

SOLAR PHOTOVOLTAIC

What is it?

Photovoltaic systems (PV system) use solar energy systems that convert sunlight into electricity.¹ A *photovoltaic array* (or *solar array*) is a linked collection of solar panels. PV arrays use an inverter to convert the direct current (DC) power produced by the modules into alternating current (AC) that can power lights, motors, and other loads.²

System Info

STAND-ALONE SYSTEM

A **stand-alone system** does not have a connection to the electricity "mains" (aka "grid"). Stand-alone systems vary widely in size and application from wristwatches or calculators to remote buildings or spacecraft.

GRID-TIED SYSTEM

A **grid-tied system** (utility-connected or line-tied systems) is connected to a large independent grid (typically the public electricity grid) and feeds power into the grid. Grid-tied systems can be used with a battery back-up or without. A battery back-up provides uninterrupted power during a power outage. Grid connected systems vary in size from residential (2-10kW) to solar power stations (up to 10's of MW).³

INVERTER

A **solar inverter**, or **PV inverter**, converts the variable direct current output of a photovoltaic (PV) solar panel into a utility frequency alternating current that can be fed into a commercial electrical grid or used by a local, off-grid electrical network. It is a critical component in a photovoltaic system, allowing the use of ordinary commercial appliances.

PANELS

Photovoltaic **panel**, the most common form of **solar panels** in the professional electrical generation industry, are able to absorb energy from the sun through a variety of smaller solar cells on their surface. Effective panel lives are typically 25 years or more.⁴

¹Types of PV systems. University of Florida.

²"Small Photovoltaic Arrays". *Research Institute for Sustainable Energy (RISE), Murdoch University*

³How Solar Power Works

⁴Solar Power (Photovoltaic, PV)". *Agriculture and Agri-Food Canada*. <http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1187620075153&lang=eng>. Retrieved 5 February 2010.

The payback period for an investment in a PV solar installation varies greatly. It is typically calculated to be between 10 and 20 years.

There are 3 basic types of construction for PV panels:

- **Monocrystalline** cells are cut from a single crystal of silicon- they are effectively a slice from a crystal. These are the most efficient and the most expensive to produce.
- **Polycrystalline (or Multicrystalline)** cells are effectively a slice cut from a block of silicon, consisting of a large number of crystals. These cells are slightly less efficient and slightly less expensive than monocrystalline cells.
- **Amorphous** cells are manufactured by placing a thin film of amorphous (non crystalline) silicon onto a wide choice of surfaces. These are the least efficient and least expensive to produce of the three types.⁵

INVERTER

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CHARGE CONTROLER

A **charge controller**, **charge regulator** or **battery regulator** limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may prevent against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk.⁶

BATTERIES

The **batteries** are required to be lead acid based. These are much more durable than a regular car battery (for example). The depth of discharge for a solar photovoltaic system battery allows it to be "drained" to a certain degree without shortening the life of the battery.

⁵<http://www.solar-facts.com/panels/panel-types.php>

⁶"Charge Controllers for Stand-Alone Systems" (Web page), part of *A Consumer's Guide to Energy Efficiency and Renewable Energy*, U.S. Department of Energy.

How Does It Work?

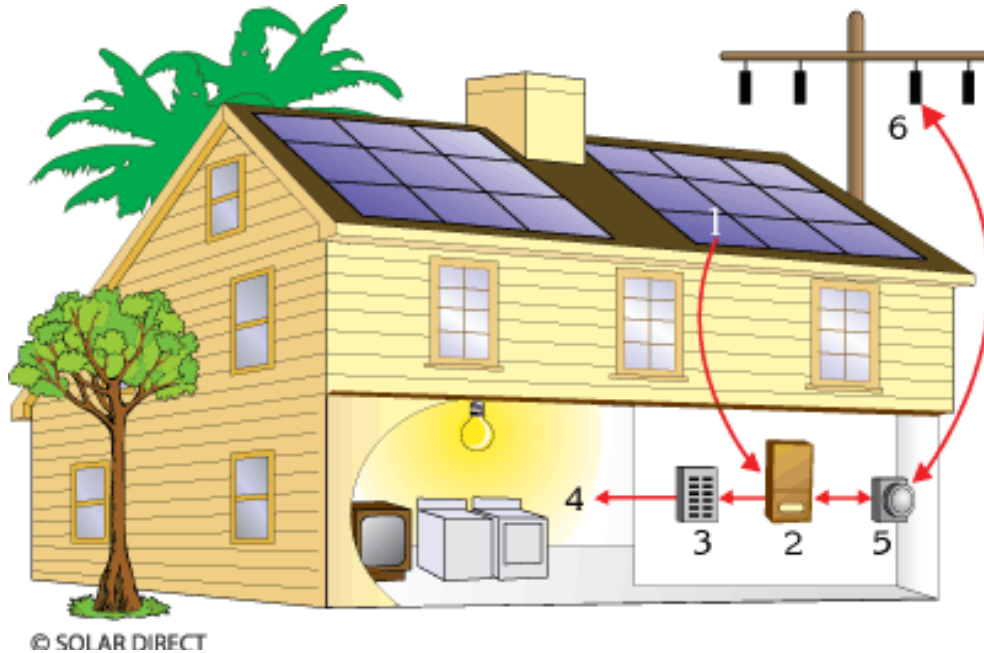


Image above shows a residential Grid-Connected Photovoltaic System. 1. solar panels 2. inverter 3. breaker box 4. home power and appliances 5. meter 6. utility power grid.

(1) Solar Electric or PV modules convert sunlight to electricity. The PV modules generate DC electricity - or direct current - sending it to the inverter. (2) The inverter transforms the DC power into AC electricity for ordinary household needs. (3) Existing electrical panel distributes solar electricity and utility power to (4) loads (appliances). For systems with a battery backup (optional), the inverter also regulates the charge of batteries. The electricity stored in the batteries can be used at night or during blackouts. A valuable feature of photovoltaic systems is the ability to connect with the existing power grid which allows owners to sell excessive electricity back to the utility with a plan known as (5) Net Metering. At times when you are not using all of the electricity produced by your system, your meter will spin backwards selling the electricity back to the (6) utility power grid at retail rate.⁷

Regional Considerations

The best climate for solar power is where there is a lot of direct overhead sun-light. These are places that have very few cloudy or rainy days. It would also be a place where the sun is high in the sky everyday of the year - like in the more southern latitudes here in North America. The closer to the equator the better because then you have more sun that is high in the sky throughout the year. When the sun is high solar electric panels produce more electricity than when it is low in the sky.⁸

⁷<http://www.solardirect.com/pv/pvbasics/pvbasics.htm>

⁸<http://electricalrevolution.com/2009/05/29/what-is-an-ideal-climate-for-solar-power-what-about-where-i-live.aspx>

There is a common misconception that hot sunny days are great for Solar Electricity Systems (photovoltaics), however this is not really true. What would be better are cool or cold sunny days. Solar cells work by converting light from the sun to electricity, so sunny days make the solar electric panels work best. However, solar cells produce less power when they are hot than when they are cool or cold. Cool sunny days produce more power over time which means more energy produced and more savings to you. Not Black and White, But Coconino County is a Fantastic Climate for Solar Electric Power.

Benefits of Solar Energy

- Solar energy is renewable. We never have to worry about running out of sunlight or using it all up. The sun is a consistent power source meaning it's always going to be there every day.
- Solar energy is environmentally friendly. Compared to fossil fuels which release greenhouses gases, carcinogens and carbon dioxide, solar cells don't release anything into the air.
- Solar panels are extremely reliable. There are no moving parts so you don't have to worry about replacing anything. In fact, most people generate electricity for 1000s of hours with little or no maintenance.
- Solar cells make no noise while collecting energy. There are no other renewable energy sources that are completely silent.
- In the long run, solar electricity is cheaper than buying it from the power company. There is a start up cost, but then it starts paying for itself. Once you break even, everything after that is profit. Compare this to paying a monthly bill and getting no return on investment.
- There is a huge variety of solar panel systems available. Some can cost tens of thousands of dollars, and some cost just a couple hundred. This means anyone can get into solar, there's an entry point for just about everybody.
- You're not required to connect to the power grid. You can be completely self-sufficient and live off-the-grid. Imagine never paying another monthly bill or hook-up charge.
- Sell excess electricity. If you build a large enough solar panel system, you can make your electric meter spin backwards! Most power companies will gladly buy or credit you for this excess electricity. Contact your local power companies for more details.
- Solar technology is constantly improving. Solar installations are increasing by an incredible 50% every year, most of which are small homemade systems.⁹

For more information on Solar Photovoltaics please visit the National Renewable Energy Labs (NREL) website <http://www.nrel.gov/> .

⁹<http://ezinearticles.com/?10-Benefits-of-Solar-Energy&id=2154024>

SOLAR THERMAL

What is it?

Solar thermal technology uses the sun's energy to generate low-cost, environmentally friendly thermal energy. This energy is used to heat water or other fluids. Solar thermal systems differ from solar photovoltaic (PV) systems, which generate electricity rather than heat.¹⁰

System Info

COLLECTORS

There are three basic types of construction for collectors:

- **Integral collector-storage systems**, also known as ICS or “batch” systems, are made of one or more black tanks or tubes in an insulated, glazed box.
- **Flat-plate collectors** are the most common type. Glazed flat-plate collectors essentially are insulated, weatherproofed boxes that contain a dark absorber plate under one or more glass or plastic (polymer) covers.
- **Evacuated-tube solar collectors** are usually made of parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin.

STORAGE TANK

Most solar water heaters require a well-insulated **storage tank**. Solar storage tanks have an additional outlet and inlet connected to and from the collector.

WATER HEATER

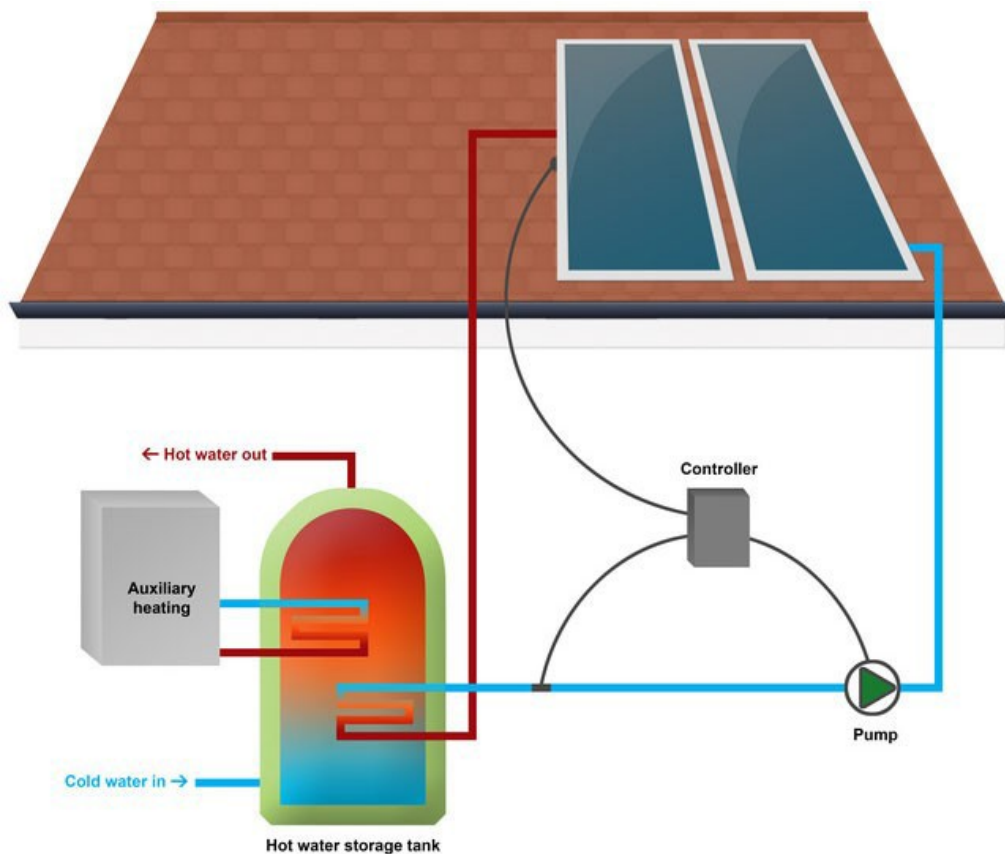
Active solar water heaters use pumps to circulate water or a nonfreezing heat-transfer fluid from storage tanks through the collectors. A temperature controller will shut off the system when the desired temperature setting is achieved. Active systems are usually more expensive than passive systems, but they are also usually more efficient.

Passive direct solar water heaters move household water or a heat-transfer fluid through the system without using pumps or electricity. Passive systems are typically less expensive to purchase and maintain than other types of solar systems. They are also inherently more reliable and may last longer. However, passive systems are not usually as efficient as active systems.¹¹

¹⁰<http://sunwatersolar.com/solar-thermal/what-is-solar-thermal>

¹¹<http://www.uksolarenergy.org.uk/solar-system.html>

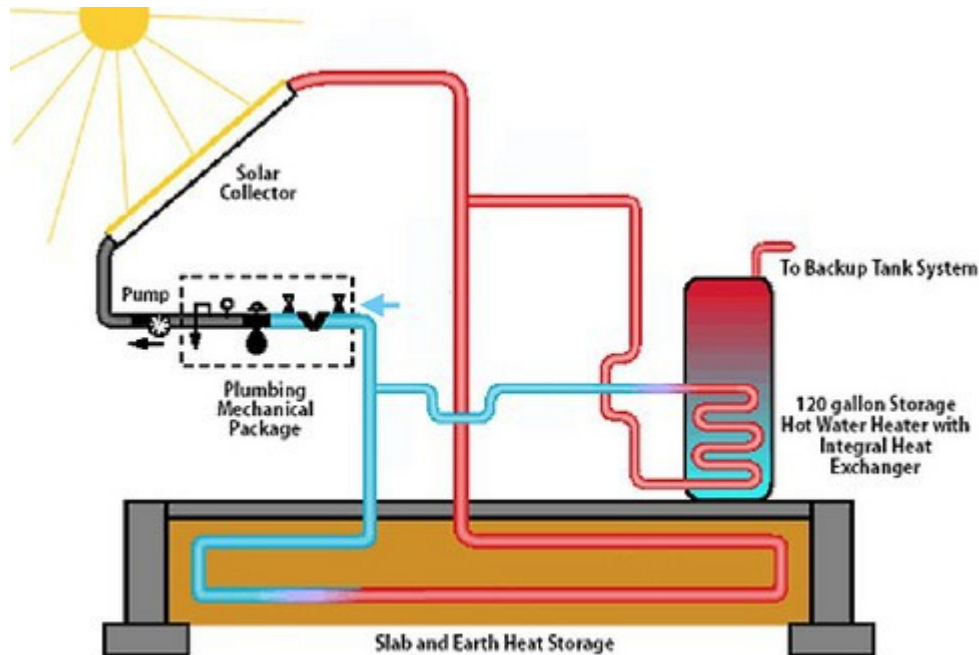
How Does It Work?



A solar thermal system (also called a solar hot water system) is really quite simple. You're using the sun's energy to heat a solar collector full of solar fluid (or water, depending on which type of solar thermal system you install), which then transfers that heat from the sun (or hot water) into your home's hot water tank. The solar fluid is then pumped back to the collector to once again be reheated. This circulation loop will continue as long as there is heat to be drawn from the collector. During times when there is little or no sun, a backup heating system will be activated to provide adequate hot water.¹²

¹²www.solartribune.com

Radiant Floor Heating with Solar Thermal ¹³



In a solar thermal radiant floor heating system warm water is pumped through the floor thus heating it to a few degrees above the air temperature. In this way the floor itself becomes a massive radiator sending out rays of heat, much like a wood stove or a wall that has been heated by the sun, into the room. These heat rays heat all the objects and people in room in a gentle, even manner.¹⁴

Regional Considerations

In cold climates solar thermal systems need to be freeze resistant. To protect against freeze damage, a solar hot water system either drains all the fluid from the collector when it's cold or circulates an antifreeze solution through the collectors.¹⁵ Glycol anti-freeze solutions degrade over time. These fluids are quickly damaged by stagnation during sunny weather. As part of normal maintenance, it's a good idea to check the pH of your antifreeze solution every year or two. If the solution has become acid, it's time to replace the antifreeze. It's important to insulate your pipes well. Protect all rooftop pipe insulation with foil-faced butyl flashing tape.

¹³www.100khouse.com

¹⁴<http://www.thermacraft.com/radiant-flooring.html>

¹⁵<http://www.greenbuildingadvisor.com/blogs/dept/musings/solar-hot-water>

Benefits of Solar Thermal ¹⁶

- Using the sun's thermal energy to heat water can dramatically reduce your electricity bill; research shows that an average household with an electric water heater spends about 25% of its home energy costs on heating water.
- Solar water heaters offer long-term benefits that go beyond simple economics. In addition to having free hot water after the system has paid for itself in reduced utility bills, you and your family will be cushioned from future fuel shortages and price increases.
- The National Remodelers Association reports that adding a solar water heater to an existing home raises the resale value of the home by the entire cost of the system. You may be able to recoup your entire investment when you sell your home.

For more information on Solar Thermal please visit the National Renewable Energy Labs (NREL) website <http://www.nrel.gov/>.

WIND TURBINES

What is it?

A wind turbine is a device that converts kinetic energy from the wind, also called wind energy, into mechanical energy; a process known as wind power. Wind turbines can be used as stand-alone applications, or they can be connected to a utility power grid.

System Info¹⁷

Modern wind turbines systems consist of three basic components:

TOWER – on which the wind turbine is mounted

ROTOR - that is turned by the wind

NACELLE – which houses the electrical generation equipment

¹⁶<http://www.nrel.gov/docs/legosti/fy96/17459.pdf>

¹⁷Arizona Public Service (APS)

The two types of wind turbines are:

- **VERTICAL AXIS WIND TURBINES** (or VAWTs) have the main rotor shaft arranged vertically. Key advantages of this arrangement are that the turbine does not need to be pointed into the wind to be effective.
- **HORIZONTAL AXIS WIND TURBINES** (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind.

Other Wind Turbine Accessories include:

BATTERIES

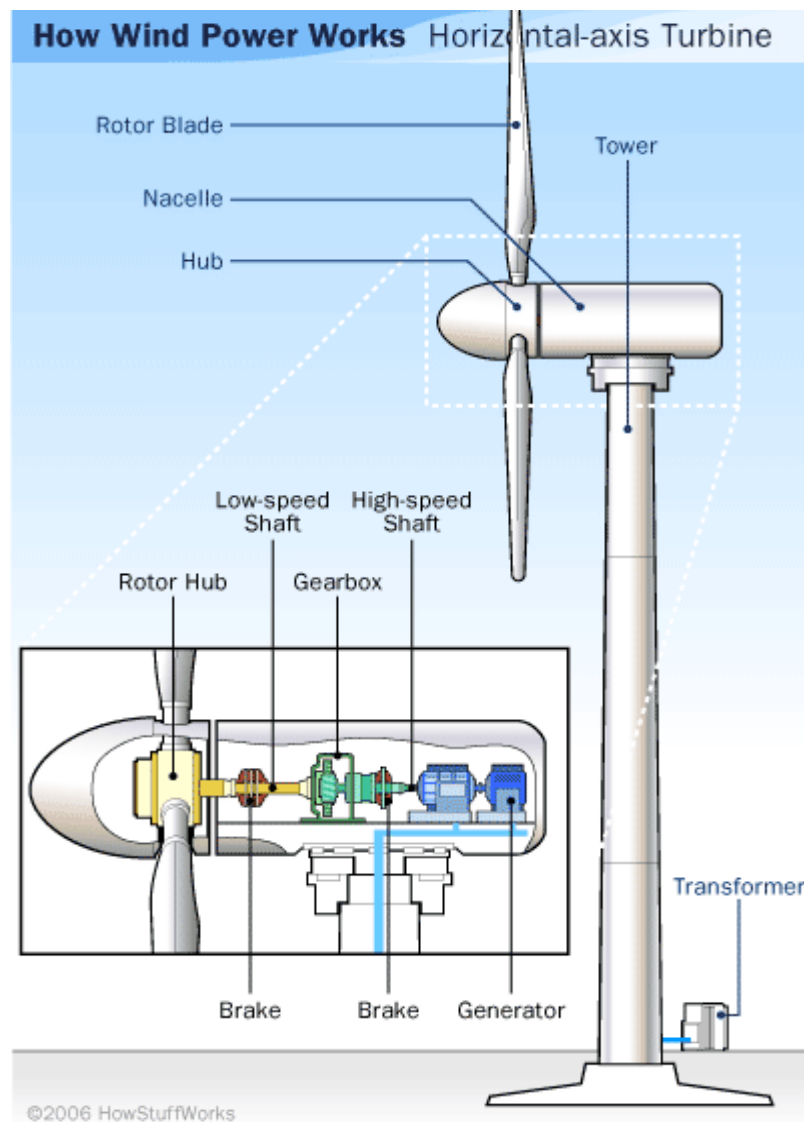
Batteries, similar to other renewable energy systems, the batteries are required to be lead acid based. These are much more durable than a regular car battery (for example). The depth of discharge for a wind turbine system battery allows it to be "drained" to a certain degree without shortening the life of the battery.

INVERTER

A **wind inverter**, converts the variable direct current output of a wind turbine into a utility frequency alternating current that can be fed into a commercial electrical grid or used by a local, off-grid electrical network. It is a critical component in a wind energy system, allowing the use of ordinary commercial appliances.

How Does It Work?¹⁸

Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity. Wind turbines are mounted on a tower to capture the most energy. At 100 feet (30 meters) or more above ground, they can take advantage of faster and less turbulent wind. Wind turbines can be used to produce electricity for a single home or building, or they can be connected to an electricity grid for more widespread electricity distribution.



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¹⁸http://www1.eere.energy.gov/wind/wind_animation.html

¹⁹http://www1.eere.energy.gov/wind/wind_animation.html

Regional Considerations²⁰

Rooftop installation can be tricky as efficiency is often lost through vibrations. Improper installation can also result in damage to the turbine and a roof. The intermittent nature of wind requires placing turbines in optimal wind resource locations. The higher the turbine, the steadier the access to wind will be. Set back ordinances for small systems using guy wires must be observed. Noise generated by the system shall not exceed fifty decibels (50 dBA), as measured from the nearest property line. Tower height must not exceed thirty five feet and shall be on one acre unincorporated lots.

Benefits²¹

- The wind is free and with modern technology it can be captured efficiently.
- Once the wind turbine is built the energy it produces does not cause green house gases or other pollutants.
- Although wind turbines can be very tall each takes up only a small plot of land. This means that the land below can still be used. This is especially the case in agricultural areas as farming can still continue.
- Remote areas that are not connected to the electricity power grid can use wind turbines to produce their own supply.

For more information about wind energy please visit the National Renewable Energy Labs (NREL) website <http://www.nrel.gov/>

GEOTHERMAL

What is it?

A **geothermal heat pump, ground source heat pump (GSHP), or ground heat pump** is a central heating and/or cooling system that pumps heat to or from the ground. It uses the earth as a heat source (in the winter) or a heat sink (in the summer). This design takes advantage of the moderate temperatures in the ground to boost efficiency and reduce the operational costs of heating and cooling systems.²²

²⁰http://www.ehow.com/about_5073497_locations-wind-turbines.html

²¹<http://www.technologystudent.com/energy1/wind8.htm>

²²http://www.nrel.gov/learning/re_geo_heat_pumps.html

System Info

OPEN LOOP SYSTEM In an open loop system (also called a groundwater heat pump), the secondary loop pumps natural water from a well or body of water into a heat ex-changer inside the heat pump.

CLOSED LOOP SYSTEM Most installed systems have two loops on the ground side: the primary refrigerant loop is contained in the appliance cabinet where it exchanges heat with a secondary water loop that is buried underground.

Geothermal heat pump systems consist of three parts:

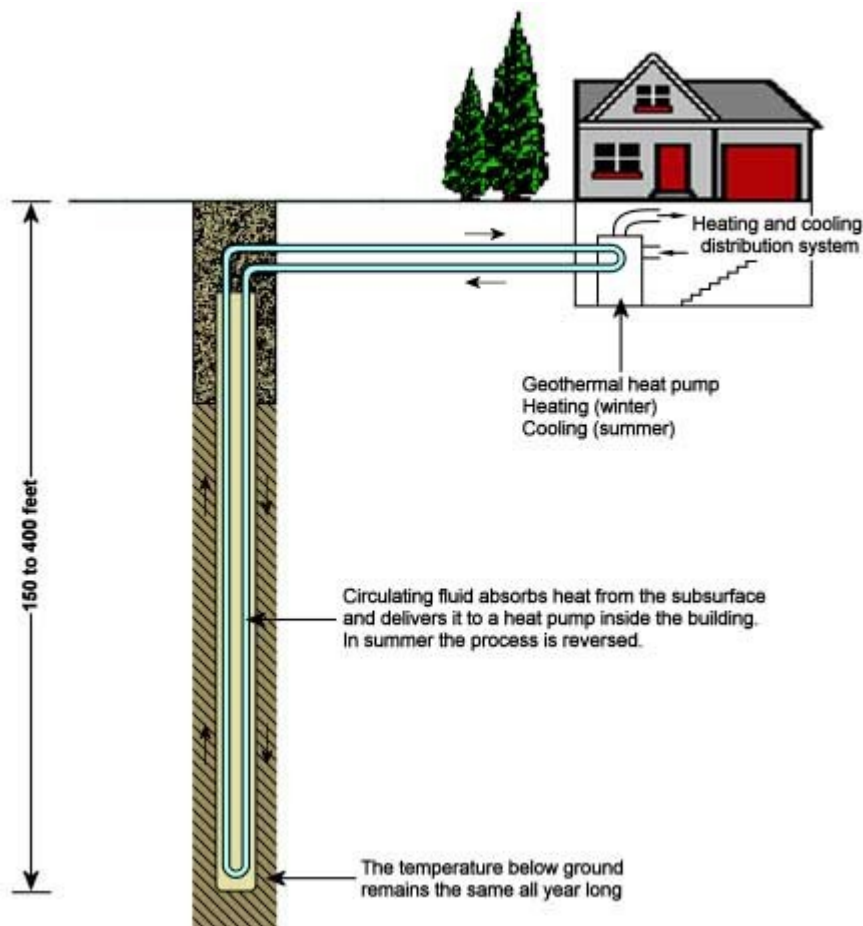
- **THE GROUND HEAT EXCHANGER** The heat exchanger is a system of pipes called a loop, which is buried in the shallow ground near the building. A fluid (usually water or a mixture of water and antifreeze) circulates through the pipes to absorb or relinquish heat within the ground.
- **THE HEAT PUMP UNIT** In the winter, the heat pump removes heat from the heat ex-changer and pumps it into the indoor air delivery system, moving heat from the ground to the building's interior. In the summer, the process is reversed, and the heat pump moves heat from the indoor air into the heat exchanger, effectively moving the heat from indoors to the ground.
- **THE AIR DELIVERY SYSTEM (DUCTWORK)** To distribute the hot or cold air to the building.

How Does It Work?

Geothermal heat pumps take advantage of the solar energy stored just below the surface of the ground. 40 – 60% of the Sun's energy is directly absorbed into the ground, making the Earth a giant solar panel. Geothermal heat pumps transfer energy between the ground and your home through a series of buried, high-density, polyethylene pipes. The pipes are filled with a water solution and sealed using heat-fusion to weld pipe to pipe. These pipes are called an earth loop.

In the **heating mode**, heat is absorbed from the ground and pumped into your home. The water circulating in the earth loop is colder than the surrounding ground. This causes the water to absorb energy, in the form of heat, from the earth. The water carries this energy to the heat exchanger in the pump. In the heat exchanger, refrigerant absorbs the heat energy from the water. The water now leaves the heat exchanger at a colder temperature, and circulates through the earth loop to pick up more energy.

In the **cooling mode**, heat is pumped out of your home and released into the ground. The water circulating in the earth loop is warmer than the surrounding ground. This causes the water to release energy, in the form of heat, into the earth.²³



²³ <http://www.gogogeo.com/about-geothermal/how-geothermal-works>

Regional Considerations

The performance of an open or closed loop ground source heat pump system depends on local geological conditions. It is important these are determined as accurately as possible when designing a system in order to maximize efficiency and minimize installation costs. Factors that need to be considered are surface temperature, sub-surface temperatures down to 150-400 feet, thermal conductivities and diffusivities of the soil and rock layers, groundwater levels and flows and aquifer properties. In addition rock strength is a critical factor in determining the excavation or drilling method required at a site and the associated costs. If freezing temperatures are expected, the loop should be freeze protected.^{24 25}

Benefits

- The biggest benefit of Geothermal systems is that they use 25%–50% less electricity than conventional heating or cooling systems.
- Geothermal units are very smooth and quiet in operation, comparable to a refrigerator.
- Since they usually have no outdoor compressors, Geothermal systems are not susceptible to vandalism. On the other hand, the components in the living space are easily accessible, which increases the convenience factor and helps ensure that the up-keep is done on a timely basis.
- Geothermal systems are usually good for 15+ years. A typical furnace will last 7-10 years with regular maintenance. The ground loop of the geothermal system (the pipes buried in your yard) will have a warranty of 50 years. The ground loop is made up of polypropylene pipe, the same pipe which is used in city gas lines.
- There is no combustion in a geothermal heat pump; therefore there is no chance of carbon-monoxide poisoning.
- Geothermal heat pump systems allow for design flexibility and can be installed in both new and retrofit situations.

²⁴geology.utah.gov/emp/geothermal/ugwg/.../ppt/chiasson0306_4.ppt

²⁵http://www.bgs.ac.uk/research/energy/docs/final_paper.pdf