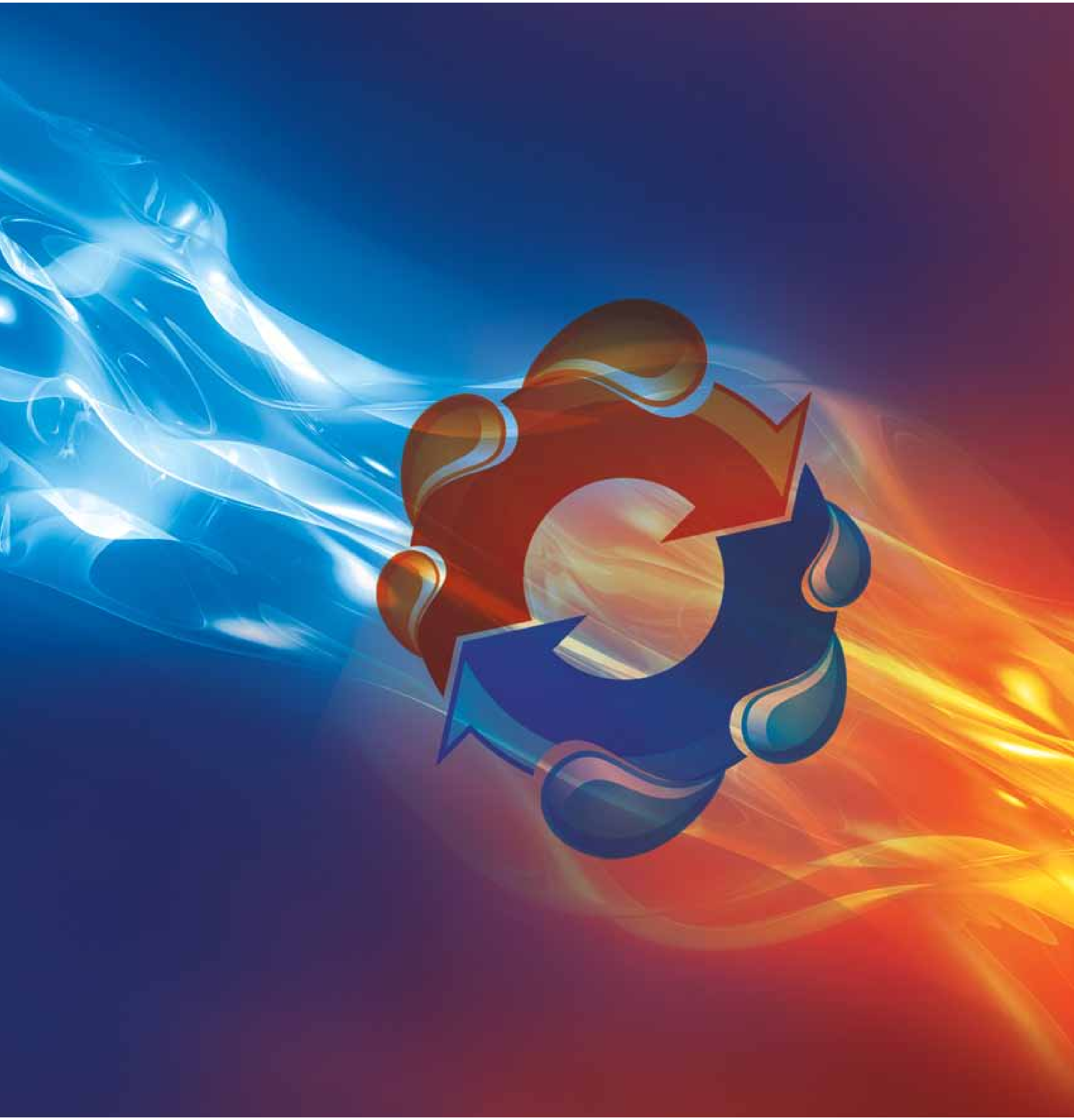


GEOTHERMAL Grows Up

By William C. Johnson
Steven Kraemer P.E.,
and Paul Ormond P.E.

Self-declared energy and carbon reduction goals on the part of progressive colleges and universities have driven ground source geothermal space heating and cooling systems into rapid evolution, as part of long-term climate action planning efforts. The period of single-building or single-well solutions is quickly being eclipsed by highly engineered approaches and district-level programs that take advantage of building diversity, hybrid system designs, and central plant integration. In this article we review where the industry has been, where it's headed, and why. We also touch on the benefits that colleges and universities are enjoying by taking advantage of their geothermal resources.

IN THE BEGINNING….

The first geothermal systems were "designed" in the 1980s by well drillers and heat pump vendors using rules of thumb. For the small residential applications typical of the time, these were adequate, although inefficient solutions. As larger-scale systems came into demand by institutions, vendors applied the "multiplier" approach, using the same single-building models and multiplying them to meet the new peak loads. This one-dimensional approach gave little consideration to long-term well field performance, well field balancing, bleeding aquifers, permitting, and other important issues. The result was unhappy system owners stuck with a legacy of inadequate system performance and outright system failures.

Facilities professionals learned the hard way that using 2- to 3-ton per well, peak load-based residential design approaches, short-well drilling techniques, and residential-scale equipment selections to meet 100- to 800-ton capacity loads have proven woefully insufficient. Unlike other energy conservation measures (ECMs) and renewables, geothermal design and, importantly, geothermal *optimization* requires knowledge and experience over a wide variety of disciplines.

GEOTHERMAL OPTIMIZATION THROUGH APPLIED SCIENCE AND ENGINEERING

A higher educational facility in the mid-Atlantic region applied for a substantial federal grant for geothermal development. In preparing the grant application, they assembled preliminary calculations and pricing from data provided by local mechanical engineering and drilling contractors. Their grant application was accepted and they were awarded project funding.

The initial "rule-of-thumb" estimate for well field sizing called for 25 wells per building. A careful engineering analysis based on area geology and building load characteristics showed conclusively that 35 wells per building would be required to handle 100 percent of the load, which made the initial estimate both for well sizing and funding low by almost 40 percent.

Further engineering analysis determined that, by utilizing a temperature management system comprising geothermal heat pumps and conventional system components to provide heating/cooling, 90 percent of the energy and carbon savings could be achieved by installing six wells per building. In this case, the owner achieved superior financial results and met energy savings goals by harnessing advanced engineering knowledge of both the ground and the building system interface.

NOT LONG AGO….

As the market for institutional-sized geothermal systems arose, mechanical engineers and geotechnical professionals began to team up to deliver more robust solutions to owners. Their evolved approach took into account variables such as groundwater flow, soil and bedrock conditions, and more robust building modeling. During this phase standard ASHRAE-style conductivity testing of the ground was performed, and standard Ground Loop Heat Exchanger Professional (GHLEPRO) models were used with greater regularity. Both tests and models were still based on residential-scale systems and problems persisted with out-of-balance well fields, oversized systems and poor financial performance of the larger systems.

Also characteristic of this phase in geothermal evolution was the tendency to design systems based on peak loads, relying on the geothermal system for 100 percent of the heating and/or cooling load. Long-term financial performance projections were unattractive under these scenarios, which effectively shelved what would otherwise have been great applications, if viewed in a slightly different manner.

WHEN SMALLER IS BETTER

A major New England university was planning a new residence quadrangle with a peak cooling requirement of 800 tons. This university desired to achieve significant carbon footprint reductions on this building complex but space was limited, subsurface conditions were challenging and permitting was difficult. If the geothermal well field was designed handle peak load, the number of wells could exceed 300 – an untenable scenario. By applying partial load modeling and a thorough understanding of the yearly building thermal load profile, the engineer determined that just 50 wells could achieve a 40 percent reduction in carbon footprint while meeting a university requirement of a 12 percent return on investment for the additional dollars spent for the project. Sizing this system for 100 percent of the load was impractical, but with careful engineering and planning, the client's programmatic and financial goals were achieved.

TODAY….

Colleges and universities are evaluating district geothermal applications (geothermal systems serving multiple buildings) for their potential to reduce energy use and carbon footprint for major portions of their campuses. By integrating geothermal

Thermal "waste" from one building can serve as fuel for one next door, with the geothermal system's water effectively serving as the thermal transfer medium.

planning into the current crop of master plans, institutions are realizing the untapped potential that is beneath their feet and accessible from the open space on their campuses.

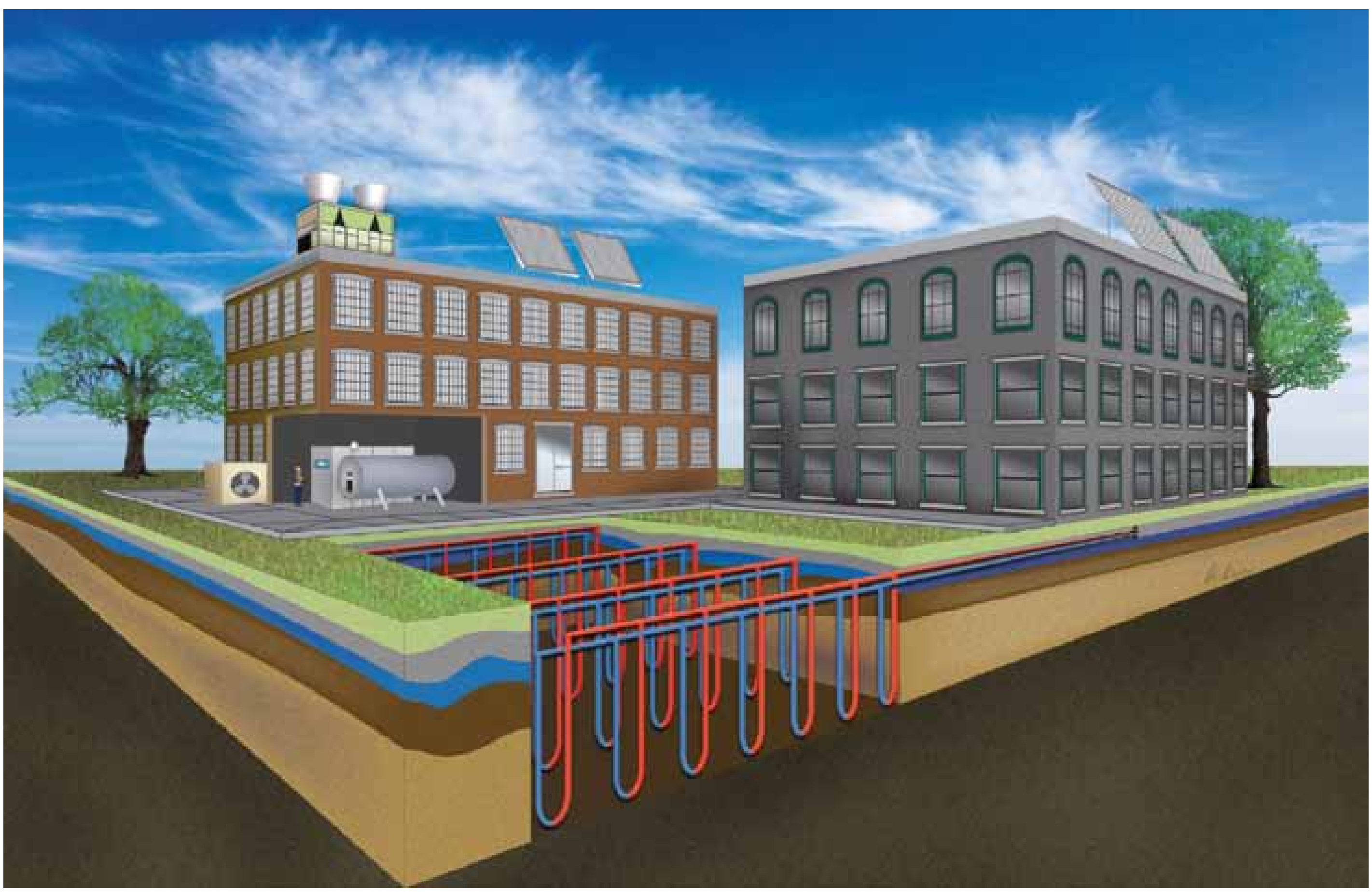
The power of district-level geothermal resides in the inherent building and load diversity, which can be utilized to positively impact the size, operational characteristics and long-term performance of these systems. By incorporating a variety of building types with different heating and cooling load profiles, a geothermal system can be used as a thermal flywheel storing heating/cooling energy for use by another building on the same well field. Thermal "waste" from one building can serve as fuel for one next door, with the geothermal system's water effectively serving as the thermal transfer medium.

By applying advanced building load profile modeling and robust long-term geothermal thermal response testing, the entire system can be optimized, well field sizes reduced, energy efficiency increased and financial performance dramatically improved. In our experience using more advanced integration and districting, well field sizes have been reduced more than 75 percent compared to those sized by using standard design techniques, *while still maintaining nearly all of the efficiency gains*.

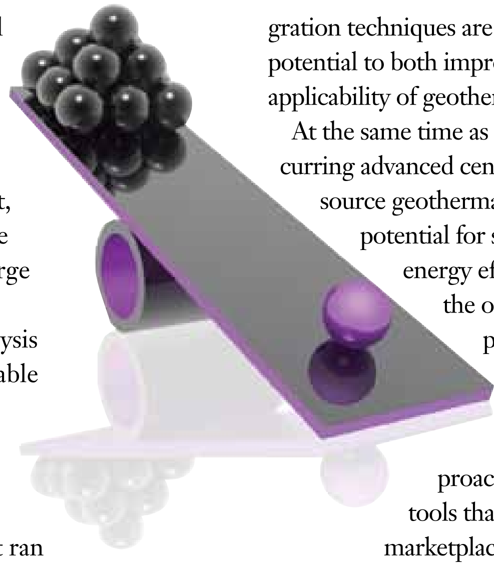
Partial Load Modeling (PLM) is a cutting-edge engineering design tool that has been developed specifically to optimize a geothermal well field size and its contribution to the district geothermal application. PLM evaluates a hybrid system design that comprises geothermal and conventional system components. This might be any combination of heat pumps, chiller heaters, chillers, boilers, dry coolers, and cooling towers depending on environmental variables and on an institution's goals and objectives for the district system design.

PLM bases its modeling on the premise that the geothermal system will meet a certain base load for the building(s) and that conventional systems will provide additional capacity to cover peak loads. By using PLM in the design process, dramatic reductions in geothermal well field sizes can be achieved while maintaining significant energy efficiency improvements and carbon footprint reductions. In our experience utilizing PLM, we have been able to manipulate numerous variables in the system design to achieve an optimal solution that we like to call the "geothermal sweet spot."

One more benefit of a smart Partial Load Modeling process is developing an understanding of the influence of groundwater flow, which can have a significant impact on well field



design, sometimes helping to reduce well field size and costs without sacrificing system efficiency.



WHEN LESS YIELDS MORE

For a major university on the West Coast, initial engineering evaluations arrived at the conclusion that the well field could be as large as 800 wells for a district-level geothermal system. The next phase of engineering analysis incorporated hydrogeologic flow data available from local resources that pointed to a potentially advantageous improvement of heat transfer characteristics due to high ground water flow rates. After verifying these flow rates, the engineering consultant ran the calculations incorporating the new data. PLM modeling showed that the well field size could be reduced to 480 wells, saving approximately $3.2M while maintaining the same performance goals and metrics. The next phase of the project will be installation of a small well field and testing over a period of months to verify engineering results prior to final design.

After a decades-long single design solution, we are beginning to see the emergence of sound and effective alternatives to standard industry practices. Advanced well field designs and building integration techniques are being developed and applied that have the potential to both improve well field performance and broaden the applicability of geothermal solutions.

At the same time as advances in well field configurations are occurring advanced central plant configurations that utilize ground source geothermal are being contemplated that have the potential for significant carbon footprint reductions and energy efficiency improvements and should be one of the options colleges and universities evaluate as part of their overall climate action plan goals. This will be the topic of subsequent articles.

Ground source geothermal is going through a rapid evolution. The design approaches, integration methodologies and modeling tools that can be applied are improving in response to marketplace demand for more robust, reliable, and effective solutions. Geothermal solutions are indeed growing up and can offer college and university campuses a significant opportunity to achieve their strategic energy and carbon reduction goals.

Bill Johnson (*wjohnson@haleyaldrich.com*) is vice president of Haley & Aldrich Inc., Boston, MA. Steven Kraemer (*skraemer@haleyaldrich.com)* is senior vice president, and Paul Ormond (*pormond@haleyaldrich.com*) is senior engineer, at Haley & Aldrich. This is the first article in *Facilities Manager* for Kraemer and Ormond.


How Much Could You Save
Not Lighting Empty Spaces?
Verve Living Systems' products offer incredibly simple, cost effective solutions for reducing energy usage in student residence rooms, hallways and common areas. Our products are incredibly simple to install, are wireless and battery-less, and require less time and money for on-going maintenance.
Contact us today for more information on how we can help you save energy without sacrificing the safety and comfort of your students, faculty, or visitors.
Toll free 1.877.874.8774 • verve@vervelivingsystems.com
140 Business Park DriveWinston-Salem, NC 27107
verve
living systems