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C&I CASE STUDIES IN
BENEFICIAL ELECTRIFICATION

Beneficial Electrification of Space Conditioning in Schools

BY **KATHERINE DAYEM**, XERGY CONSULTING, APRIL 2018

SUBJECT MATTER EXPERT FOR QUESTIONS ON THIS TOPIC

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INTRODUCTION

The wise use of electricity as part of the *Beneficial Electrification* movement has sparked widespread re-thinking of policies that encourage or mandate less electricity use and promote infrastructure planning. Advancements in electric technologies continue to create new opportunities to use electricity as a substitute for on-site fossil fuels like natural gas, propane, gasoline and fuel oil, with increased efficiency and control. It also offers local economic development and enhances the quality of the product used by the customer.

Electrifying industrial and commercial processes is a proven method to help local businesses stay competitive. Beneficial electrification strengthens the cooperative presence in the community and offers benefits to the electric system, such as reducing emissions of CO_2 and other pollutants and providing loads that can be operated flexibly, such as when electricity generation is greater than demand. Cooperatives working with C&I customers to assess need is a good place to start. To provide examples of various approaches to working with C&I customers on beneficial electrification initiatives, NRECA is developing a **series of case studies**.

NRECA
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This case study explores the use of ground source heat pump (GSHP) technology to provide space heating and cooling in schools. Alfalfa Electric Cooperative (AEC), a distribution co-op based in Cherokee, Oklahoma, and its generation and transmission co-op Western Farmers Electric Cooperative (WFEC), have promoted GSHPs for decades in both residential and commercial applications. Over the past two decades, AEC has helped convert the heating and cooling systems of all three Cherokee schools from natural gas to electric GSHP technology. The most recent conversion, at Cherokee High School in 2009, reduced winter season gas consumption by at least 85 percent and reduced total energy (electricity + gas) bills over 20 percent. Since the systems were installed, improvements in GSHP technology allows for better control and more efficient heating or cooling.

MEMBER PROFILE

Headquartered in Cherokee, Oklahoma, Alfalfa Electric Cooperative serves 4,200 members and almost 8,700 meters in five counties in north-central Oklahoma and two counties in southern Kansas (Figure 1). AEC has a long history of promoting GSHP technology, particularly in the commercial sector. To implement the technology, AEC has a heating and cooling subsidiary, AEC Services, which designs, installs, and maintains GSHP systems in the area.

AEC's generation and transmission (G&T) partner is Western Farmers Electric Cooperative. Based in Anadarko, Oklahoma, WFEC serves 21 distribution co-ops that provide electricity to members in Oklahoma, New Mexico, small portions of Texas and Kansas, and Altus Air Force Base. Like AEC, WFEC has promoted GSHP technology for many years through rebates and pilots.

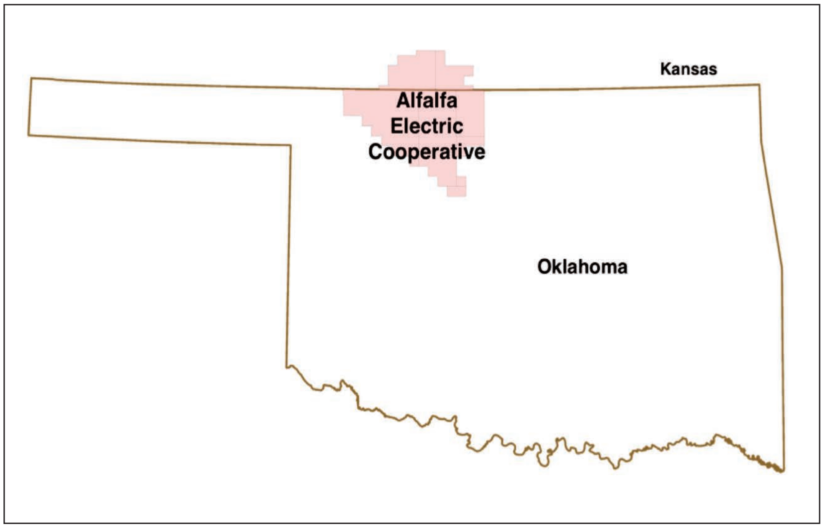

FIGURE 1: Service territory of Alfalfa Electric Cooperative.
Image provided by AEC.

AN ELECTRIFICATION OPPORTUNITY

In 2009, the natural gas heating system at Cherokee High School was badly in need of repairs. According to Terry Ryel, Director of Marketing and Key Accounts at AEC, of the 5 units in the 720 kBtu/hr system, the largest two, which served classrooms and comprised two thirds of total capacity, had been inoperable for several years. To compensate, the school used electric resistance space heaters in the classrooms. The system needed serious upgrades or complete replacement. In addition, natural gas prices were near historic high levels at over $10.50 per thousand cubic feet in Oklahoma, compared to about $8.50 per thousand cubic feet today.[1]

[1] https://www.eia.gov/dnav/ng/hist/n3020ok3a.htm

AEC had already helped Cherokee schools replace heating systems with GSHPs; Cherokee Junior High School and Cherokee Elementary School had replaced their natural gas heating systems with GSHPs in 1998 and 2005, respectively. Terry Chapman, Superintendent of Cherokee Schools from 2008 to 2011, said that the positive outcomes of these projects led Cherokee High School to secure a bond that would allow them to replace the ailing natural gas system with a GSHP.

GROUND SOURCE HEAT PUMP TECHNOLOGY

Ground source heat pumps (also referred to as geothermal heat pumps) use the ground as a reservoir from which heat pumps can extract or reject heat from a building. Because soil and rocks respond slowly to daily and seasonal air temperature changes, the temperature below a depth of about 10 feet is nearly constant and comparable to the annual average air temperature. In most areas of the country, this equates to about 40 to 50 degrees Fahrenheit.

The key components of the system are ground loop heat exchangers and heat pumps (Figure 2).

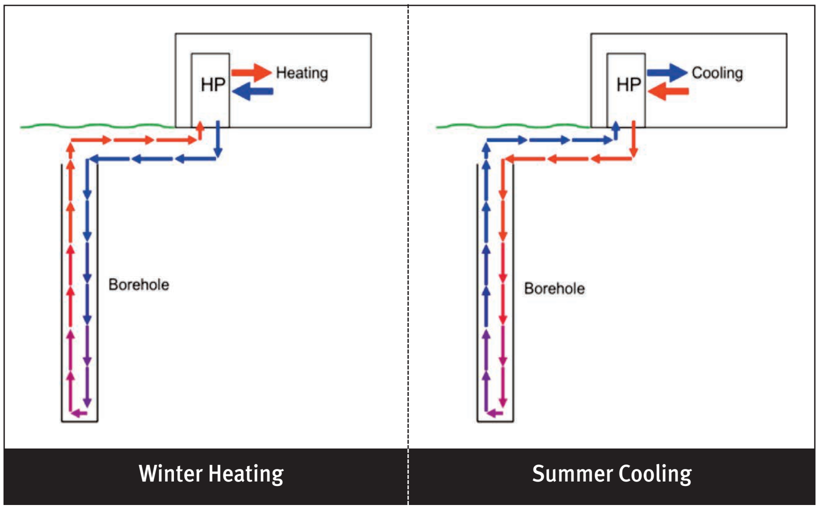

FIGURE 2: Schematic of vertical loop GSHP system.

The heat exchangers are of two general types: *horizontal loops*, which are buried at least 10 feet below the surface, and *vertical loops*, which are installed in boreholes that can be 100 feet deep or more. Water or refrigerant is pumped through the loops, absorbing heat from the earth during the heating season, and shedding heat to the earth during the cooling season. The heat pump then "amplifies" the temperature using a standard refrigeration cycle, just like a refrigerator, freezer, or air source heat pump. Compared to an air source heat pump, a geothermal heat pump is more efficient because it has a smaller temperature difference to pump heat across.[2] Ground source heat pumps can be well over 200 percent efficient, meaning for every unit of energy they draw, they produce more than double that amount in the equivalent amount of space heating or cooling energy produced.

AEC Services led the installation of the Cherokee High School system in the summer of 2009, while school was out of session, to minimize impact to the students. The system consists of 160 boreholes, drilled in the athletic fields parking lot, with vertical heat exchange loops, and 18 heat pump units totaling 67 tons. While installing the GSHP, AEC Services also replaced and sealed all ductwork to improve efficiency of the forced-air system, and installed the piping system. The total cost of the installation was about $440,000.

BENEFITS TO THE CO-OP MEMBER

Reduced Energy Costs

GSHPs can provide significant energy cost savings. In the case where a GSHP replaces a natural gas system, natural gas fuel costs are eliminated. Although electricity costs increase, the total energy bill (natural gas plus electricity costs) should decrease due to the increased efficiency of the heat pump. Before the GSHP

[2] See for example USGS, 2003, *Geothermal Energy — Clean Power From the Earth's Heat*, Circular 1249.

While the initial investment cost for a GSHP system can be high, the return on investment can be attractive given the significant efficiency savings and long lifetime of the equipment.

Benefits of GSHP systems over natural gas systems include reduced maintenance and operating costs, and improved temperature comfort for room occupants.

was installed, Cherokee High School was using the three remaining operational natural gas boilers and electric space heaters to heat the building. In the heating season prior to the system replacement, the school spent almost $17,000 on gas and electricity combined. After the replacement, that figure dropped by about 20 percent, or about $3,500. Recall that by the time of the replacement, only two of the natural gas units, which provided one third of the school's heating capacity, were still running. Gas consumption data prior to 2008 was unavailable, but we estimate that the school might have used 2 to 3 times as much gas had all units been running.

Because the GSHP is more efficient than other air conditioning technologies, the school saw benefits during the cooling season as well. Although the school is minimally occupied during the summer months, the weather-adjusted electricity use during the cooling season decreased by 30 percent. This resulted in a savings of more than $12,000 a year.

The GSHP system had an attractive return on investment (ROI) as well. Thomas Wessels, Contractor for AEC Services, estimates that replacing the natural gas system would have cost about $300,000. The incremental cost of the GSHP system was therefore about $140,000. Assuming about $15,000 per year in energy cost savings after the GSHP installation, the system will pay itself off this year. The heat pump equipment has an expected lifetime of about 20 years, and the in-ground heat exchange equipment should last much longer, so the district still has over a decade to reap returns on their investment.

Reduced Maintenance Costs

A clear advantage of a GSHP system over a natural gas one is reduced maintenance and, therefore, reduced operating costs. The high school's GSHP system requires very little maintenance beyond changing air filters. The natural gas heating system, in contrast, required additional maintenance, such as washing coils, maintaining pressure, and servicing fans. Each natural gas unit had up to six outdoor fans, which saw a lot of wear and tear.

According to Wessels, AEC Services visited the school every couple of weeks to service the natural gas system. Now, AEC Services visits the school about once a month and only to change filters.

Comfort

The GSHP system also improved comfort during cold winter mornings, noted Chapman. The school can run the GHSP at constant temperature setpoints rather than applying nighttime setbacks when the building is unoccupied, as was the case with their natural gas system. Now when students and staff arrive at school, the building is already at a comfortable temperature.

BENEFITS TO THE CO-OP

As with other beneficial electrification strategies, GSHP replacement can yield various benefits for the cooperative, including increased electricity sales, improved member relations through decreased energy bills, and, especially during the cooling season, reduced peak demand. According to Ryel, the co-op saw many benefits associated with the GSHP replacements at the Cherokee schools, such as improved member relations, and making a good investment for their members, who also fund the schools. Their subsidiary, AEC Services, is a trusted HVAC service provider in the community, and provides the installation and maintenance. AEC is a summer peaking co-op, so the reduced air conditioning load pays dividends for the entire membership. The G&T Western Farmers has used GSHP programs to reduce capital investments in new peaking generation.

ENVIRONMENTAL BENEFIT

An aim of many electrification projects is to reduce CO_2 and other emissions. Based on our estimates of natural gas and electricity consumption during the heating and cooling seasons, we estimated Cherokee High School CO_2 emissions before (with all 5 natural gas boilers functioning) and after the GSHP replacement. We used natural gas emissions information from the EIA[3] and average grid emissions factors from eGRID.[4]

Although the Southwest Power Pool, which serves AEC and WFEC, has a relatively high CO_2 emissions factor[5] compared to other regions, the school's CO_2 emissions still decreased by about 13 percent (Figure 3). WFEC has been adding more renewable resources, so we expect electricity-caused CO_2 emissions to continue to decrease with time.[6] If the same project were conducted on a relatively low carbon grid, CO_2 emissions for the GSHP system could be about 40 percent lower than for a natural gas system (Figure 3).[7] This points to an increasing CO_2 reduction benefit of an electrification project through time, as grids become less carbon intense.

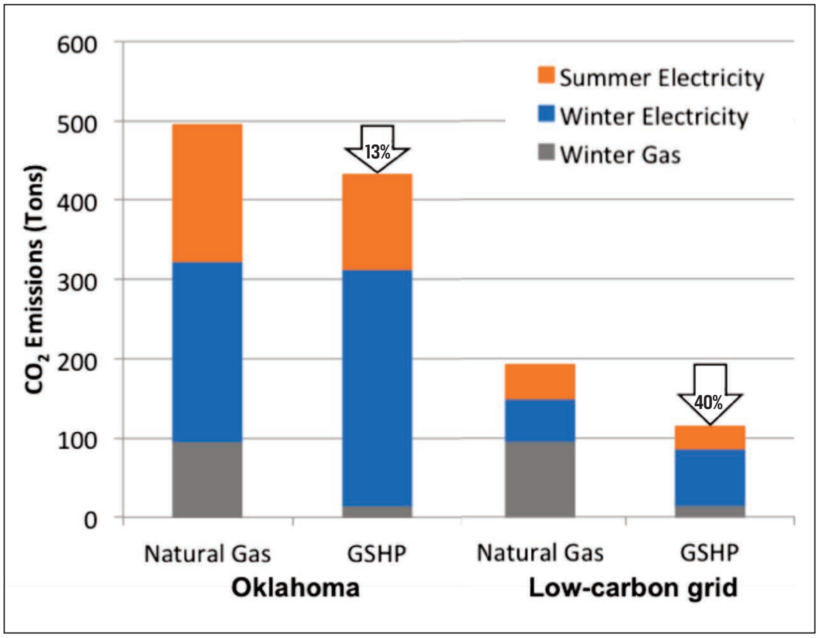

FIGURE 3: Estimated carbon dioxide emissions from original natural gas and conventional air conditioning and replacement GSHP systems at Cherokee High School. The columns on the left show estimates for the southern Southwest Power Pool grid, which serves Cherokee. For comparison, estimates for the same replacement on a relatively low-carbon grid is shown on the right.

CHALLENGES

By the time Cherokee High School installed the GSHP system, AEC Systems already had significant experience installing and maintaining these systems. One main challenge encountered, however, is finding enough space to accommodate the ground heat exchange loops. For many commercial and industrial facilities, especially in rural areas, ample space may be available in parking lots and fields, especially if vertical loops are used. Members in more urban or suburban areas may not have access to sufficient land to install loops retroactively, although designers can find creative ways to integrate loops into foundation structures in new construction. Building options on top of existing loops are limited to some degree. Parking lots, sports fields, and structures with slab-on-grade foundations can be built over loop fields, but structures with ground-penetrating foundations may interfere with the loops.

Another challenge that GSHP replacement projects face is high initial costs. Cherokee Schools utilized a bond to raise the initial capital. For

[3] https://www.eia.gov/environment/emissions/co2_vol_mass.php

[4] https://19january2017snapshot.epa.gov/energy/emissions-generation-resource-integrated-database-egrid_.html

[5] CO_2 emissions factor is the average amount of CO_2 emitted per unit of electricity generated. It is often expressed as kilograms of CO_2 emitted per million BTU electricity produced.

[6] http://www.wfec.com/sites/default/files/2016%20WFEC%20Annual%20Report%20web.pdf

[7] For this analysis, we use the emissions factor from the Upstate New York grid, which currently has the lowest factor in the U.S.

commercial and industrial members, however, the cooperative may need to provide financial incentives. Currently, a 30 percent federal tax credit is available for renewable resources, and many states offer additional credits. Co-ops can sweeten the deal by offering rebates. AEC and WFEC, for example, partner to offer a rebate of $1,000 per ton.

NEW DEVELOPMENTS

The oldest Cherokee Schools GSHP system, at the Junior High School, is now 20 years old. AEC Services is currently replacing some of the equipment in that system, and is noticing improvements in the technology. The new units have sensors that help streamline commissioning and can help spot maintenance issues earlier. In addition, the new heat pumps can include variable or two-stage fans and compressors, and can better match speed to heating or cooling demand, deepening energy savings relative to fixed speed equipment. The first stage in the new equipment installed in the Junior High School, for example, runs at 60 percent capacity, which reduces noise and saves wear and tear on the unit. AEC noted consistent efficiency and performance over the lifetime of the equipment, about 20 to 25 years, which compares well with natural gas boilers.

CONCLUSIONS

Cooperatives who are interested in GSHP need to be aware of a few issues that, if not mitigated, could reduce the chances of member adoption. First, GSHP systems have a high initial cost. These costs can be offset somewhat with federal and, in some cases, state tax rebates. Co-ops can also offer rebates to get members over the cost hump. Perhaps more important than reducing initial costs, however, is educating members as well as architects, engineers, and installers about the technology. In fact, "the backbone of our industry is education," says Wessels. To a member, the installation is disruptive, expensive, and unfamiliar. Educating your members about how the technology works and the life-cycle cost and potential CO_2 reduction benefits they can achieve is key to helping them decide to install a GSHP. Finally, finding an architect, engineer, and contractor who has GSHP experience may be challenging. As members drive demand for GSHP systems, however, those who design and build them should increase in number. ■

About the Author

Katherine Dayem, PhD, Principal, Xergy Consulting. Katherine helps U.S. and global clients investigate, analyze, and cultivate emerging clean energy resources at the grid's edge. Her research is focused on identifying impactful new ways to save energy, from product-level to building-level, and has resulted in deep energy savings through innovative utility programs and the enactment of energy-saving regulations. Her recent work has delved into a wide range of topics including DC in buildings, low power modes of electronics and other end uses, and beneficial electrification. She lives in Durango, CO and is a member of La Plata Electric Association.

Questions or Comments

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