will be established and flow rates and water requirements will be confirmed. The pipe system for the ground source heat pumps will be designed and the project's requirements for equipment and materials established. Construction drawings will be completed and reviewed and approved by the appropriate permitting agencies and Furman University.

<u>Go – No Go</u>
A Go – No Go review was conducted on the acceptability of deliverables listed below in order to determine the path forward for Phase 2. Path forward options included but were not limited to: 1) Proceed with activities described in Phase 2; 2) Gather additional data or conduct additional analysis to complete the Feasibility Report; and/or 3) Complete work necessary to complete Engineering/Design work or to obtain the required permits or water rights.

<u>Phase 1 Deliverables:</u>
- Feasibility Report
- Engineering/Design work
- Permits Required to Proceed to Phase 2

<u>PHASE 2 Construction and Commissioning</u>

Task 4.0 Construction
Description: Construction of ground source heat pump system was completed for 10 buildings, including the following: 20 wells with HDPE tubing installed for each of 10 buildings; landscape restoration; removal of refrigerant from North Village's existing

heat pumps, and also removal all existing heat pumps; installation of new ground source heat pumps; installation of new pumps and pads; installation of VFD's for each pump; reworked ductwork in all 10 buildings; installation of piping from wells to buildings; insulation of pipe and ductwork; installation of controls and electrical. Final as-built drawings and engineering plans of the completed project was required of the project engineer and contractors.

Task 5.0 Commissioning
Description: Furman University hired a third party to review the design and equipment specifications/submittals, recommend design changes, and confirm the final operation and commissioning of the ground source heat pump system.

<u>PHASE 3 Installation of Data Systems</u>

Task 6.0 Install Metering/Controls
Description: Metering and controls was installed, to monitor and analyze dynamic, real time energy data for the 10 buildings served by the new ground source heat pump system.

Task 7.0 Install Dashboard Viewing System
Description: Installed Dashboard viewing system which allows students, faculty and staff to view, monitor and analyze dynamic, real time energy data for the 10 buildings served by the new ground source heat pump system.

Comparison of Actual Accomplishments versus Goals and Objectives

Furman University met all of the primary objectives of the project but there were a number of changes made to the project scope during the design and installation process. Many of these changes were made in an effort to control expenses but always with the knowledge of the potential impact on the efficiency on the system.

The most significant change to the project scope was to reduce the number of buildings to be retrofitted from 11 to 10. The last building was not retrofitted in an effort to reduce capital expenditures and to stay within the original budget. The increased expenses were due to escalating construction costs in the drilling subcontract. In addition, in an effort to reduce drilling expenses, the scope for the vertical bores changed from 24, 350 foot deep wells per building to 20, 517 foot deep wells. This change also resulted in additional footage of heat transfer area that was needed due to the lower than expected heat transfer coefficient discovered during the installation of the test bores.

The 10 buildings that were successfully retrofitted with ground source heat pumps are operating very well and providing the expected energy savings. The dashboard system that monitors the system performance has been installed and is being monitored by the departments of Sustainability Science and Earth and Environmental Science on a periodic basis. The dashboard is also monitored on a continuous basis by Facilities Services staff to ensure the systems are operating at peak efficiency. Students and faculty affiliated with Furman's Shi Center for Sustainability have analyzed the ground source heat pump project, and the results of the grant have been disseminated on campus and discussed at regional sustainability meetings of the 16 member colleges of the Associated Colleges of the South (ACS).

Background Information and Importance of Project to Furman University

Over the past fifteen years, Furman University, a 2,600 student liberal arts college in Greenville, South Carolina, has enjoyed extraordinary support for a wide array of initiatives related to sustainability and climate action. Higher education has appropriately become the seedbed of the burgeoning sustainability movement, with Furman at the center of sustainability activity in the Southeast. Colleges and universities have a responsibility to model sustainable behavior within our institutions and to inspire students to embrace a more sustainable way of life. To that end, Furman was one of the charter members of the American College and University Presidents' Climate Commitment. Over the last fifteen years, Furman University has made sustainability one of its primary institutional goals. Sustainability and environmental citizenship were major emphasis of the university's 1997, 2001, and 2004 strategic plans. In 2001, the Board of Trustees unanimously agreed "to strengthen our commitment to the environment by promoting sustainability through educational programs, campus operations and construction practices, and public awareness initiatives." The university's approach is systemic and holistic: to weave sustainability into the very fabric of Furman's institutional life and campus culture, not just campus operations and construction practices, but the curriculum, co-curriculum, and community outreach activities.

Although Furman has been institutionally committed to sustainability since 1997, its geographic region, the Southeast, has for various reasons, lagged behind the rest of the country in addressing the implications of climate change. Low electricity rates, a growth-oriented business culture and conservative cultural climate, and a lack of government involvement in issues such as public transportation, land use planning, zoning, and even meaningful building codes, have all contributed to the region's relative indifference to energy conservation issues. The great challenge for GHP systems in particular and renewable energy in general is to overcome these challenges and demonstrate they can be utilized in the setting of an already built environment. GHP is relatively easy to install in new construction but has not proved economical for retrofits. Since significant savings in energy conservation and carbon reduction cannot come about unless older buildings can be renovated with more efficient systems. Furman saw this project as a crucial demonstration of the usefulness of this technology on college campuses and in the Southeast. Furman has one of the largest concentrations of LEED buildings in the area, is considered a national leader in sustainability, and has experience installing and managing GHP systems.

Since 2001 Furman has required that all new and renovated buildings gain LEED certification. In July 2003, Herman Hipp Hall became the first LEED building in South Carolina and was one of the first buildings in the Southeast to receive a “gold” rating. Eight buildings on campus, with approximately one quarter of Furman’s 2 million square feet of conditioned space, are now LEED certified and/or registered. At ~166 square feet of LEED-building space per student, Furman sits at the top of higher education in its commitment to green building. Thus Furman had the commitment, experience and management in place to successfully implement the installation, utilization, and analysis of an innovative ground source heat pump system. The university’s Facilities Services Department conducted an extensive preliminary study, in collaboration with a contractor and engineer who not only had direct experience in designing and installing complex systems, including ground source heat pumps, but had worked on Furman’s campus on several renewable energy projects. We completed this project in a timely manner, on time and on budget, because we had extensive experience with similar projects, we had experienced personnel in place, and we had longstanding relationships with reliable contractors and engineers. Furman University provided the 50% cost share required for this project, with an expected payback of Furman’s cost share over 20 years.
Furman’s ground source heat pump project addresses existing market barriers to installing GHP systems by retrofitting ground source heat pumps into an already existing heat pump system. This deployed GHP systems on a very large scale, as the project serves ten of the buildings that comprise North Village housing, a total of 240 apartment units. 615 tons of heating and air conditioning equipment were converted to a GHP system. We believe this project will make a significant impact on GHP market demand because it was one of the largest GHP systems installed in the area. The Southeast has not traditionally led the way concerning renewable energy; some local residential homes have been built with GHP systems, but Furman’s Cliffs Cottage is one of the larger and more innovative ground source heat pump systems installed in the region. The Cottage is a model for local builders, developers, real estate professionals and homeowners on the feasibility of green building practices in the Southeast. The Cliffs Cottage received in-kind donations from over 100 vendors during construction, almost all of which were local construction materials suppliers. Sometimes to have a market you have to create one; Furman’s commitment to sustainability has actually helped create the renewable energy market in the area. The University’s requirement that all new buildings and renovations of existing buildings be conducted to LEED standards has created one of the largest collections of LEED certified buildings in the Southeast.

The North Village GHP project demonstrated to local contractors, builders and developers that a very large ground source heat pump system is a feasible retrofit, just as the Cliffs Cottage demonstrated the feasibility of ground source heat pumps for residential new construction. We know of no other project in the area or in the Southeast that deployed GHP systems on such a large scale, and as a retrofit to an existing complex of buildings. This project familiarized local contractors and engineers with the design and mechanical aspects of installing such a system, enabling them to undertake other GHP system projects more cheaply, efficiently and quickly.

Because Furman's campus was relocated from downtown Greenville, South Carolina to a more rural and expansive campus outside of town more than 50 years ago, our existing buildings and our building systems are quite inefficient in terms of energy ratings. We are extensively exploring exactly how to retrofit aging buildings in a manner that is both technically innovative, cost-effective, and also produces significant reductions in Furman's carbon footprint. We are not alone in facing this problem, which is arguably one of the most difficult issues for renewable energy. The North Village Ground Source Heat Pump project was innovative in that it explored whether renewable energy technologies can cost-effectively be utilized for the footprint of an existing building and be retrofitted into an existing HVAC system.

Furman's staff has a depth and breadth of experience managing renewable energy that is unusual among organizations in the Southeast. Because of this commitment, Furman's Facilities Services team has extensive experience with renewable energy projects. New construction and renovations continue to be committed to sustainable and energy-efficient design and LEED practices. The detailed cost benefit analysis conducted by Furman's Facilities Services Department highlighted the cost savings of installing GHP in the North Village. Furman anticipates savings of over $2.2 million over the anticipated life of the system. Actual savings will likely be much greater because a very modest increase in electricity rates was projected in the cost benefit analysis. The North Village GHP system will save our campus approximately 780,000 kilowatt hours annually over the heat pump system it replaced and greatly assists Furman's climate commitment goal.

Furman University utilized a team approach to install a ground source heat pump system in the North Village, with a management, engineering and construction team well versed in renewable energy and experienced in working on Furman's campus. The Facilities Services Department oversaw all aspects of the project. Facilities Services hired a design-build construction and engineering firm to design the project and install the GHP system. This company had worked on many projects on our campus and was familiar with systems and management styles. Since Furman had a depth of knowledge of renewable energy projects, we did not experience any significant problems in completing this project.

Furman hired its first energy engineer in 1980. Building automation, window insulation, and relighting programs saved much money during the 80's and 90's, however, GHG reduction did not become a goal until 2000 with the establishment of the Eco-Cottage. Since 2004, GHG reduction has been the primary goal of the green building programs, energy conservation efforts, and reductions in motor vehicle usage on campus. Continued refinements in campus energy policy and conservation efficiency upgrades (VFDs, CFLs, LEDs, roofing upgrades, insulation, CO_2 sensors, more efficient appliances, water flow restrictors, direct digital control systems, and refined building automated systems) are steadily reducing campus energy usage, and have provided Furman's staff and related construction and engineering services with a wealth of experience in managing renewable energy projects.

In the Southeastern United States, current institutions and individuals have access to significantly lower-cost energy than other regions in the country. As is true of many universities, Furman's campus consists mostly of older buildings constructed before the importance of energy efficiencies was emphasized. We have completed some retrofit projects including lighting upgrades, HVAC equipment replacements, and a centralized building automation system; however, there is much more that needs to be accomplished. Because our needs exceed our available resources, our challenge is to identify cost effective retrofit solutions and phased plans that take advantage of the latest technologies, utilize internal labor resources (where possible), and effectively improve the energy efficiency of our buildings.

We continue to explore effective methods for retrofitting existing buildings with energy-saving devices and consider the North Village GHP project to be an extremely important demonstration of this possibility. Most construction research has focused on new construction, but the majority of college campuses, including Furman, have many buildings constructed long before energy-efficiency was considered in construction techniques; these, too, must be taken into account when considering how to implement strategies to minimize climate-change impacts. We need case studies and models, both on and off campus, and advice on how to convince skeptical stakeholders that retrofitting should be undertaken, even when the cost savings are not immediately apparent. We are convinced that GHP systems are a cost-effective method of retrofitting buildings, but because of the low energy costs in the Southeast, local and even regional companies are unfamiliar with new technologies/techniques that may be available in other areas of the country. We consider this project a means of identifying construction methods that really work in the Southeast.

For the geothermal system (a new Sustainability Living/Learning Laboratory), we will conduct applied research on the conservation and energy use impact (we will collect baseline data pre installation) as well as the community outreach and education impact of having this additional Sustainability Living/Learning Laboratory on campus. The Shi Center will work with student-faculty teams to monitor energy use over time. We plan to use this system as an integral part of our May Experience course on Campus Renewable Energy (corroboratively taught with faculty from another institution to share examples of wind and biomass). Inclusion of this system on Furman's campus will allow the upstate South Carolina community to have an example of this renewable energy approach. The opportunity for student-faculty research on the system and its impact on community use will be helpful in understanding the transferability and impact of the system beyond the campus boundary.

Because of Furman University's regional and national leadership role in sustainability, we have seen a great deal of interest in replicating our success with this project. Since 1997, Furman has played a leadership role with the Associated Colleges of the South's Environmental Initiative (ACSEI). The Associated Colleges of the South (ACS) is a consortium of sixteen liberal arts colleges from Texas to Virginia and from Kentucky to Florida. Our membership in ACS and leadership role in sustainability has enabled

Furman to highlight the success of the North Village Ground Source Heat Pump project to universities throughout the Southeast.

Furman is one of twelve colleges and universities collaborating with the Rocky Mountain Institute (RMI) to work on "breakthrough" projects on campus to help mitigate the effects of global climate change. RMI works to promote energy and resource efficiency. This collaboration allows Furman to work with other colleges across the nation and to learn from their diverse approaches to reducing greenhouse gas emissions. Furman's relationship with RMI and the 12 case study schools ensures our GHP project results will be disseminated and replicated on a national scale. Furman consistently has one of the largest contingents to attend AASHE meetings. Furman thus has an active and prominent role in renewable energy among academic institutions and the general community.

Furman's Shi Center for Sustainability and Sustainability Planning Council has worked with The Duke Endowment (a $3 billion foundation headquartered in Charlotte, North Carolina) to provide a **Climate Action Planning Workshop at Furman**. The workshop included student participants along with faculty/staff representatives from the four Duke Endowment-supported schools—Davidson, Duke, Furman, and Johnson C. Smith. Furman faculty and staff have drafted a Climate Action Plan that can serve as a model for the other Duke Endowment-supported schools, as well as other schools across the nation who are grappling with writing their climate action plans. In addition, a Duke Endowment sustainability task force (coordinated by Furman's Shi Center for Sustainability) has been promoting large-scale renewable energy options for the four endowment-supported universities. In this context, Furman's North Village GHP project was presented as an important facet of our climate action plan and sustainability initiatives.

The Shi Center for Sustainability has also been working to connect Furman's sustainability efforts with the greater Greenville community through applied research projects in collaboration with Greenville Forward, the non-profit organization responsible for implementing the city's strategic plan. The Center has created a student counterpart organization to Greenville Forward, called Furman Forward, which has discussed the North Village project to the greater Greenville community. Furman has provided multiple community workshops to promote energy auditing, organic gardening, rain gardens, and sustainability.

Summarize project activities for the entire period of funding, including original hypotheses, approaches used, problems encountered and departure from planned methodology, and an assessment of their impact on the project results. Include, if applicable, facts, figures, analyses, and assumptions used during the life of the project to support the conclusions.

Project Overview: Furman's Geothermal Installation in North Village Apartment Complex

In striving for campus carbon neutrality by 2026, Furman's Sustainability Master Plan outlines many strategies, including employment of solar thermal panels, solar photovoltaic panels, an ecological wastewater treatment plant, and an organic farm. Furman's current project most influential in reaching carbon neutrality is its geothermal, or ground source heat pump (GSHP), installation in the on-campus apartment complex, North Village.

The traditional HVAC systems in the university's apartment complex were traditional heat pumps and they were at the end of their anticipated life cycle when Furman applied for a grant from the Department of Energy's American Recovery and Reinvestment Act Funding for Research and Development in 2009. Furman received this award of $2,457,741 for its geothermal installation project in which Furman matched the funding received to pay for the rest of the project. Furman's 50% cost share was paid with money earlier allocated for replacing the existing, outdated HVAC systems.

This complex is made up of 10 apartment buildings, which house 1,020 students in 255 apartment units. In order to avoid disturbing the Furman community during the academic year, the installation project was divided into three phases. The construction took place during three consecutive summers with additional preparation during the university's winter breaks. This project was substantially complete in August 2013 although some testing and commissioning extended beyond this date.

The project provides a case study example for other institutions and universities, in particular, to contribute to the improved understanding of the potential to successfully install geothermal systems on a campus and more specifically in the Southeastern United States. Perhaps most important is that this geothermal installation supports large-scale traditional system retrofits to more efficient, renewable energy sources for existing buildings.

When the idea of installing Ground Source Heat Pumps (GSHP) first emerged, it was important to educate and inform the campus community regarding how the system would work. Below is an example of some of the information shared with the campus.

While air temperatures continually fluctuate throughout the year, ground temperatures remain fairly constant. Ground Source Heat Pump (GSHP) systems taken advantage of

the steady earth temperature by exchanging heat between the ground and the water running through a ground loop piping system. By installing a ground loop that circulates water through pipes; in heating mode, cold water from the heat pumps is heated by the earth and return back to the heat pump. In cooling mode, the system reverses.
Heat from the building is pulled out and input into warm loop water that is then cooled by the earth and then returned to the heat pump. GSHP systems have indoor heat pumps and do not require outdoor fan cooled units as is the case with traditional split systems. The elimination of the outdoor unit eliminates outdoor noise, aesthetic issues and provides a much more pleasant outdoor environment. Major components of GSHP systems include the heat pumps, ground loop pumps, ground loop distribution piping, and a heat source/sink which usually consists of vertical wells drilled into the earth. These systems take advantage of the relatively constant temperature of the geothermal gradient. The ground loop becomes a source of heat in the winter and becomes a place to store rejected heat during the summer.

Studies show ground source heat pumps reduce energy consumption and further reduce energy cost. Preliminary analysis projected that Furman's geothermal system retrofit will reduce energy consumption by over 1,000,000 kilowatt-hours each year, eliminating over 600 metric tons of carbon dioxide emissions and cutting energy costs by $55,000 annually. These savings project a payback period of roughly 20 years for Furman's financial investment. Other advantages of this system include installation capability in a variety of structures (residence, office, etc), ability to heat water with installation of de-superheater, creation of local employment, and production of a more comfortable built environment without uneven heating and cooling.

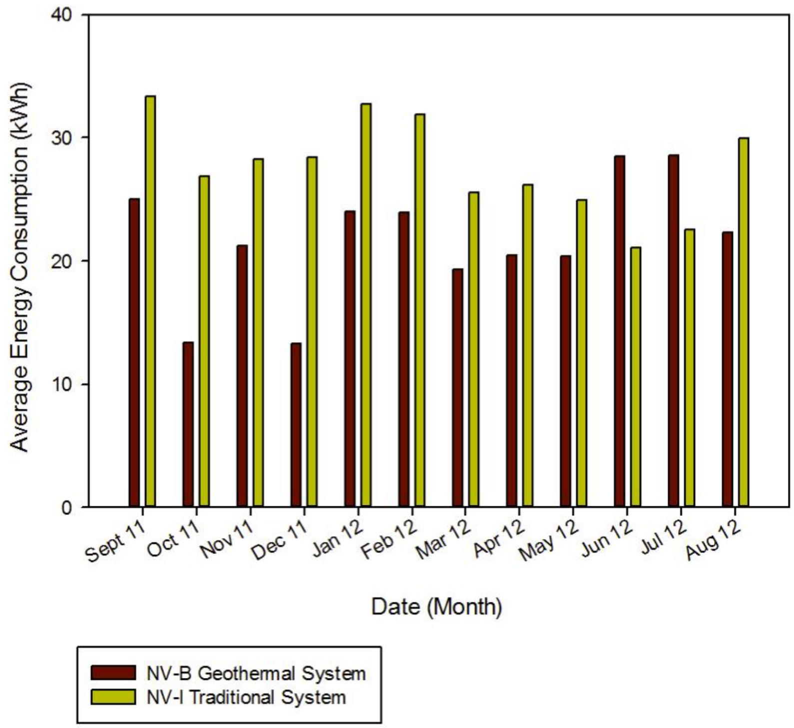


FIGURE 1 - *Energy Consumption in Traditional and Geothermal HVAC Systems.* This figure compares energy consumption in a building using ground source heat pumps (NV-B) and energy consumption in a building that has not been retrofit (NV-I). This graph shows the consistent reduction in energy consumption for the geothermal unit except during the summer months. The increased energy consumption during June and July is a result of the geothermal building (NV-B) being occupied while the traditional building (NV-I) remained vacant during this time.

INSTALLATION PROCESS

Vertical closed-loop systems, instead of horizontal, were installed in order to account for the amount of piping needed as well as to reduce the land area required. All 10 apartment buildings is connected to its own ground loop made up of 20 wells. Each well averages a depth of 517 feet. The geothermal wells are not visible to building occupants because they are installed under each building's asphalt parking lot.

FIGURE 2 - This diagram displays the layout of the geothermal well fields for all apartment buildings that were renovated. Each dot represents a well that is connected to the building's geothermal ground loop.

Originally, the wells were designed to be installed in grassy areas adjacent to each building. However, after drilling several test wells, the contractor team soon realized that it was going to be extremely challenging to control the water and solids runoff from the drilling process. Options were reviewed and it was decided that moving the well fields to the adjacent parking lots would greatly enhance our ability to control this water runoff due to the hard surface and storm water piping infrastructure that was already present. This change added a small amount of expense to the project due to the repaving process but it certainly made the project proceed much more efficiently and smoothly.   Figure 3 below shows the drilling process taking place in a parking lot.

Figure 3 – Drill rigs installing vertical wells in North Village parking lot

Below is an illustration of the details of the vertical wells that were installed. Granite was encountered at vary depths ranging from 67 to 148 feet and casing was utilized in each well until the solid granite layer. Based on the test wells that were installed, 75 feet of casing was estimated for each well. However, the actual amount of casing required exceeded our estimated amount and this contributed to budget related problems.

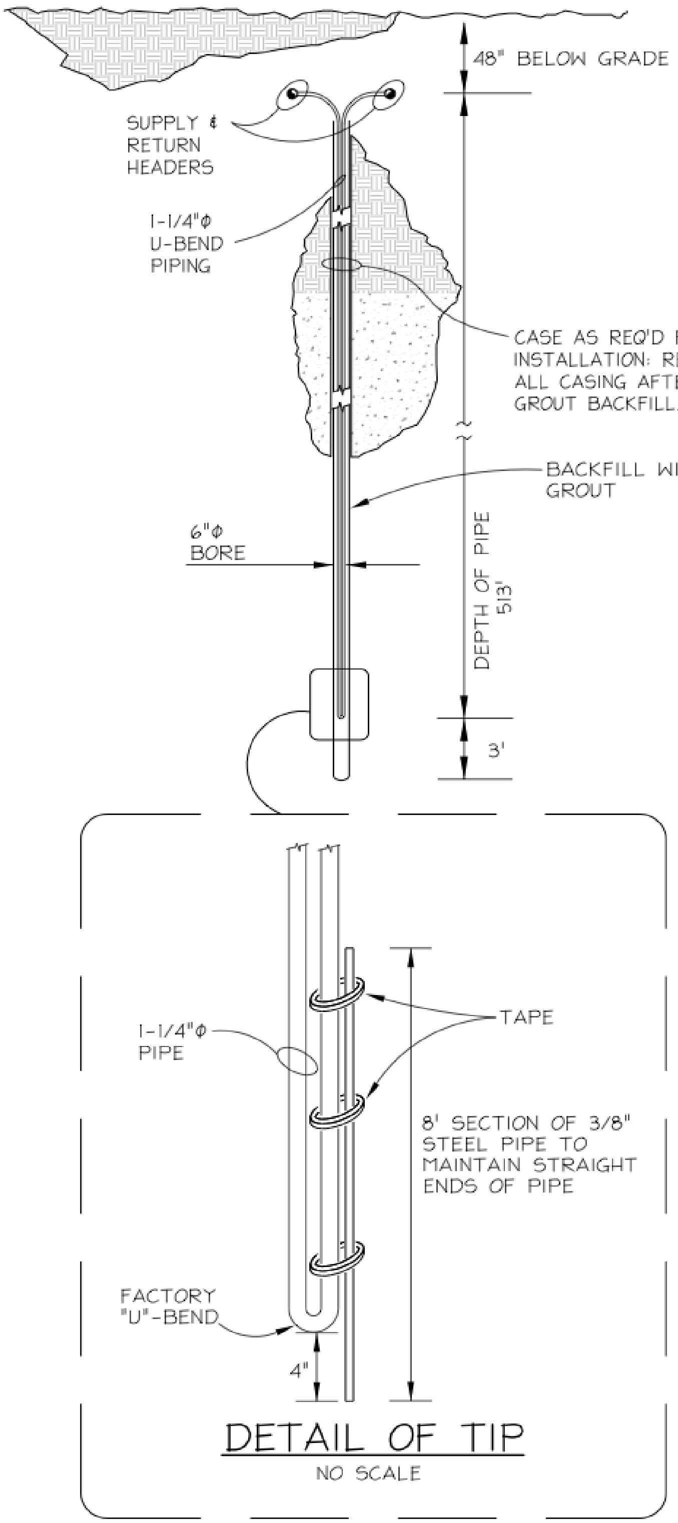


FIGURE 4 - This diagram illustrates the detail of a 517-foot geothermal well.

Figure 5 – Well field that shows the plastic tubing protruding from vertical well.

Wells were installed in either a square or rectangular patter at a minimum of 20 foot spacing between each well. Based on available empirical evidence, this spacing would greatly minimize eliminate the thermal impact the wells would have on each other.

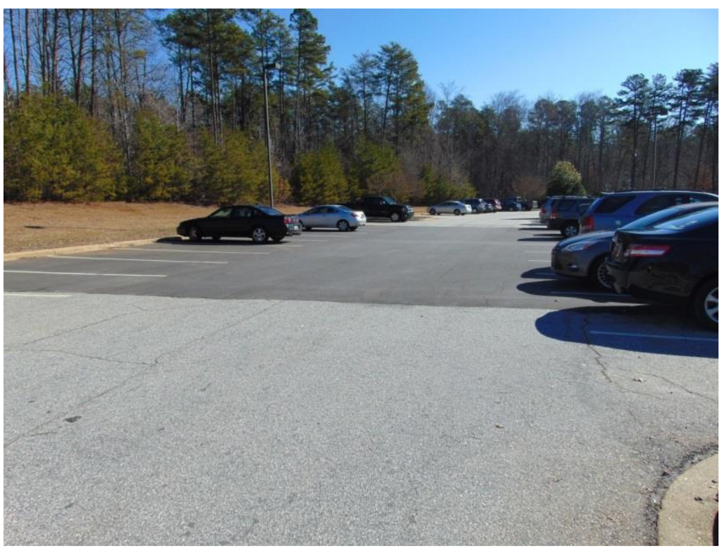


Figure 6 – Completed parking lot with new asphalt and vertical wells/piping below

When students arrived back to school each fall term, little evidence existed that their building had just been renovated to utilize geothermal heat pumps. A fresh patch of asphalt where the wells were installed was the most visible reminder.

Below is a summary of the well drilling data for the project. The number indicated is the depth (in feet) below grade where granite was first encountered. Granite has a significantly better heat transfer coefficient than the other substrate (clay dominant region) typically found. We expect the well fields with the higher granite content to perform better over time. The base temperature of each well field will be measured over time and from this data, the correlation between well field temperatures and heat transfer of the substrate should be better understood. Additionally, the effect that underground water flows has on well field efficiency will be analyzed. The blue highlighted wells were found to have water flows above 100 gallons per minute and the green highlighted wells had water flow above 200 gallons per minute. The high water flows should greatly improve the ability of these to transfer heat from the loop and data will be analyzed over time to verify this assumption.

Well/Building	A	B	C	D	E	F	G	H	I	K
1A	148	142	98	67	67	26	107	94	106	68
1B	148	130	97	67	67	20	105	104	112	75
1C	148	120	100	67	67	20	105	97	107	74
1D	142	120	102	67	69	20	108	104	93	79
2A	128	144	87	67	67	41	107	87	98	68
2B	128	130	82	67	67	26	107	97	104	79
2C	142	127	80	67	69	26	105	97	105	79
2D	142	120	80	62	62	26	108	97	94	82
3A	127	144	87	67	67	77	107	87	98	68
3B	128	130	85	67	62	42	102	90	139	75
3C	142	127	83	69	69	41	100	84	102	82
3D	148	115	87	65	62	43	88	84	104	82
4A	122	144	94	67	67	60	102	68	106	79
4B	125	130	90	62	67	57	107	76	112	79
4C	148	127	90	67	69	62	118	68	102	82
4D	148	115	88	62	67	43	88	76	107	84
5A	128	130	97	69	77	62	102	68	106	75
5B	125	144	94	69	77	64	107	68	112	79
5C	142	130	70	62	72	62	113	84	106	82
5D	139	130	95	68	72	41	83	84	104	82
Average	**137.4**	**130.0**	**89.3**	**66.3**	**68.2**	**43.0**	**103.5**	**85.7**	**105.9**	**77.7**

<u>Well Depth Chart:</u>

- Numbers represents the depth (in feet) to solid granite from the surface
- Blue highlighted fields indicate wells with underground water flow between 100 and 200 GPM
- Green highlighted fields indicate wells with underground water flow over 200 GPM

As shown below, a small room (7' by 12') was built for each North Village building to house the circulation pumps and associated well field piping manifolds. Sound absorbing panels were installed between this room and the adjacent original building walls to minimize noise transmission from the pumps.

Figure 7 – Construction of pump room in North Village building.

As noted earlier, a total of 20 wells were installed for each building and those wells were piped together such that every 5 wells were connected to a common supply and return header. Therefore, a total of 4 supply and return manifolds were installed in each pump room as shown in Figure 8.

Figure 8 – Piping Manifold

A pair of circulation pumps was installed for each building with each being size to meet 100% of the calculated load. The typical pump arrangement is shown in Figure 9. Each pump has a variable frequency drive (VFD) installed to meet part load conditons. In the event of electrical power failure, a generator can operate 1 pump to keep circulation of water flowing when cold weather conditions exist.

Figure 9 – Pump for Geothermal System

The pump room addition blends quite well with the existing building and proved to be an excellent location for the installation of this equipment. Just above the pump room, a small pipe chase was installed that connected the pump room to the attic space. The piping to/from the pumps and the geothermal heat pumps is installed thru this chase and distributed through the attic space.

Figure 10 – Completed Pump Room

Figure 11 shows a 2.5 ton heat pump which is the primary sized unit for this project. As you can see, the condensate piping is insulated but the geothermal piping is not. Flexible tubing was utilized to allow easy removal of the unit if major maintenance or replacement is required.

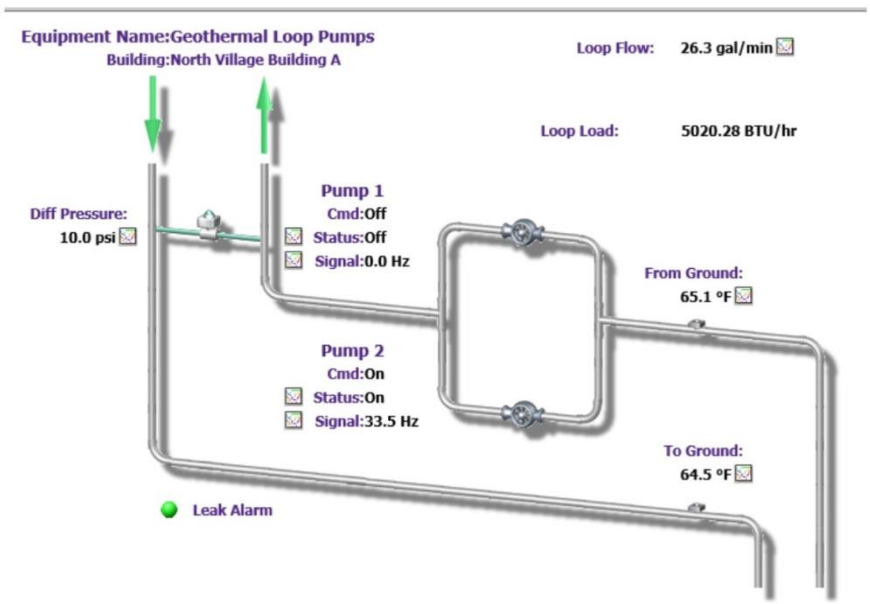
Figure 11 – 2.5 Ton Geothermal Heat Pump

The heat pumps are installed in a mechanical closet with an exterior entrance as show in Figure 12. The original building was designed for a split system heat pump and this room was used to house the indoor unit. The ability to use this room for the geothermal heat pump was ideal from an installation standpoint. The exterior closets for each floor was stacked on top of each other so installation of the geothermal loop from the attic was greatly simplified.

Figure 12 – Mechanical Closet

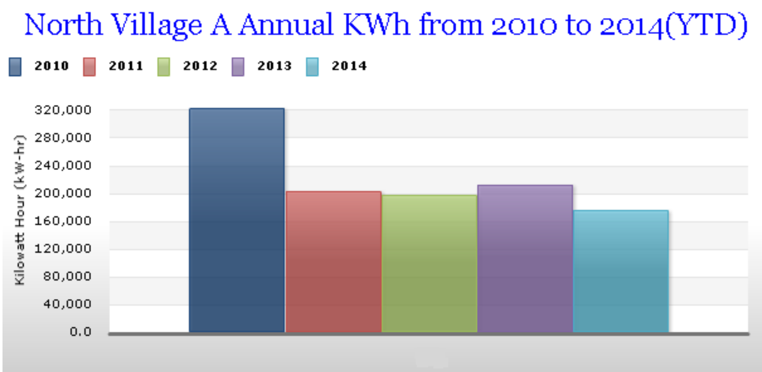
As part of this project, Furman's Facilities Services installed building-scale metering in each building to monitor energy consumption. In addition, six individual apartment units have been sub-metered in NV-B (geothermal unit) and in NV-I (currently traditional unit). These apartment units share identical floor plans and are located in the middle of each building on all three floors. These buildings (NV-B and NV-I) were chosen for comparison due to their similarity in northeast orientation. This sub-metering allows comparative data to consider variables such as behavior, building orientation, and floor location in relation to energy consumption.

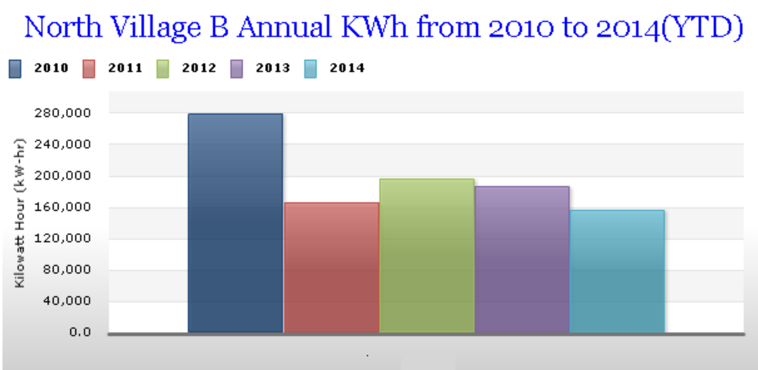
Furman University North Village Building A Geothermal Loop Graphic

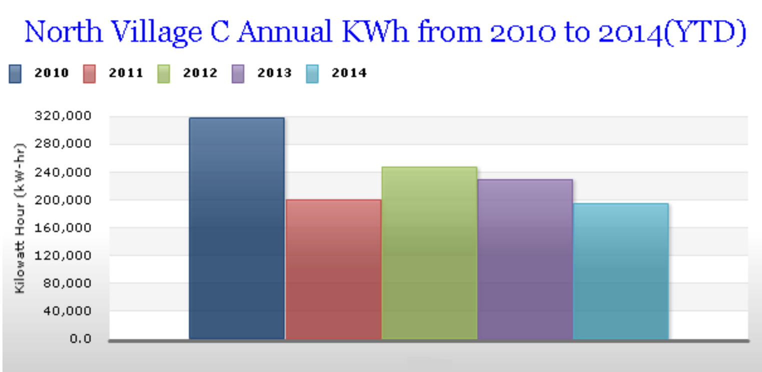


The data collected for each building utilizes a building automation system from Johnson Controls. This metering device has generated electricity consumption, electric power demand, electric power cost, natural gas consumption, natural gas cost, fluid temperature and fluid flow rate data for the geothermal systems. This data is then delivered to a web application through Periscope by Activelogix, LCC and displayed on Furman University's Energy Dashboard, an online resource that collects and exhibits campus energy data in real time. The dashboard stores the data, which can be accessed for analysis.

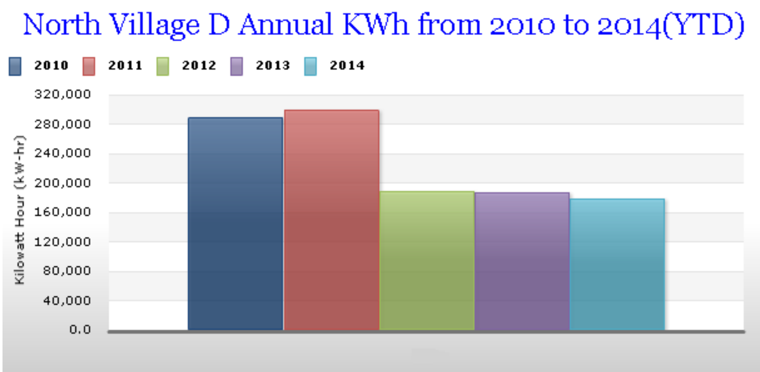
Below is the energy consumption data for the buildings (A, B, C) associated with Phase 1 of this project. Phase 1 was completed in the summer of 2011 and the average 40% reduction in building energy consumption is evident after examining these graphs.

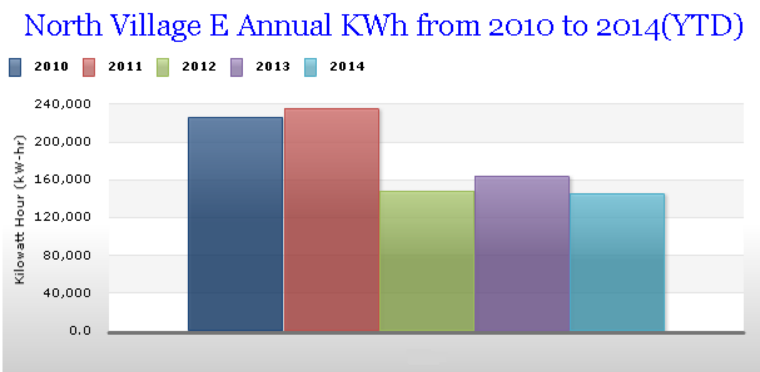


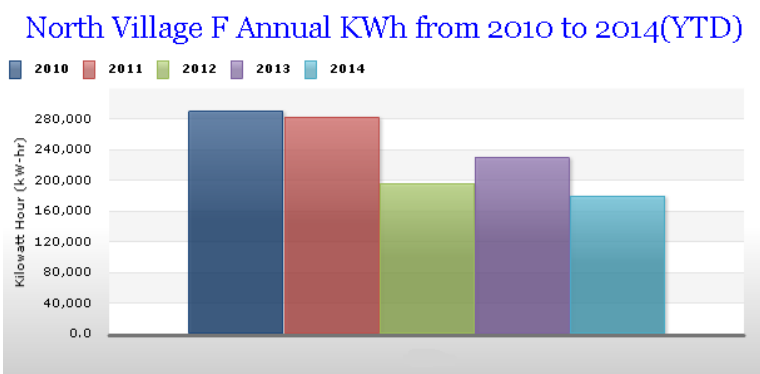




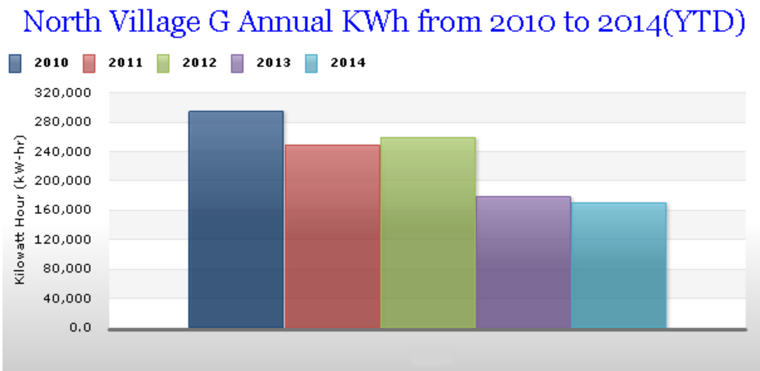
Below is the energy consumption data for the buildings (D, E, F) associated with Phase 2 of this project. Phase 2 was completed in the summer of 2012 and the average 40% reduction in building energy consumption is evident after examining these graphs.

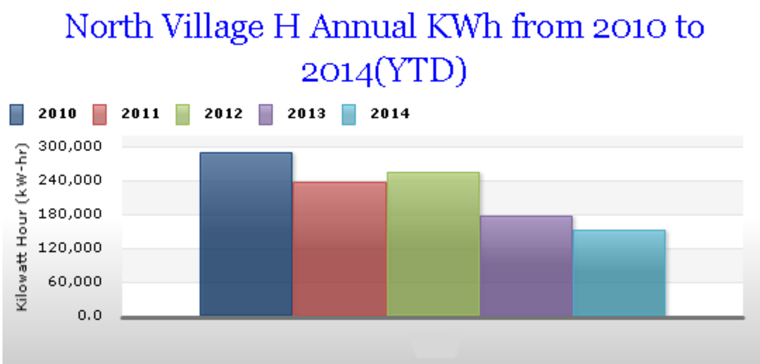


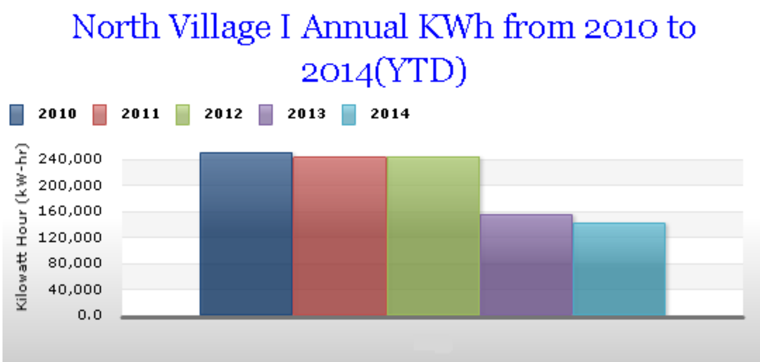


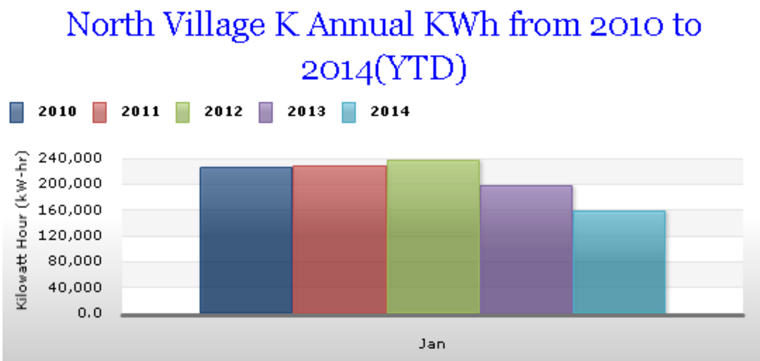


Below is the energy consumption data for the buildings (G, H, I, K) associated with Phase 3 of this project.   Phase 3 was completed in the summer of 2013 and the average 40% reduction in building energy consumption is evident after examining these graphs.







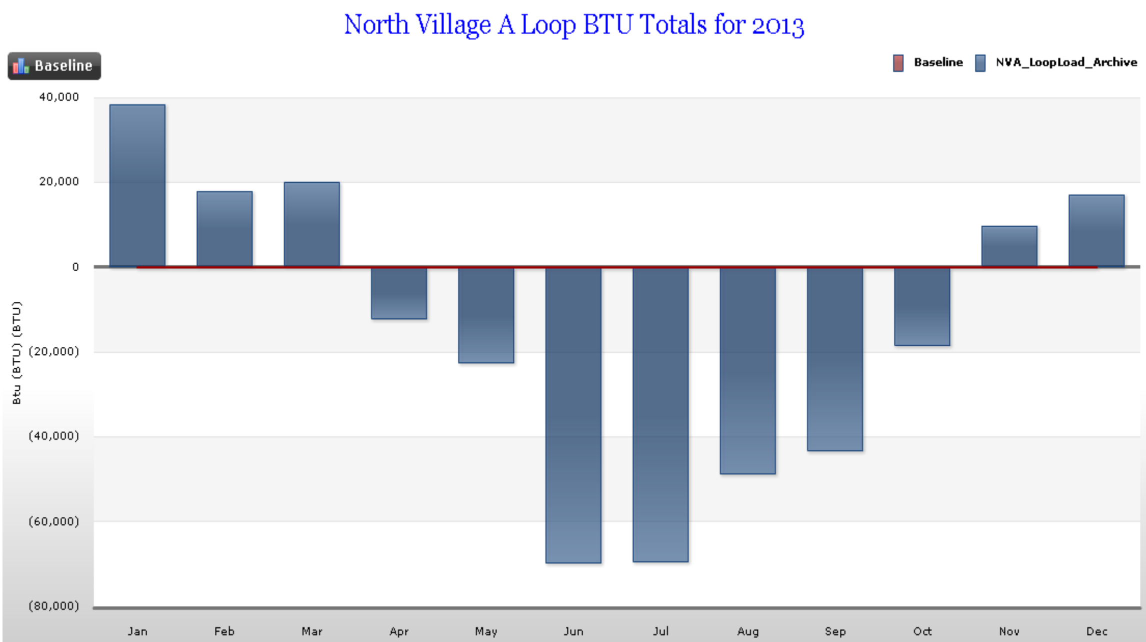


PROJECT CHALLENGES

There were several significant obstacles and challenges to work through on this project.

The most challenging barrier involved with renewable energy system installations is the initial investment required. While geothermal systems provide huge environmental incentives by cutting energy consumption and greenhouse gas emissions, the initial financial burden plays a substantial role in evaluating the cost benefit analysis of a system retrofit. For this project, the capital costs associated with the vertical bore drilling process proved to be the most expensive portion of the project. The higher than expected drilling expenses were due to a number of factors including granite substrate that was predominant below 30 feet. Granite is an excellent substrate for heat transfer but is costly to drill thru due to its density and hardness as compared to other substrates. In addition, a significant amount of water was discovered during the drilling process. Although the presence of these undergrounds streams can improve heat transfer, so much water was found that 2 wells had to be abandoned due to tubing that was lost during the installation process. Lastly, the higher than expected drilling costs could likely be attributed to a lack of available licensed contractors in the area. No qualified local contractors were identified and the nearest contractors were several hundred miles away. The added travels expenses and the relatively limited competitive market played a role in the higher than expected costs. Lastly, the assumption made in the feasibility study regarding soil conductivity was lower than what was actually determined through the test bore process. An additional 19,400 feet of well footage was needed for the heat transfer process and this added footage played a part in the higher than expected expenses.

Another challenge encountered occurred during the design phase of the project and centered on the optimum design strategy for the system. There were differences of opinion between the local engineer tasked with designing the system and the larger, national firm that was selected to perform design review and commissioning services. The issues centered on how critical it was to design a system that provided an annual net zero energy heat transfer impact to the earth. Greenville SC is in a cooling dominant area of the country and as a result, over the course of a year, more energy will be put into the earth than will be removed. Over time, this may cause the well field to heat up and potentially negatively impact the ability of these systems to provide the needed cooling to our buildings. We are closely monitoring the heat balance to the earth as you can see from the graph below.



PROJECT BENEFIT SUMMARY

The primary benefits for the project are noted below and quantified in various places throughout the report.

- Energy Reduction – Over 1,000,000 kWh's saved annually.
- Energy Cost Savings – Over $55,000 saved annually.
- CO2 Reduction – Over 600 metric tons saved annually.
- Reduced and ease of maintenance – Over $17,000 saved annually.
- No outdoor ambient noise
- Improved exterior aesthetics – No more outdoor units
- Improved Reliability and fewer coil freeze ups
- Electrical capacity in building free up for other uses

The project was a tremendous success for the university as we were able to replace an aging, inefficient system with a new, more efficient, renewable energy system that aligned perfectly with our institutional sustainability goals. We would like to extend our thanks to the Department of Energy for selecting our project for this transformative grant opportunity.

Acknowledgment: "This material is based upon work supported by the Department of Energy under Award Number DE-EE 00002817 / 002."