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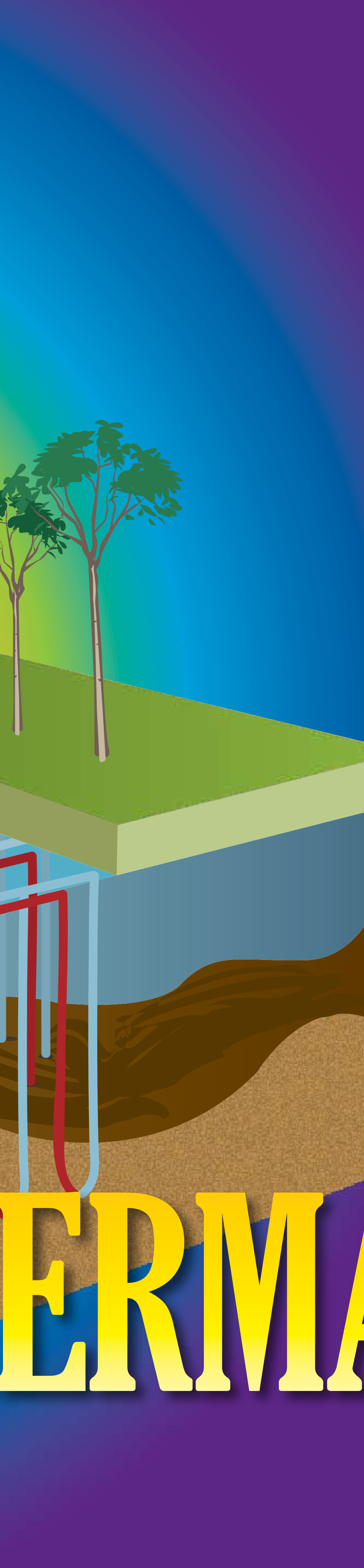


TAPPING THE POTENTIAL

ERMAL ENERGY

BY BILL JOHNSON

Your institution has signed the American College & University Presidents Climate Commitment, or the school has otherwise mandated greenhouse gas reduction goals. Plus, the rising cost of energy has your institution focused on improving energy efficiency on campus. Now it's up to you and your fellow campus facility managers to create mitigation strategies. One such strategy might be right there under your feet.

Ground source geothermal energy enables us to tap into the earth's stored renewable energy for heating and cooling facilities. Proper application of ground-source geothermal technology can have a dramatic impact on the efficiency and financial performance of building energy utilization (30%+). At the same time, using this alternative energy resource can provide significant contributions to an institution's carbon reduction goals.

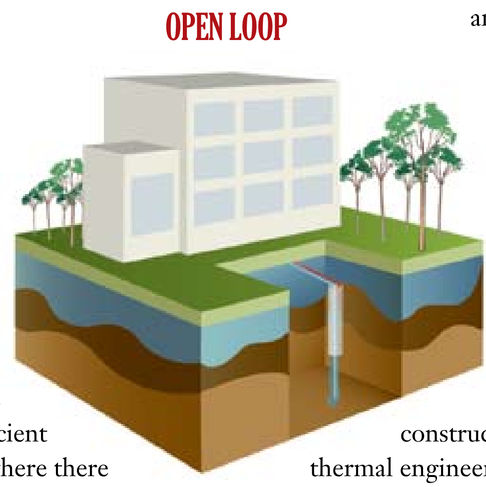
How can you take advantage of this potential energy source to meet campus carbon footprint reduction goals, capital budgets, and return on investment?

This article reviews the state-of-the-practice and the kinds of engineering and programmatic expertise that are required to properly scale geothermal applications up to the institutional level and provide optimized benefits. Some pitfalls of poorly-designed systems are described, and approaches to avoid these are presented. But first, the big picture on geothermal systems.

WHAT ARE OPEN AND CLOSED GEOTHERMAL SYSTEMS?

Both open and closed systems have their place in the geothermal universe of applications. Open geothermal systems use groundwater directly. These include withdraw/recharge systems, which cycle water from one or more withdrawal wells and return the water to one or more recharge wells; and standing column systems, which circulate the water to and from the same well. Closed systems are geothermal systems that cycle fluids through closed loops installed in the ground and do not directly use groundwater.

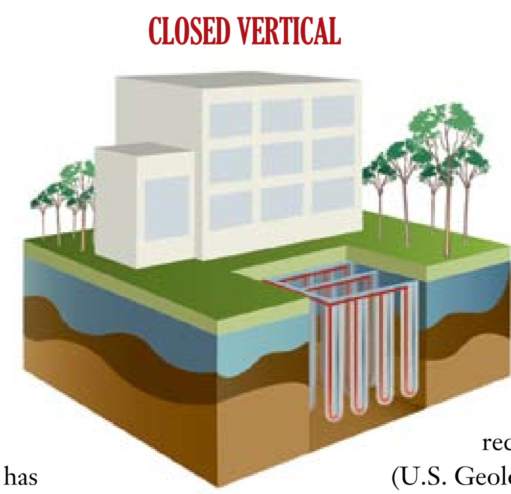
Where bedrock is closer to the surface and there is limited space for well fields, an open system may be the optimal choice. Where applicable, these systems can provide heating and cooling capacity that is several orders of magnitude greater than that of a closed system. A closed system, which relies on conductive heat transfer properties, may be the best system alternative where there is sufficient space, bedrock is very deep (200 ft+), and/or where there may be contamination or water resource issues. Geology and the site have a significant amount to "say" about the type of system and the applicability of geothermal, so evaluating them thoroughly at the beginning of the process is a key step.



STATE-OF-THE-PRACTICE

At this writing, the majority of the geothermal applications in the United States are residential systems. Heat pump technology suppliers and water well installers have been primarily responsible for the growth of this industry; and the equipment, design, and installation procedures are scaled for residential applications. Most of these systems are closed loop designs and have been used in the Midwest and Mid-Atlantic where the geologic conditions and available space accommodate vast closed loop fields. Rules-of-thumb based on small-scale, closed loop system experience have been the primary design criteria.

Recently, demand for geothermal systems has increased and larger suppliers, including energy service companies, have been moving to serve the educational facilities market. However, the state-of-practice shows high geothermal system failure rates, particularly in large-scale applications. This is especially true for open or standing column well designs, which require specialized geologic and hydrogeologic expertise.



A PHASED APPROACH TO ACHIEVE SUPERIOR RESULTS

With the pace of the geothermal energy industry quickening in response to increased demand, a higher level of responsibility and performance is expected in the marketplace. Current system failure rates and a state-of-practice based on rules-of-thumb are unacceptable by today's standards and limit the potential for campuses to integrate ground source geothermal systems into their energy master plans.

The following overview presents a phased approach that, in our experience, has led to sound financial and programmatic results. This approach uses existing information at the earliest stages and integrates it into the decision-making process. Further information is added at key decision points throughout to assist the institution and design team in making the most effective use of financial resources to achieve project goals. Due to the complexity of the geothermal development process, and its impact on many phases of planning, design, and construction, we recommend engaging a geothermal engineering professional early in the process.

PHASE 1: THE PRELIMINARY STUDY

The purpose of the preliminary study is to collect, organize, digest, and provide financial performance data with which the design team can make informed decisions regarding the use of the potential geothermal resource. The preliminary study is guided by the financial (return on investment) and programmatic (greenhouse gas reduction, energy efficiency, reduced central plant demand) goals of the institution, and keeps these as line-of-sight goals as the process proceeds.

Technical information collected during Phase 1 encompasses site conditions, geologic, hydrogeologic and environmental data, permitting and regulatory issues, campus master plans, utility master plans, water well information, geotechnical records from previous projects, and USGS (U.S. Geological Survey) and other governmental research commonly available.

Also part of this phase, preliminary building(s) HVAC load performance and site footprint data is collected to integrate with the geothermal well data. We have found that, by integrating geothermal and building performance data into energy modeling software, the ability to compare a variety of system configuration options with resulting benefits is vastly improved.

Once the existing data have been assembled and analyzed, this information can be incorporated into the appropriate financial model for the institution. Institution-specific escalation rates, energy cost data and greenhouse gas emission targets and investment goals are critical elements to this analysis. We recommend using life-cycle cost analysis to inform long-range financial performance, compare options, and make final decisions.

If, at the end of this phase, an institution decides to move forward, its project team can choose a preliminary geothermal system and layout, and can identify the location for the first test or production well.

During Phase 1, all permitting implications are evaluated and applications for any early items that need permits can be completed.

PHASE 2: THERMAL RESPONSE TESTING AND MODELING

Phase 2 calls for installation of a full-scale test well for thermal response testing, which will eventually be reused as a production well for the chosen project. The thermal response test will artificially load the well while monitoring temperature gradients, water quality, flow rates, and heat inputs. This full-scale test well will provide critical data that is necessary to accurately determine the number and depth of the wells and layout of the well field. This information will enable a refined decision-making process yielding superior financial and engineering performance.

Your geothermal engineer (staff or consultant) uses the thermal response test results to develop long-term data and applies advanced modeling in order to provide the building mechanical engineer with hour-by-hour load profiles of the well system. This information is important in order for the geothermal engineering professional and the building mechanical engineer to properly size and integrate the well system, heat exchangers, and ground source heat pump equipment into a fully functioning, seamless HVAC system. Omitting the modeling step can lead to oversizing or undersizing system components resulting in wasted time, money, and resources.

The thermal response test data inform the well field layout and provide thermal balancing information. These tests also provide information on the sequence of operation for the combined systems. The sequence of operation of these systems is an often overlooked component. If this sequence is improperly developed, implemented, and not combined with the appropriate training of operational personnel, it can result in poor system and financial performance. There have been instances in which incorrect sequence of operations, combined with valving and pressure control problems, resulted in major flow imbalances in well fields.

The outcomes of Phase 2 are a well field design, heat exchanger specifications, and an optimal sequence of operation with simultaneous completion of the building mechanical engineering design.

During Phase 2, all withdrawal, recharge, state department of environmental protection, and local water district permitting for the well fields can be completed.

PHASE 3: CONSTRUCTION AND COMMISSIONING

By this point in using the phased approach, the design and construction team is generally "on the same page" with respect to the scope and execution of Phase 3. This phase calls for engineering oversight of the installation of the well field, associated pumps and piping, controls and wiring, and all structures. These are expensive installations and must be right the first time, so we recommend that well installation procedures be monitored by trained geotechnical engineering field technicians.

GEOTHERMAL PITFALLS AND WHY THESE HAPPEN

If you've "inherited" a geothermal system that functions less than optimally or suffers from programmatic failure, you're familiar with some of the technical and financial problems that can result from improperly designed, installed, and operated systems. The following summary may help in understanding existing system problems.

Problem: Well field thermal imbalance where temperatures and/or flow rates do not meet or are moving out of specification. Possible causes are:

- Ground and soil characteristics coupled with changing hydrogeologic and water quality conditions
- Incomplete understanding of site conditions, adjacent environmental conditions, soil types, rock structure, fracture zones, rock types, and water chemistry and turbidity
- Lack of geologic/hydrogeologic expertise applied early in the process
- Original geothermal well system was designed using rules-of-thumb, ignoring site-specific geologic conditions
- Original decision to go with the existing, inadequate geothermal system was based on randomly applied well testing
- Fragmented decision making, particularly at the intersection of well field and building envelope modeling.

Problem: Improperly sized, installed, and operated well fields leads to the owner's decision to "bleed" the system to improve thermal performance. Possible results are:

- Bleeding the aquifer leads to water table depression with subsequent impacts on adjacent foundation support performance, environmental contamination transport zones, and long-term well performance degradation
- Bleeding triggers permitting and regulatory requirements and raises the possibility of well failure
- With excessive bleed or increases in well pumping flows, the cone of depression drops below the pump's return line level and exposes the return water to air entrainment causing excessive bacteriological growth, system fouling, strainer plugging, and well failure. This cone of depression can also lead to exposure of the well pump and potentially result in cavitation and failure.

Problem: Geothermal system doesn't meet the institution's risk tolerance, financial, and programmatic goals. Possible causes are:

- The geothermal engineering professional is too far removed from the project owner and the decision-making process
- The geothermal provider is an equipment vendor and/or well driller whose primary interest is in providing a particular piece of equipment and/or style of well.

CONCLUSION

Proper application of ground source geothermal technology can dramatically impact the efficiency and financial performance of energy utilization (30%+) in a building or on a campus. At the same time, this alternative energy resource can significantly contribute to the institution's carbon reduction goals. Geothermal applications also offer the possibility of aesthetic and noise abatement benefits (eliminating cooling towers and dry coolers in sensitive locations or on historic structures) and, when combined with "green" or lower cost, on-site electrical power, the benefits are many.

An efficient, optimally functioning geothermal system can contribute to building and campus carbon footprint reduction goals. Colleges and universities are in a unique position to be able to educate the next generation about the possibilities available to solve some of the toughest issues of our time, and to use innovative technology on their campuses as a powerful teaching tool.

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