SIR CHHOTU RAM INSTITUTE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

RENEWABLE ENERGY RESOURCES (BT-806)

NOTES ON GEOTHERMAL ENERGY

GEOTHERMAL ENERGY

Geothermal energy—geo (earth) + thermal (heat)—is heat energy from the earth.

Geothermal energy comes from the heat within the earth. People around the world use geothermal energy to produce electricity, to heat buildings and greenhouses, and for other purposes.

The earth's **core** lies almost 4,000 miles beneath the earth's surface. The double-layered core is made up of very hot **molten** iron surrounding a solid iron center. Estimates of the temperature of the core range from 5,000 to 11,000 degrees Fahrenheit (F). Heat is continuously produced within the earth by the slow decay of radioactive particles that is natural in all rocks.

Surrounding the earth's core is the **mantle,** thought to be partly rock and partly magma. The mantle is about 1,800 miles thick. The outermost layer of the earth, the insulating crust, is not one continuous sheet of rock, like the shell of an egg, but is broken into pieces called **plates.** These slabs of continents and ocean floor drift apart and push against each other at the rate of about one inch per year in a process called **continental drift.**

Magma (molten rock) may come quite close to the surface where the crust has been thinned, faulted, or fractured by plate tectonics. When this near-surface heat is transferred to water, a usable form of geothermal energy is created.

Geothermal energy is called a renewable energy source because the water is replenished by rainfall, and the heat is continuously produced by the earth.

HISTORY OF GEOTHERMAL ENERGY

Many ancient peoples, including the Romans, Chinese, and Native Americans, used hot mineral springs for bathing, cooking, and heating. Water from hot springs is now used world-wide in spas, for heating buildings, and for agricultural and industrial uses. Many people believe hot mineral springs have natural healing powers.

Using geothermal energy to produce electricity is a relatively new industry. It was initiated by a group of Italians who built an electric generator at Lardarello in 1904. Their generator was powered by the natural steam erupting from the earth.

The first attempt to develop geothermal power in the United States came in 1922 at The Geysers steam field in northern California. The project failed because the pipes and turbines of the day could not stand up to the abrasion and corrosion of the particles and impurities that were in the steam. Later, a small but successful hydrothermal plant opened at the Geysers in 1960. Today 28 plants are operating there.

Electricity is now produced from geothermal energy in 21 countries, including the United States.

WHERE IS GEOTHERMAL ENERGY FOUND?

What does geothermal energy look like? Some visible features of geothermal energy are volcanoes, hot springs, geysers, and fumaroles. But you cannot see most geothermal energy. Usually geothermal energy is deep underground. There may be no clues above ground to what exists below ground.

Geologists use many methods to find geothermal resources. They may study aerial photographs and geological maps. They may analyze the chemistry of local water sources and the concentration of metals in the soil. They may measure variations in gravity and magnetic fields. Yet the only way they can be sure there is a geothermal resource is by drilling wells to measure underground temperatures.

The earth is a hotbed of geothermal energy. 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 known as the "Ring of Fire." The Ring of Fire rims the Pacific Ocean and is bounded by Japan, the Philippines, the Aleutian Islands, North America, Central America, and South America.

GEOTHERMAL ENERGY RESOURCES

There are four main kinds of geothermal resources: hydrothermal, geopressured, hot dry rock, and magma. Today hydrothermal resources are the only kind in wide use. The other three resources are still in the infant stages of development.

Hydrothermal resources have the common ingredients of water (hydro) and heat *(thermal)*. These geothermal reservoirs of steam or hot water occur naturally where magma comes close enough to the surface to heat ground water trapped in fractured or porous rocks, or where water circulates at great depth along faults. Hydrothermal resources are used for different energy purposes depending on their temperature and how deep they are.

Low Temperature: "Direct Use" or Heating

When the temperature of a hydrothermal resource is around 50F and up, it can be used directly in spas or to heat buildings, grow crops, warm fish ponds, or for other uses. Hydrothermal resources suitable for heating occur throughout the United States and in almost every country in the world. Most of the people in Iceland and over 500,000 people in France use geothermal heat for their public buildings, schools, and homes. In the United States, geothermal heat pumps are used in 45 states to heat and cool homes and buildings. Idaho, Oregon, Nevada, and some other states use geothermal energy to heat entire districts.

Heat from geothermal resources is also used to dry ceramics, lumber, vegetables, and other products.

High Temperature: Producing Electricity

When the temperature of a hydrothermal resource is around 220F and up, it can be used to generate electricity. Most electricity-producing geothermal resources have temperatures from 300 to 700F, but geothermal reservoirs can reach nearly 1,000F.

Two main types of hydrothermal resources are used to generate electricity:

- Dry steam (vapor-dominated) reservoirs, and
- Hot water (liquid-dominated) reservoirs.

Dry steam reservoirs are rare but highly efficient at producing electricity. The Geysers in California is the largest and best known dry steam reservoir. Here, steam is obtained by drilling wells from 7,000 to 10,000 feet deep. In a dry steam reservoir, the natural steam is piped directly from a geothermal well to power a turbine generator. The spent steam (condensed water) can be used in the plant's cooling system and injected back into the reservoir to maintain water and pressure levels.

Hot water geothermal reservoirs are the most common type. In a liquid-dominated reservoir, the hot water has not vaporized into steam because the reservoir is saturated with water and is under pressure. To generate electricity, the hot water is piped from geothermal wells to one or more separators where the pressure is lowered and the water *flashes* into steam. The steam then propels a turbine generator to produce electricity. The steam is cooled and condensed and either used in the plant's cooling system or injected back into the geothermal reservoir.

Geothermal Energy Production and Economics

Geothermal energy is put to work in many places around the world. The best known geothermal energy sources in the United States are located in western states and Hawaii. Some moderately hot geothermal resources also exist in the Dakotas, along the Atlantic coast, and in Arkansas and Texas. Someday we may be able to use these resource too.

Most geothermal energy is produced in four states--California, Nevada, Utah, and Hawaii. Today the total installed capacity of geothermal power plants in the United State is 3,200 megawatts

(MW) That's the energy equivalent of three nuclear power plants. American geothermal power plants range in size from a few hundred kilowatts to more than 130 megawatts.

In 1994, geothermal energy produced 18 billion kilowatt hours (kWh) of electricity, or 0.3 percent of the electricity used in this country. Still, this was enough to serve the electrical energy needs of over three million households. California gets six percent of its electricity from geothermal energy, more than any other state.

Geothermal supporters say geothermal energy production will grow in the 1990s despite the fact that geothermal energy production peaked in 1987 and has since declined. Geothermal supporters say at least 400 MW more capacity is planned for the next five years and estimate that geothermal energy could provide 10 percent of the electrical capacity of the western United States by the turn of the century.

Economics of Geothermal Energy

Geothermal power plants can produce electricity as cheaply as some conventional power plants. It costs 4.5 to seven cents per kWh to produce electricity from hydrothermal systems. In comparison, new coal-fired plants produce electricity at about four cents per kWh.

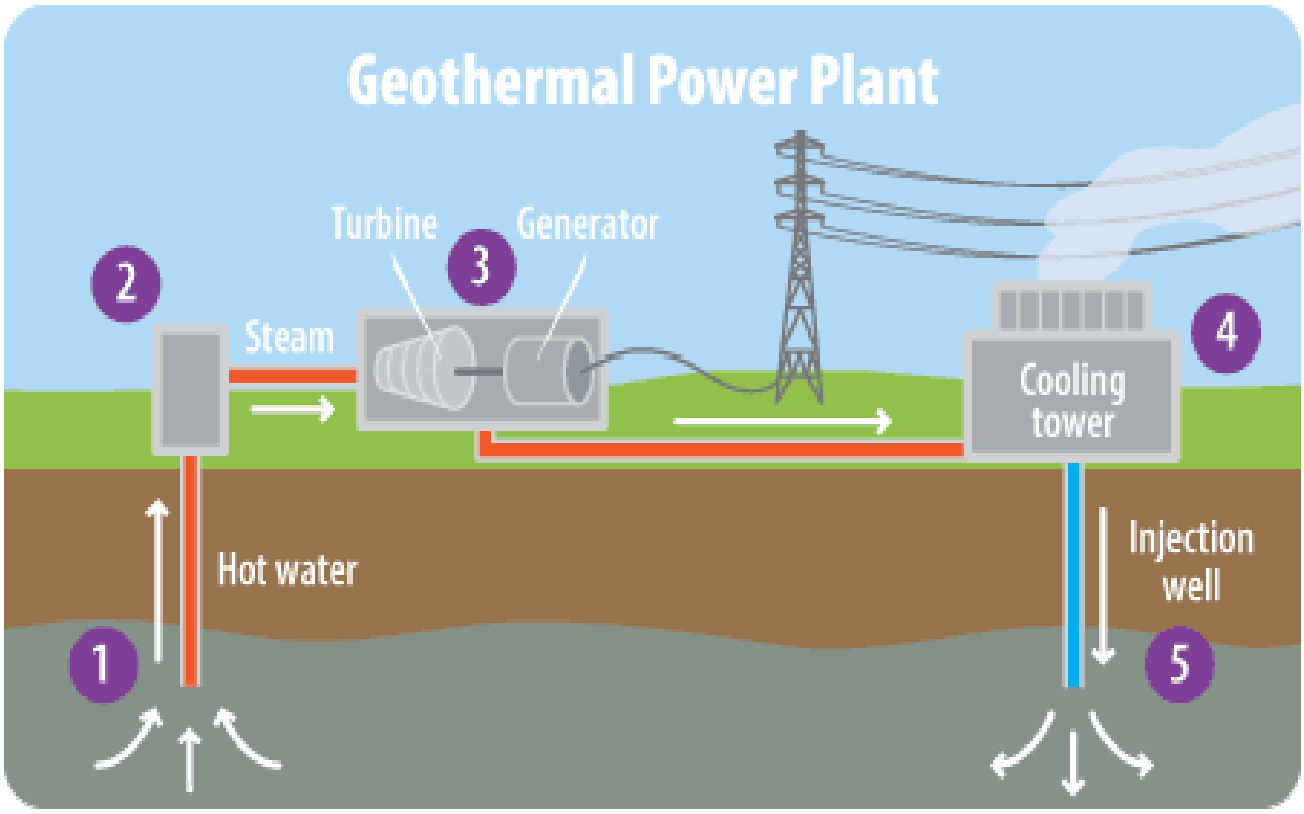
Initial construction costs for geothermal power plants are high because geothermal wells and power plants must be constructed at the same time.

But the cost of producing electricity over time is lower because the price and availability of the fuel is stable and predictable. The fuel does not have to be imported or transported to the power plant. The power plant literally sits on top of its fuel source.

Geothermal power plants are also excellent sources of **base load** power. Base load power is power that electric utility companies must deliver all day long. Base load geothermal plants sell electricity all the time, not only during peak use times when the demand for electricity is high.

Until recently, utilities were required to buy the least-cost electricity, without regard to environmental impacts. Federal and state energy and environmental agencies are studying ways to give preference to nonpolluting energy sources such as geothermal energy.

WORKING OF GEOTHERMAL POWER PLANT



1. **Hot water is pumped from deep underground through a well under high pressure.**
2. **When the water reaches the surface, the pressure is dropped, which causes the water to turn into steam.**
3. **The steam spins a turbine, which is connected to a generator that produces electricity.**
4. **The steam cools off in a cooling tower and condenses back to water.**
5. **The cooled water is pumped back into the Earth to begin the process again.**

GEOTHERMAL ENERGY AND THE ENVIRONMENT

Geothermal energy is a renewable energy source that does little damage to the environment.

Geothermal steam and hot water do contain naturally occurring traces of hydrogen sulfide (a gas that smells like rotten eggs) and other gases and chemicals that can be harmful in high concentrations. Geothermal power plants use "scrubber" systems to clean the air of hydrogen sulfide and the other gases. Sometimes the gases are converted into marketable products, such as liquid fertilizer. Newer geothermal power plants can even inject these gases back into the geothermal wells.

Geothermal power plants do not burn fuels to generate electricity as do fossil fuel plants. Geothermal power plants release less than one to four percent of the amount of carbon dioxide (C02) emitted by coal plants.

Emissions of sulfur compounds from motor vehicles and fossil fuel plants are also major contributors to acid rain. Geothermal power plants, on the other hand, emit only about one to three percent of the sulfur compounds that coal and oil-fired power plants do. Well-designed binary cycle power plants have no emissions at all.

Geothermal power plants are compatible with many environments. They have been built in deserts, in the middle of crops, and in mountain forests.

Geothermal development is often allowed on federal lands because it does not significantly harm the environment. Before permission is granted, however, studies must be made to determine what effect a plant may have on the environment. Geothermal features in national parks, such as the geysers and fumaroles in Yellowstone and Lassen National Parks, are protected by law, so geothermal energy is not tapped in these areas.

BENEFITS OF GEOTHERMAL ENERGY

Renewable: Through proper reservoir management, the rate of energy extraction can be balanced with a reservoir's natural heat recharge rate.

Base load: Geothermal power plants produce electricity consistently, running 24 hours per day / 7 days per week, regardless of weather conditions.

Domestic: U.S. geothermal resources can be harnessed for power production without importing fuel.

Small Footprint: Geothermal power plants are compact; using less land per GWh (404 m2) than coal (3642 m2) wind (1335 m2) or solar PV with center station (3237 m2).*

Clean: Modern closed-loop geothermal power plants emit no greenhouse gasses; life cycle GHG emissions (50 g CO2 eq/kWhe) are four times less than solar PV, and six to 20 times lower than natural gas. Geothermal power plants consume less water on average over the lifetime energy output than the most conventional generation technologies.