Geothermal Heat Pumps for the Grafton County Correctional Facility

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Geothermal Heat Pumps and Geothermal Energy

- **Geothermal heat pumps should not be confused with "true Geothermal Energy".**
- **True geothermal energy is normally in the form of hot water or steam geysers or hot springs that may be used directly for space heating, agriculture/aquiculture, and even in some cases electric power generation.**
- **To varying degrees geothermal heat pumps make limited use of energy from the earth, however largely they use the earth as an energy storage device.**

So what is a Geothermal Heat Pump?

- **Heat normally flows from regions/bodies at warmer temperatures to colder ones, analogous to water flowing down hill.**
- **If we want to make heat move in the opposite direction on the temperature scale, energy must be input, just as we must input energy to move water to a higher elevation.**
- **Moving heat up the temperature scale is the purpose of a heat pump, air-conditioner, or refrigerator.**
- **In terms of the basic physics involved they are all the same, the nomenclature is strictly a function of the application.**

Heat pumps, Air-Conditioners, and Refrigerators: what's the difference?

	Purpose	Heat Source (T_h)	Heat Sink (T_c)
Refrigerator	Cool interior of refrigerator	Interior of refrigerator	Room Air
Air-Conditioner	Space Cooling	Room air	Outdoor air or other
Heat Pump	Space Heating	Earth, air, or ground-water.	Room Air

What does a heat pump look like?

Most common type is water-to-air:

- Water (or a water-based solution) is supplied to the unit as it's heat source/sink.
- Air is the medium that delivers the heating/cooling to the room.

Many configurations of heat pumps are available. This unit is mounted above a ceiling with ductwork down to the conditioned space. Other units are configured for mounting in enclosures, within the room, etc..

Why is a heat pump advantageous?

- It turns out that if you don't need to move the heat very far up the temperature scale, it takes a lot less energy to do so than to create the heat by another means (i.e. burn fuel).
- A "lot less" is the order of one third to one forth.
- It's also a simple matter to change the direction of the refrigerant flow such that a heat pump can provide both heating and cooling; i.e. air-conditioning becomes part of the system at negligible extra cost.
- In larger buildings like the proposed Grafton County Correctional Facility, multiple heat pumps are often connected to a single circulating loop of water and not only is it possible for one unit to be heating while another is cooling, it's advantageous.

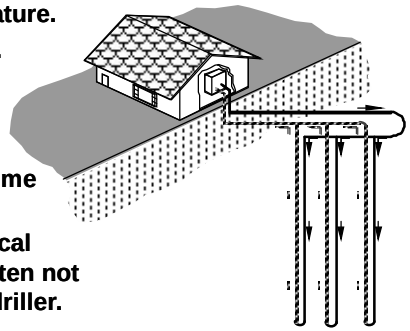
So what's the downside?

- A heat pump is an electric driven technology in most all cases and electricity is a high value/high cost form of energy.
- Recent escalation in heating fuel cost has greatly decreased this disadvantage.
- Thermally connecting the heat pump to the ground, i.e. ground-coupling, can be expensive and is most often the cost driver in these systems.
- Understanding the site and the technology is important in determining feasibility and economics; it's not simple like specifying a boiler and/or chiller.

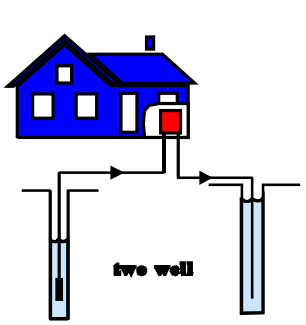
Basic System Types of Interest for the Grafton County Correctional Facility

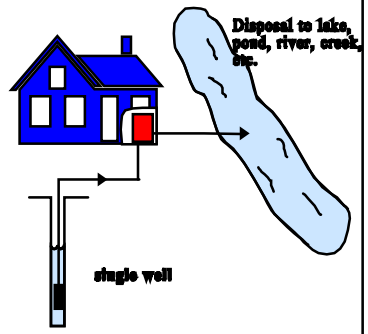
CLOSED-LOOP
Vertical Ground Coupled

- Advantages
  - low land area requirement.
  - stable deep soil temperature.
  - adaptable to many sites.
- Disadvantages
  - may have high cost.
  - does not work well in some geological conditions.
  - needs experienced vertical loop installer. That is often not your conventional well driller.



OPEN-LOOP
Ground Water





Open-Loop ground water system

- Advantages
  - May have lowest first cost, especially for large loads
  - Stable source temperature, high efficiency
  - Some direct cooling possible
  - Oldest, lots of experience (a lot of the early systems had corrosion/scaling problems, most of which would have been solved by a heat exchanger isolating the ground water)
- Disadvantages
  - Environmental requirements can be tougher, but they are not expected to be here at the GCC
  - Site specific analysis is required
  - Poor water quality can cause difficulties, isolating ground water from heat pumps is often necessary

Geothermal Feasibility Study Tasks

- Assess water yield and chemistry including identifying previous water supply studies.
- Look at the permitting requirements for an open loop system.
- Based on available building loads from designers determine the water production requirements.
- Provide a simple schematic of a geothermal system and first order approximate costs.
- Review the vertical ground-coupled option that was previously dismissed.
- Recommend further courses of action.

Tasks not included in the Geothermal Feasibility Study:

- Direct well yield or drawdown tests.
- Provide construction or design level details.
- Remove all doubt of geothermal feasibility and cost effectiveness.
- Note that while it was not in our scope, we did prepare estimates of the heating and cooling loads for the GCCF because the design engineer would not release his calculations to us.

Geothermal study preliminary findings on Open-Loop

- The geology of the CT river valley bottomland is variable consisting largely of "stratified drift materials" (sands, silts, gravels layers and clay).
- This geology is capable of producing large quantities of water in some circumstances.
- While there is no direct experience at the Grafton County Complex site, a 150 foot gravel packed well across the river at the Knox farm produces about 50 gpm (gallons per minute).
- High yield municipal wells in this type of geology include Lisbon-700 gpm, Littleton-400 gpm, Norwich-975 gpm, and Fairlee-900 gpm.

Geothermal study preliminary findings on Open-Loop (cont.)

- With more sand and less gravel layers the local geology at the Grafton County Complex site appears to be not as favorable as in other parts of the CT river valley where conditions are very favorable for open-loop systems.
- Test drilling could uncover areas with significant gravel deposits capable of high water production.
- If not, it is still possible to do an open-loop system using multiple wells with more modest yields than the municipal wells discussed earlier.

Geothermal study preliminary findings on Open-Loop (cont.)

- Based on the heating and cooling loads we approximated, the flow rate required for an open-loop system is estimated at approximately 200 gpm.
- Assuming that each well would produce about 50 gpm, around six wells would be needed including backups. A similar number of re-injection wells would also be used.
- We estimate that the installed cost of the wells, pumping, and piping would be less than the cost of the chillers that would be deleted from the project if geothermal heat pumps are used.

Geothermal study preliminary findings on a Vertical Closed-Loop system:

- Based on heating and cooling loads we approximated a vertical ground coupled system would require about 144 vertical bores of approximately 200 feet depth each. This would require about 1 acre of surface area (could be located under parking lots).
- The 200 foot depth is not a rigid requirement; the contractor could decide to drill deeper and thus fewer bores (and less surface area) would be required.
- The installed cost of the bore field would be approximately equal to the cost of the chillers to be deleted from the project.

Geothermal study preliminary findings applicable to both open-loop and closed-loop options:

- The heat pumps would in essence replace the VAV boxes distributed within the building, they would probably be somewhat larger.
- Heat recovery would be maintained, but any preconditioning of ventilation air would probably be done via heat pumps.
- Service hot water would be heated with water-to-water heat pumps to the maximum extent possible.
- A portion of the current mechanical room space of approximately 2500 square feet would be freed up; likely requiring only half the space for circulating pumps (and heat exchangers for open-loop).

Geothermal study preliminary findings applicable to both open and closed loops options (cont):

- It is expected that the additional cost of the heat pumps above the VAV boxes would be roughly equivalent to the boilers, fuel handing, and fuel storage equipment that would be deleted from the project. Control costs could also be reduced by the geothermal system.
- Thus overall project capital cost would be roughly the same for a closed-loop system and perhaps a bit lower for an open-loop system.
- Operating costs are expected to be significantly lower for the geothermal system.
- Maintenance cost would be reduced by approximately 50% by the geothermal system.

Summary

- Both closed-loop and open-loop systems appear to be possible.
- The economics depend largely on the actual building loads which we only estimated in a very crude fashion.
- Significant design rework would be required for either geothermal heat pump option.
- The geothermal option is easily expanded if additions to the building are anticipated.

Next Steps

- **A detailed heating and cooling load determination should be undertaken to provide results in a form suitable for geothermal system design.**
- **A test well for an open-loop installation should be drilled and evaluated for its yield (gpm) & drawdown (feet).**
- **If the open-loop system well test does not appear to indicate that such a system is possible, a closed-loop test bore with thermal properties measurements should be commissioned.**

Questions?