Steam Press

THE JOURNAL OF GEOTHERMAL EDUCATION

GEOTHERMAL · EDUCATION · OFFICE ·

SPRING 1995

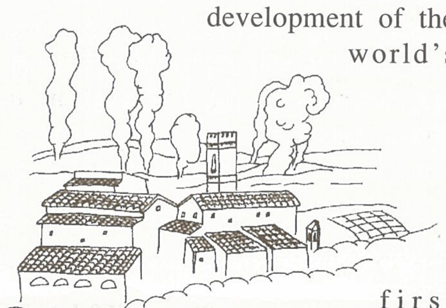
NUMBER 4

Generating with Geothermal

Where it all began…

In the land where Etruscans bathed in natural hot springs almost 3,500 years ago, warm geothermal water has been in use for centuries, treating skin diseases, offering relaxation, heating buildings, producing useful chemicals like borax, and growing plants.

But Italy's greatest geothermal claim to fame is the development of the world's



first geothermally-driven electrical power plant in Larderello. Opened in 1904, the plant was producing 132 megawatts by the 1940s.

Even when the power plants were destroyed in World War II, the geothermal reservoir remained and so the energy source was not lost. Soon the power plants were rebuilt, and today the area produces enough clean geothermal electricity for over a half a million lucky Italians.

This power plant in the Imperial Valley of California is surrounded by productive agricultural land. Because geothermal power plants produce almost no emissions or waste, they can be located in farming or other sensitive areas without affecting the adjacent environment.
Photo courtesy of California Energy Company.

A Sustainable Energy Future

Dream or Reality?

Imagine this. The year is 2030 A.D. Renewable energy sources are supplying over 50% of the United States' energy needs. Total energy use has decreased dramatically from its exorbitant 1990's level. Multi-megawatt windfarms, solar thermal farms and biomass plants dot the landscape. Biofuels and solar-derived hydrogen make many of our cars, trains and buses go. Photovoltaic energy technology is converting sunlight directly into electricity in remote locations. Hydropower continues to provide electricity using such technology as run-of-the-river facilities which don't need huge dams. High-temperature and direct-use geothermal energy are household words; and geothermal heat pumps warm homes everywhere.

Is this a futuristic dreamscape? No, it is part of the sustainable energy forecast of many energy experts who are encouraging major state and federal policy shifts in order to make the above scenario a reality. The concepts of the sustainable energy strategy—combining energy conservation, environmental protection, and the use of "renewable" resources—are becoming integral to plans for wise energy use. In fact, many of these ideas are no longer dreams for the future. They are being put into motion today by leaders who want to see a cleaner, brighter tomorrow.

Electricity… Courtesy of Mother Nature

In the United States, we use lots of watts…of electricity, that is. Much of this electricity is made by burning fossil fuels that are dirty and irreplaceable. Fortunately, there are alternatives. Here are some of the big players in the sustainable energy marketplace.

GEOTHERMAL - From the first power plant in Larderello, Italy, to the state-of-the-art facilities found all over the world today, geothermal plants use natural hot water and steam from the earth to run turbine generators. Technological advances are making this a cost-effective resource. Expect to see its increased use in the near future, especially in the geothermally active western United States, Indonesia, and other "hot spots" around the Pacific.

HYDRO - Turbine electricity generators can do their work without steam by using the force of falling water. For centuries water has been turning water wheels and even water clocks (used 2000 years ago in the great Library of Alexandria). Today, the force of falling water, hydropower, produces more electricity than any other "alternative" resource.

BIOMASS - Electricity can be generated by burning organic wastes as fuel to heat water for steam. The most common form of biomass is wood; however, today's biomass resources also include agricultural and municipal solid wastes and landfill gases.

WIND- The Persians had the right idea. They figured out how to use wind to turn mills to lift water for irrigation in vast windy Persian plains. Since that time, all over the world, windmills have been grinding grain, pumping water, charging batteries and now, since the 1940's, producing electricity.

SOLAR - The brilliant rays of the sun have benefitted our planet for millions of years. As of the 1970s we have perfected methods to concentrate those rays in order to convert them into electricity. At a solar thermal plant, the sun's rays are focused by large mirrors onto a large water tank creating steam for power generation.

Every Breath You Take

The benefits of industrialization are many, but one of the dark sides of the era in which we live is air pollution. Some of the main ingredients of this nasty problem are nitrogen oxides (NOx), carbon monoxide (CO), sulfur oxides (SOx), particulate matter, things called "volatile organic compounds" (VOCs), and ozone (the ground level kind, not the beneficial type which occurs naturally as a protective layer in the upper atmosphere).

These are six of seven government-regulated emissions which are proven health hazards, and some 300 other non-regulated emissions are also known to contribute to health damage.

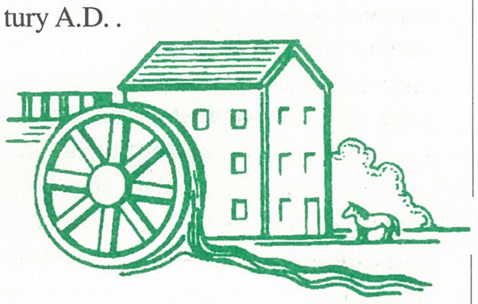
Where are all the toxics coming from? Power plants, factories, and transportation vehicles are the obvious big culprits. But there are other contributors too: wood stoves, fossil fuel-burning furnaces, paints, dry cleaners, and (surprise!) bakeries (due to the fermentation process). It's time we get to work ridding ourselves of these hazardous emissions. A good place to start is by using (whenever we can) energy sources which don't pollute, including geothermal energy.

How Did We Get Into this Mess?

A brief (not definitive) history of power

When prehistoric man began to make and use fire, we began the long road to harnessing the powers of nature. This need to command the use of power eventually accelerated us into the Industrial Revolution, on into the Modern Age and, with a final thrust, into the Technological Revolution. We are now at the point where our use of power has begun to harness us, often resulting in a not-so-healthy way of life — for people and for the planet. How did we ever get into this mess?

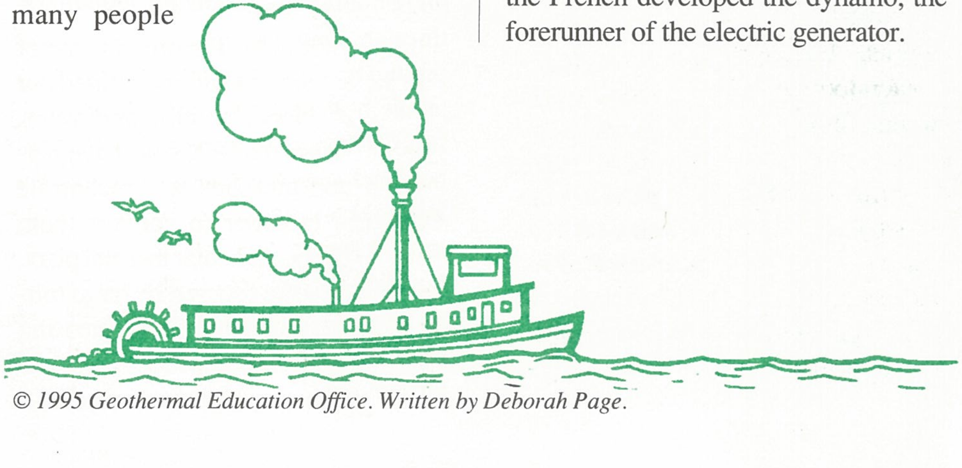
For early man, wood was the mainstay of life, providing fuel, shelter and transportation. Wind, water, the sun and animals were also significant power sources for centuries. As early as the 5th century B.C., Socrates was recommending passive solar homes. Records of water-mill use by both the Greeks and Romans date back to the 1st century B.C., while at the same time the Romans were luxuriating in geothermally-heated and wood-heated baths. Efficient windmills with horizontal sails came into use around 1180 A.D., and blast furnaces, introduced in Holland around 1400 A.D., used wood to generate very hot temperatures for the melting of cast iron. Though the use of coal had been recorded as early as the 1st century A.D., wood, wind, and water dominated the "power market" of Western civilization until the 16th century A.D. .



The Industrial Revolution

By the late 1600's, coal had become the preferred fuel choice for heating in Britain. Then English coal mines flooded and prompted the need for a machine which could pump water out of the way of the miners. In 1698, the first patented steam engine was developed to do just this, paving the way for the development of steam power and ushering in the beginning of the Industrial Revolution.

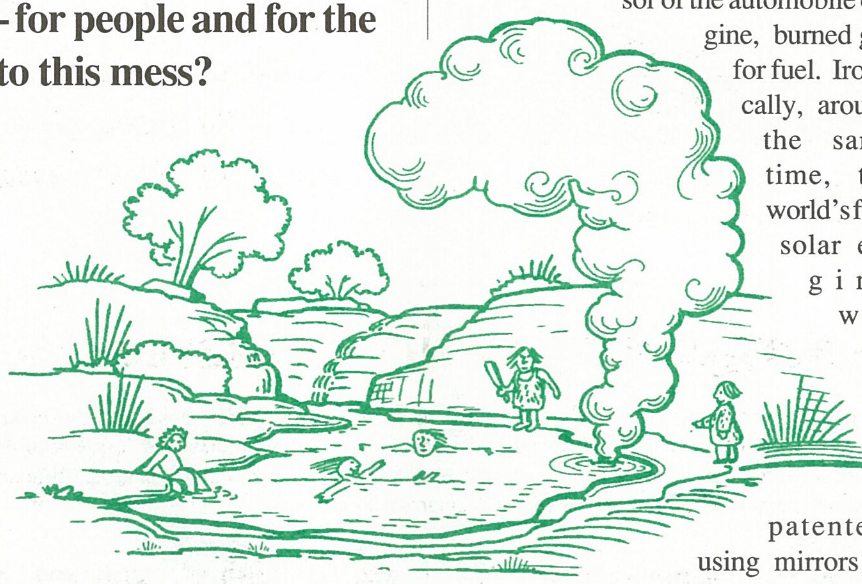
At the same time, textile production was big business in Britain. Machines were soon invented to spin and weave faster and more economically. First driven by water power, they were soon run by steam engines which gobbled ever larger quantities of coal. The miners worked even faster, and many people began to move from the country to live near the factories and the mines. Thus, the first industrial cities were born.



A coal derivative, coke, which burned very hot, was developed, allowing an increase in the production of iron. This meant an increase in the number of machines. In 1712, pistons were added to these steam engines, enabling the engines to work even faster. While Ben Franklin flew his famous kite in 1752 (proving the existence of static electricity), James Watt developed further improvements to steam engines which, by 1782, made them even more efficient and convenient to use. In 1783, the first working paddle wheel steamboat chugged down a French waterway, and by 1792, charcoal was providing gas for lamps which lit the streets of Cornwall. Now goods and people could travel faster, while working and shopping later into the evening.

By 1800, high pressure engines were providing five times the pressure that Watt's engines ever could. In Italy, Allessandro Volta produced the first electricity from a wet-cell battery. By 1821, Englishman Michael Farraday had invented the first electric motor. Electromagnets soon followed, and by 1831 American engineers had produced one which could lift 2,086 pounds! The French by now were running the first practical water turbines, used, of course, to drive machinery. By the end of the 19th century, these would entirely replace water wheels in factories. Meanwhile, the French developed the dynamo, the forerunner of the electric generator.

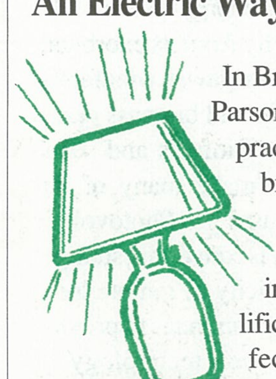
Fossil Fuels Power Progress



The hunger for coal increased as more factories popped up in Britain, Germany, France and the United States. Soon came more inventions to extract and remove coal faster. In 1859, the first oil well was drilled in the United States. The following year, in Belgium, the first internal combustion engine, predecessor of the automobile engine, burned gas for fuel. Ironically, around the same time, the world's first solar engine was patented, using mirrors to focus heat onto a boiler to make steam for steam engines. This and other inventions which used "cleaner" energy sources seemed to be lost in the surge of progress when, a year later in 1862, the French perfected the four-stroke internal combustion engine. Now power could really be made mobile.

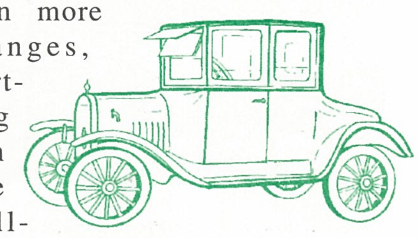
By 1885, the German Karl Benz had produced the first gas-driven, three-wheeled motor car, soon followed by the four-wheeled design of Gottleib Daimler in 1887. Quickly two French designers turned out the first prototype of a modern car, while Michelin, another Frenchman, developed the first tires which contained air. These were much easier to make and use than the original solid rubber tires.

An Electric Way of Life



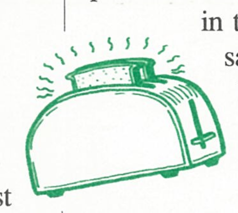
In Britain, Charles Parsons built the first practical steam turbine used for the generation of electricity, while, in 1879, the prolific Tom Edison perfected his electric light bulb. Soon after, Edison designed the first commercial electric generation station, burning coal to produce the steam needed for turbine generators.

In 1897, Parsons installed his steam engine in his boat, *Turbinia*, and outran every ship in the water — even the huge three-masted clippers, the fastest ships in those days. Soon steam-driven ships were dotting the waterways, while on land the taste for "clean," convenient electric lighting was increasing. By 1891 the world's first hydroelectric power stations were built simultaneously — one near Frankfurt, Germany, and the other at Niagara Falls, U.S. At that time, no one could foresee that hydropower would later provide one fourth of the world's electricity.



The turn of the century ushered in even more changes, starting with the drilling of the first offshore oil well off the coast of California. This was soon followed by the first cheap, mass-produced car, the Model T, which rolled off of Henry Ford's production lines in 1908. At the same time, the first geothermal power plant started churning out electricity in Italy, and Einstein published his revolutionary theory that mass can be converted to energy (later important in the discovery of nuclear fission power). The power of wind was soon harnessed for electricity in the 1920s when an electric generator windmill began operating in the U.S., and advanced "egg-beater" windmill designs were tested successfully in France. Cheap oil and gas, however, believed plentiful at this time, continued to dominate the power scene.

Then came the development of nuclear power. Otto Hahn, a German chemist, discovered, in 1939, the process of nuclear fission (releasing energy by splitting uranium atoms). Soon, in 1942, Enrico Fermi, an Italian physicist working in the United States, designed and built the first nuclear fission reactor in Chicago. By 1954, the first nuclear-powered electricity station had opened in the U.S.S.R., while in the same year, Bell Telegraph Laboratories in the U.S. began using solar cells for electric generation. Even so, fossil fuel use still took the lead, and by 1983, three out of every four power plants in the United States burned fossil fuels. At the same time, almost every household either owned a car or used fossil fuel-powered public transportation.



In spite of the development of cleaner alternative energy sources, the United States continues to have a tremendous hunger for fossil fuels—resources that are limited, often purchased from (sometimes unfriendly) foreign countries, and environmentally unsafe.

"Treat the earth well. It was not given to you by your parents. It was lent to you by your children."

African Proverb

Geothermal Solutions

Clean Enough to Bathe: *Icelanders in Grindavik enjoy a salty pond of water given off by the geothermal power plant behind.* *Photo courtesy of Gudmundur E. Sigvaldason, Nordic Volcanological Institute, Reykjavik, Iceland.*

Our earth is a bountiful source of heat.

So much thermal energy exists in the earth that, if we could tap into only 1% of the heat energy found in the earth's uppermost six miles, we would have 500 times the energy contained in all the gas and oil resources of the world.

Geothermal Energy: A Versatile Resource

For centuries humans have enjoyed geothermal energy — in the form of natural hot springs — right up on the earth's surface. Now, with 20th century technology, we can drill wells into the hot and often water-rich rock far below the surface to get geothermal water and steam hot enough to power turbine electricity generators. Geothermal energy has proven to be an impressively versatile resource. This chart shows how and when we can use this natural heat according to: how deep it is; how hot it is; and, whether the rock is dry or filled with lots of steamy water.

	WELL DEPTH				TEMPERATURE				WATER CONTENT			AVAILABILITY	
	Very Shallow 0-50 ft	Shallow 50-1000 ft	Deep 1000 ft-2 mi	Very Deep 2-6 mi	Cool to Warm 40°-70°F	Very Warm 70°-200°F	Hot 200°-350°F	Very Hot 350°-700°F	No Water	Lots of Water	Mostly Steam	Now	In the Future
GEOTHERMAL ELECTRICITY													
• Dry Steam Plant			✓					✓			✓	✓	✓
• Flash Plant			✓					✓		✓		✓	✓
• Binary Plant		✓	✓				✓			✓		✓	✓
• Binary w/ Deep Crustal Heat				✓				✓	✓				✓
GEOTHERMAL DIRECT USE													
• Aquaculture	✓	✓				✓				✓		✓	✓
• Bathing	✓	✓				✓				✓		✓	✓
• Agriculture		✓				✓				✓		✓	✓
• Building and Water Heating		✓	✓			✓	✓			✓	✓	✓	✓
• Industry		✓	✓			✓	✓			✓	✓	✓	✓
GEOTHERMAL HEAT PUMPS	✓	✓			✓				✓	✓		✓	✓

Heat & Water

A Perfect Union

Heat and water. A match made in heaven. Or—in this case—earth.

First, there's the heat. Natural heat generates deep in the earth, where it is actually hot enough to melt rock. This molten rock, called magma, flows up towards the surface of the earth, and—like a giant mobile furnace—heats other nearby rock.

Now comes the water. Seeping far below earth's surface, huge amounts of rainwater can get trapped in porous rock (rock filled with many holes). If the water-filled rock is hot, it becomes a "reservoir" of steamy hot water — "carrier" of earth's internal heat. It might surface as a powerful geyser or an inviting hot spring. Or it might stay right where it is. Then, if a well is drilled into it, up comes the steam and hot water, bringing us clean energy from the earth.

Geothermal Power Plants—

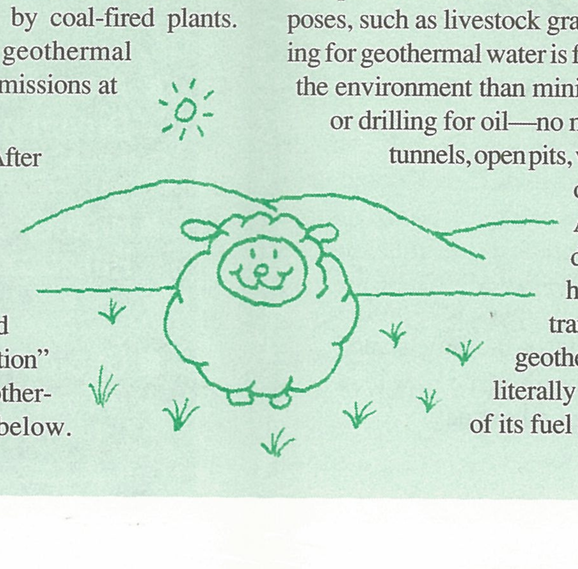
SOFT ON THE ENVIRONMENT

Geothermal power plants provide electricity without pollution.

AIR - Geothermal power plants leave the air clean, because they do not burn fossil fuels. They generate no nitrogen oxides, only a minuscule amount of sulfur, and less than 5% of the carbon dioxide emitted by coal-fired plants. And "binary" geothermal plants have no emissions at all.

WATER - After doing its job in the power plant, cooled geothermal water is safely returned through an "injection" well into the geothermal reservoir below. The geothermal water never mixes with other groundwater.

LAND - Land areas for geothermal plants are smaller, per megawatt, than for other types of power plants. Better still, the land around a geothermal plant can be used for other purposes, such as livestock grazing. Drilling for geothermal water is far easier on the environment than mining for coal or drilling for oil—no mine shafts, tunnels, open pits, waste heaps or oil spills. And fuel does not have to be transported: a geothermal plant literally sits on top of its fuel source.



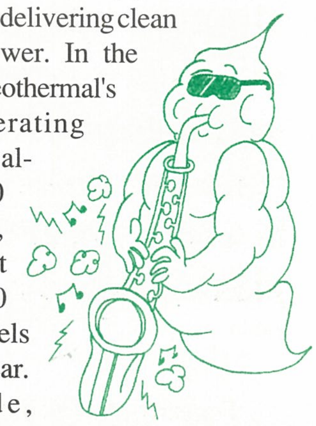
Geothermal Resources have:

Many Uses

Do Watt, Do Watt

GEOTHERMAL ELECTRICITY

Around the world, geothermal resources are delivering clean electrical power. In the U.S. alone, geothermal's power-generating capacity is already 2,800 megawatts, the equivalent of burning 60 million barrels of oil each year. Worldwide, about 6,000 megawatts of electricity are "currently" being generated from geothermal resources in 21 countries. The method used by different geothermal power plants varies—depending on the temperature and other characteristics of its geothermal water or steam—but all geothermal plants use basically the same process: the hot water (usually 250°F - 600°F) and/or steam is brought up to the surface through a well and piped right into the power plant to provide the force that spins the turbine.



Hot Water on Tap

GEOTHERMAL DIRECT USE

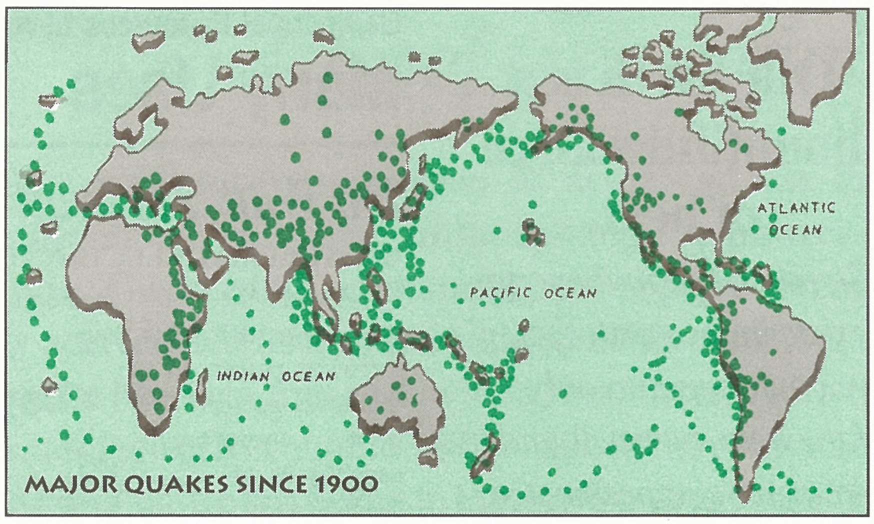
Geothermal water is being used all around the globe, replacing or supplementing the need for conventional energy sources. Ranging in temperature from 70°F to over 200°F, hot water from the earth bathes and soothes humans, helps grow poinsettias and cucumbers in greenhouses while snowdrifts pile up outside, cajoles alligators and fish into growing faster, dries onions and wood, washes wool, and provides space heating the world over. Space heating, both for individual buildings and even for entire districts of buildings, is the most common and oldest direct use besides bathing. Here, geothermal water is run through a heat exchanger to heat clean city water, and then returned to the geothermal reservoir where it heats up to be used again.

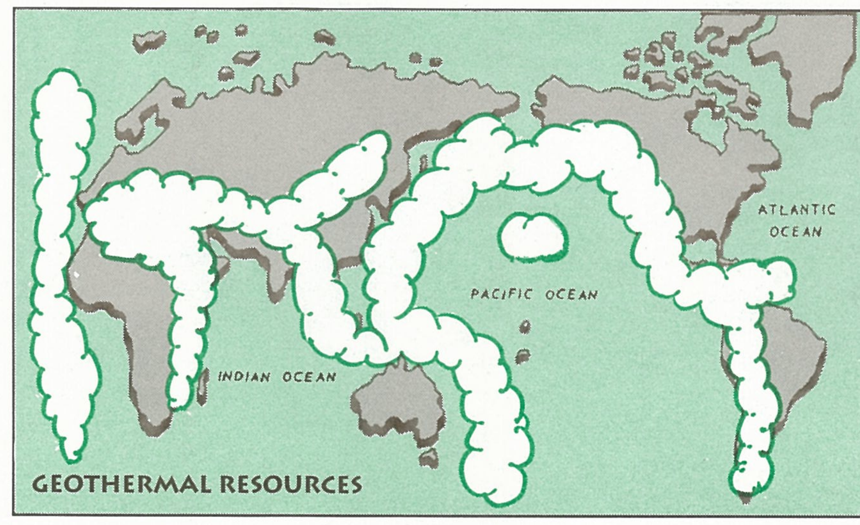
A "Constant" Friend

GEOTHERMAL HEAT PUMPS

Earth heat is used worldwide to warm or cool buildings. In the U.S. alone, the temperature inside over 100,000 homes and offices is kept comfortable by energy-saving **g**eothermal **h**eat **p**umps (GHPs). GHPs rely on the relatively constant temperature of the earth (around 55°F) just a few yards below the surface. GHPs circulate water or other fluid through many lengths of closed-loop piping, buried either horizontally or vertically underground. With the help of a heat exchanger, the fluid "extracts" earth's heat and transfers it into a building during cold weather; and, by switching it into "reverse," it removes heat from a building during hot weather and deposits it into the earth. GHPs use very little electricity and are very easy on the environment.

EARTHQUAKE !!





When the Kobi earthquake hit in January, 1995, it was but one of a series of 24 major quakes (of greater than 6.8 magnitude) that have rocked Japan since the turn of the century. This is not surprising, since Japan rides along on the boundary of two colliding crustal plates within the geologically-active "Ring of Fire." In fact, wherever crustal plates collide - sliding along, pushing over, or shoving under each other - earthquakes (and volcanoes) abound. Despite the destruction wreaked by these often violent forces of nature, there is a positive side to living on the edges of these restless plates: these same areas also have geothermal energy in greatest abundance.

HOT STUFF

Do Try This at Home

PROCEDURES:

- Hold a small mirror (with a handle or tongs for safety) above a lit candle or a kerosene or oil lamp. Soot and condensed water will form on the mirror. The soot is carbon, such as is produced by the burning of fossil fuels.

- Hold a mirror above a source of steam (e.g., teapot, vaporizer.) Only condensed water will form.

DISCUSSION:

- Most electricity is made by burning fuel to boil water, *making* steam to turn turbines. Geothermal steam is a *natural* resource which can turn turbines. Discuss environmental implications of this demonstration in relation to energy sources.

SAFETY TIPS: *Wear a hot mitt. Don't hold the mirror too long over the heat, or it may slip due to moisture. Wash/dry the mirror before/between demonstrations.*

Steam Press
THE GEOTHERMAL JOURNAL

Steam Press is published annually by the Geothermal Education Office, a nonprofit organization partially funded by the U.S.Department of Energy. Contributions are appreciated and deductible to the extent allowed by law. Tax ID#68-0234213. Geothermal Education Office, 664 Hilary Drive, Tiburon, CA 94920, 1-800-866-4GEO.

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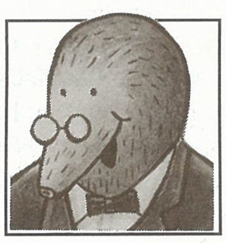
THE HOT SEAT

Ask Arthur



Q. I've heard that we could be using a lot more geothermal energy if we make a greater investment in research and development. Is this true?
J.B., H.S. Junior, Hawaii.

A. Great question! That rumor is right on! Today, electric power from geothermal energy faces stiff competition from cheaper power generated from natural gas. So, one of the main ways to increase geothermal usage is to reduce its cost. The way to cut the cost is to improve the technology. And the way to improve the technology is through research and development (R&D).

You will be pleased to learn that the geothermal industry, in partnership with the U.S. Government, is pursuing R&D to cut the costs of making electric power from hydrothermal (hot water) geothermal reservoirs. Active projects include:

- new methods for exploration to find geothermal resources hidden beneath the ground surface;
- advanced technology for drilling in the hard, hot rock formations that are typical of geothermal reservoirs;
- better ways of managing the production of geothermal fluids to achieve the greatest energy recovery; and,
- engineering improvements for geothermal power plants, so that they can make more power at a lower cost.

Also, there are enormous amounts of geothermal energy stored in rock formations that contain no water ("hot dry rock") and in liquid magma deep within the earth's crust. Scientists and engineers have developed ways to recover this energy, but these ways are not yet cheap enough for use. Further R&D is need to bring down costs, but these unconventional geothermal resources hold a bright promise for the future.

Arthur

G. Arthur Mole

Cover Photo:

Geothermal power plants have a very "gentle touch" when it comes to the environment. A state-of-the-art example is this exceptionally quiet, low-profile (only 24 feet high), 30-megawatt "hybrid" (binary/flash) plant on the "Big Island" of Hawaii. This plant alone produces 19% of the base load needs of the Hawaiian Electric Light Co., replacing 1,000 barrels of imported fuel oil per day.

Photo courtesy of Ormat, Inc..

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