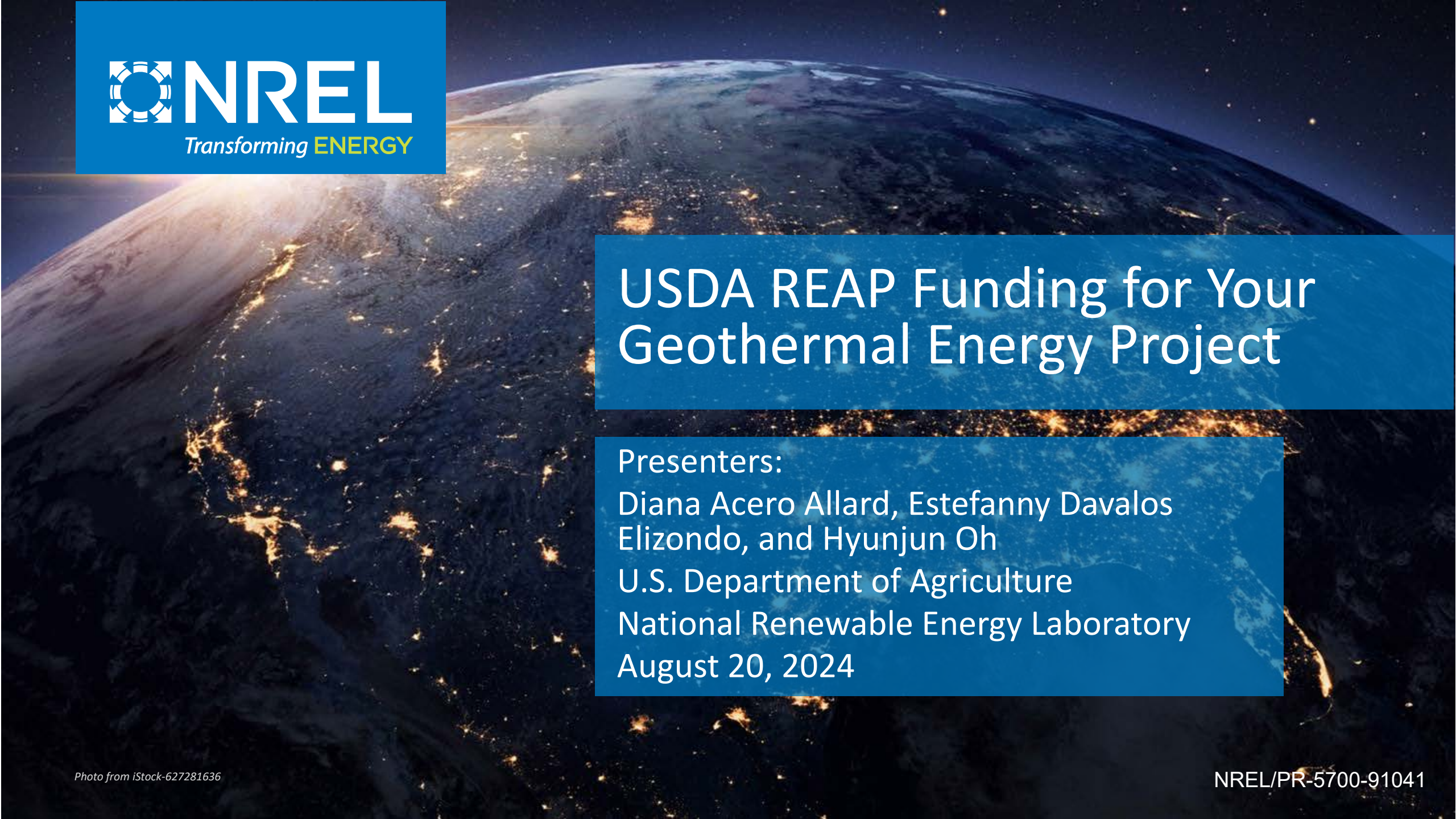


USDA REAP Funding for Your Geothermal Energy Project

Presenters:
Diana Acero Allard, Estefanny Davalos Elizondo, and Hyunjun Oh
U.S. Department of Agriculture
National Renewable Energy Laboratory
August 20, 2024

Photo from iStock-627281636

NREL/PR-5700-91041

Agenda

1. Welcome, Webinar Overview, & Intro to REAP (5 mins) - USDA
2. Geothermal (40 mins) - NREL
3. Geothermal Applications for REAP (15 mins) - NREL
4. Q&A (30 mins) - USDA/NREL

Welcome

USDA REAP and RAISE

RAISE Initiative

Rural and Agricultural Income & Savings from Renewable Energy (RAISE) initiative will provide savings and additional revenue sources for small agricultural businesses in rural America:

- Since 1981, the nation has lost nearly 545,000 farms and 155 million acres of former farmland.
- The nation has enjoyed record farm income in recent years, but the income has been concentrated among 7% of farms that cumulatively account for 89% of income.
- In the face of increased costs, competition for land use, and consolidation, small family farmers shouldn't have to work twice as hard; we should find ways additional ways for them to generate revenue from the land.

Based on collaboration between the U.S. Department of Energy (DOE) and the U.S. Department of Agriculture (USDA), this effort will:

- Advance opportunities for small and mid-sized farmers to earn savings and income from underutilized renewable energy projects.
- Pilot new and innovative business models for farmers, rural electric cooperatives, and developers that utilize distributed energy resources (DERs) to generate revenue for farmers.
- Lead to 400 individual farmers deploying small-scale wind projects within 5 years using Rural Energy for America Program (REAP).

Other USDA/NREL Webinars

USDA REAP Funding for Your Hydropower Project (for applicants)

- September 19, 9:30 a.m. – 11 a.m. MST

Relevant Resources

New NREL/REAP website: https://www.nrel.gov/state-local-tribal/rural-energy-for-america-program.html

- Webinar slides and recordings will be made available on this site

REAP Information and Application

REAP State Rural Energy Coordinators

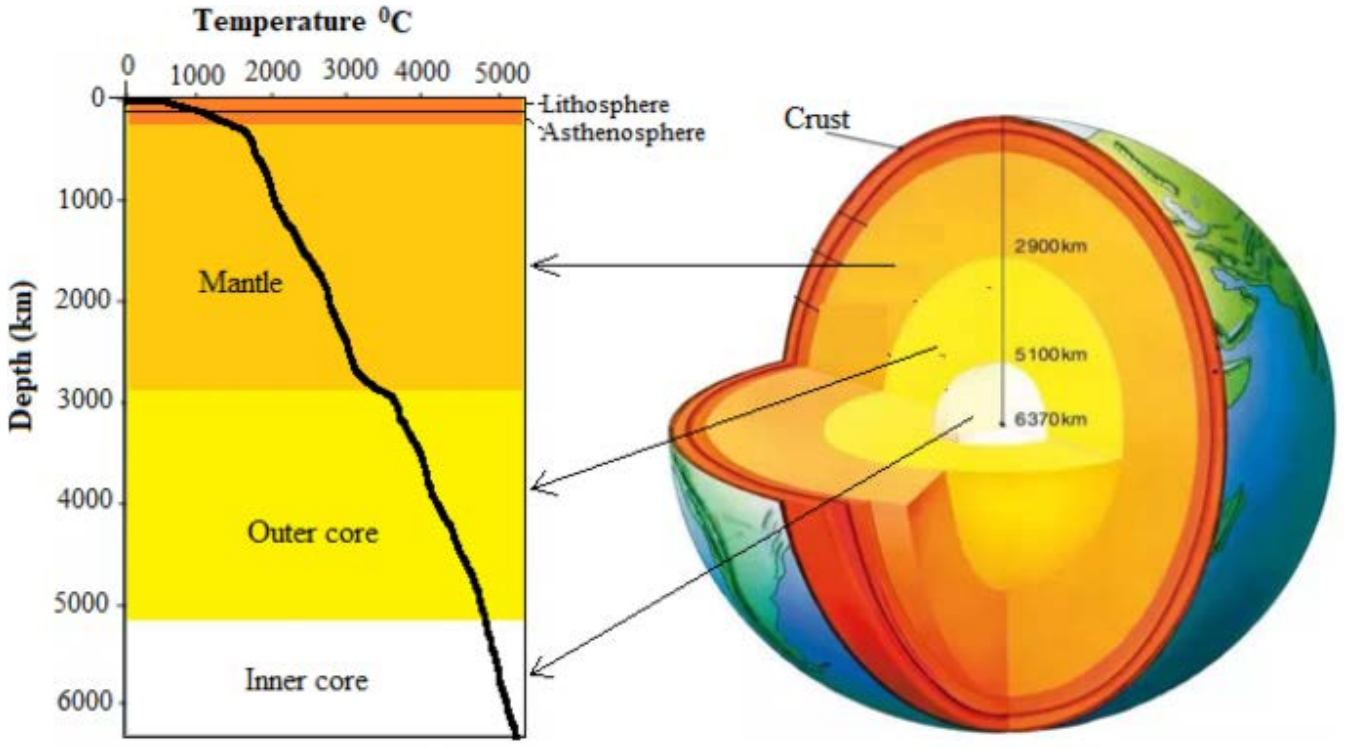
REAP Frequently Asked Questions

Geothermal Energy Fundamentals

Basic Concepts

- Geothermal Gradient

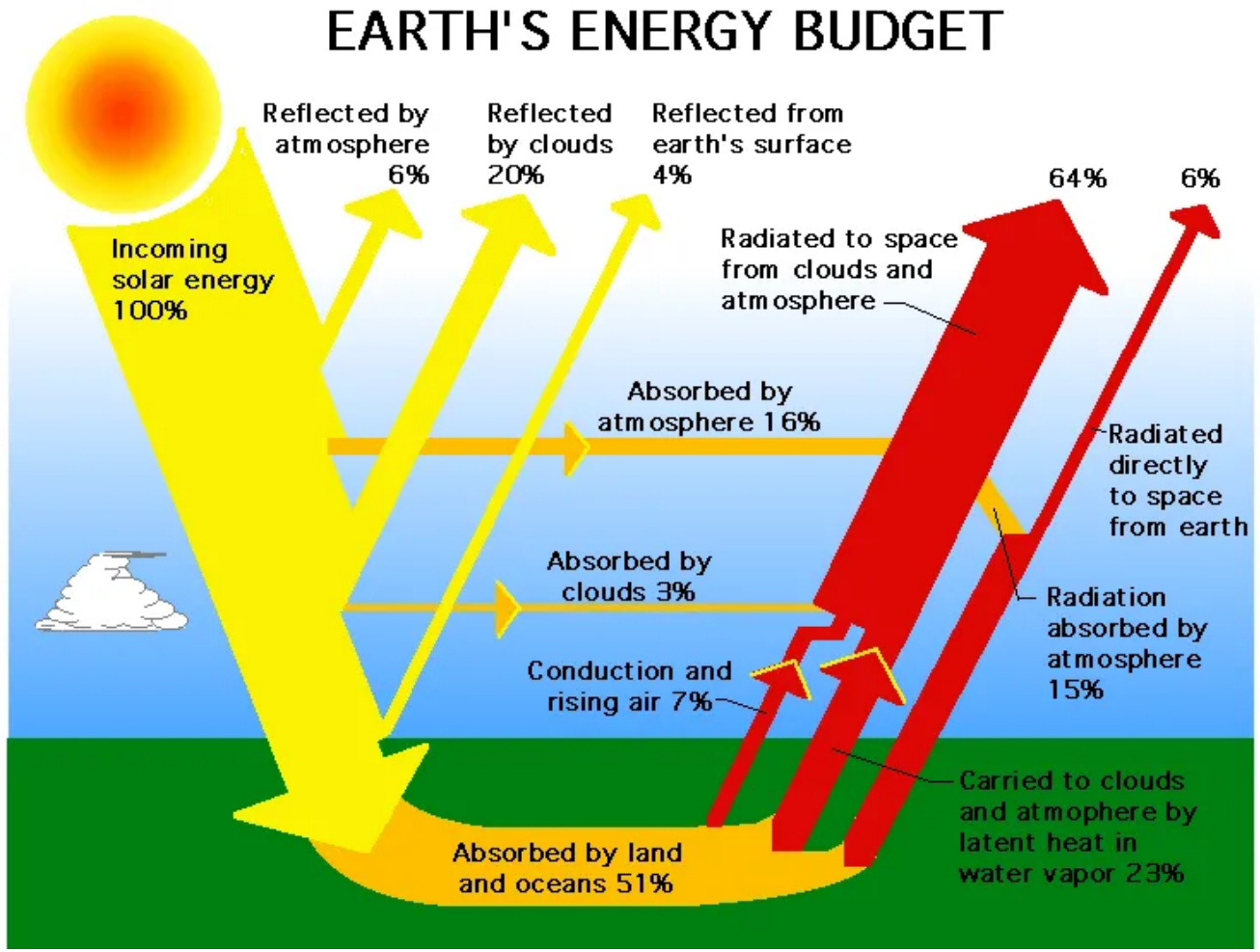
is the rate at which the temperature of the Earth's crust increases as you go deeper. It's also known as the thermal gradient. The geothermal gradient is determined by the flow of heat outward through the crust and can vary by region and rock type. For example, in normal continental crust, the geothermal gradient is usually around **25°C/km within the first 2–3 miles of the Earth's surface**, but it decreases to about 16°C/km at a depth of 40 km. The geothermal gradient can also change significantly with depth, dropping to zero or even negative in areas with a lot of groundwater flow



https://link.springer.com/article/10.1007/s12665-022-10236-9

Basic Concepts

- Keep in mind that some geothermal energy is due to the **heat flux** from the earth's core.
- However, some "geothermal" energy comes from the sun being stored in the earths surface.
- Because of this, earth's surface temperature is nearly constant year-round.



https://scied.ucar.edu/learning-zone/how-climate-works/energy-budget

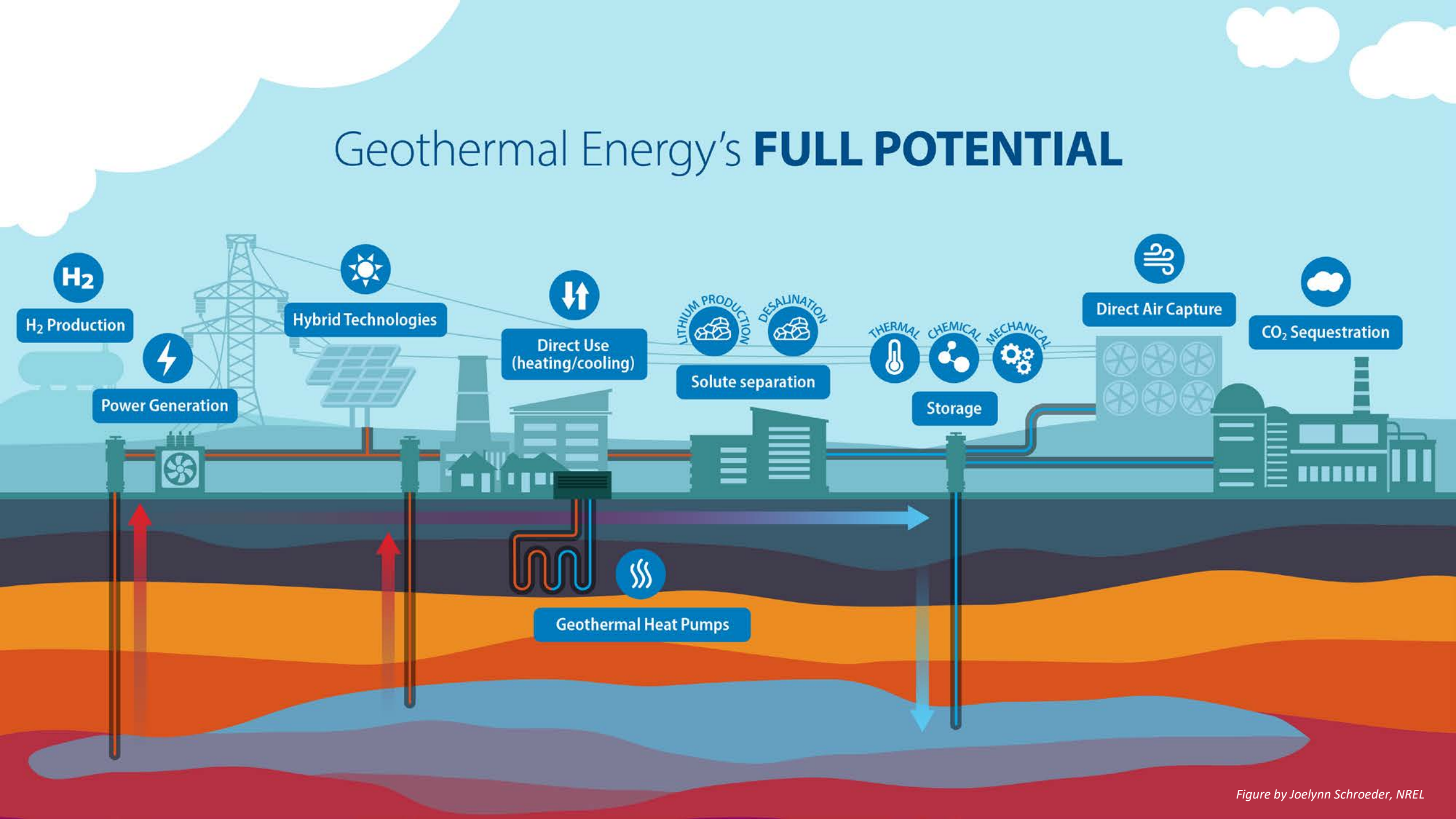
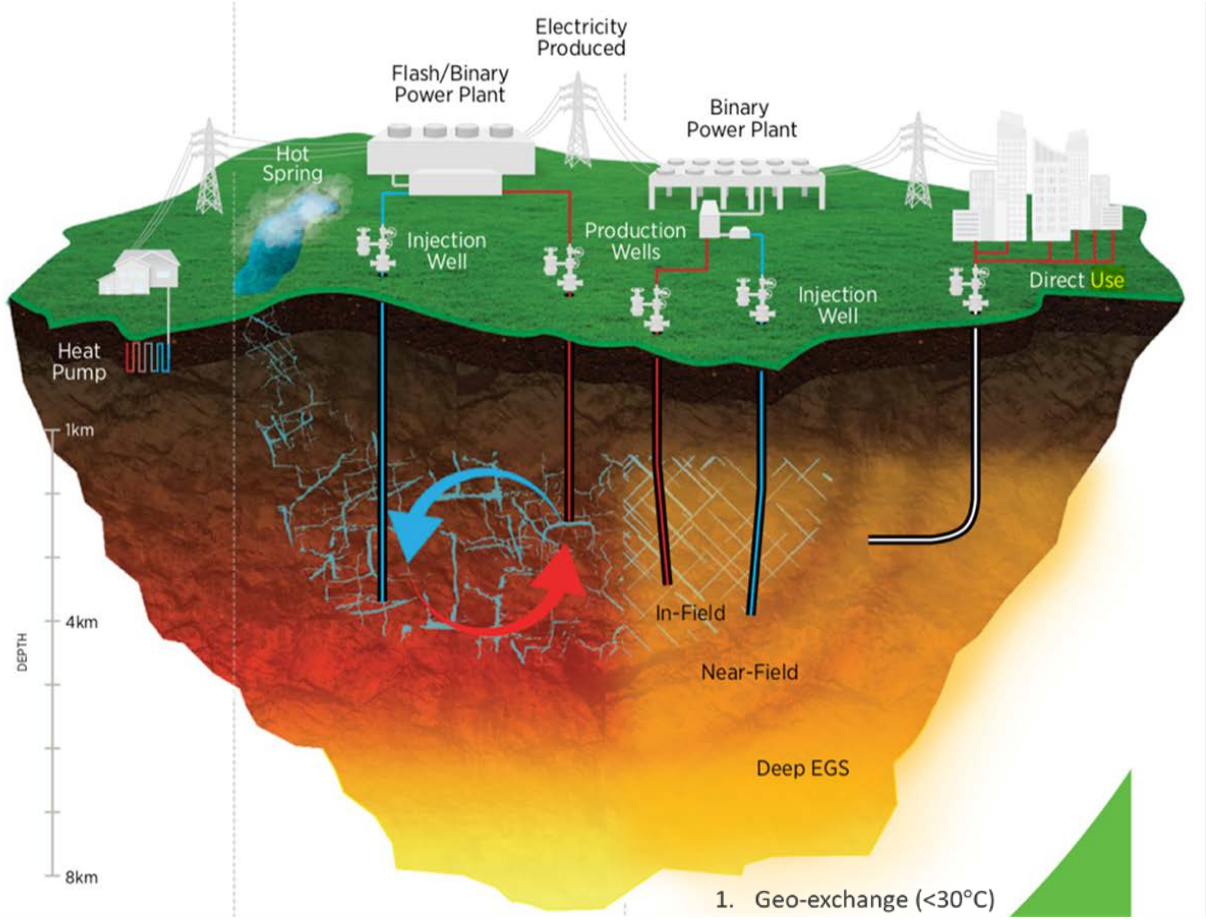
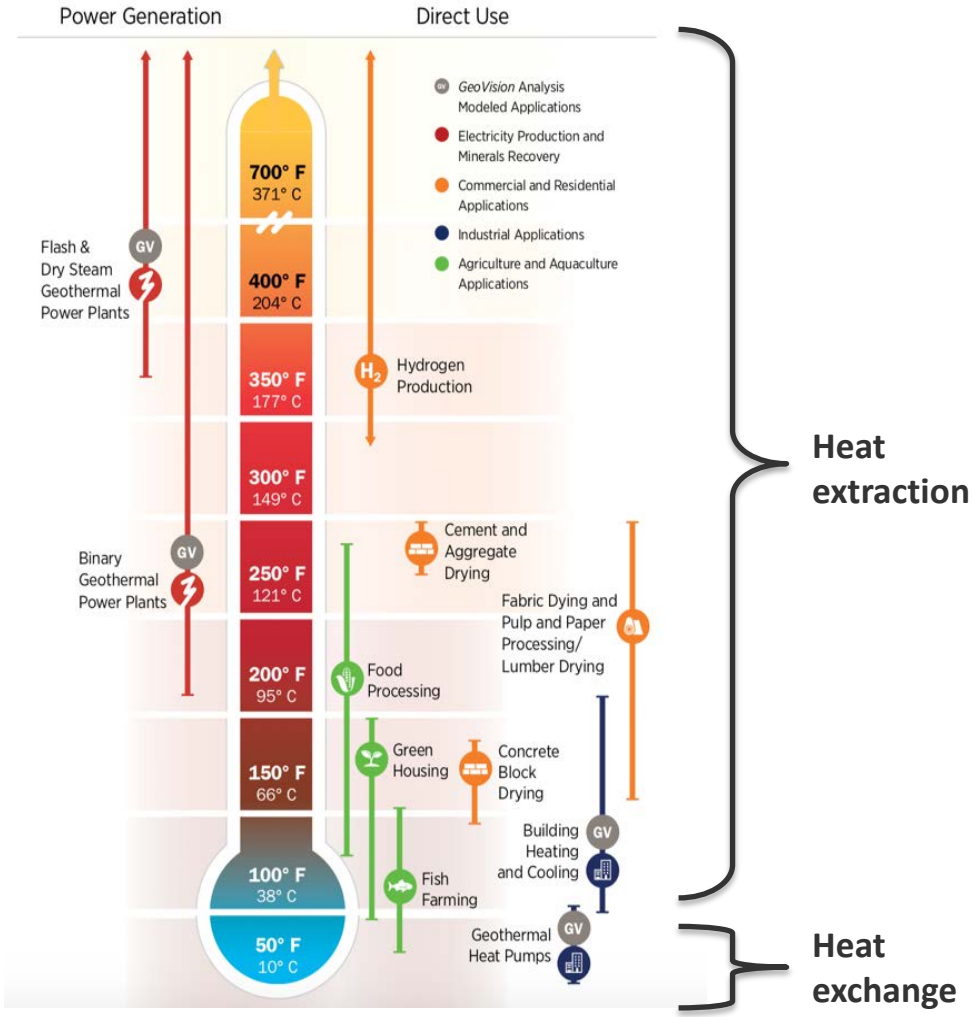


Figure by Joelynn Schroeder, NREL

Resource Requirements for Geothermal Energy Applications



Source: Geovision (2019)



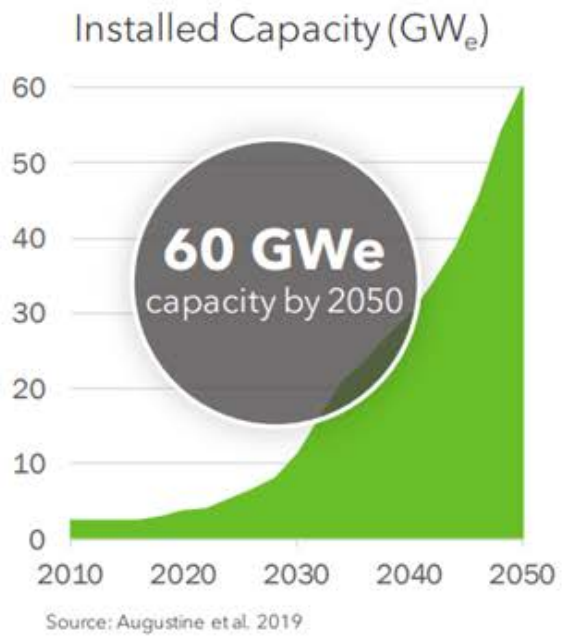
Source: Geovision (2019)

U.S. Geothermal Resources

Geothermal Can Do Big Things

ELECTRIC

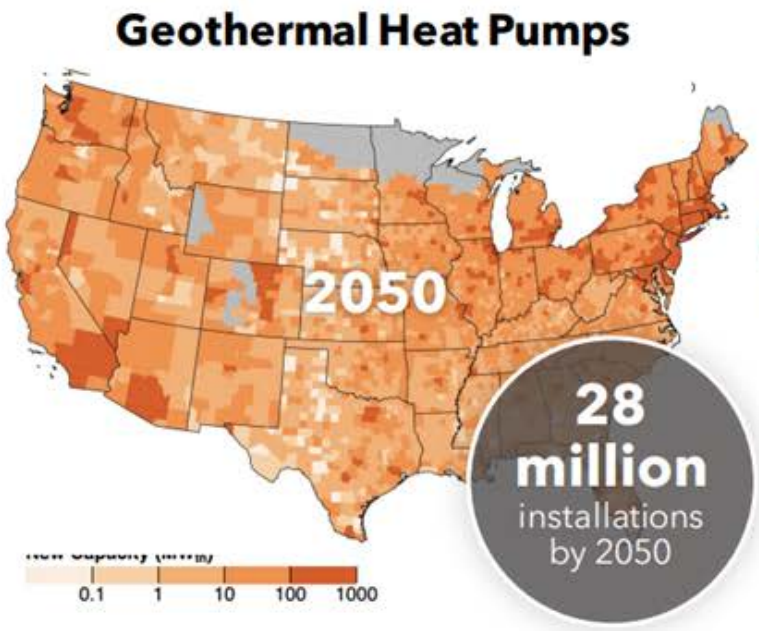
8.5% of all U.S. generation by 2050

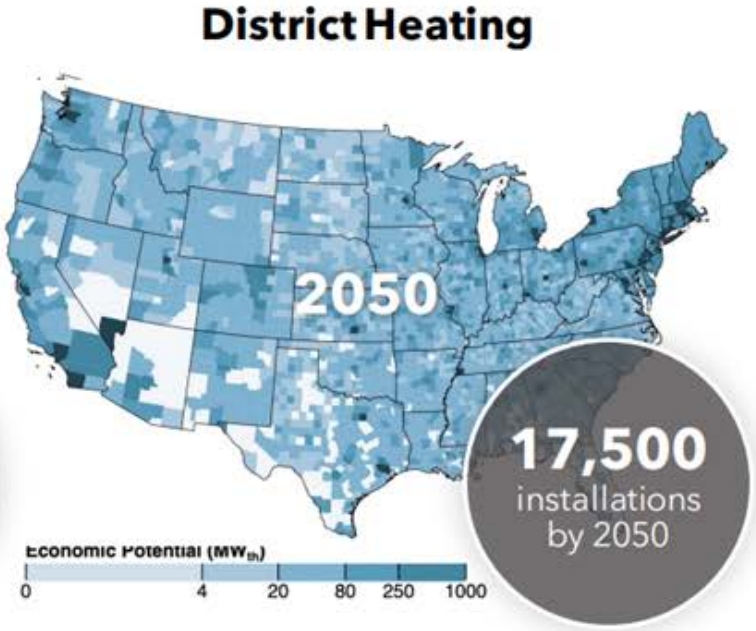


Source: Augustine et al. 2019

HEATING & COOLING

23% of U.S. Heating and Cooling market by 2050





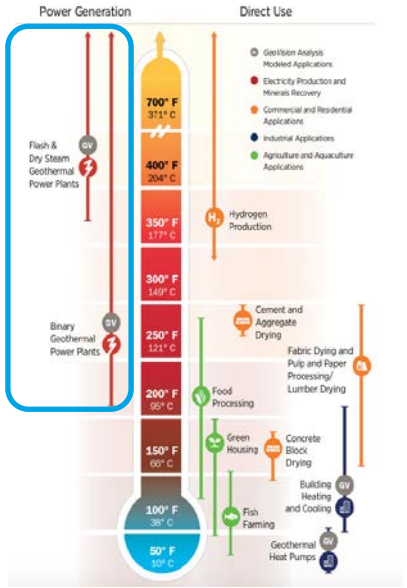
up to **516 MMT** of avoided CO2e

up to **1,281 MMT** of avoided CO2e

Total Emissions Reductions = removal of **26 million** cars per year

Source: Geovision (2019)

Geothermal Power Technologies: Conventional



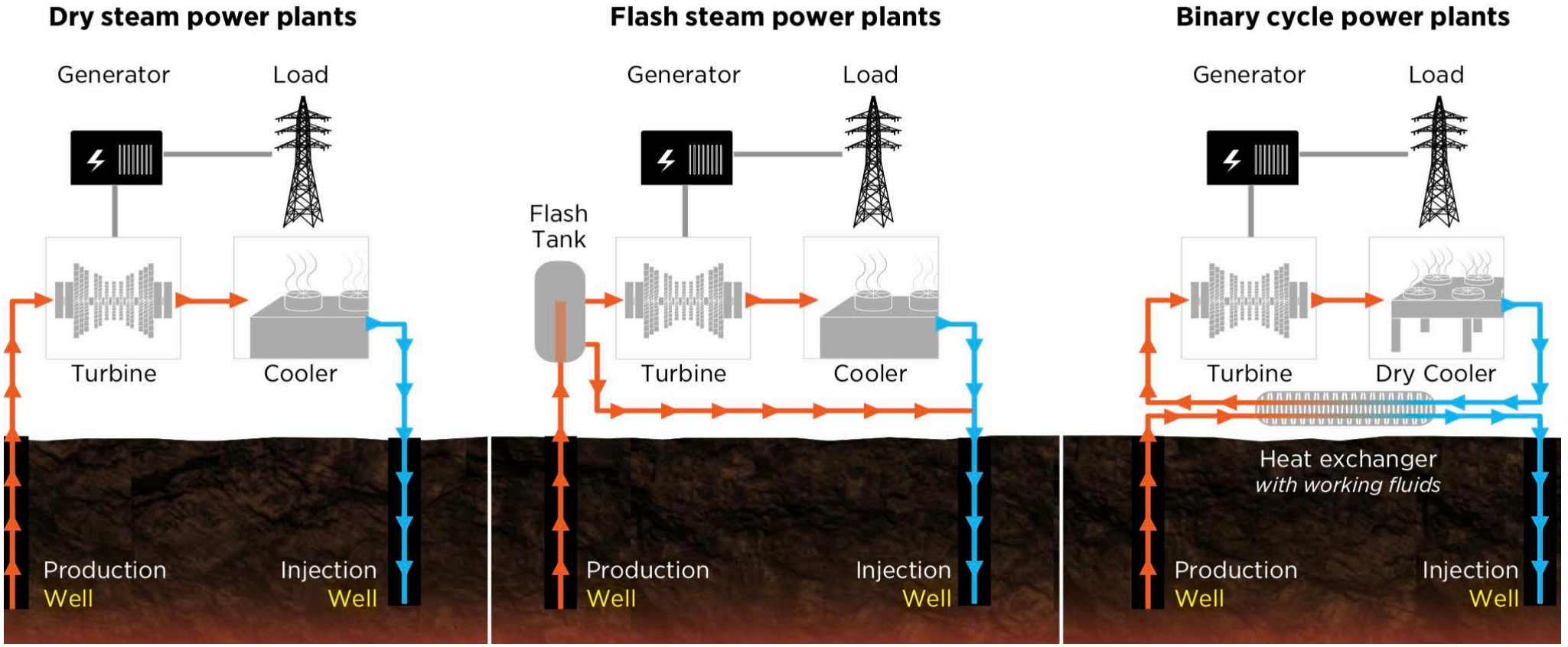


Image source: GeoVision (2019)

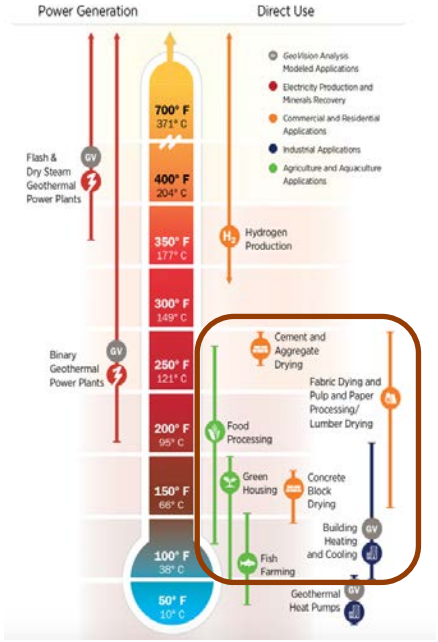
Three types of geothermal power plants:

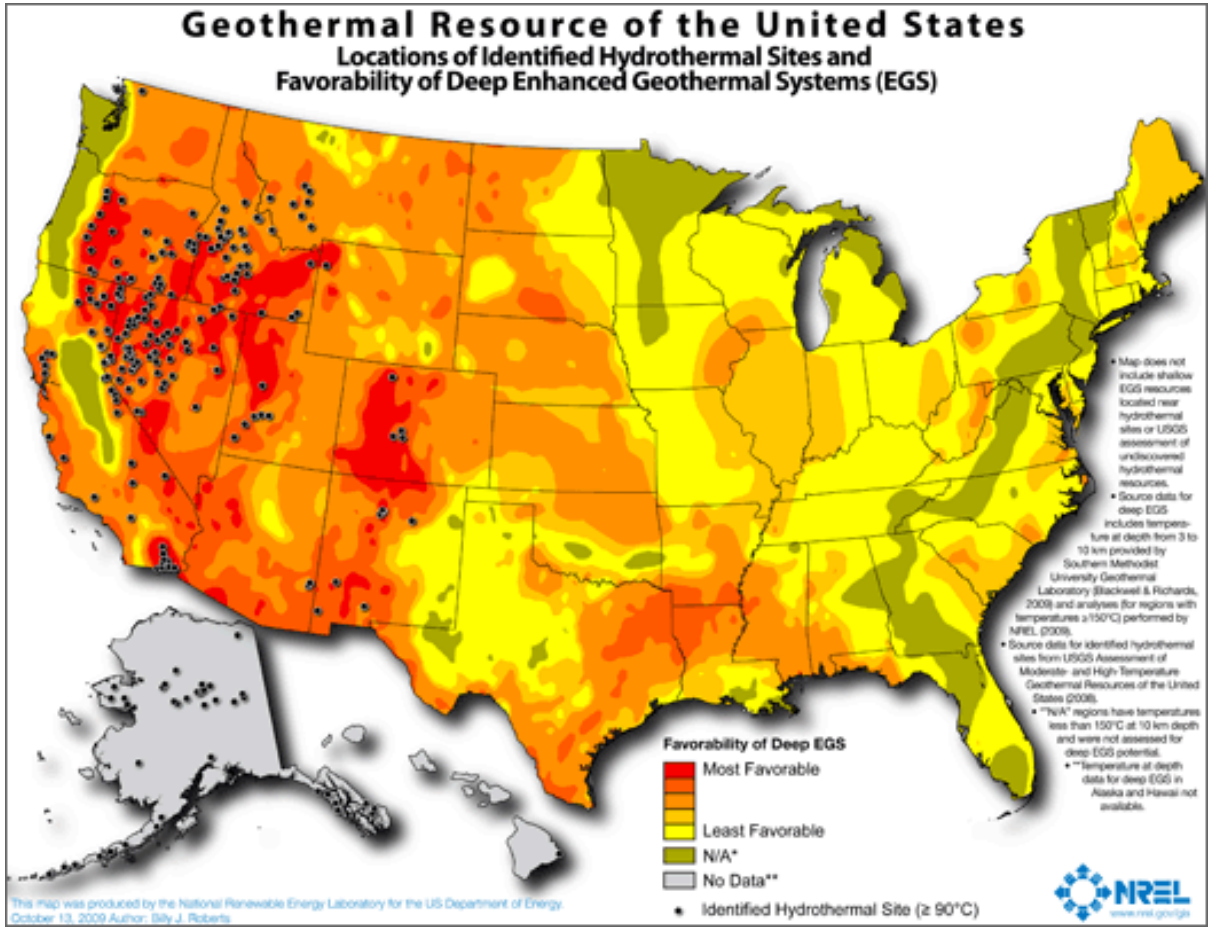
- **Dry steam plants** draw steam from underground reservoirs directly into a turbine/generator unit.
- **Flash steam plants** utilize steam "flashed" from high temperature fluids pumped to the surface under pressure.
- **Binary cycle plants** utilize a secondary fluid, heated by lower temperature fluids via a heat exchanger.

Geothermal Low Temperature Technologies

Direct-use Geothermal

- Directly using hot water from geothermal resources in the earth
- Most favorable where high temperature resources can be found near the earth's surface.





https://www.wbdg.org/images/geothermal_energy_03.gif

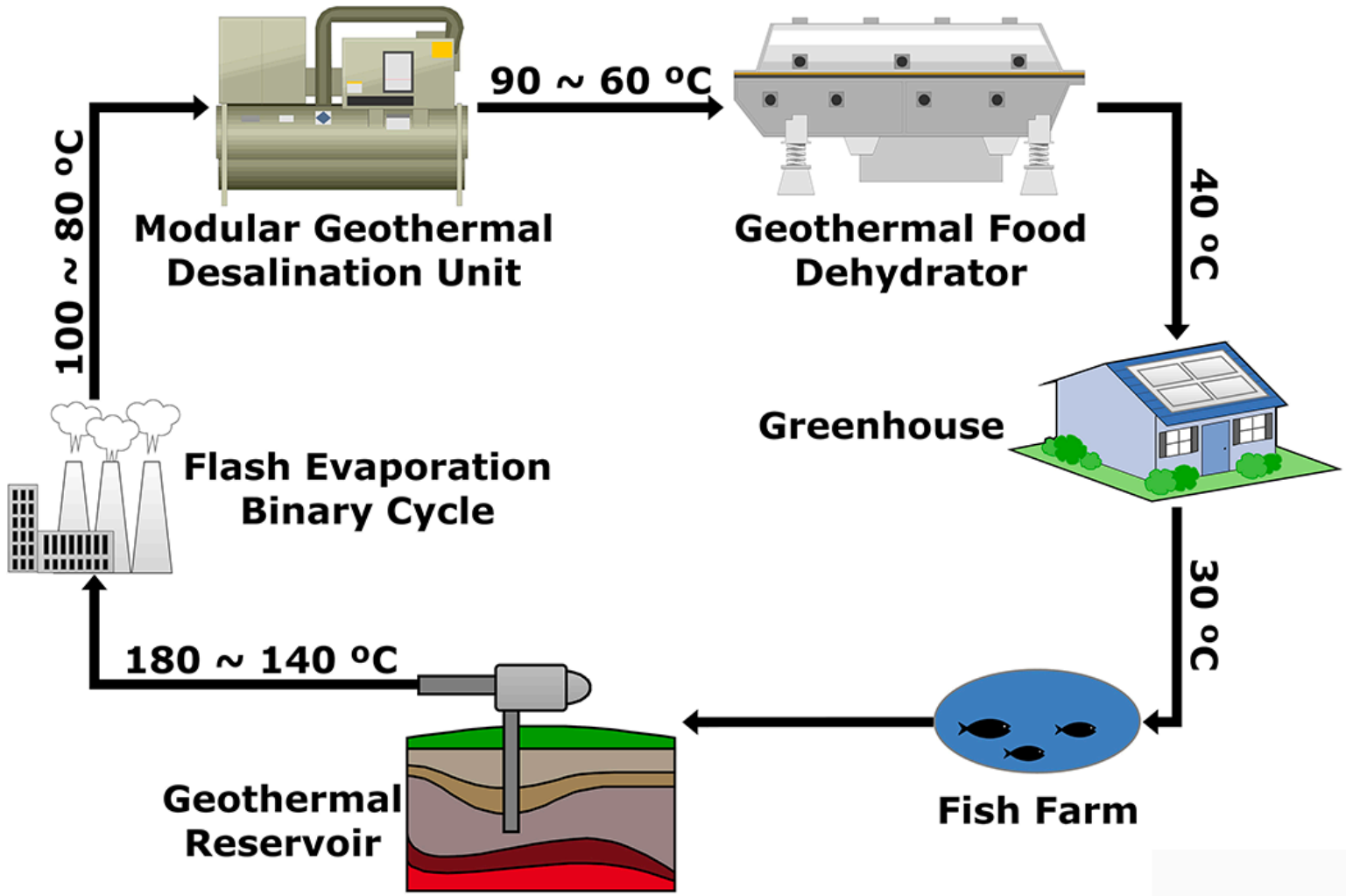
Direct Uses of Geothermal

Direct use includes a wide range of heating, agricultural, and industrial applications.

World leaders in direct use

MWt	MWt/population
China	Iceland
Turkey	Sweden
Japan	Finland
Iceland	Switzerland
Hungary	Norway

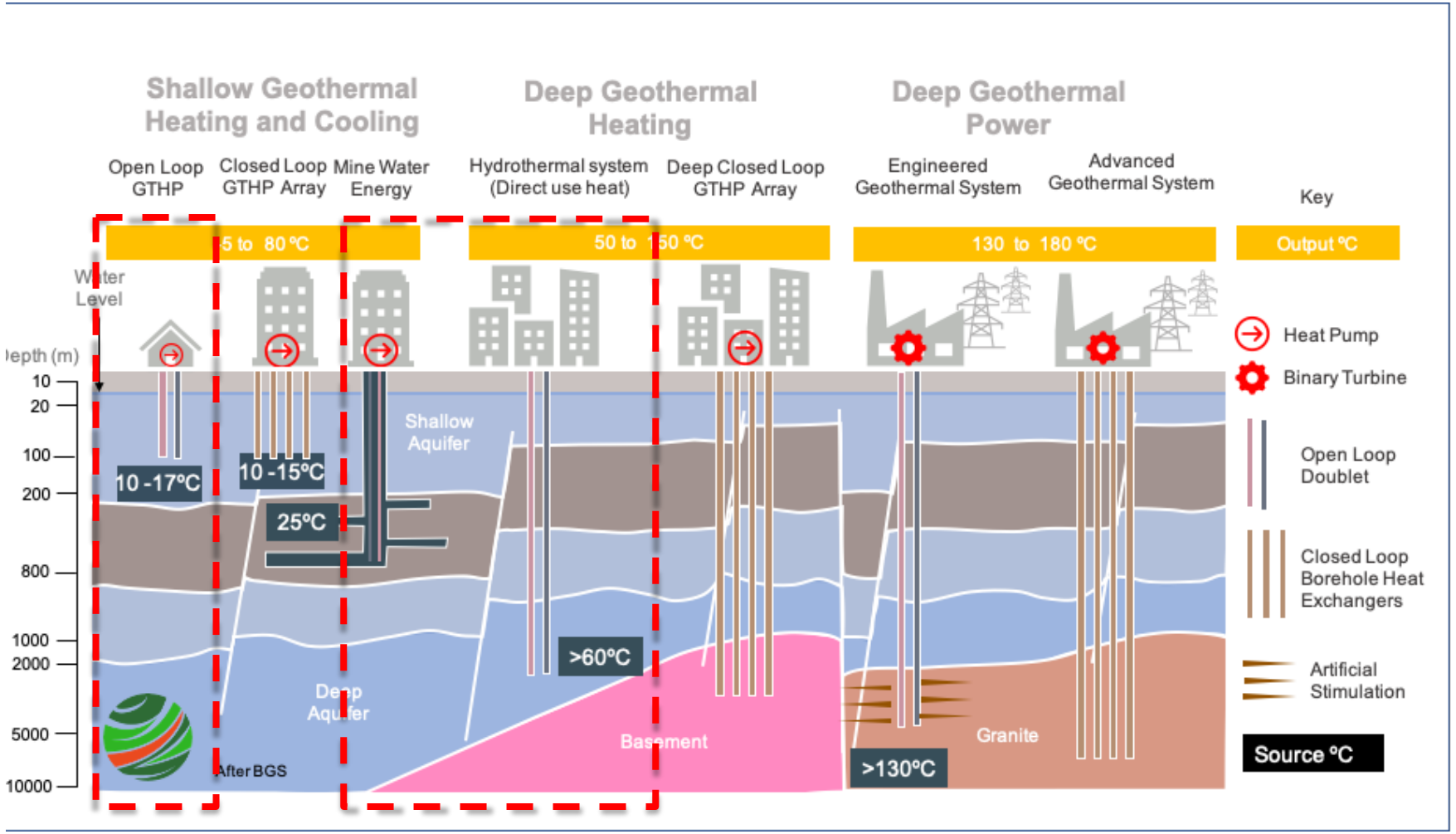
This diagram shows an example of cascaded uses of geothermal.



Source: Avina Jimenez, Torreblanca, and Gutierrez (2016)

Direct uses

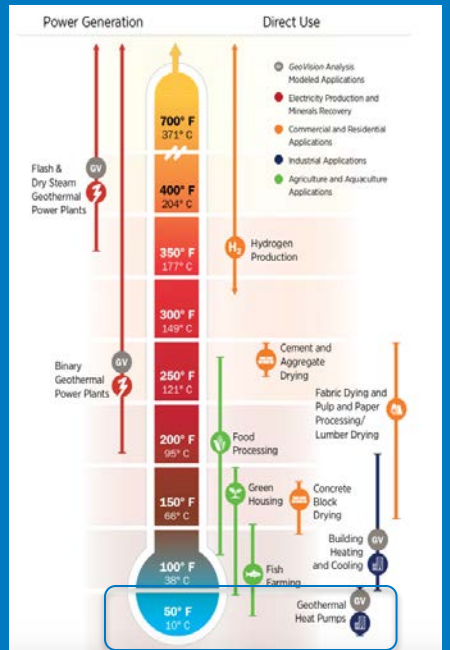
- Can use wide range of subsurface temperatures
- Can be used efficiently in all climate zones

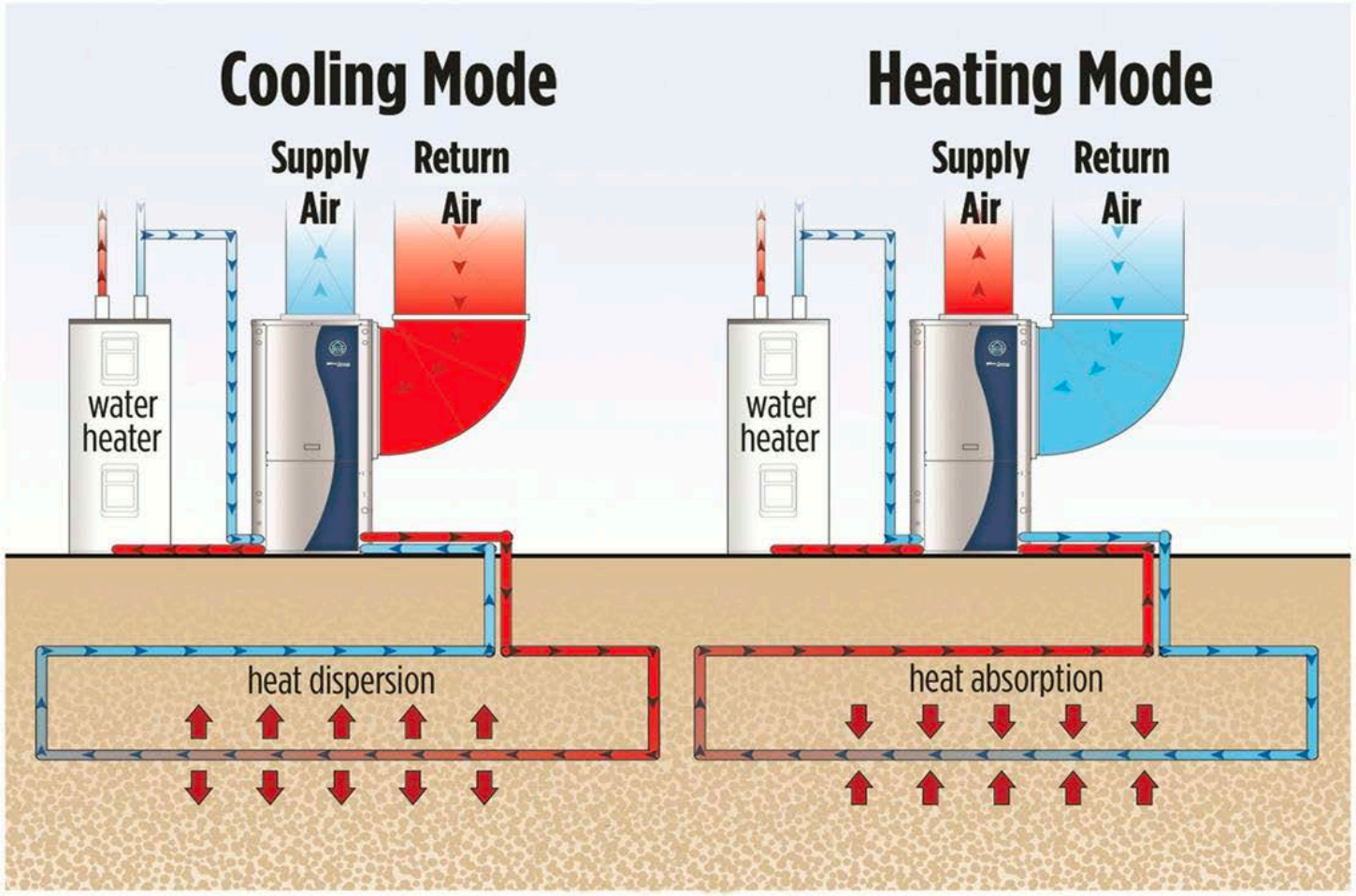


https://causewaygt.com/2023/02/geothermal-system-archetypes-classification-applications-and-technology-development-opportunities/

Geothermal Heat Pumps or Geo-Exchange Technology

- Provides cooling and heating by rejecting or extracting heat from the ground.
- High efficiency due to constant moderate earth temperature.



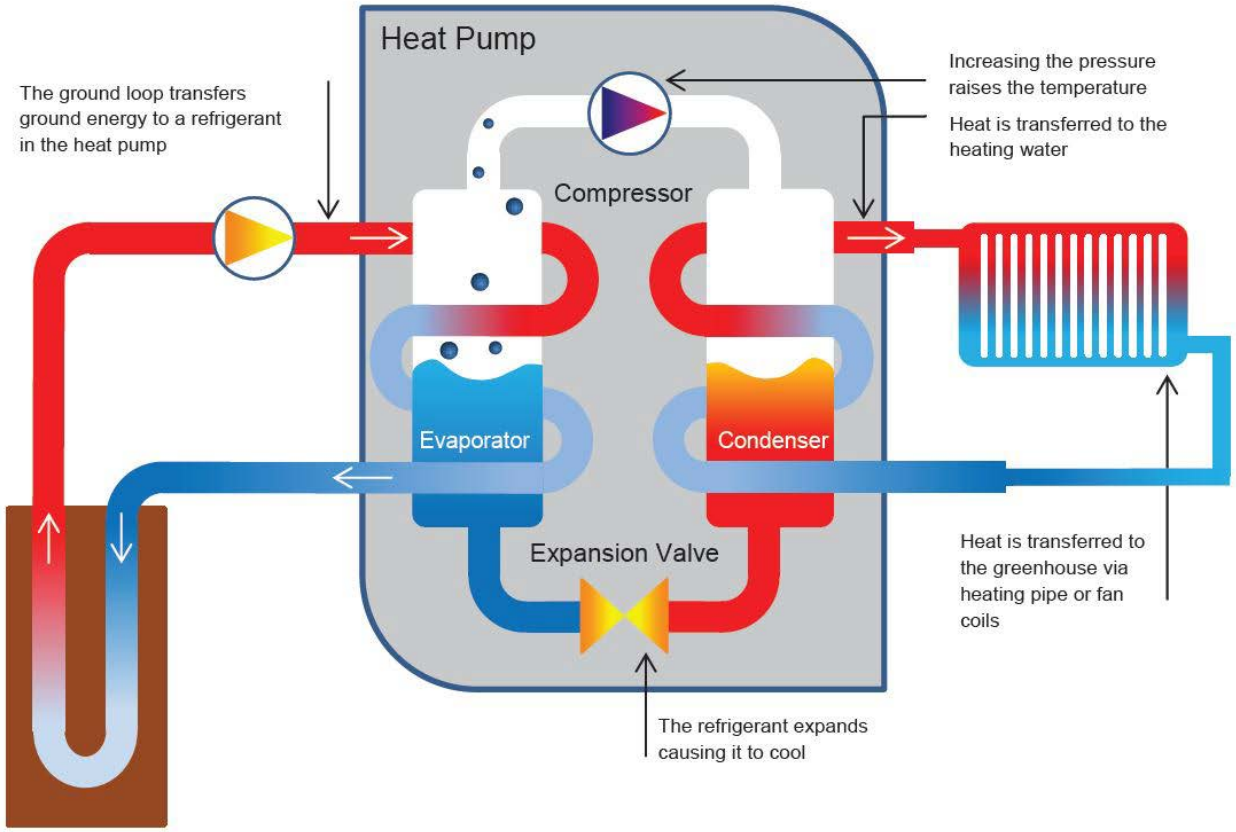


https://www.geoexchange.org/geothermal-101/

NREL Transforming ENERGY

Heat Pump

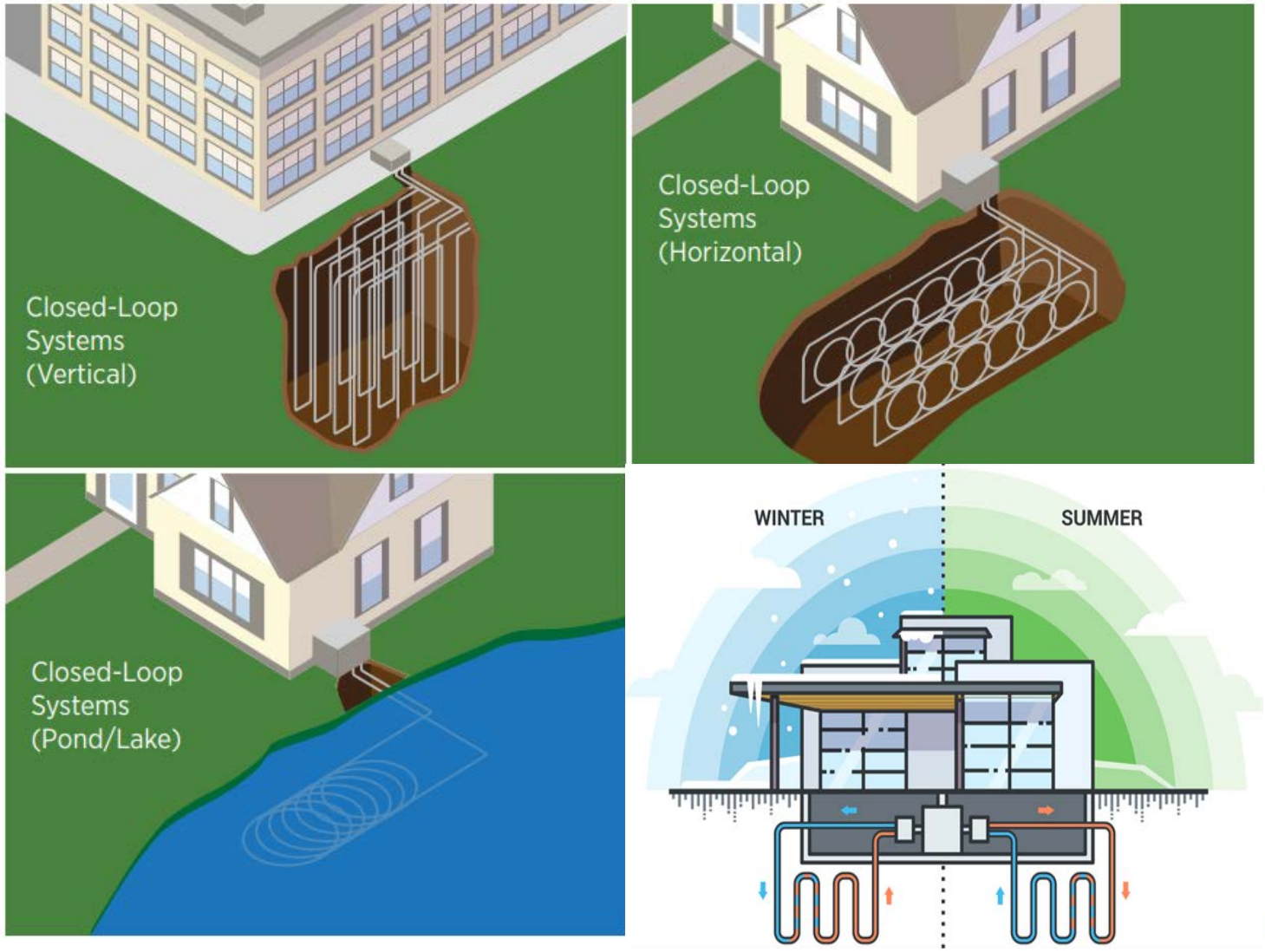
- Functions like conventional air conditioner or refrigerator, taking advantage of ideal gas law (PV = mRT)
- Compressor compresses refrigerant, which increases its temperature.
- Condenser cools refrigerant.
- Expansion valve reduces pressure, which cools refrigerant.
- Evaporator absorbs energy.
- Cycle repeats continuously.



https://horticulture.ahdb.org.uk/knowledge-library/how-heat-pump-works

Geothermal Heat Pumps or Geo-Exchange Technology

- Uses energy from the ground
- Constant temperature of the shallow earth (40°-70°F/4.5°-21°C) to efficiently exchange temperatures, heating homes in the winter and cooling homes in the summer.



Source: Geovision (2019)

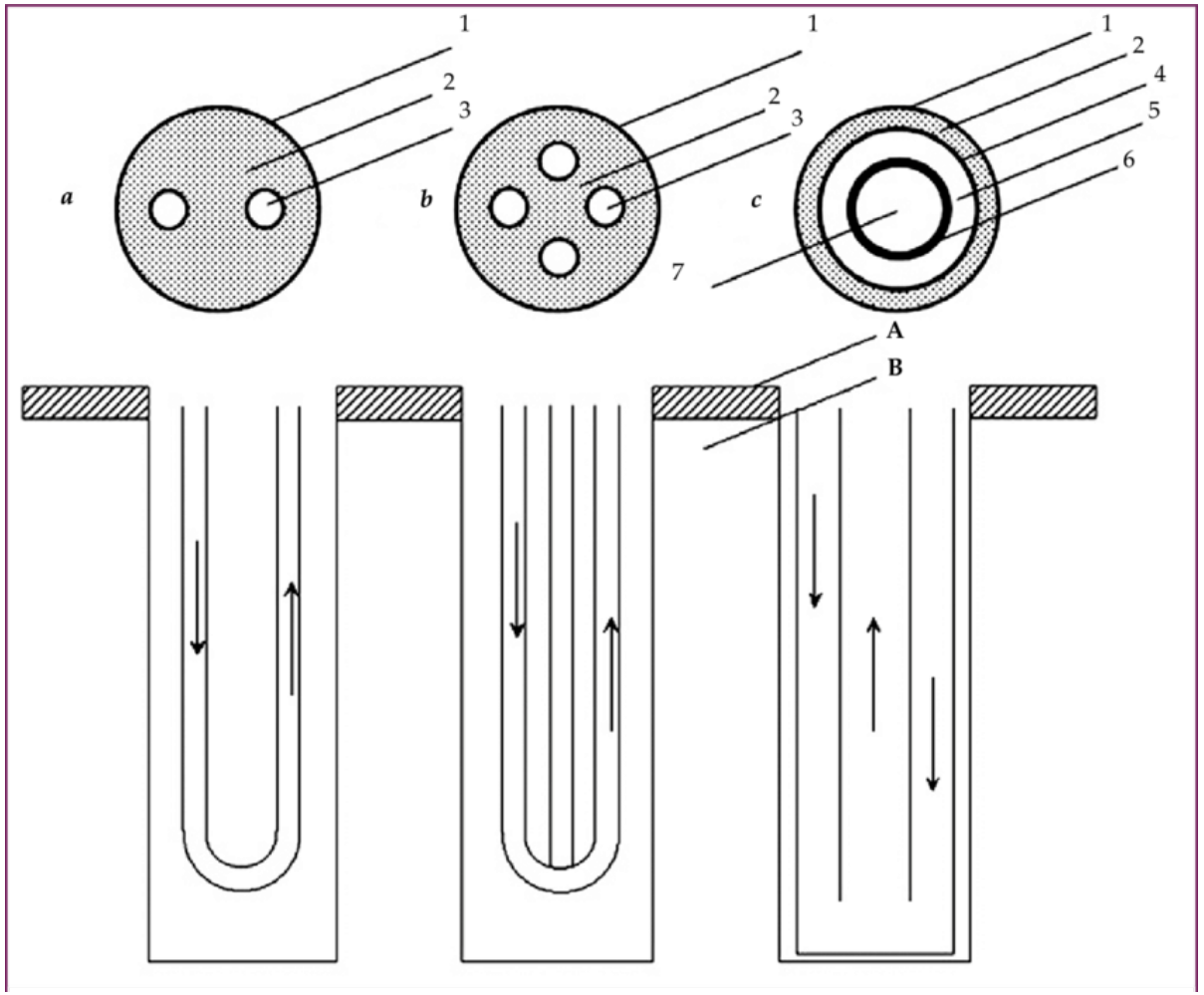
Vertical Borehole Heat Exchanger

- Vertical borehole heat exchangers are the most common form used.
- Typically installed at depths of 300-500 ft but could go deeper.
- Drilled with mobile drill rigs, like water well drilling equipment.
- Borehole diameter 4-6 inches.
- Different type of drilling technologies available, depending on the subsurface type.

https://www.geothermalindustries.com.au/

Vertical Borehole Heat Exchanger

- Single u-tube
  - Uses a single u-tube (pipe connected with u-bend at bottom.
  - Closed-loop, i.e., no fluid exchange with environment.
  - Area between u-pipe and borehole wall grouted to prevent ground water contamination.
- Double u-tube
  - Two u-pipes, can be connected in series or parallel.
  - Decreases the resistance to heat transfer with soil.
- Coaxial
  - Fluid pumped through center pipe and annular region.
  - Can require casing to full depth.



Sliwa, Tomasz & Nowosiad, T. & Vytyaz, Oleg & Sapińska-Śliwa, Aneta. (2016). Study on the efficiency of deep borehole heat exchangers. SOCAR Proceedings. 29-42. 10.5510/OGP20160200276.

Vertical Borehole Heat Exchanger

- Borehole
  - 4-6-inch diameter typical.
  - Typically uncased, except as needed to maintain borehole integrity during drilling.
- Pipe
  - High density polyethylene pipe (HDPE)
  - DR-11 pressure rating (**D**iameter-to-thickness **R**atio)
- Grout
  - Bentonite-sand mixture
  - Prevent water infiltration, enhance thermal conductivity.
- Fluid
  - Water bio inhibitors can be used in cooling-only applications.
  - Antifreeze mixtures used in heating applications.

https://hydrogeo.co.uk/hydrogeology-groundwater/ground-source-heat/

Horizontal Heat Exchanger

- Installed in top 3-10 ft of soil.
- Higher surface area.
- Lower cost to install.
- Performance is lower than vertical systems because soil temperatures are closer to ambient air temperatures during the year.

Hikari FUJII, Shohei YAMASAKI and Takahiro MAEHARA. (2013). "NUMERICAL MODELING OF SLINKY-COIL HORIZONTAL GROUND HEAT EXCHANGERS CONSIDERING SNOW COVERAGE EFFECTS". PROCEEDINGS, Thirty-Eighth Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, February 11-13, 2013 SGP-TR-198

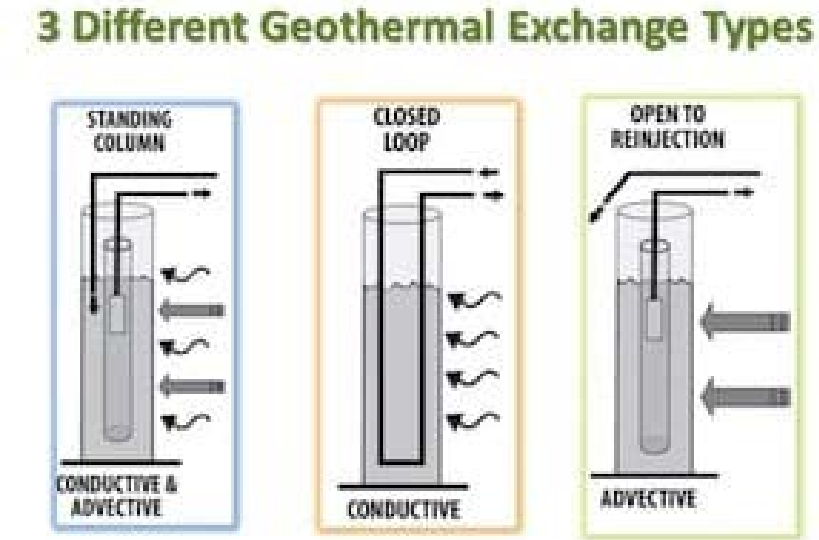
Surface Water Heat Exchange

- Surface water heat exchangers can be used effectively when surface water is available.
- River, lake, ocean, pond, etc. are all viable.
- If designed appropriately, can be removed and serviced.
- Need freeze protection - ice build-up during heating can float the HX.

https://www.sciencedirect.com/science/article/pii/B978008100311400008X#f0035

Aquafer Heat Exchange

- Sometimes referred to as “standing column wells.”
- Can be successful when subsurface is permeable.
- May pump groundwater between multiple wells depending on mode of operation (heating/cooling).
- Some amount of “bleed” may be required to maintain temperature.
- Local environmental regulations can be sensitive to systems.

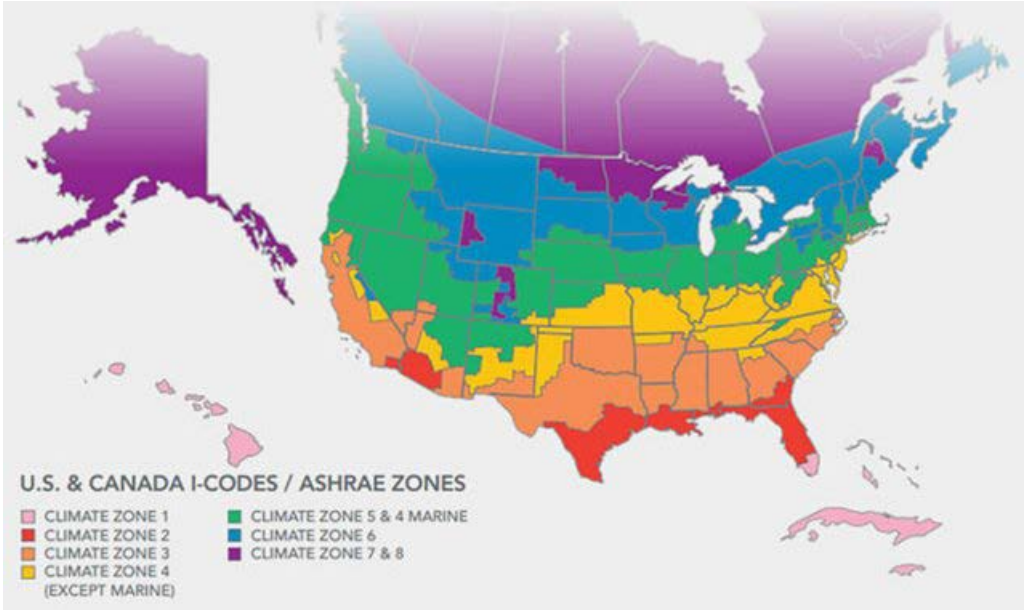


https://plumbingperspective.com/what-is-a-standing-column-well-geothermal-hvac-system

Benefits & Considerations

- Efficiency
- Low maintenance
- Heating savings
- AC savings
- Anywhere (*variation of efficiency and savings)
- Decarbonization

- Space considerations
- Climate Zone
- Soil Properties



https://www.greenbuildingadvisor.com/article/climate-zone-map-including-canada

Geothermal Applications Examples

Coveyou Farm in Northern Michigan

- GHP heated greenhouse and cooled fridge
- Below the parking lot sit five trenches, each 200 feet long, containing a series of plastic tubes that circulate fluid.
- Fluid enters the tubes at a temperature of ~50°F , and then the pump continuously transfer heat from the fluid into the tank until reaches about 90 °F.
- The greenhouse concrete floor has four in-floor heat zones that contain another series of plastic tubes. When a floor zone becomes too cold, the ~90 °F fluid is circulated through the corresponding tubes.

- Efficient and cost-effective system
  - The entire farm's produce cooling system costs just a fraction of a conventional system (about $100 per month in summer, versus THOUSANDS with conventional methods).

Geothermal Greenhouse Heating

Geothermal heating and cooling are used extensively throughout our farm operation. Our five thousand square-foot seed propagation greenhouse is heated geothermally. The heated concrete floor helps us germinate hundreds of thousands of plants each year. The best part? Geothermal heating is 100% renewable and extremely efficient, transferring five times more heat energy than it uses to run!

Geothermal for Cooling, too!

Our geothermal system also powers the refrigeration for our large walk-in produce storage coolers located underneath the Barn Market, as well as our display coolers you can see on the market floor. We move thousands of pounds of produce through our walk-ins each season, removing field heat and safely storing it until we need to use it again in the spring!

We also use a chilled tank of potable water to instantly cool brocooli, kale, salad greens, and other crops coming in from harvest. This "flash chilling" process enhances the quality and freshness, literally locking in the farm-fresh taste just minutes after being harvested. And yes, that too, is chilled geothermally!

https://coveyouscenicfarm.com/green-energy/

Greenhouse Nebraska

- Keep the greenhouse above 28°F in winter
- Only resource ground heat 53°F at 8 ft deep
- Figs and citrus crops
- Indirect benefits to decarbonization – transportation

Nebraska Geothermal Oranges

19 December 2019

While those three words seem unrelated it's a real thing. A fellow in Alliance Nebraska is using geothermal energy to power a greenhouse in which he grows lots of food including oranges, lemons, and grapefruit! You can check it out with this link.

https://www.youtube.com/watch?v=4O3ifR-3zvs

I was really psyched to see this video, the possibilities are amazing. We could grow so much food this way with inexpensive power, on inexpensive/cold land, that has previously been barren. Every community could grow their own oranges and save on the shipping costs.

Another way we could use geothermal power is with the Groundhog Geothermal Heat Pump. Imagine using the heat that exists in the ground to not only warm you house in the winter, you can also use it to cool your house in summer. If you'd like to learn more about that you can check it out with this link. https://www.atlas4ac.com/air-source-ground-source-geothermal-heat-pump.html. If you have any questions about the Groundhog Geothermal Heat Pump, give us a call at 703-335-1730

https://www.atlas4ac.com/heating-and-ac-blog/32-nebraska-geothermal-oranges.html

Camp Southern Ground Georgia

- Camp Southern Ground is an intentionally designed facility that utilizes form and function to mesh state of the art technology, award winning architecture, and sustainability
- Dedicated Outdoor Air Systems
  - Geothermal ground loop system that uses ground water from strategically placed wells to help condition the air before it enters the building.

https://campsoutherngground.org/sustainability/

Geothermal Projects Development and Costs

Costs, Lifetimes, Maintenance

- Costs
  - Ground heat exchanger(s) are biggest part of cost.
  - Ground-source heat pumps are more expensive than air-source heat pumps.
  - Circulation pumps add some cost to installation and operation costs.
- Lifetimes
  - GSHP have lifetimes of 20-25 years. ASHP have lifetimes of 10-15 years.
  - GHE have lifetimes > 50 years.
- Maintenance
  - GSHP systems need minimal maintenance.
  - Clean air filters.
  - If designed and installed properly, ground loop requires no maintenance.

Resources

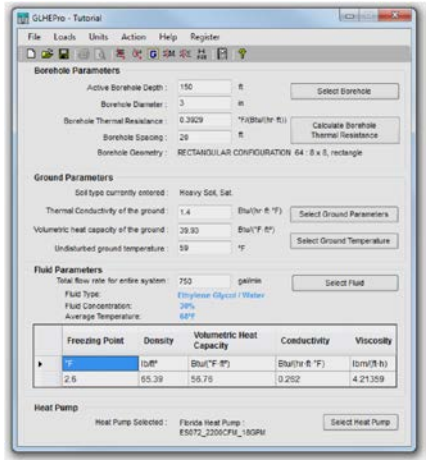
Software

- GHEDesigner (open-source)

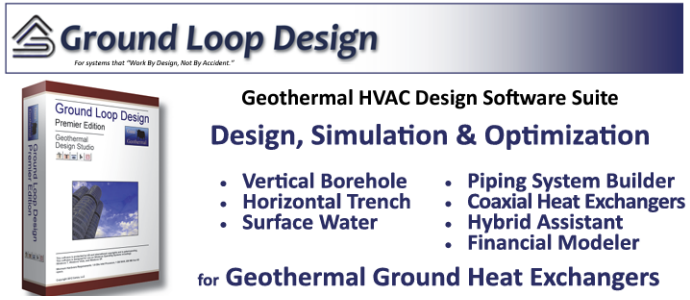
GHEDesigner - A Flexible and Automatic Ground Heat Exchanger Design Tool

pypi v1.5 | PyPI Downloads 316/month | python 3.8 | 3.9 | 3.10 | 3.11 | Flake8 passing | Python Testing passing

- GLHE Pro (commercial license)



- GLD Software (commercial license)



Standards

- IGSHPA – International Ground Source Heat Pump Association (https://igshpa.org/)
  - Certified GSHP contractors, designers.
  - Installation, testing standards.
- IAPMO – International Association of Plumbing and Mechanical Officials (https://www.iapmo.org/)
  - Design standards.

Other Resources

- GEO – The Geothermal Exchange Organization (https://www.geoexchange.org/geo/)
  - Promotes manufacture, design, and installation of GSHP
- ASHRAE – The American Society of Heating, Refrigerating, and Air-conditioning Engineers (https://ashrae.org/)
  - Techincal committee focused on GSHP to promote research and advancement of the technology.
  - Publishes HVAC design handbooks, with chapter focused on GSHP.

How to Prepare Geothermal Applications for REAP

Hyunjun Oh, PhD

Thermal Energy Science and Technologies Group

National Renewable Energy Laboratory

Overview

- Qualifications of the Project Team
- Agreements and Permits
- Resource Assessment
- Design and Engineering
- Project Development
- Equipment Procurement and Installation
- Project Economic Assessment
- Operations and Maintenance

Qualifications of the Project Team

- Describe the project team, their professional credentials, and relevant experience.

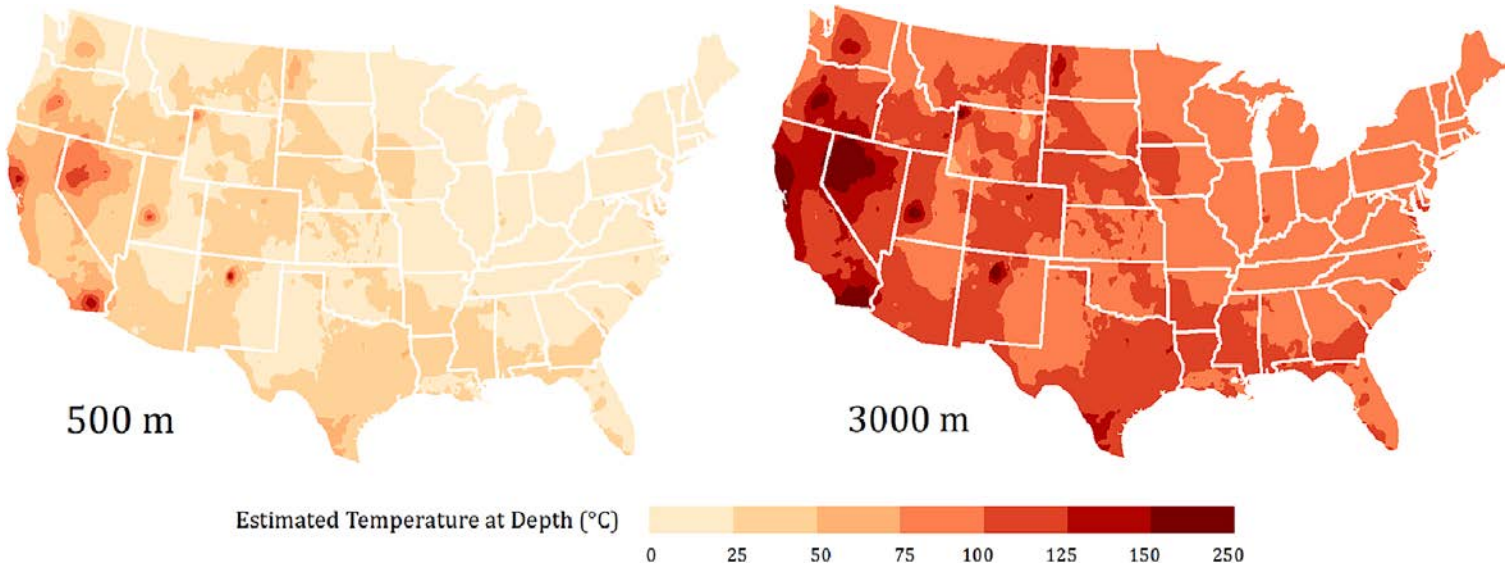
- The description shall support that key service providers in the project team have the necessary professional credentials, licenses, certifications, and relevant experience to develop the proposed project.

Agreements and Permits

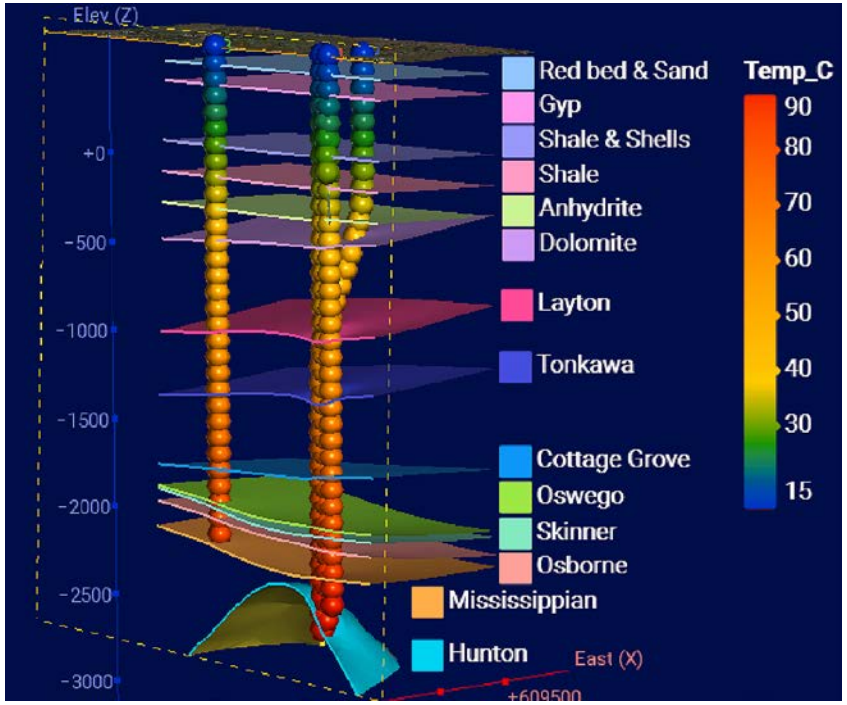
- Any necessary local agreements and permits
- Interconnection and power purchase agreements

Resource Assessment

- Describe the quality and availability of geothermal resources and the amount of energy generated through the deployment of the proposed system.



The U.S. geothermal resource potential in shallow and deep subsurface (Oh et al. 2024)

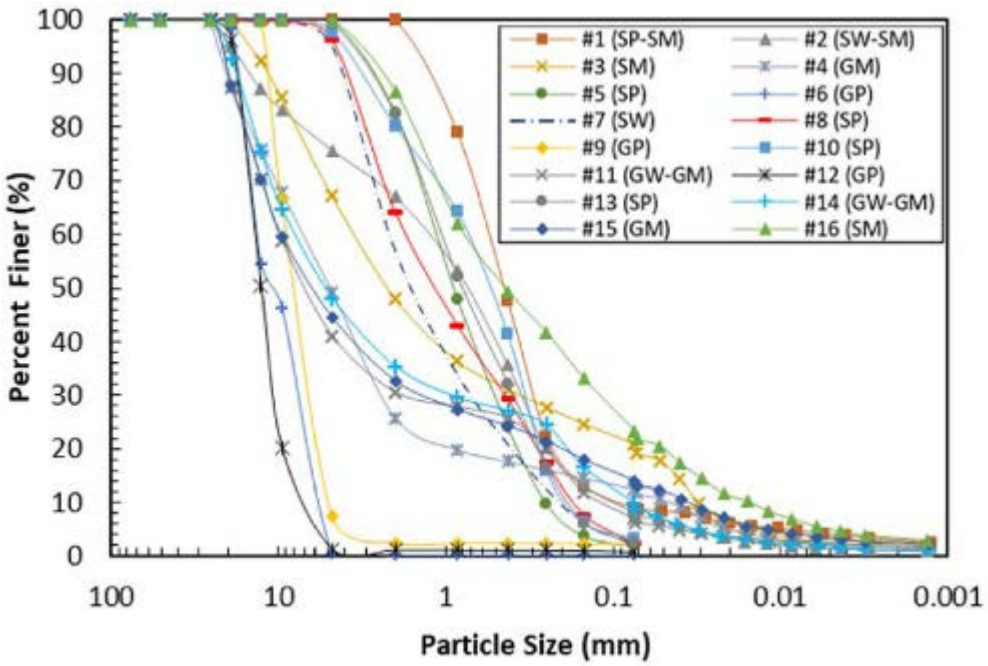


Deposit contact surface with wellbore temperature distribution(Oh et al. 2024)

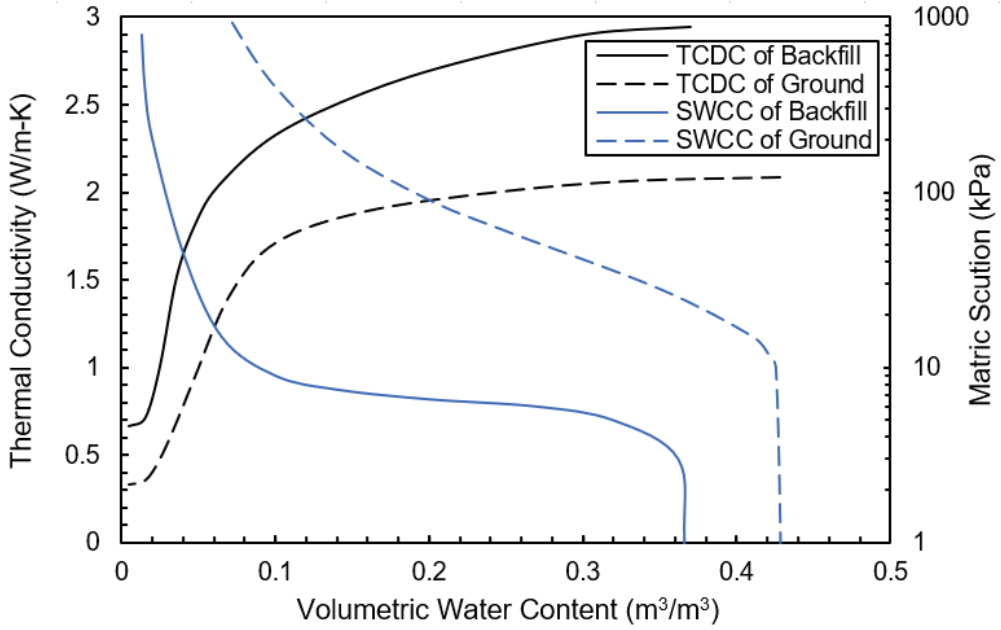
Design and Engineering

- Describe objectives of the project.
- Describe the design, engineering, testing, and monitoring details with supporting materials.
- Identify all major equipment is commercially available, including proprietary equipment, and justify how this unique equipment is needed to meet the requirements of the proposed design.

Example Supporting Materials



Particle size distribution curves for soil classifications (Oh et al. 2022)



Thermal conductivity dry-out and water retention curves (Oh and Tinjum 2020)

Project Development Schedule

- Describe the overall project development method, including the key project development activities and the proposed schedule for each activity.
- The description shall address cash flow for the project development.
- Details for equipment procurement and installation shall be addressed.

Equipment Procurement and Installation

- Describe the availability of the equipment required by the system.
- Describe the plan for site development and system installation, including any special equipment requirements.
- In all cases, the system or improvement shall be installed in conformance with manufacturer's specifications and design requirements, and comply with applicable laws, regulations, agreements, permits, codes, and standards.

Operations and Maintenance

- Describe financial performance of the proposed project, including simple payback estimation.

- The description addresses the project costs and revenues, such as applicable investment and production incentive and other information to allow the assessment of the project’s cost effectiveness.

Q&A