Abstract: Geothermal Integration in Cooling

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The growth of computing means a surge in energy demands to meet these rising needs. Already staggering energy costs are going up, and as the data center demands increase, the energy costs to cool it also rise. The increase is not just in the overall need for more computing, but also densities are increasing significantly as well.

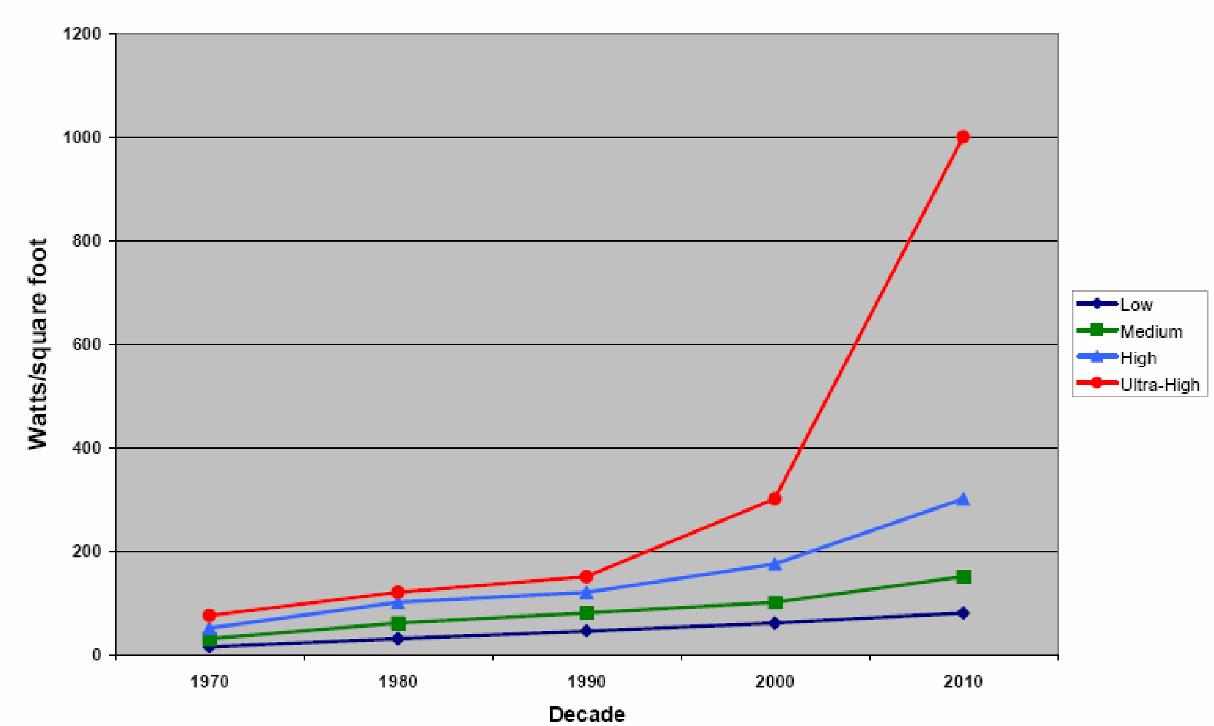

Figure 1: Increasing energy demands for data centers by decade

Companies are increasingly looking for alternatives to reduce their energy costs and also to meet higher standards that coincide with energy reduction - going 'green'. Meanwhile, obtaining LEED certification for a data center has never been tougher than it is now, as the USGBC requirements and interpretations that have guided the engineering have become more stringent year after year.

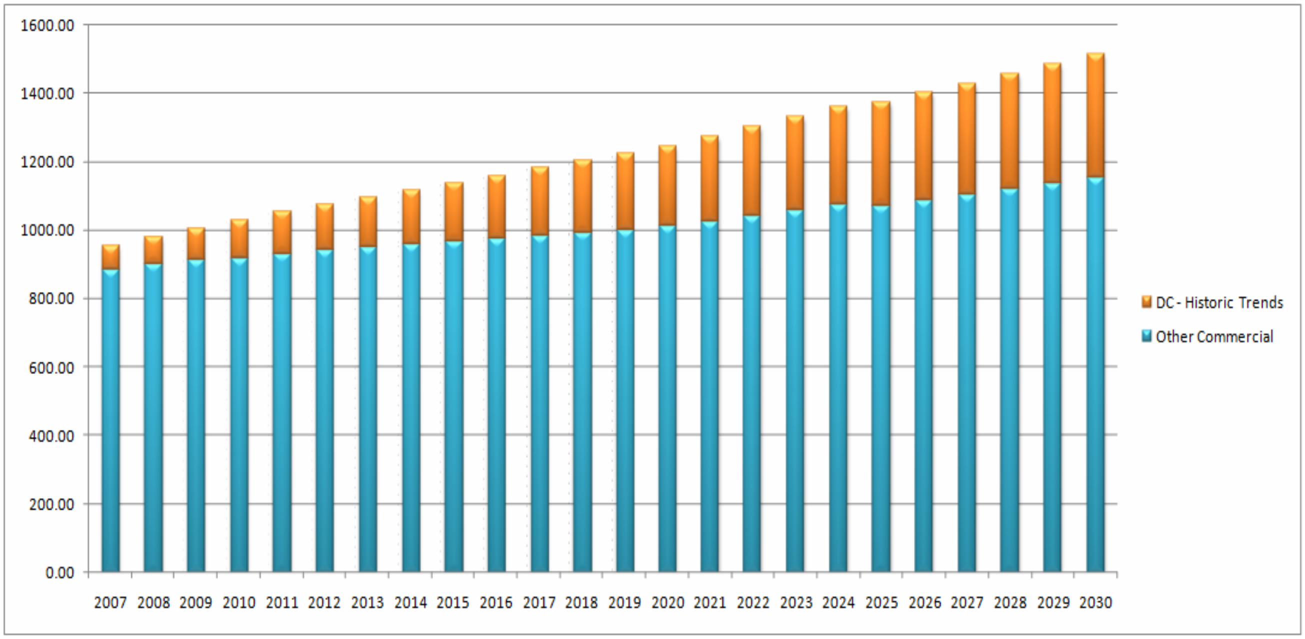

Figure 2: Data Center (orange) and other Commercial (blue) energy trends; Data center energy use is projected to outpace all other commercial energy use

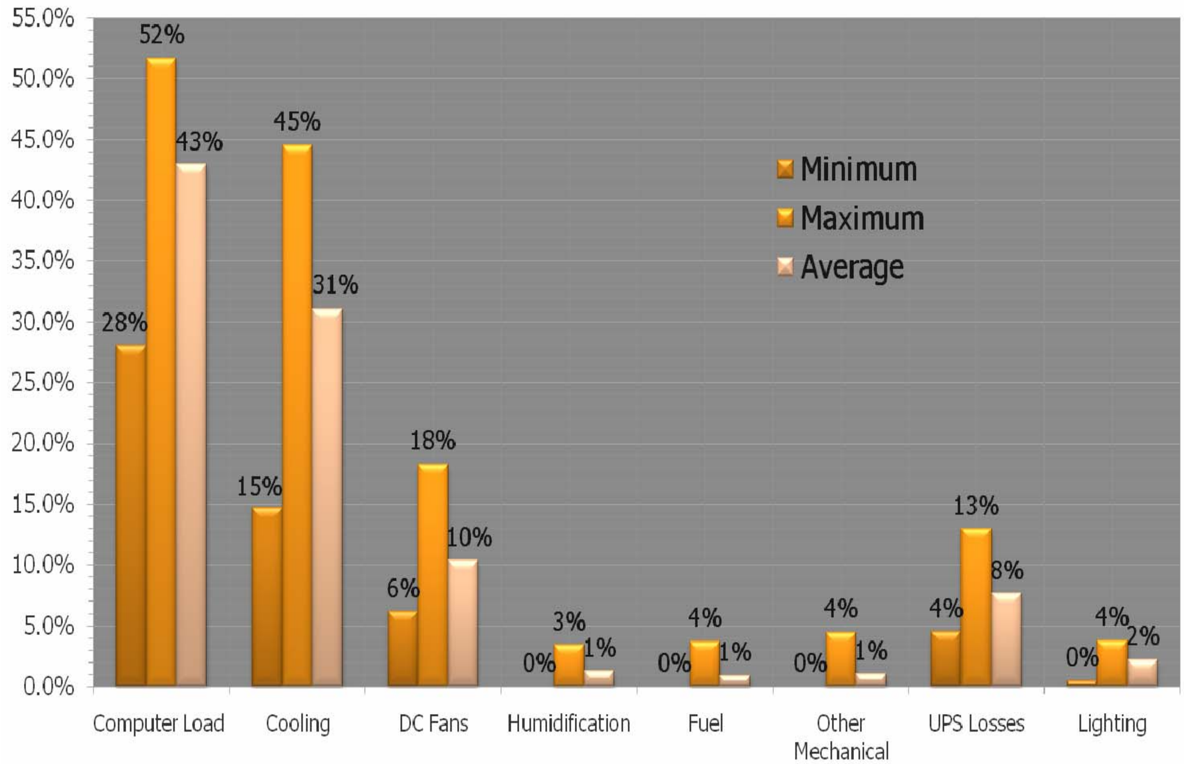

Figure 3: Annual power use in a data center

A great solution to fit these many needs is a geothermal system for cooling.

Geothermal Introduction

The use of geothermal systems (also known as ground source systems) for cooling has increased in popularity as its reliability and efficiency have become proven methods of design. By means of piping installed underground to reject heat allows the system to take advantage of the constant temperature of the earth. The efficiency of a geothermal system can be quickly realized, offsetting the high cost of installation in a much shorter period than other systems.

Synopsis of the advantages of geothermal systems:

- Longer system lifespan than conventional systems
- Payback periods for data centers as short as 5 years or less
- Less maintenance and operation costs as compared to conventional systems
- Large energy savings over the life of the system

A geothermal system requires less energy to operate, as there are no fans that normally reject heat to the atmosphere. Another key to using the ground as the heat sink is that the performance isn't beholden to the outside dry or wet bulb temperatures that limits other equipment. In this manner a geothermal system easily outpaces the efficiency of typical systems and can yield a payback in a short time.

Geothermal Types

There are a number of methods for arranging a geothermal system, but the most common applied with larger, energy-intense buildings is a closed loop ground-coupled geothermal system, and it is the primary geothermal design discussed here. In most cases a ground coupled system is composed of an array of vertical wells beneath the ground, spaced anywhere from 15 to 30 feet apart. Together the wells form what is known as a well field, with all of the piping buried safely below the frost line to escape freezing conditions in the winter.

Each vertical well can reach up to 800 feet deep, unless bedrock shortens the well to the average of 200-300 feet. The amount of heat transfer averages around 1 ton of cooling per 200' of well depth, although this is very dependant on the ground soil conditions. Most sites considering a geothermal-coupled design should establish a test well and monitor the well for approximately a month to properly gage the amount of heat transfer and determine the proper well field size for the design.

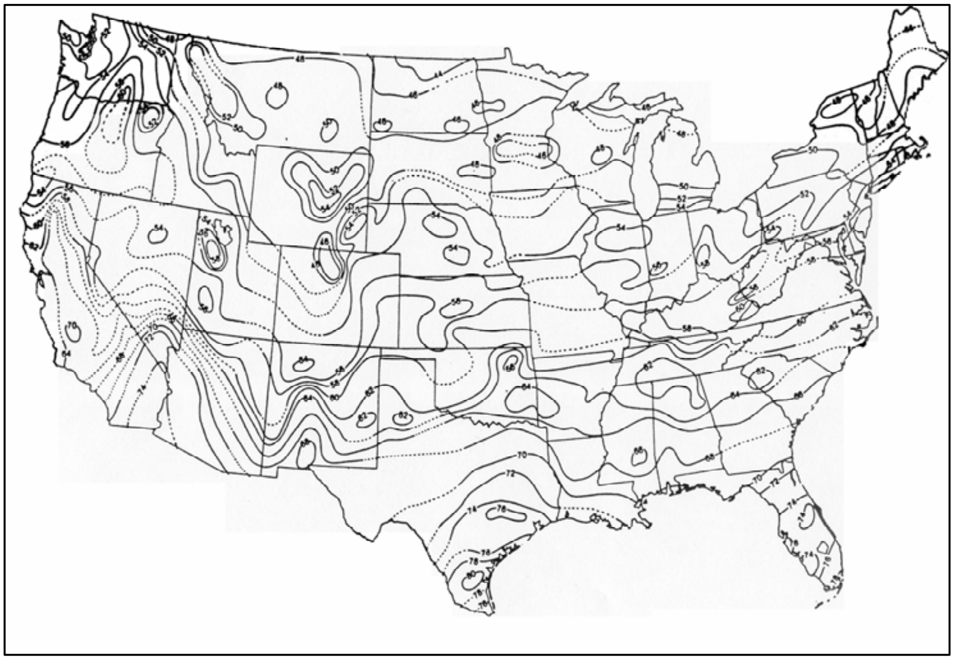

Figure 4: Geothermal Deep Earth Temperatures throughout the continental United States.

Geothermal First-Cost and Operation Comparisons

A thorough cost comparison should be performed for each project, as the upfront capital cost of a geothermal system will be greater than conventional systems. While a conventional system might cost about $1000 to $1400 per ton of cooling, a geothermal system may possibly cost up to three times as much. This cost might appear unattractive, but a geothermal system will pay for itself in energy savings in perhaps as little as four years versus a conventional design.

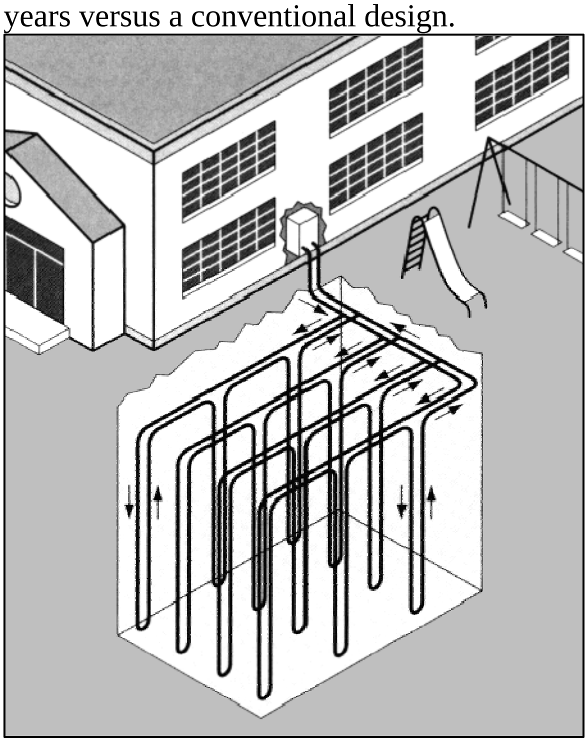

Figure 5: Typical Geothermal system

The main reason behind the larger first-cost is largely the labor and materials to install the geothermal field. Long lengths of piping and heat transferring fill need to be buried in the wells, and all of the piping must be below the frost line to prevent the piping from freezing, requiring six feet or more of excavation below the finished grade. A geothermal system requires a relatively large amount of land to install the wells, but the well field can be located beneath a parking lot or similar areas. Once installed the geothermal system requires almost no regular maintenance. Should a rare leak develop in a well, it can be isolated to prevent water and system losses.

While a conventional design utilizing cooling towers might be cheaper at the beginning, the maintenance and costs of operation are much higher than a geothermal system. Cooling tower fans must operate to provide even minimal cooling, and their efficiency is directly dependant on the outside air temperature. Chemicals are necessary to prevent growth of contaminants in the cooling tower basins. Both the cooling towers and the associated chemical treatment system need to be monitored and maintained by the building staff, which must also include costs for replacement parts such as belts, motors, and basin heaters. Also of concern is cooling tower down-time, as during this time the overall facility cooling system has temporarily lost either capacity or redundancy.

> Project Highlight: "Unnamed Government Computer and Office Building"
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> This building will be 550,000 square feet of office space, raised floor server rooms, and computer laboratories. The building load is approximately 1500 tons total, and a geothermal well field will be installed to match 100% of this load. The geothermal wells are split into two equally sized fields. Each well field has a central piping system with valves so that any one branch can be isolated from the rest.
> An array of four evaporative coolers is designed to match 50% of the load to provide an overall N+1 design in combination with the well fields.

A geothermal system begins to save energy as soon as it is operational, significantly reducing the amount of energy consumed by the mechanical cooling systems since there are fewer motors required for operation. Since the system is a closed loop, there is little contamination of the water as it circulates through the system. There is also little need for replenishing water to the system, which can save over 30 gallons per minute of water when compared to a cooling tower.

Integration with Data Center Facilities Equipment

From a cooling system design perspective, a geothermal system rejects heat from the condenser water system, the same water system that a cooling tower typically serves. The geothermal system can be designed to completely replace the cooling towers, but often the geothermal system is coupled with a type of cooling tower called an evaporative cooler. The evaporative cooler, also called a closed-circuit cooler, can provide extra cooling during occasional high load conditions, and it is able to recharge the geothermal system during off-peak seasons and hours when the cooler can operate more efficiently.

A geothermal system incorporating an evaporative cooler in this way is known as a hybrid system.

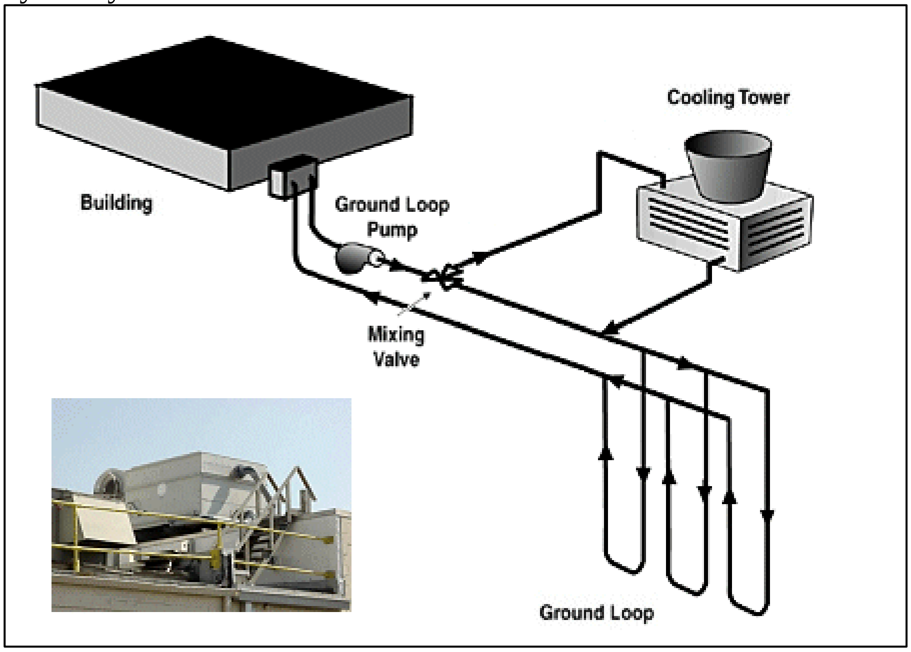

Figure 6: Hybrid Geothermal System schematic

A hybrid system design can shrink the well field size and thusly reduce the high initial capital cost of installation from 20% to 45% as compared to a ground coupled system. The geothermal and cooling plant designer should consider closely the amount of cooling for the data center and need for future expansion and flexibility, perhaps utilizing the hybrid solution at a later time when the demand for cooling has increased.

The geothermal system will operate in a wider temperature range, using ground temperatures as low as 45 degrees F to 70 degrees F, dependant upon the geographic location. The equipment coupled with this, most often chillers, should be considered when operating over the wider temperature range. A heat exchanger may be utilized to keep the geothermal system separate from other cooling equipment; however this reduces overall efficiency of the geothermal system.

Project Highlight: “California University Residence Halls”

The university drilled 150 wells and dug 400 feet deep to install the piping for its first three new dorms. As a result, it invested about $1 million into the project. The university president has said it took less than three years for the college to receive a full payback on its geothermal investment.

When operating in the lower temperature range it is important to also consider free cooling – either bypassing the chillers to serve a chilled water system through a heat exchanger or serving water-side economizers at the air handling units.

A geothermal system will have an operational life span of up to 200 years and are often given warrantees for 50 years, longer than the life of a typical 30-year cooling tower. During its operational lifespan, a geothermal system may see an increase in water temperature, especially over a prolonged period with a constant load almost equal to the geothermal field capacity. At this point the well field temperature is gradually rising and loosing its ability to discharge heat into the ground. This causes the equipment to be less efficient, in turn adding more heat to the field – unless checked, this downward spiral will continue. Fortunately, there is an easy solution.

Like a battery, the well field can be recharged. As mentioned above, this can be done by operating an evaporative cooler or cooling tower to assist with cooling; the equipment can recharge the well field during the winter to take advantage of the lower ambient temperatures. The cooling equipment can also operate at night while electricity costs are lower and the tower efficiency is higher. Operating the equipment during normal hours can also assist a discharged geothermal system with high peak loads. The evaporative cooler can completely recharge the geothermal system during the winter and off-peak hours, resetting the well fields to reduce the high energy costs during the summer months.

Taking full advantage of a geothermal system requires planning and foresight to properly couple with the rest of the cooling system, and geothermal should always be considered as a possible energy saving solution for data center heat rejection.

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