Optimizing Shallow Geothermal Energy

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Problem Statement

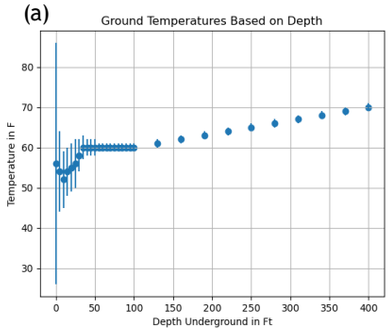
This project focuses on using shallow geothermal energy to provide clean and optimal energy to a 2000 Sq.Ft. house test site in Dodge City, Kansas.

The described test site aims to maintain a consistent temperature of 70°F year-round, 24 hours per day, using the most efficient methods of geothermal energy for the local environment.

What is Shallow Geothermal Energy?

- Geothermal energy thermal energy extracted from the Earth's crust
  - Shallow Geothermal energy specifically pertains to depths from the surface down to ~200 ft underground
- This is done through heat transfer of water/liquid circulation
  - Specific process depends on external factors (aquifer access/weather/maintenance/etc)
- Temperatures underground below 10 ft become quickly regulated
  - This consistency in temperature can be utilized to both heat and cool temperatures above ground

(a)



(b)

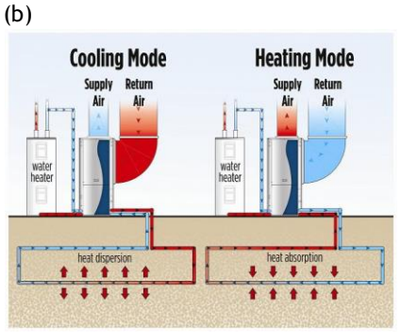


Figure (a) shows ground temperatures as related to depth below the surface as well as corresponding uncertainties.
Figure (b) depicts how heat can be transferred through a geothermal process for both heating and cooling purposes

Proposed Solution

Geothermal System Design

Dodge City has access to the Ogallala Aquifer at a depth of ~46ft below the surface (T~59.3°F), making open loop systems desirable for geothermal uses as well as residential water access. Closed would be preferable in drier climates with less access to aquifers and would circulate an antifreeze/water mixture instead of potable water.

(c)

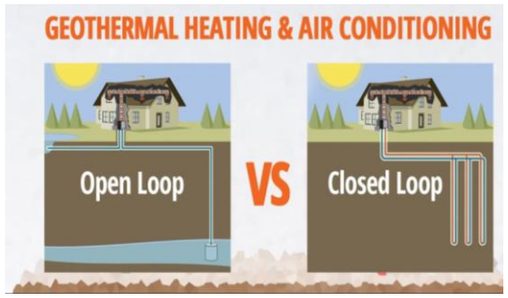


Figure (c) is a visual representation of the different loop systems (open vs. closed).

With the aquifer, vertical loops would allow the water to be brought up to the house, transfer heat, and then return back to the ground allowing the temperature of the earth to return the water to ~59.3°F before being brought up again. Horizontal loops could be beneficial for transfer between houses.

(d)

Figure (d) is a visual representation of the different loop systems (vertical vs. horizontal).

The system would take the water from the aquifer, up through the vertical loops into a heat pump system that then allows circulation throughout the given test site tranfering heat for both heating and cooling and then returning back to the ground through additional vertical loops. An example of this overall system can be seen below.

(e)

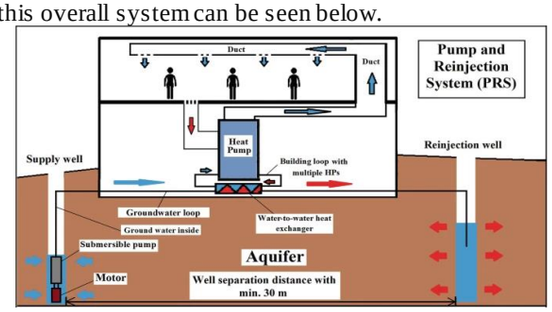


Figure (e) demonstrates the overall physical system of the geothermal solution

Weather Data

We used weather data of average temperatures to calculate heat/cooling loads, energy needs, and additional values necessary to keep house temperature at 70°F all year long.

(f)

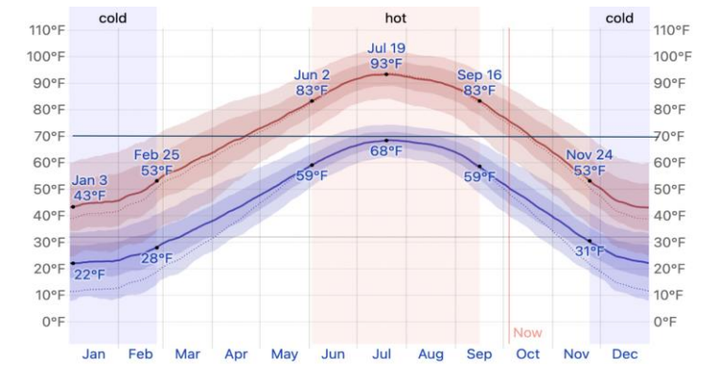


Figure (f) depicts average weather data from years 2014-2024 in Dodge City, KS where the red line represents daily highs, blue is daily lows, and the shaded regions outline the 25th-75th percentile boarded by a lighter shaded region for 10th-90th percentile.

Conclusion and Future Applications

Determined Solution:

- Install vertical loop with an open-source pumping system from Ogallala Aquifer
- Connect system with water-to-air heat pump with circulation of adjustable 5-10 GPM and 12,000 BTU energy capabilities

The results demonstrate that cooling can be effectively managed with circulating water from a shallow aquifer, while achieving a temperature of 70°F for heating requires supplemental energy due to the aquifer's temperature of 60°F.

Future Applications:

- This process/design can be expanded for multiple houses (i.e. neighborhood access) by connecting houses with horizontal loops.
- These analysis techniques can also apply to any location with the adjustments that each location will have different temperature profiles and aquifer accessibility

[1] J. Randow et al., "Modeling neighborhood-scale shallow geothermal energy utilization: A case study in Berlin - geothermal energy," SpringerOpen, https://geothermal-energy-journal.springeropen.com/articles/10.1186/s40517-022-00211-9 (accessed Oct. 20, 2023).
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[3] "Dodge City, KS electricity rates," Electricity Local, https://www.electricitylocal.com/states/kansas/dodge-city/ (accessed Sep. 10, 2023).
[4] "Load and energy consumption: Energy," U.S. Agency for International Development, https://www.usaid.gov/energy/powering-health/analyze-demand-supply/load-consumption#:~:text=The%20load%20of%20a%20particular,an%20array%20of%20PV%20panels (accessed Oct. 10, 2024).
[5] Y. Yu and G. Olson, "Ground source heat pump systems," SpringerLink, https://link.springer.com/referenceworkentry/10.1007/978-3-662-49120-1_3 (accessed Oct. 6, 2023).
[6] "Weatherspark.com," Dodge City Climate, Weather By Month, Average Temperature (Kansas, United States) - Weather Spark, https://weatherspark.com/y/5269/Average-Weather-in-Dodge-City-Kansas-United-States-Year-Round (accessed Sep. 6, 2023).

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