Steam Press

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Everybody's Getting into Hot Water

Geothermal the "Direct" Way

Think for a moment of all the ways hot water makes life better - baths, clean clothes, and hot meals. Did you think of using hot water for growing tomatoes and cucumbers? or even fish? for heating houses or mining gold? Around the world, people living close to geothermal "hot spots" have invented creative ways to put warm water from the earth to "direct use."

As early as ten thousand years ago, Native Americans used hot springs for cooking, for recuperation from warfare and for the stresses of old age. Their Great Spirit lived in sacred hot pools whose warm vapors were The Spirit's breath. A thousand years ago, Turks gathered at geothermally-warmed pools for Turkish baths. Japan also has a long tradition of communal bathing derived from ancient Buddhist cleansing rituals. In Beppu, Japan, **balneology** is the town's main industry. The 4,000 springs and elaborate baths attract 12 million tourists a year. Folks in Beppu also use hot water from the earth to treat arthritic and rheumatic patients, to heat zoo animal houses, to warm greenhouses for flowers and to wash laundry. Baths where Beethoven, Bach, Chopin and Napolean once soaked are still in use in Czechoslovakia, where "curative waters" are so valued that they are legally protected.

An unemployed engineer in Boise, Idaho invented the world's first **district heating** system in 1892. Sending hot water from a central plant, through pipes, to and through residents' homes, the Artesian Hot & Cold Water Company offered geothermal home heating for a flat rate of $2.00 a month, when coal cost $7.00 a month. Parts of Boise are still heated with geothermal water, as are parts of San Bernardino (California), Klamath Falls (Oregon), and a few other areas of the western U.S. The world's largest district heating system is Hitaveita Reykjavikur in Iceland, which provides home heating to 140,000 residences in Reykjavik (57% of the nation). Other Icelandic *hitaveitas* bring this figure to over 80%! Today, as it was one hundred years ago, direct geothermal heating is inexpensive compared to oil, gas, or fossil-fueled electric heat. Modern district heating systems also serve homes in Russia, China, France, Sweden, Hungary and Japan.

With the invention of downhole heat exchangers and ground source heat pumps, people can tap earth's natural heat themselves by drilling wells to extract hot water, or simply heat, to warm or cool both water and building space. One of the oldest heat pumps used for **space heating and cooling** is in the United Illuminating headquarters building in New Haven, Connecticut. Heat pumps typically can save $300 to $800 in annual energy bills, depending on the home size and location.

Heat pulled from geothermal resources is used worldwide to boost **agriculture** production. For hundreds of years, Tuscany in Central Italy has produced out-of-season vegetables from ground heated by natural steam. Today, Tuscany-grown vegetables and flowers are also cultivated in greenhouses warmed by geothermal hot water and steam circulated in small tubes. In Hungary, thermal waters provide 80% of the energy demand of vegetable farmers, and make Hungary the world's geothermal greenhouse leader.

Woman in Beppu, Japan carries a load of washing from a hot spring laundry. (Paul Chesley Photographers/Aspen)

Geothermal **aquaculture** uses natural warm water to speed growth of fish, amphibians and other denizens of the shallows. Direct use of geothermal resources in China is growing so fast that fish farming alone covers almost 2 million square meters. In Japan, aqua farmers use the earth's heat to grow eels and even alligators for dinner. "Geothermal alligators" are also grown in Nevada. Two of the largest U.S. geothermal aquaculture projects are in California and Idaho, where delicious catfish and tilapia swim, grow and multiply. Icelandic aqua-culturists are working with U.S. abalone growers to raise imported abalone in tanks heated by geothermal waters. The Icelanders hope to raise up to two and a half million abalone a year for sale in European markets along with their geothermally-grown salmon.

The use of geothermal heat in **industrial processes** is growing, too. Geothermal waters and gases have been used in Pacific Rim countries for cloth dyeing and fruit drying. The Hawaiian Papaya Products Company uses a geothermal drying chamber to produce papaya powder for sale in health food stores. In Brady Hot Springs, Nevada, a geothermal-driven dehydration plant processes heaps of onions. And in Guatemala new facilities are being developed to use geothermal heat for food drying, where canning is not an option. The Tasman Pulp and Paper Company in New Zealand uses geothermal heat in manufacturing paper. Lumber mills in Japan and Taiwan dry timber products with geothermal steam. In Iceland, high-temperature saturated steam is used to dry diatomaceous earth. And in Nevada, thermal waters are used to "heap leach" gold and silver from ore.

From Australia to Zambia people around the world are living in harmony with the earth's heat, putting it to direct use.

Geothermal Takes First Place!

Exclusive Interview with the Winner

In a recent Power Plant Competition with coal, gas and oil, Geothermal Power was the clean winner. We sent our greenest reporter to find out why:

Steam Press: Congratulations! You must be awfully tired after such a high pressure trip through the turbine.

Geothermal Power: Oh, no... I never get exhausted. In fact, I'm at my best when I'm moving around.

S.P.: How do you feel about your big win?

G.P.: Happy, but not surprised. Frankly, all those Fossil Fuels ever seem to do is muck up the air!

S.P.: How are you any different?

G.P.: Well, as you know, I come right out of the ground - clean and ready for action! Sometimes I take the form of dry steam, sometimes I'm mixed with hot water and other things. But I'm always ready to use my heat to spin a turbine, to heat a building - sometimes even to heat a fish pond. And no one *ever* has to light a match to me!

S.P.: What's lighting a match got to do with this?

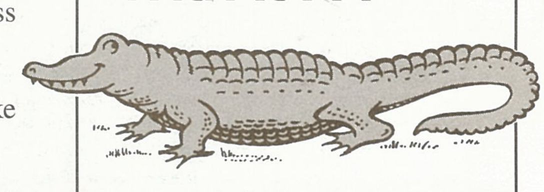
G.P.: Everything! See, I'm already hot. I come from the ground bursting with heat energy. I *am* energy. People can use me just the way I am. No offense, but those Fossil Fuels are *nothing* by themselves - just a bunch of crummy old chemicals. They're nothing unless they're burned. *Burned!*

S.P.: How does burning them make them useful?

G.P.: Simple.... Fossil fuels are burned to boil water which *makes* the steam that powers the turbine that generates the electricity. Can you believe it?! People burn fossil fuels to *manufacture* exactly what *I am already*. And when they are burned, they put all kinds of dangerous pollutants into the air we breathe.

S.P.: Wow! Scary! I can see why you won. Guess I don't need to "strike up" a conversation with those other guys. I'll take your kind of steam anytime!

Folks in Japan Are Growing Alligators With It . . .



. . . people in Sweden heat baths with it, New Zealanders are staying warm with it, and everywhere computers, televisions, lights and refrigerators are powered with electricity from it.

From Iceland to Italy, from Hungary to the Himalayas, hot stuff is happening.

Turn the page for a terrific technical tour . . .

A Global GEOTHERM

1 **Russia.** Several areas of the former Soviet republics are near plate margins. The most intensely active is the subduction boundary at Kamchatka, north of Japan. This is the only place in Russia with geothermal electric power (11 MWe capacity since 1984), but there is much use of geothermal waters for district heating (about 3000 GWh/yr). In many parts of Russia, geothermal heat is used for wool washing, wood drying and paper production. Geothermal water also heats 230 acres of greenhouses and many swimming pools. The water itself is even bottled (in 84 plants) for drinking. In Siberia, geothermal heat is used to thaw out frozen ground. The same plate margin related to volcanic activity in eastern Turkey passes close to **Georgia** which uses medium temperature geothermal waters for bathing and space heating.

2 **Japan.** The best known example of a volcanic country on the Pacific "ring of fire", Japan has been volcanically active over the past 20 million years. The country has cold winters and little heating, so the "hot bath" has been a national ritual from early times, and for this reason *Japan is the world's largest user of direct geothermal heat.* The total use of hot water is enormous, exceeding 8500 GWh in 1990 for bathing, with an additional 1000 GWh used for agriculture and aquaculture (including raising alligators). Although direct use is ancient, electrical generation is recent, with the first production (22 MWe) starting in 1966 with a dry steam plant in Matsukawa. Japanese geothermal development is often restricted by surrounding national parks and spas, so areas available for drilling and the fields themselves tend to be small (40 MWe average). By 1982 seven power plants of 10-55 MWe were operating, and another 55 MWe plant was added in 1990 for a total of 270 MWe. This figure should more than double by 1997 when an additional eight plants will be in operation.

3 **Eastern China.** Eastern China is not close to a plate boundary, but has hot water in sedimentary basins similar to those in northern Europe. In Tianjin and Beijing, more than 400 wells provide hot (50-70°C) water for space heating, cloth dyeing and paper processing. In rural areas hot water is used for greenhouses, drying crops and fish farming (430 acres of fish ponds). Throughout the country hot water is used for bathing and sanitariums. Expansion of geothermal greenhouses in northeast China may soon allow early starts of rice plants and an additional yearly crop. *Direct use geothermal development in Eastern China is doubling every year.* Small geothermal power plants of 50 to 590 kWe capacity (total 1.54 MWe) are in use in 7 eastern China provinces. Nearby **Taiwan** is close to a plate boundary and has a large high-temperature volcanic-geothermal field at Tatun (too acid for development at present), as well as lower-temperature fields at Chingshui (3 MWe flash plant) and at Tuchang (300 kWe binary plant).

4 **Himalayan Geothermal Belt.** The collision of the Indian plate with the Eurasian plate resulted in the Himalayas and *one of the largest geothermal areas in the world.* The Himalayan geothermal belt, over 150 km wide, extends 3000 km through parts of **India, Tibet, Yunnan (China), Myanmar** and **Thailand**. Replete with more than 1,000 hot spring areas, the region gave birth to a myth that *at Manikaran (India) the goddess Parvati lost her earrings and struck the ground in rage, causing hot springs to gush forth, carrying pearly sinter to please the goddess.* Over 150 of these areas are hot enough to generate electricity. Thailand has a binary plant which produces not only 300 kWe (from 117°C water), but also excess heat for crop drying and cold storage. Yangbajang, in Tibet, generates 20 MWe, providing Lhasa with about 40% of its electricity and helping to grow vegetables in this cold, dry region.

5 **The Philippines.** These islands have remarkable geothermal resources. Rapid plate subduction results in active faulting and volcanism - i.e. lots of earthquakes and volcanoes (remember Mt. Pinatubo?). Philippine geothermal fields are large (average 220 MWe) and development is active. Geothermal resources are most developed on Luzon (the population center) and on the island of Leyte. Subsea cables may soon be used to carry power between islands. Geothermal has been on a fast track here. The first plant started as recently as 1979, and electrical capacity is already at 890 MWe with another 260 MWe to be on line by the end of 1994. At this rate *the Philippines may well be number one in geothermal power production early next century.* In the Philippines, geothermal heat is also used directly for fish processing, crop drying and salt production.

6 **Indonesia.** In the Indonesian islands, a great subduction plate boundary between the Eurasian and Australian plates has formed nearly *200 volcanoes and 100 geothermal fields.* Geothermal development started in the 1920's with the first shallow steam wells drilled at Kamojang. This field, which produced 250 kWe in 1979, has been producing 140 MWe from dry steam since 1985. The Dieng field (surrounded by ancient temples) now produces 2 MWe from hot water and will soon expand to 55 MWe. Other fields scheduled to begin production over the next few years are Salak (110 MWe), Darajat (55 MWe), and Lahendong (15 MWe). The development of geothermal energy use in Lahendong is intended to encourage local industry in this remote district. In Indonesia, natural steam and hot water are also used locally for cooking and bathing.

7 **New Zealand.** This small Pacific "ring of fire" country along the southeast subducting boundary of the Pacific plate has many hot-spring areas and several active volcanoes. In the early 1950's, with no oil and little hydropower on the North Island, geothermal development was started at the Wairakei field. By 1960 the power plant was generating 69 MWe of electricity and now produces 157 MWe. Wairakei was the *first large "hot-water" field ever developed.* The Broadlands field produces an additional 116 MWe. Geothermal direct heat is used to dry pulp in a paper mill at Kawerau, which also generates 12 MWe of electricity for use at the plant. Some steam is used at Broadlands to heat a Maori tribal pool and to dry crops, and homes are heated from shallow wells in Rotorua and Taupo. Hot spring waters are widely used for bathing and greenhouses. Total direct use is about 1760 GWh each year. **Australia** uses 29 GWh for swimming pools and district heating; far more is cooled for stock watering. The great Australian aquifer, the major source of agricultural water for inland New South Wales, gets as hot as 75°C. In southern Australia, hot water is also used for wool dyeing.

TEXT KEY

- Electrical generation by geothermal energy (higher temperature)
- Direct use of geothermal hot water (medium and lower temperature)
- Use of ground source heat pumps and down hole heat exchangers
- Lesser use of these resources

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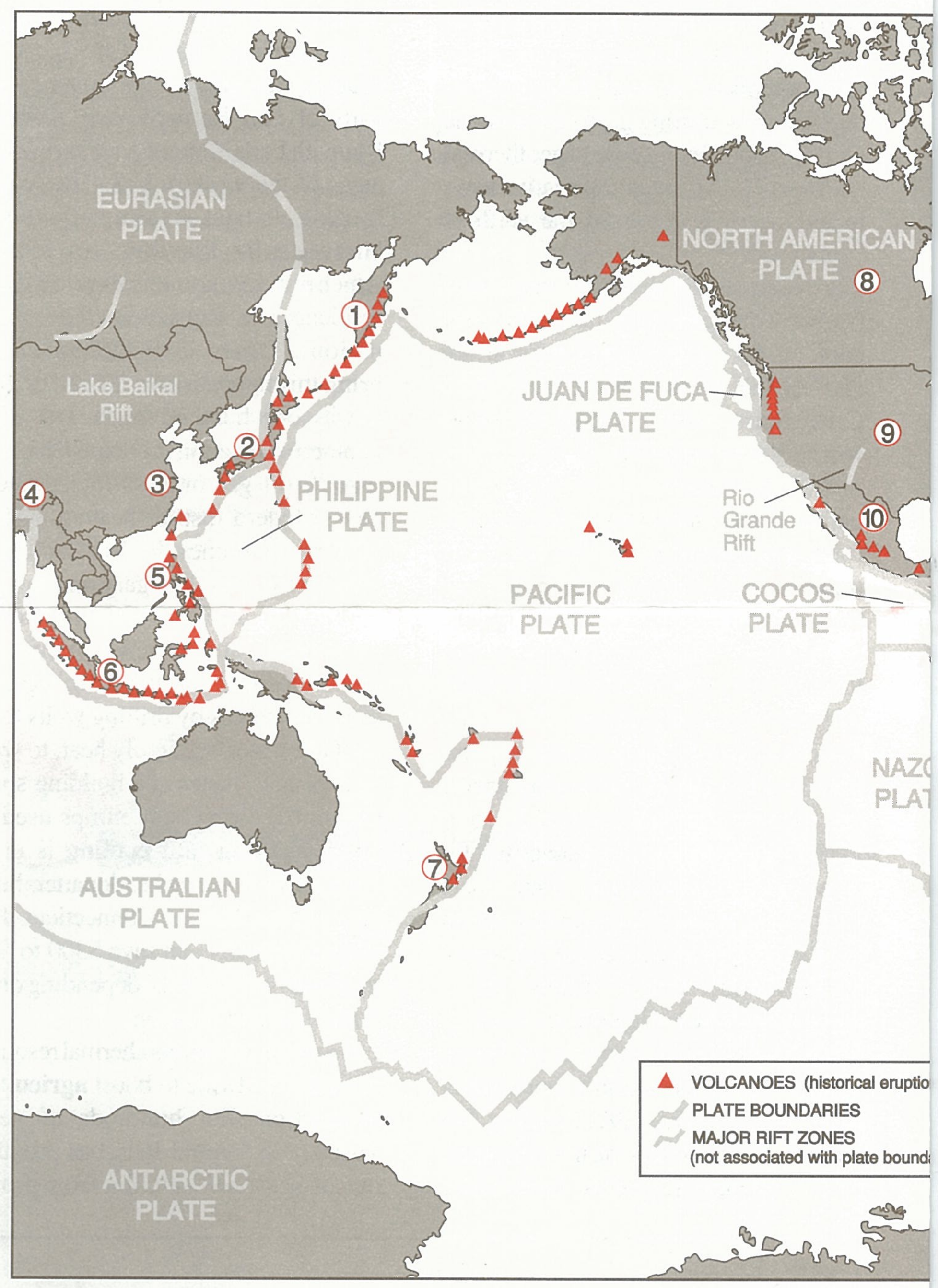
8 **Canada.** Canada shares with the United States part of the subducting plate boundary responsible for the Cascade volcanoes. British Colombia has a 230-260°C geothermal field awaiting development. Over 30,000 eastern Canadian houses use heat pumps with deep vertical heat exchangers. A Novia Scotia coal mine has been flooded to extract 20°C water for heating a plastics plant. Geothermal also warms buildings in the Yukon and Saskatchewan as well as greenhouses in Calgary.

10 **Mexico.** A huge hot-water (280-350°C) geothermal system occurs at Cerro Prieto along an onshore segment of the East Pacific Rise which bounds the North American and Pacific plates. This field now produces 620 MWe from reservoirs up to 4000 m deep. Other geothermal power developments are in the Central Mexico Volcanic Belt at Los Azufres (97 MWe) and Los Humeros (20 MWe with 15 MWe more scheduled). Throughout Mexico there are many hot springs; in fact, one Mexican state is named *Aguascalientes* (hot waters). Direct uses of geothermal heat in Mexico include industrial laundries, refrigeration, district heating, greenhouse heating, production of concrete blocks and timber drying.



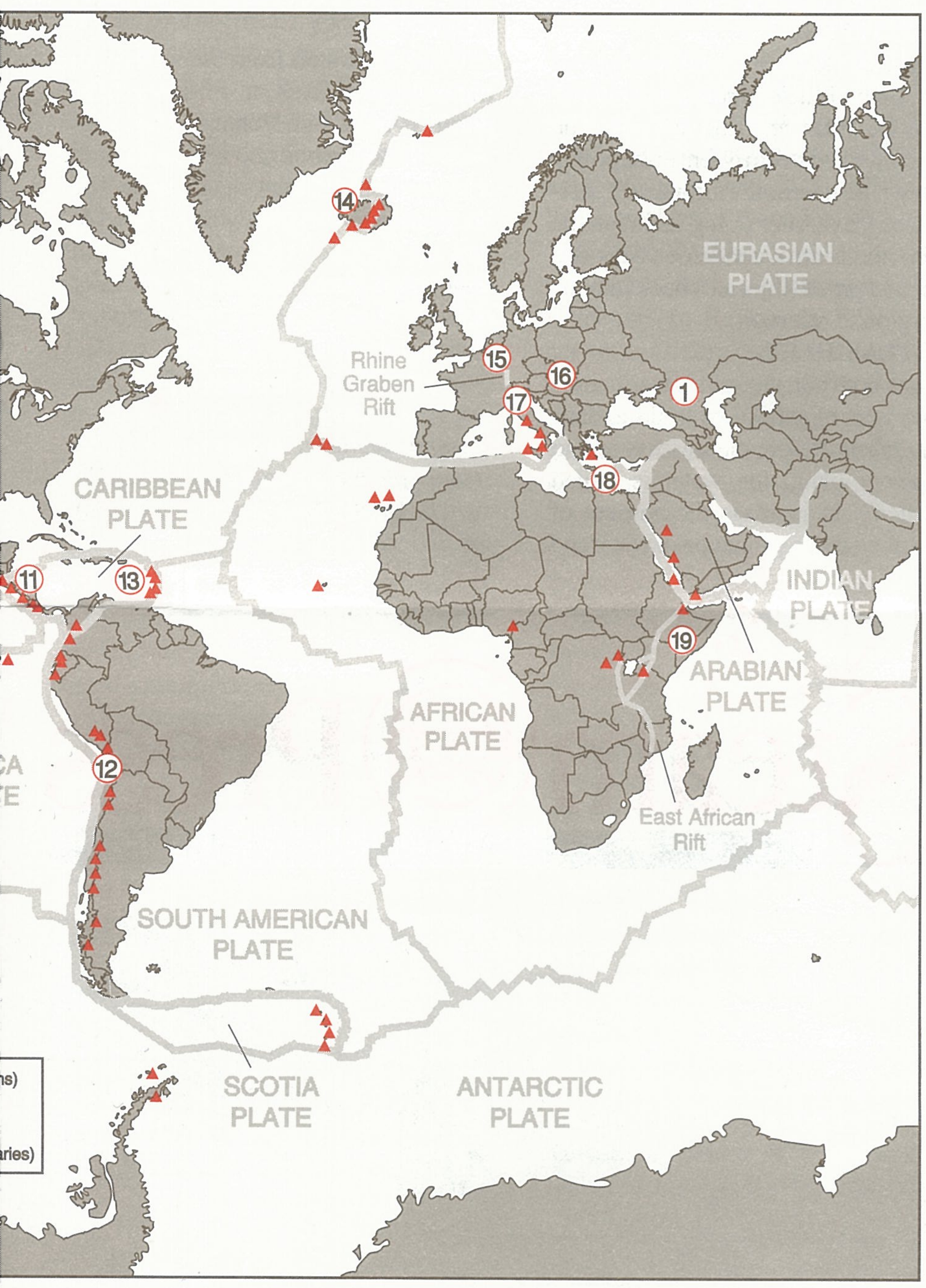
11 **Central American Volcanic Belt.** Central American volcanoes extend along a subducting plate boundary through **Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica** and into **Panama**. This area, replete with active and recently active volcanoes, has many geothermal systems, some still undrilled. Development is most advanced in El Salvador, with a total of 105 MWe at Ahuachapan and Berlin. *This represents more than half of El Salvador's electrical power.* Nicaragua produces about 70 MWe at its Momotombo field. A 55 MWe plant at Miravalles, Costa Rica, will be on line next year; a plant of about 20 MWe is being built at Zunil, Guatemala; and several other areas in Central America are being considered for development.

GLOSSARY

Aquifer - a porous or fractured rock carrying cold or hot water.
Basin or Sedimentary basin - a bowl-shaped depression in the earth filled with sedimentary rocks (rocks usually formed in water such as sandstone, limestone, etc.).
Fault - a break in the earth's crust which extends a considerable distance (horizontally and vertically) along which relative (sliding) movement occurs.
Fumarole - a flow of steam from the ground. Fumaroles can be weak or strong, noisy and superheated (heated above boiling).
Hot spot - a relatively small area of a plate heated by a rising plume of magma from deep within the mantle which produces local volcanic activity over a long time period.
Plate - a rigid part of the earth's crust that moves relative to other plates. The map shows eight major plates and several minor ones.
Plate boundary - where two plates meet. When plates move apart they form a *rift boundary* (e.g. the North American and Eurasian plates). When they move together they can bump to form a *collision boundary* (e.g. the Indian and Eurasian plates) or one can slide under the other to form a

...l View of ...AL ENERGY

⑨ **United States.** On the eastern side of the Pacific "Ring of Fire," the United States has a boundary between the North American and Pacific plates. This boundary is "sliding" along the San Andreas fault (lots of earthquakes but few volcanoes) from the Gulf of California up to northern Calfiornia, and subducting from below the Cascade volcanoes north through the Aleutians. There are also volcanic hot spots under Yellowstone and Hawaii and intra-plate extension with hot springs in the Great Basin. California generates the most geothermal electricity with 1650 MWe capacity at the Geysers, 375 MWe in the Imperial Valley, 240 MWe at Coso Hot Springs, and 46 MWe at smaller (2-32 MWe) plants throughout the state. There are also several power plants in Nevada (165 MWe total) and Utah (35 MWe), and a 25 MWe plant in Hawaii. Direct use of geothermal energy has skyrocketed (to 1420 GWh in 1990) due to environmental advantages and low capital and operating costs. In the western United States, hundreds of buildings are heated by downhole heat exchangers (Klamath Falls, Oregon) and district heating (Boise, Idaho; San Bernardino, California and elsewhere). Large greenhouse and aquaculture facilities in Arizona, New Mexico, Utah and Idaho use low-temperature geothermal waters. In the United States, more than 100,000 ground source heat pumps are being used for heating and cooling.



⑫ **Andean Volcanic Belt.** The Andes run the length of the west coast of South America from western **Venezuela** through **Colombia, Ecuador, Peru, Bolivia, Chile** and **Argentina**. The subduction of the Nazca plate under the South American plate has produced many active and recently-active volcanoes. Several high-temperature geothermal systems occur in these sparsely populated areas, but since electrical demand is low, they are not developed. The first major United Nations geothermal project (1965) was El Tatio, Chile, which could provide all of the energy needed (about 30 MWe) to run the great copper mine at Chaquicamata, 100 Km to the west. There is a 670 kWe electric power plant at Copahue, Argentina, and some geothermal waters are used for bathing and district heating.

subduction boundary (e.g. the Nazca and South American plates). Sometimes plates just slide past each other along a *fault boundary* (e.g. the San Andreas fault between the North American and Pacific Plates). Some boundaries (e.g. through Siberia) are poorly defined.
Rift - a part of the crust that has been pulled apart, usually bordered by faults. A **rift zone** is a rift with bordering faults. When rifting occurs, magma can move near the surface forming volcanoes and geothermal systems. Rift zones may become plate boundries.
Sinter - a white or gray surface deposit from a hot spring or geyser consisting of silica (SiO_2). Travertine is a similar deposit consisting of carbonate (usually $CaCO_3$).

ENERGY UNITS
GWh - gigawatt hour thermal. A unit of heat energy for non-electrical uses equal to 1000 megawatt hours (MWh). A GWh can heat 860 thousand tons of water one degree centigrade (or bring about 9 million quarts of freezing water to a boil).
MWe - megawatt electrical. A unit of electrical power equal to 1000 kilowatts (kWe) - enough (in the U.S) for about 1000 people.

⑬ **The Caribbean.** The Lesser Antilles islands in the eastern Caribbean are associated with a small subducting plate boundary and have some active volcanoes and fumarole fields. Exploration on **Guadeloupe** began in 1969, and drilling of shallow high temperature wells has resulted in a 4.2 MWe double flash plant (on line since 1984). Exploration has also been encouraging on **Dominica, Monserrat** and **St. Lucia**, but electricity is not yet being produced.

⑭ **Iceland and other Atlantic Islands.** Iceland is a volcanic island on the Mid-Atlantic Ridge rift zone. From the earliest settlement (ninth century) crops were planted in naturally-heated ground for rapid growth and early harvest. Iceland has many high and low temperature geothermal systems. If hydropower were not so abundant, geothermal electrical production would be far greater. Even so, geothermal energy is Iceland's second largest source of energy, with more than 4,290 GWh used each year for heating, bathing, greenhouses, fish farming and industry, along with 50 MWe of electrical generation. Reykjavic, the capital, with more than 100,000 people, pipes hot water to every house at a cost less than cold water. In the 1980's Iceland decreased its dependence on imported oil by increasing heating with geothermal. *The connection between volcanoes and geothermal is so close in Iceland that hot magma once erupted through a geothermal well.* The **Azores**, just off the Mid-Atlantic Ridge, have volcanoes, hot springs and a 3 MWe power plant. Further drilling and development is underway on San Miguel to provide 40% of its electricity needs. Geothermal hot springs and fumaroles are also found on the **Canary Islands.**

⑮ **Northern Europe.** In **France** hot water (886 GWh/yr) is used in the Paris and Aquitaine sedimentary basins (from wells up to 1600 m deep and 45-85°C) to heat 148,000 homes. Similar basins are found in **Belgium** (24.5 GWh/yr), **Germany** (21 GWh/yr), **Denmark** (8 GWh/yr), the **Netherlands** and **England** where heating systems like those in France are being tested. Researchers have experimented with Hot Dry Rock projects in England, France and Germany to see if water pumped into hot dry rocks can be heated economically. Heat pumps are used now to extract largely geothermal heat from (5 to 10° C) groundwater in **Sweden** (200,000 houses), **Switzerland** (4000 houses), and other northern European countries. Parts of Switzerland, Germany, France and **Austria** have alpine geothermal spas like those in Eastern Europe.

⑯ **Eastern Europe.** Warm water (to 80°C) from deep (500-2000 m) wells in sedimentary basins is used in **Hungary** (3354 GWh/yr), **Rumania** (987 GWh/yr), **Bulgaria** (770 GWh/yr), the former **Yugoslavia** (602 GWh/yr) and **Slovakia** (276 GWh/yr), mostly for swimming pools and greenhouses. Medium-temperature geothermal aquifers exist beneath almost all of Hungary, so wells can usually be located wherever heat is needed: for bathing (45%), greenhouses (42%), industry (10%) and space heating (3%). Large amounts are also cooled for drinking. In southwest Hungary, where thermal aquifers are the deepest and hottest (to 140°C), more than 80% of all greenhouses are heated by geothermal waters. In **Poland** and the **Czech Republic**, hot water rich in mineral salts from crystalline rocks is used for bathing and as medicine. *The famous Czech thermal spas of Carlsbad and Marienbad have been popular for 500 years.*

⑰ **Italy.** Volcanoes and geothermal fields in central Italy are related to a poorly-understood microplate connected to the African-Eurasian plate boundary. In 1904, the Larderello field in Tuscany - known from Etruscan times for its geothermal baths and, later, for the production from condensed steam of boric acid antiseptic - produced the *world's first geothermal electricity.* Major production at Larderello began in the 1930's and by 1970 power capacity reached 350 MWe. Since the 80's, there has been more drilling and increased power production, bringing Italy up to a total of 637 MWe. The Roman legions built 57 Roman baths using natural hot water throughout their empire (which extended from North Africa to Northern England and from Spain to Turkey). They heated these buildings using hot vapor carried through hollow tiles from the thermal springs - not the first, but undoubtedly the best-organized early use of direct geothermal heating. Modern direct use projects are expanding, with district heating at Vicenza, San Donato, Larderello, and Cesano. At Castelnuovo, greenhouses and district heating use water heated by low-pressure steam; at Monte Amiata, waste heat from a geothermal plant warms a large greenhouse complex. *The fumaroles at the Campi Flegrei near Naples are said to have been so impressive they became the model for Dante's Inferno.*

⑱ **Eastern** and **Southern Mediterranean.** A complex plate boundary crosses **Turkey** and **Greece** where several high-temperature geothermal prospects have been found. Since 1984, the Kizildere field in western Turkey has produced 20 MWe. A dry ice plant was built in the late 80's. The plant makes dry ice using CO_2 from geothermal wells, supplying a large part of the Near East market. Lower temperature hot water (625 GWh/yr) is used for greenhouses and heating at Izmir, and more geothermal facilities are planned for other locations. On the Greek island of Milos an experimental 2 MWe flash plant was operated for several years. In **Israel** and **Jordan**, at the Red Sea - Jordan Valley Rift (between the African and Arabian plates), many hot springs (to 102°C) are used for bathing. Geothermal hot water is used in **Tunisia** (400 GWh/yr) and **Algeria** (117 GWh/yr) for bathing, greenhouses, drinking and watering crops.

⑲ **East Africa Rift System.** The active East African rift (an incipient plate boundary) runs through **Zambia, Malawi, Tanzania, Uganda, Kenya, Ethiopia** and **Djibouti** and touches six other countries. Active volcanoes occur in Kenya, Ethiopia and Tanzania. An experimental 200 kWe electrical generator operates in Zambia, and in Kenya there is a 45 MWe geothermal power plant at Olkaria. Intensive exploration is under way in Kenya to increase electricity production to keep pace with population growth. In dry parts of Ethiopia, some nomadic tribes condense steam from fumaroles to water sheep and goats.

Contributors: Research and text by Alfred Truesdell. Concept and additional text by Marilyn Nemzer (Geothermal Education Office). Base map by Ellen Lougee (U.S. Geological Survey) using plate boundaries from Charles DeMets (U.Wisc.). Locations of volcanoes with historical eruptions by Robert Tilling (USGS). Most energy production figures (MWe and GWh/yr) from articles by G.W. Huttrer and D.H. Freeston in the Geothermal Resources Council (GRC) Bulletin for July/August 1990. Further information from U.N. Conferences on Geothermal Energy in Rome 1961, Pisa 1970, and San Francisco 1975, and GRC international meetings in Hawaii in 1985 and 1990. Good advice and reviews by Patrick Muffler (USGS), Marcelo Lippmann (LBL), and numerous readers of the first printing. Graphic art by Tara Eglin.

HOT DRY ROCK

Everywhere in the world there's lots of hot rock very deep down in the Earth's crust. Most of it is more than ten miles deep, but in some places it's close enough to the surface for water to trickle down, get all steamed up and create hot underground reservoirs and geothermal systems with hot springs, fumaroles and geysers. We take heat from this *hot wet (hydrothermal)* rock to make electricity and to heat all sorts of things.

But most of the hot rock doesn't have water trickling through it. Most is Hot *Dry* Rock (nickname HDR), the scientific name for this kind of geothermal resource. Scientists from the U.S. Department of Energy - along with researchers from Japan, England, France and Germany - have found a way to *add* the water. In areas where the hot dry rock isn't *too* deep (up to three and a half miles), engineers drill two parallel wells about 10 inches in diameter. Then they pump water, under pressure, through one of the wells. This pressurized water opens up natural cracks, or *fractures*, in the rock at the base of the two wells to connect them up. After the rock fractures have been opened, the engineers run cool water down one of the wells to the hot dry rock.

You can guess what happens next! The cool water runs through the large cracks in the hot dry rock and - *voila!* The water gets hot! *Muy caliente! Molto caldo! Totemo atsui! The Hot Dry Rock system creates (with a little help) its own hydrothermal resource!*

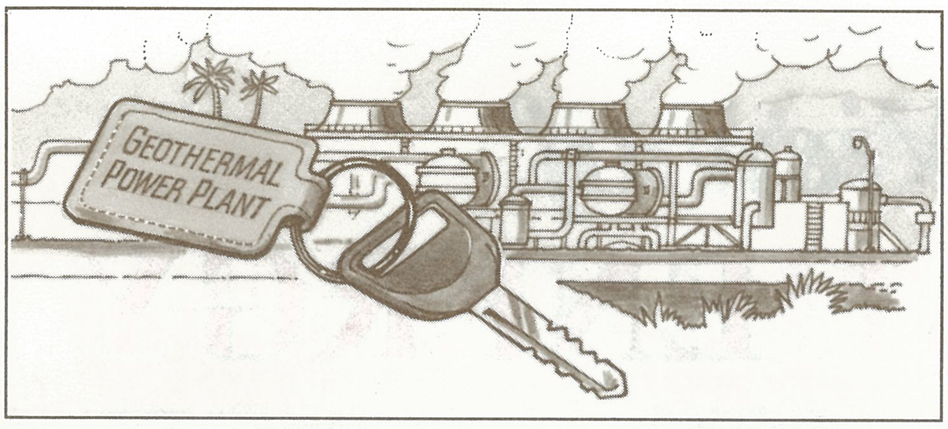
Then, of course, the hot water (up to 300°C) comes up the second well, providing the precious clean energy that will be needed to turn the turbines in the power plant above. One of the best parts about Hot Dry Rock technology is that when the heated water has done its job at the surface, it is sent right back down through the well to the hot dry rock underground. And around and around it goes!

In future years, drilling technology will improve, allowing us to drill deeper and deeper, making geothermal energy from hot dry rock potentially available everywhere!

In geothermal energy circles, being "all wet" is a real advantage.

Did You Know?

Did you know that today geothermal energy produces 7.5 times more electricity than solar energy and 13 times more than wind energy?



Test Drive Some Power Plants

Dry Steam, Flashed Water or Binary?

You wouldn't try to use a Stock Car Race to feature your Ferrari or the Grand Prix to show off your Chevy. It's the same with geothermal. We have to suit the power plant to what comes up the pipe.

THE HOTTEST

When only hot steam whooshes up our wells, we build a ***dry steam power plant.*** This is the oldest and simplest way. The hot, pressurized steam is sent to the power plant, where it turns the turbine to generate electricity. After doing its job in the turbine, the steam is condensed back into water and piped (injected) back into the underground reservoir.

THE FLASHIEST

When both hot water and steam come up the well together, we build a ***flash power plant.*** Before the steam is sent to the power plant, the water is boiled ("flashed") to increase the amount of steam; then the combination of water and steam is "whirled" to separate them. The hot water is sent back underground through the injection well, and the pressurized steam moves on to turn the turbine - just as it does in the dry steam plant.

THE COOLEST

When the water from the well is not hot enough to flash, a ***binary power plant*** is built. In a "binary" plant, hot water is used to boil another liquid with a lower boiling point than water. The liquid turns into a gas, which is used to turn the turbine. The gas, cooled and condensed back to a liquid, is later reused. Here, it isn't underground steam that powers the turbine, but geothermal water lends its heat to help get the job done.

So rev up the turbine and pour on the steam, spin the generator and throw the switch. Geothermal power plants stay put, but they're going places!

The HOT SEAT

(Ask Arthur)

Dear Arthur,

You're always talking about magma. So what is it, where does it come from, why is it hot, and where can I go to see some?

Sincerely,

Amanda N., San Francisco, California

Dear Amanda,

Wow! Well, first, magma is melted rock. It's made within the mantle - the layer of rock that lies just beneath the earth's crust. That means it comes from 60 to 200 miles down. The rock keeps melting because it's so hot down there.

And it stays hot! Sounds unbelieveable but it's true. The heat inside the earth is always being *regenerated* by breakdown of radioactive elements. So the rock stays melted. (Earth's heat will always be around. That's why geothermal energy is a renewable energy source.)

You have seen hot magma if you have seen a volcano erupt (maybe on TV). Lava is really the magma which is breaking right through the earth's crust. (The "Ring of Fire" article in the 1990 *Steam Press* tells all about it).

Arthur

G. Arthur Mole

P.S. Send your questions to me c/o the Geothermal Education Office, 664 Hilary Drive, Tiburon, CA 94920. And by the way, have you heard about my video on geothermal energy? It's called "An Underground Adventure." I think you'd like it. Get yours for only $19.95 from the Geothermal Education Office (1-800-866-4GEO).

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