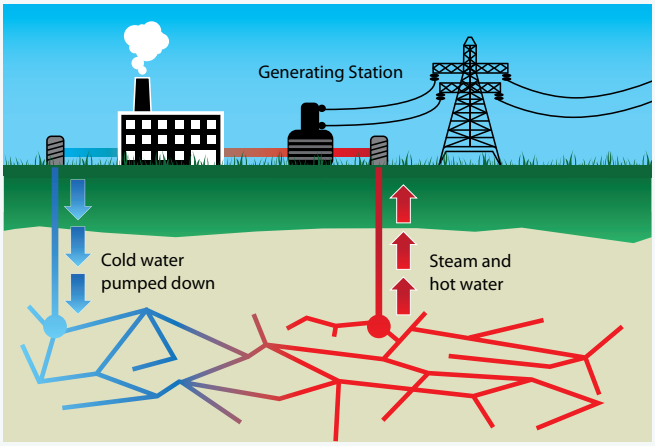
# Geothermal Energy Overview

## About geothermal energy

**Geothermal energy originates from the radioactive decay of minerals within the Earth's core and also from solar energy absorbed at the surface. The heat stored in the Earth can be used for direct heating applications, generating electricity, or a combination of the two (cogeneration).**

Geothermal power is considered a renewable resource as the heat extraction is minute compared to the almost unlimited amount of heat generated by the Earth's core. Geothermal energy produces base load electricity as it is available 24 hours a day, 365 days a year, unlike many other renewable technologies that are affected by weather and seasonal variations.



Simplified version of geothermal electricity plant

Historically, geothermal power plants have been located near tectonic plate boundaries where high temperature geothermal resources are available relatively close to the surface. This is because industrial scale electricity generation requires higher resource temperatures to be efficient, whereas small scale resources for heating homes can use shallower, lower temperature sources.

Geothermal power plants operate in at least 24 countries, with the vast majority of global capacity in eight countries: the United States, the Philippines, Indonesia, Mexico, Italy, Iceland, New Zealand, and Japan. Iceland generated about 26% of its electricity with geothermal power in 2010, and the Philippines generated approximately 18%[1]. While only 46 countries were considering geothermal power development in 2007, some 70 countries had projects under development or consideration by 2010[2].

## What are the advantages of geothermal over other renewable technologies?

- Geothermal energy is available 24 hours a day, 365 days a year, producing base load electricity unlike many other renewable technologies that are affected by weather and seasonal variations.
- Geothermal power plants have high Capacity Factors so are a more direct substitute for fossil fuel plants than many other mature renewable technologies. Capacity Factor is the total amount of electricity a power plant produces in a given period of time divided by the total amount it theoretically could produce. Modern coal, nuclear and geothermal power plants all have very high Capacity Factors as they are generally only offline during maintenance.
- Geothermal energy conversion equipment is relatively compact, making the overall plant footprint small. On average, a typical solar PV plant uses about 45 times more land than a geothermal binary plant.

### Geothermal's high Capacity Factor

Goethermal's high average Capacity Factor compared to other technologies makes it a more direct substitute for fossil fuels:

| | |
|---|---|
| Nuclear | 90% |
| Geothermal | 85-90% |
| Coal | 80-85% |
| Wind | 20-50% |
| Solar | 20% |

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[1]Renewables 21 Global Status Report 2012
[2]Renewables 21 Global Status Report 2012

## What are the advantages of geothermal over fossil fuel plants?

- In addition to the extensive GHG emissions reductions, geothermal plants do not have the other particulate matter discharges associated with the combustion of fossil fuels.
- There is no need to extract and process fuel and then transport it to the power plant, which avoids GHG emissions and other environmental impacts.
- Geothermal power plants are immune to fuel availability and cost fluctuations.
- Geothermal energy conversion equipment is relatively compact, making the overall plant footprint small. A typical coal plant uses almost 30 times more land than a geothermal binary plant.

## The different types of geothermal technology

### Geothermal electricity

Geothermal power plants harness the Earth's heat by utilising natural hot springs, drilling a well into a hot aquifer (an underground layer of fluid bearing rock), or creating artificial aquifers by pumping high pressure water into the hot rock (see Enhanced Geothermal Systems). The power plants route the steam or hot liquid from the geothermal reservoir through turbine/generator units – either directly or through heat exchangers - to produce electricity.

#### Steam plants

Geothermal resources rich in steam, such as geysers near or at the surface, use the steam to directly run turbines. These are called dry steam power plants and were the first type of geothermal power plants built. However these sites are rare, so it is more common for a geothermal fluid from underground to be pumped at high pressure into a depressurised tank to flash it into steam. These flash steam power plants are the most common power plants in operation today.

#### Binary plants

Binary plants take advantage of resources where the geothermal fluid is of lower temperature and potentially more difficult to access. They differ from steam plants as none of the geothermal fluid comes in to contact with the turbines. Instead they transfer the heat from the geothermal fluid to a working fluid that vaporises and passes through the turbines. Both the secondary fluid and the geothermal fluid are in closed loops, so the secondary fluid is recycled back through the heat exchanger and the geothermal fluid is returned to the underground reservoir.

These plants generally have higher equipment costs than steam plants, but have even stronger environmental benefits, with virtually no emissions. Binary cycle plants are actually the most common type of geothermal electricity plant being constructed today, as the technology can utilise cooler geothermal fluids than steam plants.

### Enhanced Geothermal Systems (EGS) or Hot Dry Rock (HDR)

Until recently, geothermal power systems only exploited naturally occurring hot reservoirs, with the vast majority of accessible reservoirs being located near tectonic plate boundaries. EGS expands the potential of geothermal energy by exploiting hot rock that may be dry and non-porous, so can theoretically be installed anywhere there is sufficiently hot rock.

EGS technologies replicate natural conditions by injecting high pressure water into the rock. The injection process fractures the rock, allowing the water to travel through the fractures, enhancing and/or creating hot reservoirs.

Similar to traditional geothermal technologies, the hot fluid is then pumped back out and converted to electricity using either a direct steam process or binary system.

Due to the high pressure water forced into the ground to fracture rocks with EGS plants, there is a slight risk of induced seismic activity. There have been two EGS plants where mild induced seismicity did occur – one in San Francisco, USA and one in Basel, Switzerland. Steam and binary geothermal plants do not have this risk and to date there have not been any cases of induced seismicity occurring with these technology types.

EGS is too new a technology for a definitive decision on its safety record to be reached. More work will take place to ensure it is as reliable as the more 'conventional' systems before it becomes mainstream. Currently there are no carbon finance projects for EGS power plants.

## Geothermal heating

### Ground source heat pumps (GSHP)

Ground source heat pumps (sometimes referred to as geothermal heat pumps) utilise heat retained in the ground for direct heating and cooling applications. GSHPs can be installed almost anywhere in the world, as even in the coldest climates the ground temperature stays at 10-15°C at relatively shallow depths of below three metres. The GSHP pumps circulate a carrier fluid (usually a water/antifreeze mix) through pipes below the ground. As the fluid circulates it absorbs heat from the ground. The fluid passes through a heat pump and electricity is used to extract heat from it. The rechilled fluid is sent back through the ground, continuing the cycle.

The GSHP system can switch the direction of the heat flow, so in the summer it can act as an air conditioner, transferring the heat from the warm air to the cooler ground.

Geothermal heat is often used for industrial processes, but GSHP technology can also be applied at household level. Current upfront costs for a household system are generally above that of conventional heating systems so GSHPs are usually installed in multi-family developments. However, 40% of detached houses in Sweden utilise GSHP, which started at the end of the 1970s with research heavily supported by public funding after an oil crisis during the same period[3].

# The environmental impacts of geothermal energy

## Do geothermal electric plants emit greenhouse gas (GHG) emissions?

Binary plants have essentially zero GHG emissions, as all of the geothermal fluid is returned to the reservoir and the secondary fluid is also in a closed loop cycle that is not exposed to the atmosphere.

Even open loop steam plants, which are considered to have the highest levels of air emissions amongst geothermal systems, are far more environmentally benign than fossil fuels – a coal fired plant emits about 25 times more $CO^2$ per MWh than a dry steam geothermal plant and over 36 times more than a flash steam plant.

If there were any GHG emissions in connection with a geothermal carbon offset project, these would be monitored and included in any calculations.

## Can geothermal power plants cause earthquakes?

There is no scientific concern pertaining to induced seismicity with conventional (i.e. steam and binary) geothermal plants, as the injection of waste fluids does not require high pressures and there is minimal disturbance of natural reservoirs. There has not been a case to date of induced seismicity occurring with these technology types.

However, new EGS projects often require more serious attention as on two occasions this new technology has caused mild seismic activity related to the fracturing of rock.

The most efficient sites for EGS plants have the hottest rocks. However, these hottest rocks often tend to be more seismically active and so engineers must carefully balance how much fluid they pump in and at what speed. The volume and rate of the water injected alters the stresses in the subsurface and such stresses can be released in the form of an 'induced seismicity', a degree of which is actually expected in EGS. In order for the technology to work, rock must be fractured or existing cracks must be enlarged. This can be reduced to safe levels with careful management and monitoring and the induced seismicity created by EGS is intended to be too small to be felt.

No carbon projects currently exist for EGS power plants, as the technology is still in its infancy. Before it becomes widespread, more testing and development will be required. EGS could expand the reach of geothermal enormously to provide access to a clean, virtually inexhaustible technology in almost any location in the world.

## How do geothermal power plants affect water use?

Goethermal plants generally require cooling water for condensation of the plant's working fluid, but closed loop systems reuse this cooling water, keeping water consumption to a minimum.

## Are geothermal fluids being depleted with these plants?

No. In binary systems, the geothermal fluid is reinjected into the ground to preserve the fluid volume in the reservoir.

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[3]Swedish Ground Source Heat Pump Case Study, GNS Science Report 2010/54, January 2011
[4]Massachusetts Institute of Technology, "The Future of Geothermal Energy" 2006. 8-7 Page 5: http://www1.eere.energy.gov/geothermal/pdfs/egs_chapter_8.pdf) http://www1.eere.energy.gov/geothermal/future_geothermal.html
[5]Massachusetts Institute of Technology, "The Future of Geothermal Energy" 2006. 8-5 Page 5: http://www1.eere.energy.gov/geothermal/pdfs/egs_chapter_8.pdf) http://www1.eere.energy.gov/geothermal/future_geothermal.html

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