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Cooling Technology Integration with Communities Using Waste Heat from Geothermal Electric Generating Facilities

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ABSTRACT

In today's renewable HVAC market there are a growing number of geothermal electric generating facilities (GEGF). Many of the owners and officials that have authority over these facilities and the communities that may surround them are reasonably skilled and informed on the distribution of waste heat from these facilities to provide for the heating needs of the surrounding community. However, it has become clear that many of these facilities have abundant heat that goes to waste during the cooling season.

This abstract will shed light on cooling strategies that take advantage of the infrastructure placed into communities that surround geothermal electric generating facilities such as:

1. Absorption Chiller Technologies

2. Reheat and Desiccant Regeneration

3. Ambient Geothermal Distribution Pipelines

4. Ambient Temperature Surface & Aquifer Exchange

1. Absorption Chiller Technologies

According to the US Department of Energy absorption chillers are refrigeration system that cool a process fluid or dehumidifies air and are commonly found in commercial and industrial facilities (Department of Energy 2017). Absorption **c**hillers are used in more commercial and industrial plants to provide year-round air conditioning or large space air conditioning needs, refrigeration, and process fluid cooling due to their fluid chilling temperature of greater than 40^{o}F. Examples of absorption chillers with such needs include hospitals, hotels, large commercial office buildings, and college campuses. Thermal sources can include hot water, preferably from geothermal waste heat operation, steam, or combustion exhaust with thermal energy supplied indirectly to the chiller. The single stage absorption chiller uses a binary solution of a refrigerant and an absorbent, and different solutions allow absorption chillers to meet a range of site cooling needs (see Figure 1). For space conditioning and other requirements that require chilling fluid temperatures of 40°F or higher, water/lithium bromide (refrigerant/absorbent) is the most common solution and can be driven with hot water or a low pressure. For lower temperatures, ammonia/water (refrigerant/absorbent) is typically used. Sites that may require steady year-round cooling include manufacturing plants with process cooling needs, cold storage warehouses, data centers, ice rinks and district energy plants.

A geothermal electric generating facility (GEGF) works with high energy steam from the geothermal boreholes, piped to a steam driven turbine to generate electricity. After the steam has run through the turbine, it can be sent through cooling towers to condense it back to liquid. The steam can be used prior to the cooling towers as the source energy for absorption chillers to provide cooling for any purpose from HVAC to refrigeration. Available in single and two stage designs.

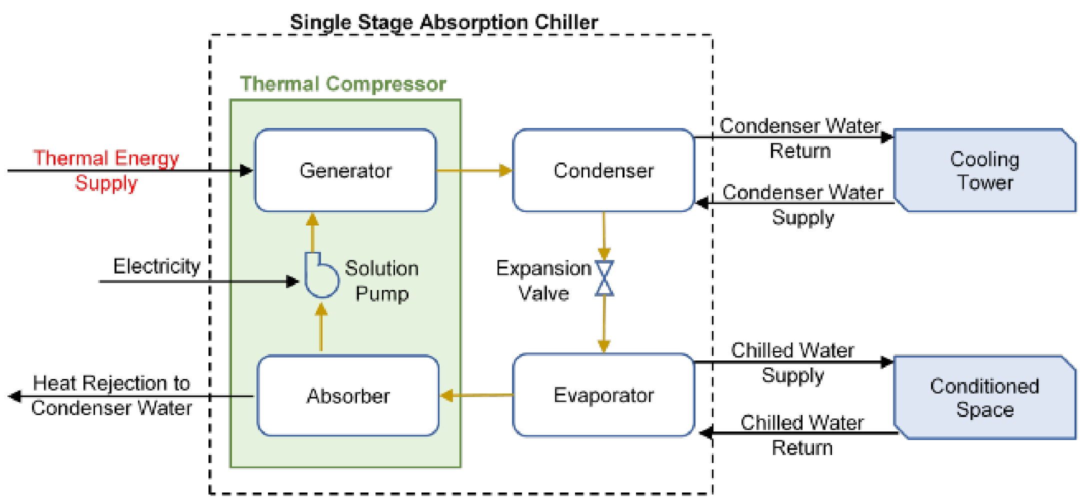

Figure 1. Single stage absorption cycle.
Graphic credit Exergy Partners

Figure 1: The absorption cycle is like the vapor compression cycle except the prime mover (typically an electric motor) and compressor are replaced by a thermal compressor system consisting of an absorber, solution pump, and generator. Figure credit (Lowenstein 2006)

When compared to the single stage absorption chiller, the two stage machines require higher temperature hot water or higher-pressure steam and are often unfortunately used with combustion turbine CHP installations.

2. Reheat and Desiccant Regeneration

Liquid Desiccant Air-Conditioning Technology (LCID) is a technology that uses waste heat to dehumidify conditioned air in buildings (Lowenstein 2006). Typically, to provide dehumidification in buildings, a process of overcooling and reheating building spaces is required with vapor compression systems. LCID can reduce peak electricity demand compared to vapor compression systems if thermal energy sources such as natural gas, solar thermal energy, and waste heat are used for regenerating the desiccant.

The thermal energy required for regeneration can be provided by fossil fuel boilers; solar thermal collectors; or heat recovered from reciprocating engine generators, microturbines, turbines, fuel cells, or other processes with recoverable heat at 150°–210°F (Lowenstein 2006). The desiccant used in LDAC systems is most often, LiCl or lithium chloride. In some cases, calcium chloride or $CaCl_2$ is used because it is significantly cheaper, however it does not dry as deeply as LiCl. If the storage needs of the desiccant are greater than an hour, LiCl is the more economical choice in the long run.

For the purposes of this abstract, the source for regenerating the desiccant will be the waste heat form the geothermal electric generating facility (GEGF). After the steam has run through the turbine, it is normally sent through cooling towers to condense it back to liquid. The steam can be used prior to the cooling towers as the source energy to be provided to the LCID Regenerator, causing the desiccant to desorb from the desiccant [Figure 2]

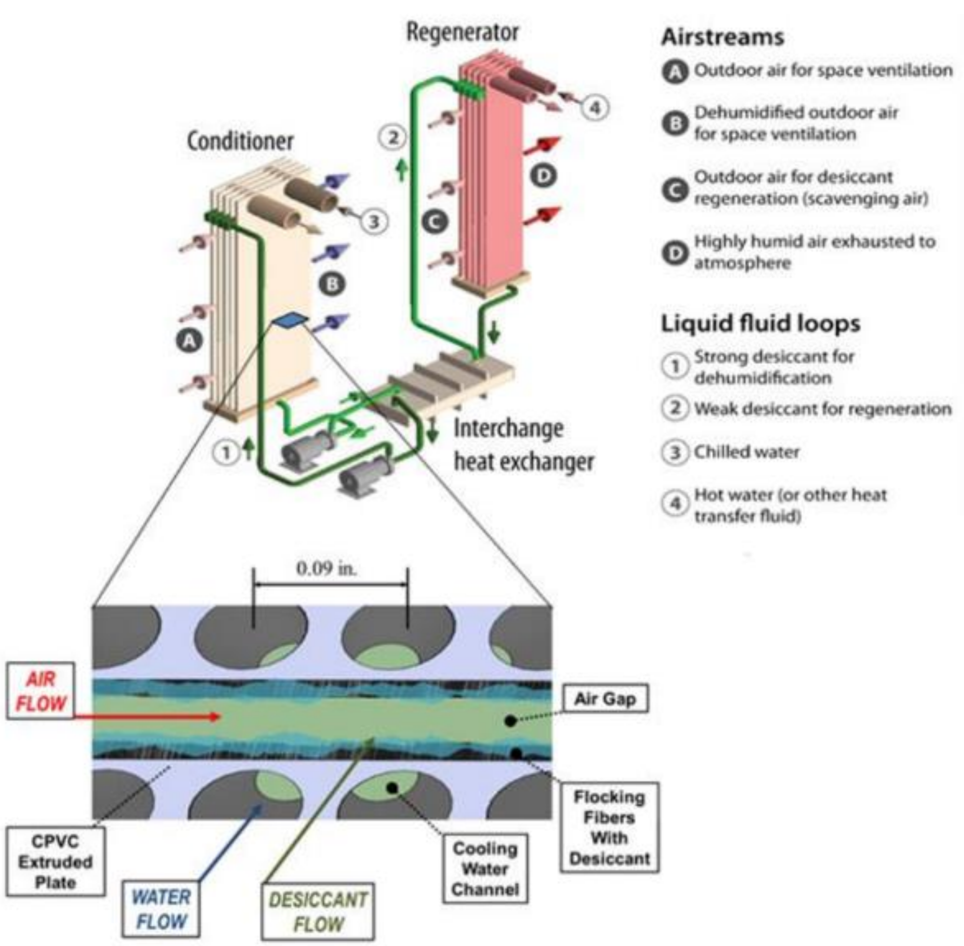

Figure 2: Components of a low-flow LDAC

Picture Credit adapted and used with permission from (Lowenstein 2006)

Thus far in the paper, we have discussed the two most effective technologies for using waste heat from GEGFs to provide dry and comfortable cooling on a large scale.

The remaining two points address District Geothermal Energy Networks that use an ambient temperature heat source and heat sink. This ambient temperature is typically the same as the undisturbed earth at a depth of 27 feet; which is often close to the average annual temperature in a given location.

Using Heat Pump and the Stable Earth Temperature

Ground Source Heat Pumps have been used throughout the world for generations, one example is Tampa's Church of Christ Scientists that was initially installed in 1949 (EggGeo 2014). Combining a ground source heat pump and the stable temperature of the earth is a proven technology that continues to provide the most energy efficient cooling and heating available. This is attributed to the steady temperature of the heat source and heat sink, being the earth and its stable temperatures.

Installation at a building requires excavation and /or drilling to access the earth's ambient temperatures, which drives the cost of the technology. The outside ground source pipe and work can be responsible for 60% or more of the total cost.

The costs for excavation are brought down by creating a geothermal pipeline that is installed in place of or into already existing typical natural gas pipeline, like a water main. Each home and building are connected to the District Geothermal Energy Network, just as they are to City or County Water. They will pay a connection and / or an energy fee just as they would for electricity or water.

3. Ambient Geothermal Distribution Pipelines

Eversource, has applied to do geothermal districts for multifamily buildings, dense urban or mixed-use, and purely residential. (Hasan 2020). The system will use ground-source heat pump technology, which uses electricity to transfer heat from the ambient temperature GeoMicroDistrict (in the ground) to a network of geothermal heat pumps to provide clean heating and cooling for the buildings within each district.

In this case, the pipelines will be buried in place of or into the existing natural gas pipelines, providing the heat exchange needed for each of the buildings on the circuit. Some buildings need heating, and others need cooling at the same time; normally wasted energy is harvested for use in the pipeline. An example of this is the Stanford Energy System Innovations (SESI). The project illustrates the capability to combine waste heat from cooling operations with the heat needed for heating operations, reducing energy consumption by sharing as much as 80% of the energy moved on campus (Stagner 2015). (See Table 1)

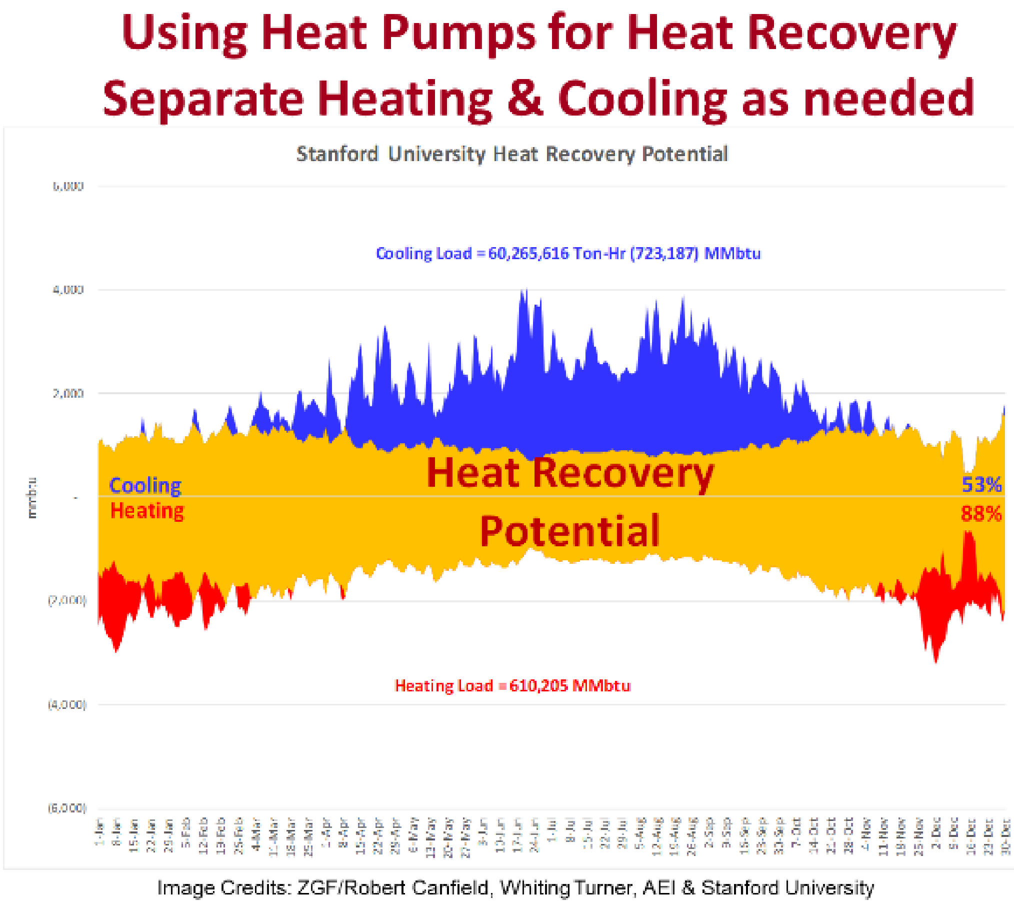

Table 1: Stanford Energy System Innovations (SESI) shows the shared energy from buildings needing heat, and those rejecting heat.[9]

Similarly, District Geothermal Energy Networks will enable energy access for all of buildings in a community to tap into one central exchange source, without the added cost of onsite excavation and drilling [Figure 3].

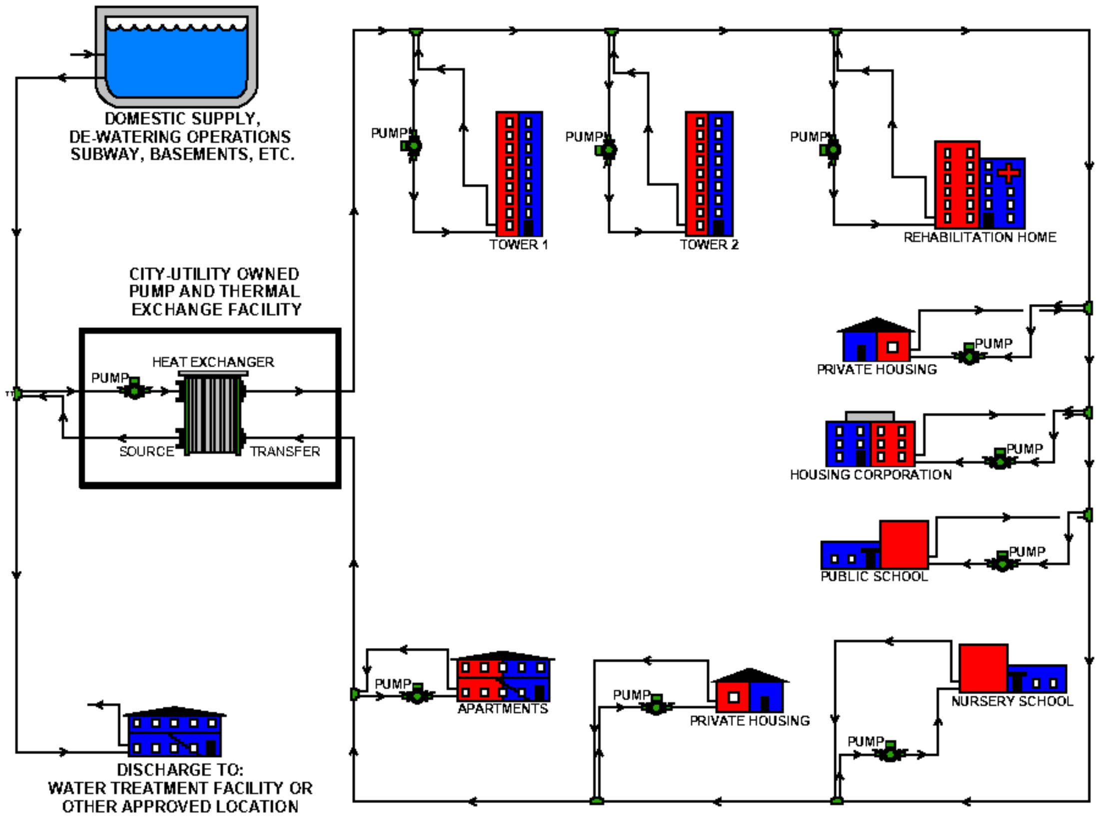

Figure 3: A District Geothermal Energy Network has many different buildings served, and many different heat sources and heat sinks

4. Ambient Temperature Surface Water & Aquifer Exchange

There are dozens of variations for earth-coupled heat exchange. The possibilities are wide and varied. Some of the solutions have a lower first cost than others for a variety of reasons. Some are listed below and depicted in Figure 4.

- **Closed loop vertical exchange:** Can be configured in 2-pipe, 4-pipe, concentric and many more adaptations.
- **Closed loop horizontal exchange:** Can be configured in many various ways to apply open-trench based exchangers.
- **Closed loop pond/lake/ocean:** These can be configured to use fabricated plate exchangers, or polyethylene pipe arranged in the body of water.
- **Closed loop energy piles:** Like closed loop vertical exchange, these can be adapted in many different ways.
- **Open standing column wells:** Primarily allows for reduction in boreholes, allowing for a smaller footprint. Needs specific geology (competent bedrock).

- **Open Class V well doublets:** Primarily allows for reduction in boreholes, allowing also for a smaller footprint. Needs a specific geology (abundant aquifer). Great for large-scale applications in hot and humid climates (cooling dominant).

Figure 4: Some of the variations for heat sources and heat sinks in a District Geothermal Energy Network (Egg 2014)

Efforts are underway to prepare a heat map like that which has been created in the UK for the Department of Energy & Climate Change. Surface water thermal exchange includes rivers, ponds, lakes, aqueducts, and water features. Surface water exchange can consist of plate exchangers or pipe in the water, water extraction and rejection, or any variations of submerged exchangers.

The UK Department of Energy and Climate Change commissioned a study of surface water exchange potential. The study shows 6 GW of thermal capacity, enough to heat and cool 7 million homes (Department of Energy & Climate Change 2015). Though the United States has no such research, it is reasonable to suppose U.S. capacity would be greater.

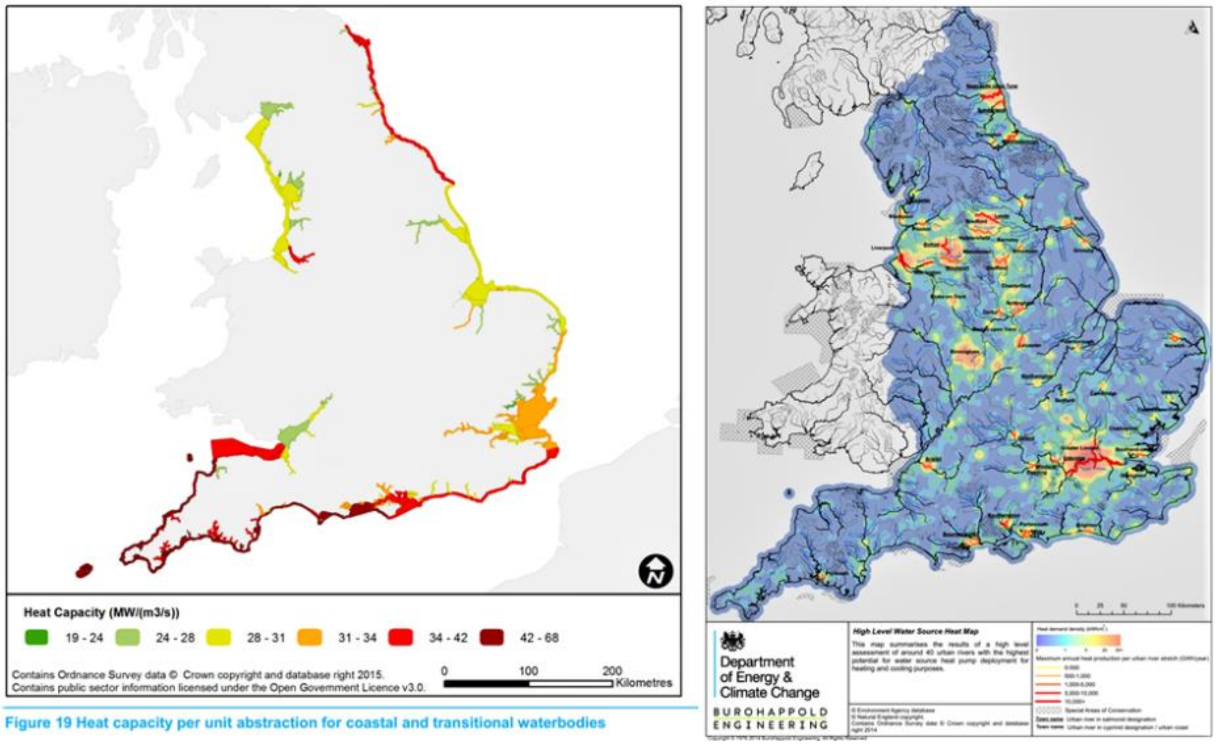

Figure 5: UK National Heat Map for Surface Water (Department of Energy & Climate Change 2015)

Infrastructure dewatering thermal exchange includes ongoing efforts for low-lying cities and infrastructure, subways and conduits that need to be kept dry and, of course, the need for current and future efforts to handle ocean rise. Where relative sea-level rise occurs, it amplifies near-term vulnerability to storm surge and increases long-term flood and inundation risk.

Well Water Thermal Energy Exchange is another of the technologies identified along with surface water energy exchange that can significantly reduce first cost. It is depicted in the Figure 6a and is identified as either "Aquifer or "Well Water" Thermal Energy Exchange. Water is pumped from one well, used for thermal exchange, then injected into another. This method is considered environmentally friendly and a good use of resources.

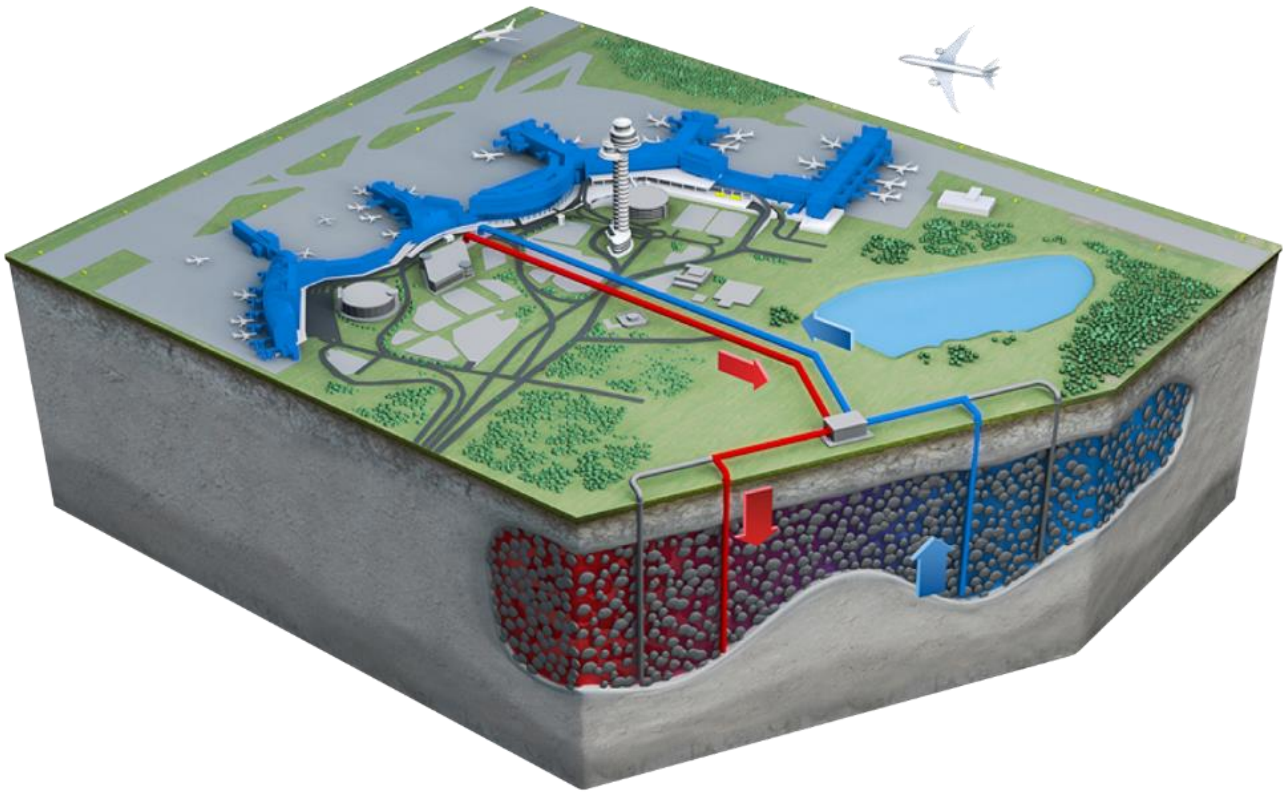

Figure 6a: Depiction of Aquifer Thermal Exchange

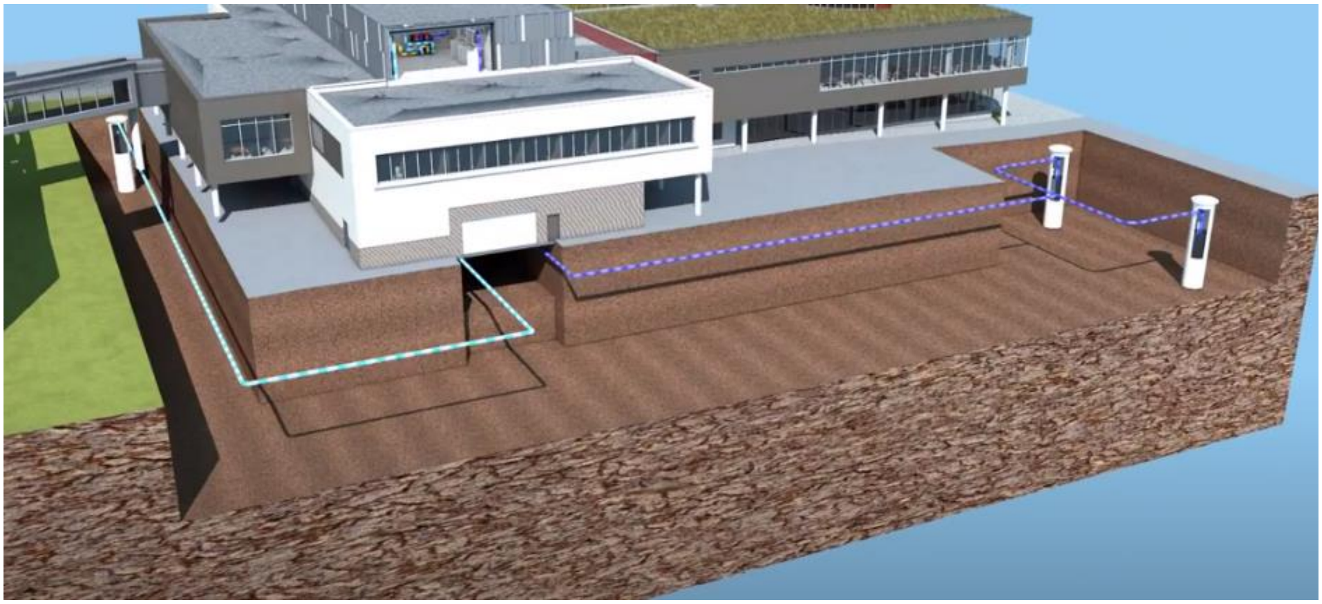

Figure 6b: Another depiction of Well Water Thermal Exchange

We have the means of heat transfer already in the ground, which can eliminate the need for much of loop infrastructure that is normally identified as prescribed by the ground source heat pump industry. Tapping existing pipe infrastructure for thermal exchange helps to reduce the first cost well below that of single geothermal systems, and adds load sharing and diversity, significantly reducing energy consumption beyond stand-alone systems, once again as in the Stanford example. The water/energy utility can own the exchange facilities and sell the energy.

Note: The terminology ***GeoMicroDistrict, Ambient Geothermal Networks, Pipelines, or Distribution*** *as applied to geothermal systems are used interchangeably. These all have the common thread of an ambient, or an earth temperature fluid pipeline used as a utility to provide energy exchange for geothermal heat pump systems in homes and buildings.*

Ground Source Heat Pump (GSHP) and Geothermal Heat Pump (GHP) mean the same thing.

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