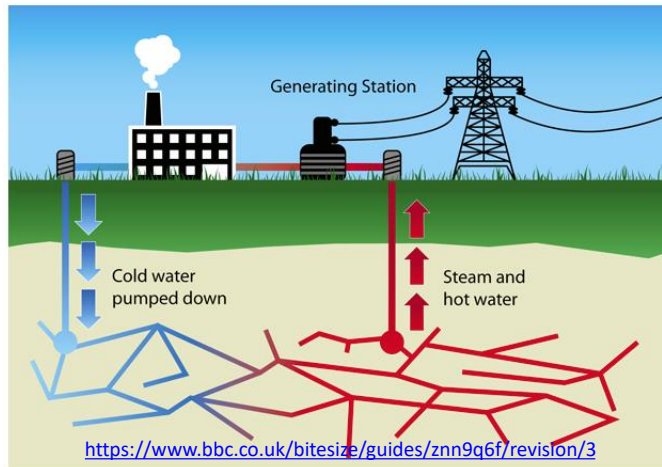


Renewable Energy Systems (12210588)

15. Thermal Energy: 1. Geothermal Energy



Fathi Anayah, PhD

Lecture 15

What is geothermal energy? I

- The word **geothermal** comes from the Greek words **geo** (Earth) and **therme** (heat). **Geothermal** energy is **heat** from within the **Earth**.
- **Geothermal** energy is generated in the **Earth's core**, almost **4,000** miles beneath the Earth's surface.
- Very high **temperatures** are continuously produced inside the Earth by the **slow decay of radioactive particles**. This process is **natural** in all rocks.
- **Geothermal** energy is called a **renewable** energy source because the **water** is replenished by **rainfall** and the **heat** is continuously **produced** deep within the Earth. We will not run out of geothermal energy.

<http://lsa.colorado.edu/essence/texts/geothermal.html>

2

What is Geothermal energy? II

Heat near surface of the earth =
geysers, volcanoes, hot springs



Source: Renewable Energy Sources PPT by Dragica Vasileska



Old Faithful
Geyser, Yellow
Stone National
Park

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Characteristics of geothermal resources?

- Some **visible features** of geothermal energy are **volcanoes, hot springs, geysers,** and **fumaroles**.
- But you **cannot see** most geothermal resources. They are **deep underground**. There may be no clues above ground that a geothermal reservoir is present below.
- **Geologists** use different methods to find geothermal **reservoirs**. The only way to be sure there is a reservoir is to **drill a well** and **test the temperature** deep underground.
- The **most active** geothermal resources are usually found along major plate boundaries where **earthquakes** and **volcanoes** are concentrated.
- Most of the geothermal activity in the world occurs in an area called **the Ring of Fire**. This area borders the **Pacific Ocean**.



Where to find geothermal energy?

In rocks under the ground, **radioactive decay** of elements, such as **uranium**, releases heat energy that warms up the rocks.

In some areas, **hot water** and **steam rise** to the **surface**.



<http://bioblocks.weebly.com/uploads/8/7/9/6/8796967/8796967/renewable-energy.pdf>
© David Parsons/NREL

Isotope	Half-life (x 10 ⁹ y)	Heat generation (mWkg ⁻¹)
K ⁴⁰	1.3	2.8 x 10 ⁻²
Th ²³²	13.9	2.6 x 10 ⁻²
U ²³⁵	0.7	56.0 x 10 ⁻²
U ²³⁸	4.5	9.6 x 10 ⁻¹

The **steam** and **hot water** which rises naturally to the surface can be **harnessed** to generate **electricity**.

In fact, the **largest** single geothermal power plant is a flash-steam facility in Malitbog, **Philippines**. One of the **largest** geothermal power plant is in **California**.

<https://www.nationalgeographic.org/encyclopedia/geothermal-energy/>

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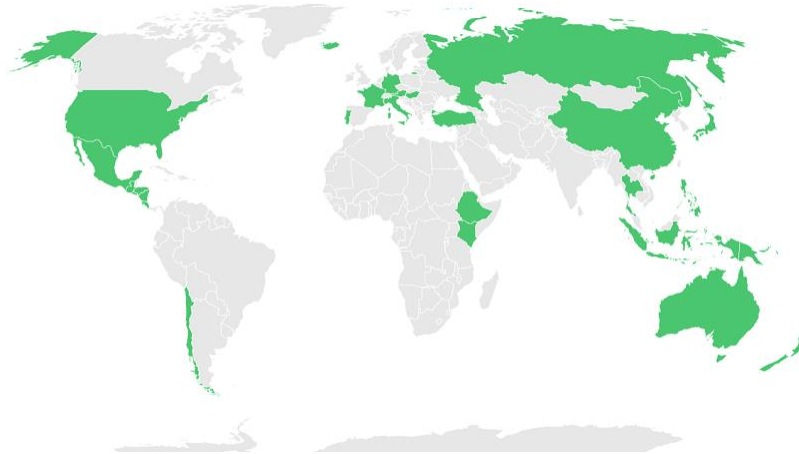
Worldwide electricity generation

- A group of Italians first used it in **1904**. The Italians used the natural steam erupting from the Earth to power a turbine generator.
- The first successful American geothermal plant began operating in **1960** at the Geysers in northern California.
- Geothermal power plants are producing over **8,200 megawatts** of electricity.
- Supplying about **60** million people in **21** countries, mostly in developing countries.
- Since **2015** the three countries with the **greatest** capacity for geothermal energy use have included the **United States**, **Indonesia**, and the **Philippines**.
- **Turkey** and **Kenya** have been steadily building geothermal energy capacity as well.

<https://www.nationalgeographic.org/encyclopedia/geothermal-energy/>

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All countries currently generating electricity from geothermal energy are in green

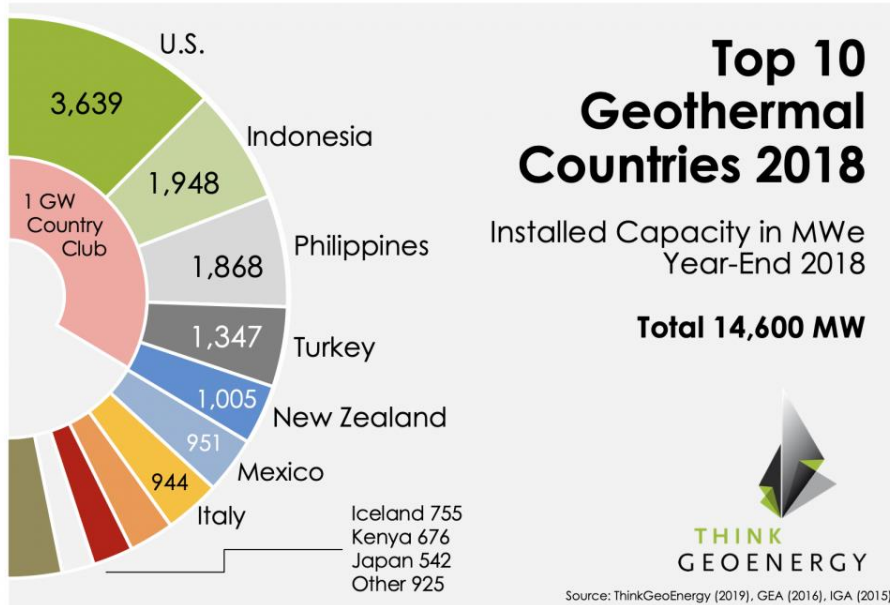


World wide distribution of volcanoes, hot springs, etc.

Japan, Iceland, New Zealand are big users of geothermal.

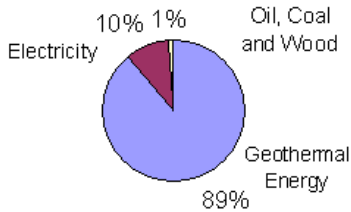
https://energyeducation.ca/encyclopedia/Geothermal_electricity

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<https://www.thinkgeoenergy.com/the-top-10-geothermal-countries-2018-based-on-installed-generation-capacity-mwe/>

How do People in Iceland Heat Their Homes?



<https://sites.suffolk.edu/magisparker2/iceland/geothermal-use-for-energy-heat-electricity/>

The **Swartsengi** geothermal power plant by the **Blue Lagoon** in Iceland.



<https://archive.12/mag/articles/2019/03/06/hotwater-geothermal/>

Iceland as a model

Reykjavik has the world's **largest** and most sophisticated geothermal **district heating system**, which has used natural **hot water** to heat its **buildings** and **homes** since **1930**.

https://www.c40.org/case_studies/the-worlds-largest-geothermal-heating-system-saves-up-to-4m-tons-co2-annually



Photograph: Paul A. Souders/Corbis

Benefits of geothermal power

- Provides **clean** and **safe** energy using **little land**
- Causes **no disturbance** to the surrounding **environment**
- Is **renewable** and **sustainable**
- Generates **continuous, reliable** “baseload” **power**
- Conserves **fossil fuels** and contributes to **diversity** in energy sources
- Avoids **importing** and benefits local **economies**
- Offers modular, incremental **development** and village power to **remote** sites

https://docs.google.com/presentation/d/12N_AQBScQKrFcPn0KgwTdAo05f0ShqyfHkuKH8XjZ74/htmlpresent

<https://www.twi-global.com/technical-knowledge/faqs/geothermal-energy/pros-and-cons> ¹⁰

Disadvantages of geothermal power

- Not **widespread** source of energy
- High **installation costs**
- Can run **out of steam**
- Suited to **particular region**
- May release **harmful gases**
- **Transportation**
- Does **little damage** to the **environment**

<https://www.twi-global.com/technical-knowledge/faqs/geothermal-energy/pros-and-cons>



<https://nea.is/geothermal/>

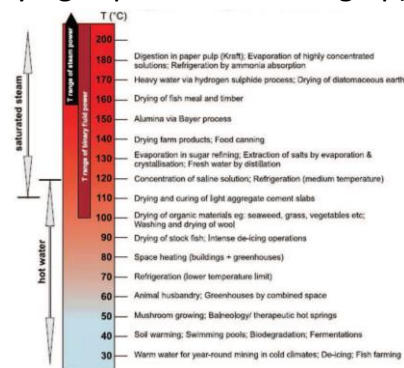
<https://sites.suffolk.edu/maggieparker2/icelandis-geothermal-use-for-energy-heat-electricity/>

Uses of geothermal power

- **Balneology** (hot spring, spa bathing, and swimming)
- **Agriculture** (greenhouse and soil warming)
- **Aquaculture** (fish, shrimp and alligator farming)
- **Industrial** uses (food and grain drying & product warming up)
- **Electricity** generation
- Residential and district **heating** system (space and water)
- **Geothermal** (ground-source) **heat pumps** (GHP), used for both **heating** and **cooling**

https://docs.google.com/presentation/d/12N_AQBScQKrFcPn0_KgwTdAo05fQShqyfHkuKH8XjZZ4/htmlpresent

<https://geothermalcommunities.eu/assets/elearning/5.8.Direct%20Application%20of%20GE.pdf>





This small **greenhouse** is **heated** with **geothermal** water. Plants grow faster and larger when they have additional heat available.

In several western US states, many long **greenhouses** are built and **heated** with **geothermal** water. This one is in New Mexico.



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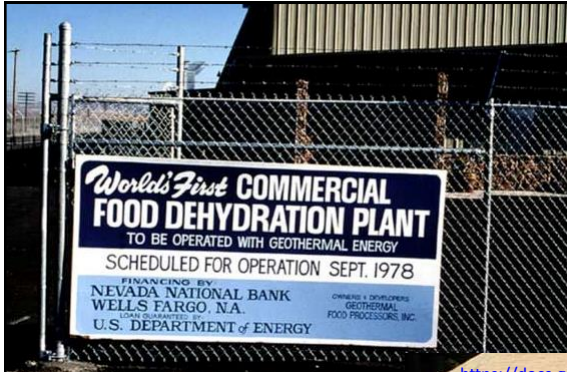
This net full of **fish** was grown in **geothermally** heated waters in California's Imperial Valley.



https://docs.google.com/presentation/d/12N_AQBScQKrFcPn0_KgwTdAoO5fOShqyfHkuKH8XjZZ4/htmlpresent



These **alligators** are grown in **geothermally** heated water in Idaho.



Geothermal water is also used for industrial uses, like drying lumber or food products. This plant in Brady, Nevada, provides dried onions to Burger King.

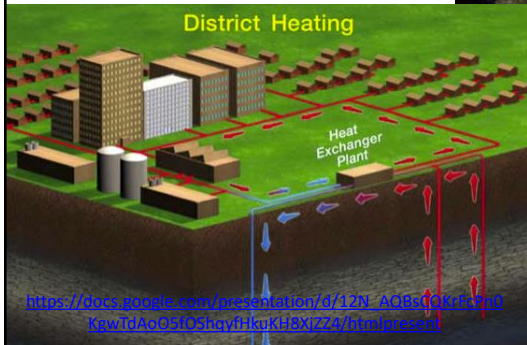
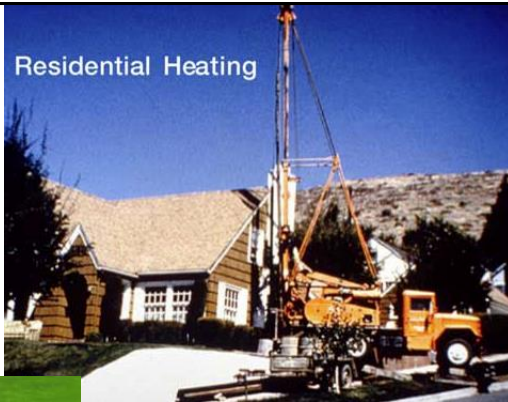
https://docs.google.com/presentation/d/12N_AQB5CCW6GPa9KgwTdAoO5fOShqyFHkukH8XjZZ4/htmlpresent

Pipes of geothermal water can be installed under sidewalks and roads to keep them from icing over in winter, like this sidewalk in Klamath Falls, Oregon.



Geothermal water is piped from wells to heat single homes or whole residential or commercial districts. This truck-mounted drill rig is drilling a well for use in Klamath Falls, Oregon.

Residential Heating



Hot water from one or more geothermal wells is piped through a heat exchanger plant to heat city water in separate pipes. It can be used to warm up the air.

https://docs.google.com/presentation/d/12N_AQB5CCW6GPa9KgwTdAoO5fOShqyFHkukH8XjZZ4/htmlpresent



This is a "plate type" **heat exchanger** which passes hot **geothermal** water past many layers of metal plates, **transferring** the heat to **other water** passing through the other side of each plate.

These pumps are used to **pump** the **heated water** to **buildings** in a district heating system, after it has passed through the heat exchanger.



This photo of **Reykjavik, Iceland**, was taken in **1932**, when buildings were all heated by burning of (imported) **fossil fuels**.

<https://geothermaleducation.org/GEOpresentation/sld094.htm>



Reykjavik Using Fossil Fuels

<http://geothermaleducation.org/GEOpresentation/sld095.htm>



Reykjavik Using Geothermal

Today, about **95%** of the buildings in **Reykjavik** are heated with **geothermal** water. Reykjavik is now one of the **cleanest cities** in the world.

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Geothermal energy

In some areas, the **warm rocks** are **very deep underground**.

Where this occurs, **wells** are drilled down to the **hot rocks** and **cold water** is pumped down. The water is heated by the rocks and returns to the surface as steam.

This **geothermal power plant** in **California** has **57 wells** and produces **52 MW** of **electricity**.

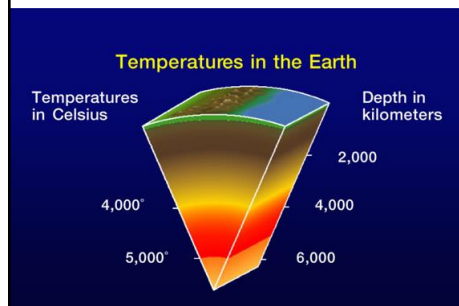
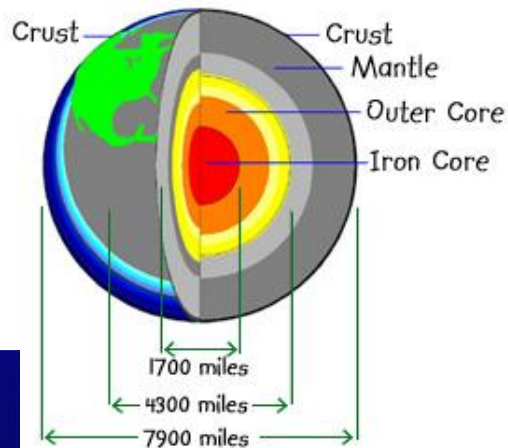


http://bioblocks.weebly.com/uploads/8/7/0/6/8706802/notes_renewable_energy.pdf

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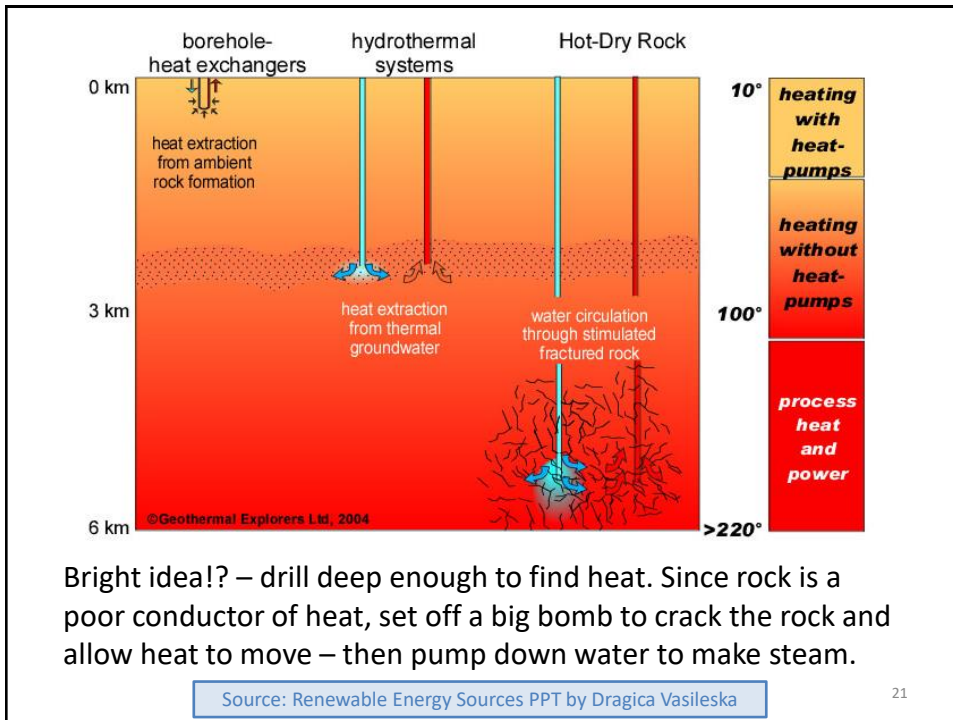
Cross Section of the Earth

Although **hot areas** near surface are limited, the earth is hot **everywhere** if you go **down far** enough.



https://docs.google.com/presentation/d/12N_AQBScQKrFcpn0KgwTdAoO5fOShyfHkuKH8XjZ4/htmlpresent

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Geothermal energy in more details

Binary Cycle Power Plant

Power Generator Turbine

Heat exchanger

Rock Layers Injection Well Production Well

Use **heat** to make **steam** to turn **turbine** for **electrical** generation

Note: **deep hot waters** are **corrosive** to best to inject clean water in a closed system & bring it back to the surface as steam.

The Geysers, Calistoga, CA
Photo credit: National Renewable Energy Laboratory

Source: Renewable Energy Sources PPT by Dragica Vasileska

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Classification of geothermal systems •

Deep geothermal energy reservoirs

Low enthalpy reservoir

Hydrothermal systems

Thermal power
extraction

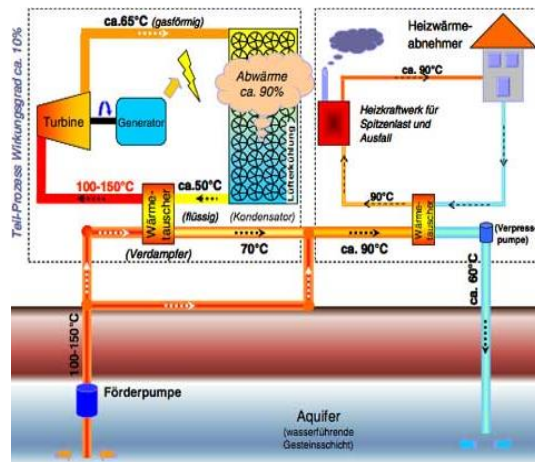
$$P_{\text{therm}} = \rho c_p Q_{\text{flow}} \Delta T$$

ρ = density of water

c_p = specific heat

Q_{flow} = flow rate

$\Delta T = T_{\text{hot}} - T_{\text{cold}}$



<http://www.sliderbase.com/spitem-1585-3.html>

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Geothermal Heat Pumps (GeoExchange Systems)

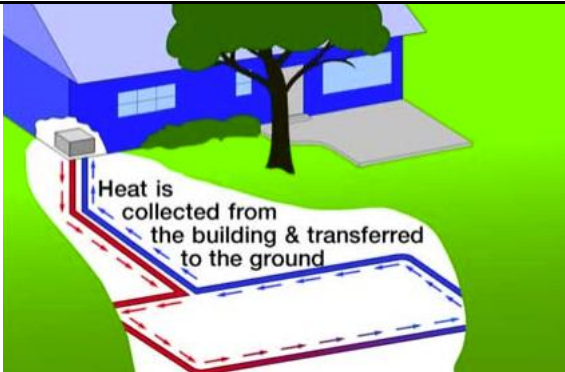
- **Residential** and **commercial heating and cooling** without a geothermal reservoir
- **Geothermal heat pumps** can be used almost **everywhere** in the world, without a geothermal reservoir. The **insulating** properties of the **earth**, just below our feet, can keep us **warm** or **cool**.

https://docs.google.com/presentation/d/12N_AQBScQKrFcPn0KgwTdAoO5fOSHqyfHkuKH8XjZ4/htmlpresent

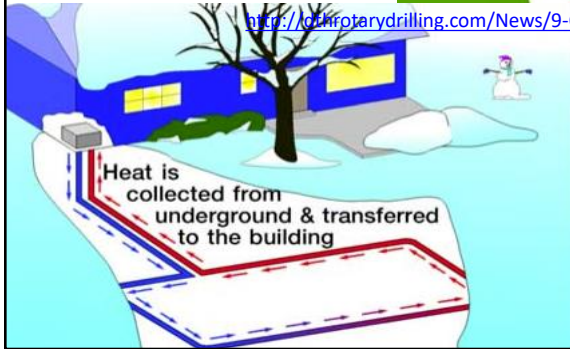
<https://geothermaleducation.org/GEOpresentation/sld101.htm>

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Heat pump in summer



Heat is collected from the building & transferred to the ground




Heat is collected from underground & transferred to the building

Heat pump in Winter

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http://okrotarydrilling.com/News/9-October-2010/geothermal_heat_pumps.html

Types of Geothermal Heat Pumps

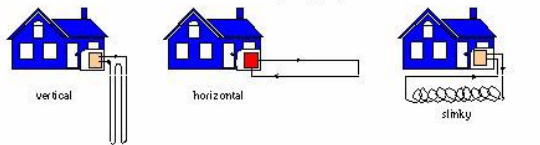


GEOTHERMAL HEAT PUMPS (GHP)

a.k.a. Ground Source Heat Pumps (GSHP)

Ground Coupled Heat Pumps (GCHP)

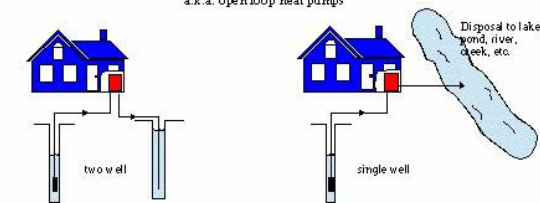
a.k.a. closed loop heat pumps



vertical horizontal Slinky

Groundwater Heat Pumps (GWHP)

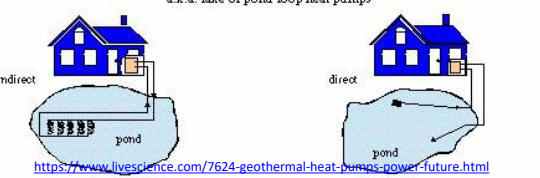
a.k.a. open loop heat pumps



two well single well Disposal to lake, pond, river, creek, etc.

Surface Water Heat Pumps (SWHP)

a.k.a. lake or pond loop heat pumps



indirect direct pond pond

<http://www.livescience.com/7624-geothermal-heat-pumps-power-future.html>



Geothermal heat pump systems, consisting of the heat exchanger (left) and the heat pump (right), heat and cool a home by transferring heat to and from the earth.

https://www.energy.gov/sites/prod/files/guide_to_geothermal_heat_pumps.pdf

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Benefits of geothermal heat pumps

- Can be used almost **everywhere** worldwide
- Are **energy-** and **cost-efficient**
- Is **renewable** and **sustainable**
- Conserves **fossil fuel** resources
- Provides **clean** heating and cooling **source** – no emission

https://docs.google.com/presentation/d/12N_AQBScQKrfPn0KgwTdAoO5fOShqvfHkuKH8XjZ4/htmlpresent

In a poll, over **95%** of people who had installed a geothermal heat pump said they would **recommend** it and would do it again.

The U.S. Environmental Protection Agency (**EPA**) has rated geothermal **heat pumps** among the most **efficient** heating and cooling **technologies** available today.

<https://www.greenmatch.co.uk/blog/2015/07/the-benefits-of-a-ground-source-heat-pump#:~:text=One%20of%20the%20main%20advantages,one%20unit%20of%20electric%20power.>

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