France & Geothermal, 1334 to 2011

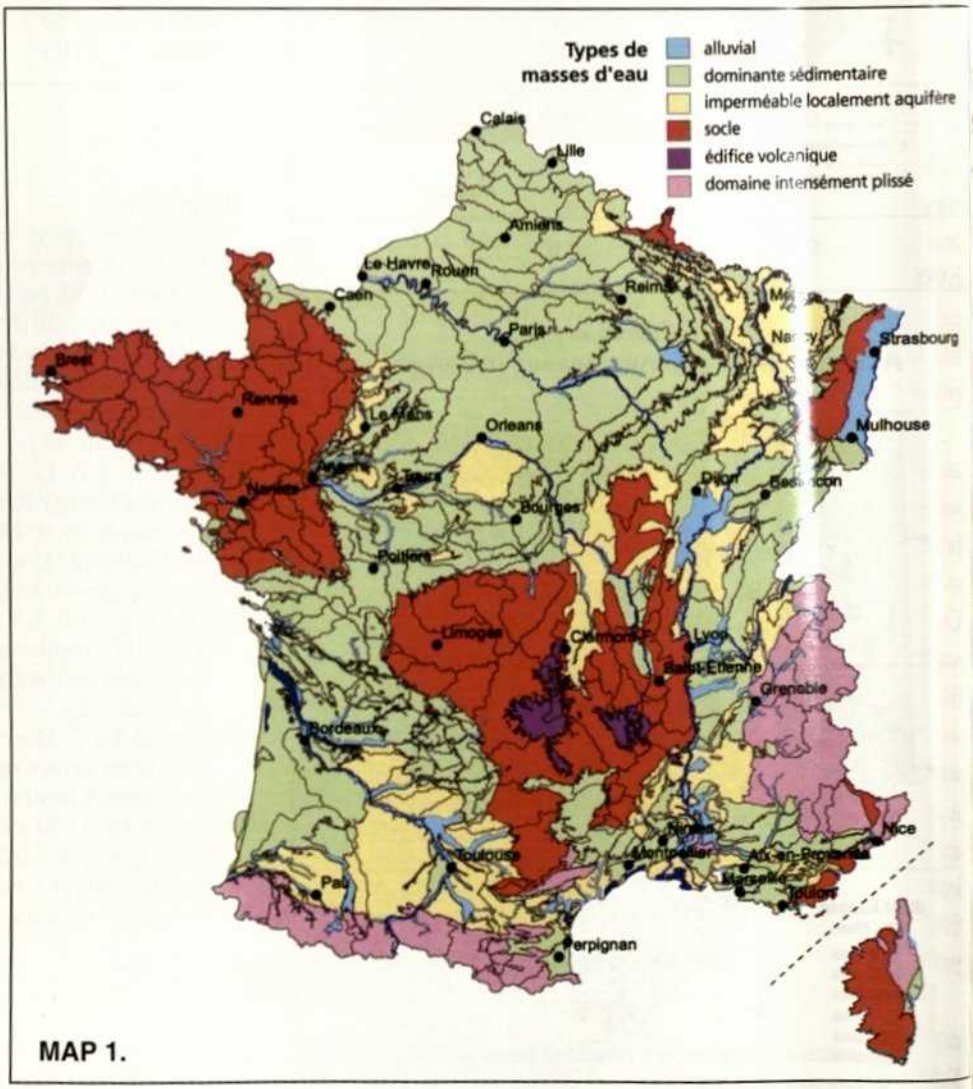
by Susan Fox Hodgson

Geology and Geothermal Projects

Sitting in his third floor office, Romain Vernier, director of the Geothermal Department for the French geological survey, known as BRGM, was framed by windows overlooking the lawn and trees surrounding a complex of governmental buildings outside of Orleans. We discussed the survey's goals. "BRGM," he said, "has a three-fold mission. It undertakes geothermal scientific-and-technological research and development projects; it advises French public services on geothermal policy and rules; and it undertakes international activities. A BRGM subsidiary, CFG Services, is more business oriented. It is an engineering company specializing in geothermal energy, with expertise in exploration, drilling, production, maintenance, corrosion, and the chemical treatment of fluids."

The geothermal resources of France extend throughout the country (map one). "French

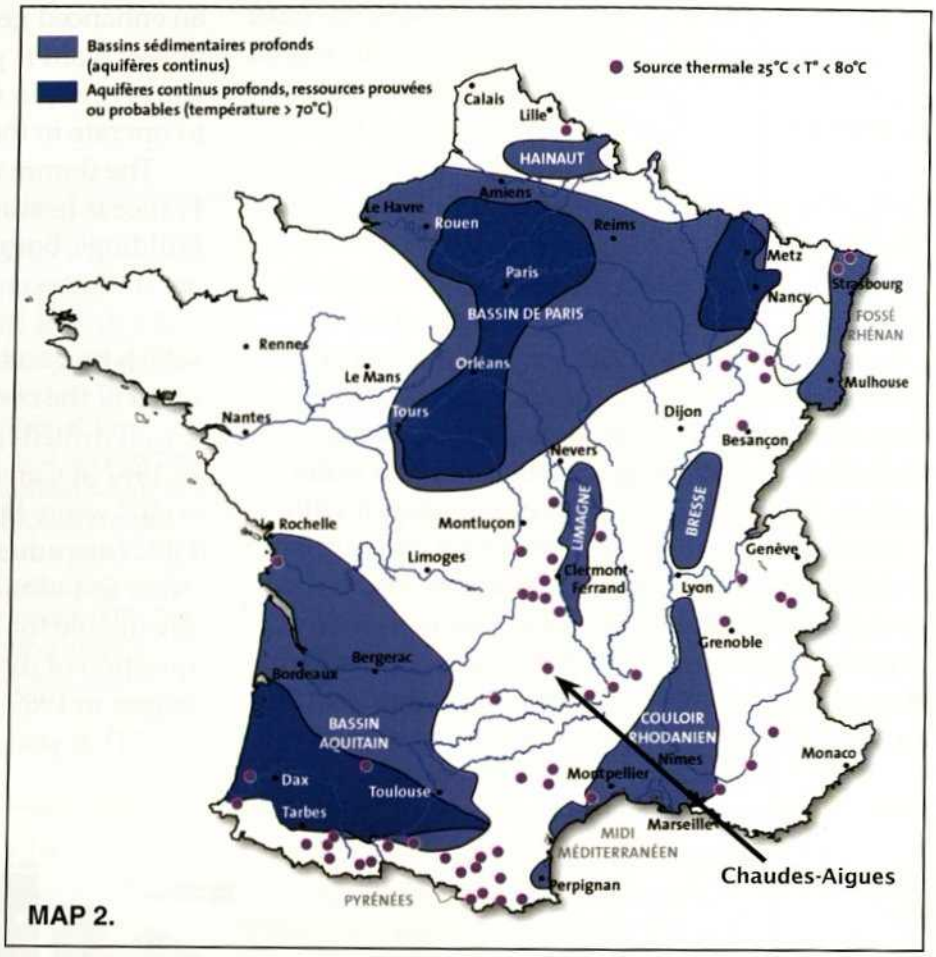
The offices in Orleans of BRGM, the French geological survey. PHOTO BY S. HODGSON.



MAP 1.

Principal reservoirs of underground waters beneath France. The island in the bottom right-hand corner is Corsica. Six main-reservoir types are identified in the legend and most of the words have English cognates. Socle *means "basement" and* plissé, *"folded."* REPRINTED WITH PERMISSION. FROM: *"LA GÉOTHERMIE, QUELLES TECHNOLOGIES POUR QUELS USAGES?"* © BRGM-IM@GE.

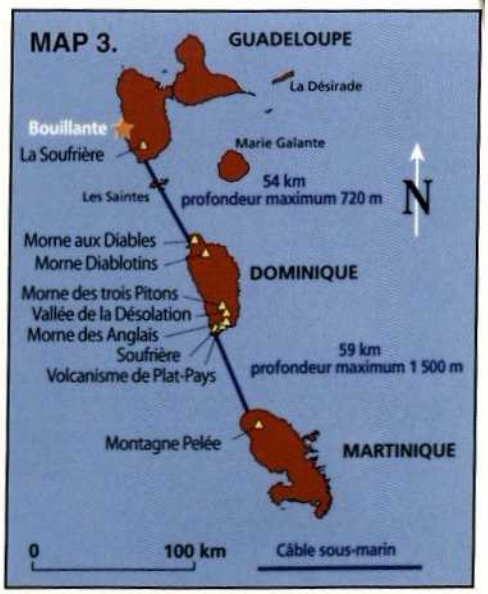
geothermal resources are mainly low-enthalpy from several hot-water aquifers with temperatures above 50 °C in the country's two major sedimentary basins: the Paris Basin including Paris and Orleans, and the Aquitaine Basin to the southwest (map two)," wrote Philippe Laplaige[3].* "A low-enthalpy geothermal potential exists in other regions, but there the geological conditions are more complex and the resources more localized. French metropolitan regions also contain many shallow aquifers suitable for heat pumps." Dr. Laplaige was referring to large-scale, geothermal space heating and cooling projects, but private households have installed geothermal heat pumps, as well. In total, around 20,000 heat pumps were sold in France in 2008 for private households.



The deep-geothermal resources beneath France. REPRINTED WITH PERMISSION. FROM: *"LA GÉOTHERMIE, QUELLES TECHNOLOGIES POUR QUELS USAGES?"* © BRGM-IM@GE.

There are many other ways low-enthalpy geothermal waters are used, mostly in the south of France. Sometimes the geothermal waters are used directly and more often they flow through a heat exchanger, heating other waters—as in the case of some swimming pools. Both types of swimming pools are in Chaudes-Aigues, a town in central France (map two). Geothermal waters are used to heat greenhouses and subsoil; crustaceans and fish—including sturgeon raised for caviar—live in geothermal waters, their growth stimulated by the heat. Geothermal waters are used to clean wool (since ancient days in Chaudes-Aigues[2]), dry industrial products and foods, recover tannins, and make *papier-mâché*. They are mined for minerals, like salt, iodine, bromine, boric acid, and lithium. Health and beauty spas throughout France incorporate hot spring waters and minerals in their services—traditions from long ago.

"High-enthalpy resources exist in France's three overseas departments," Laplaige continued, "on Guadeloupe and Martinique, two Caribbean islands (map three), and probably



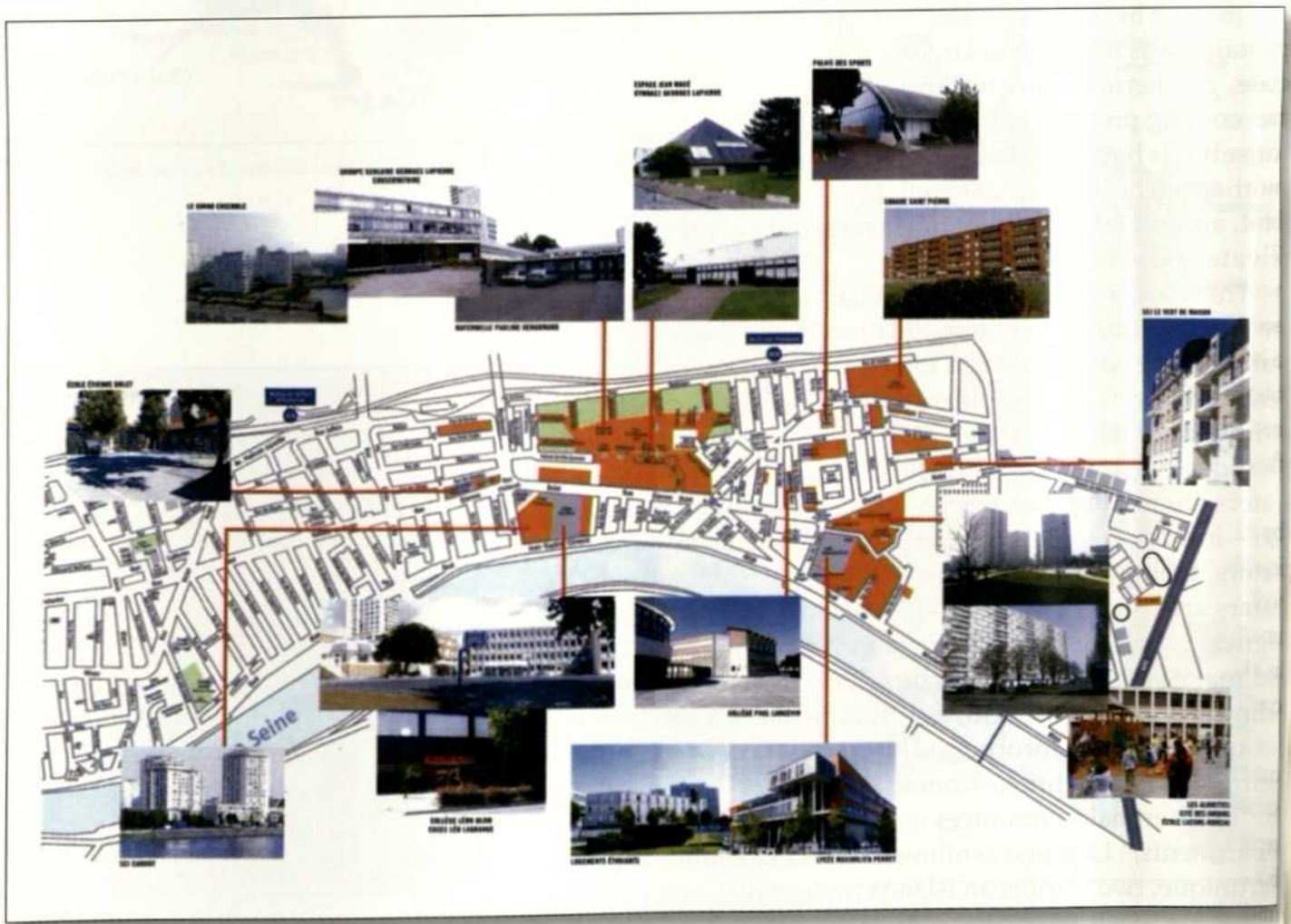
The location of the Island of Guadeloupe in the Caribbean Sea. REPRINTED WITH PERMISSION. FROM: *"LA GÉOTHERMIE, QUELLES TECHNOLOGIES POUR QUELS USAGES?"* © ADEME-BRGM.

*Superior figures refer to entries in the list of references at the end of this article.

on La Reunion in the Indian Ocean, near Madagascar." On Guadeloupe the resources generate electricity at a geothermal power plant called Bouillante Guadeloupe, operated by Geothermie Bouillante, a subsidiary of BRGM and Electricite de France (*see* cover). The two-unit plant (one a double flash and one a single flash) has a condensing turbine and a sea water-cooled, direct-contact condenser equipped with a barometer pipe. The total-installed capacity is 15 MWe, 9% of the island's electricity. Plans exist to drill exploratory wells for an extension of the Bouillante plant in the northern part of Bouillante Bay, with the goal of an additional capacity of 20 to 30 MWe, wrote Fabrice Boissier[1]. In addition, an enhanced geothermal system, pilot geothermal-power plant is generating 1.5 MWe, net, in Soultz-sous-Forêts, in eastern France—the first such plant to operate in the world.

The dominant use of geothermal waters in France is heating and (sometimes) cooling large buildings, both public and private. The projects are undertaken with hot waters extracted from wells drilled into the basins noted on map two, which by good fortune underlie the most populous areas of the country. Such projects all began with a well drilled in the Paris Basin *(Bassin de Paris)* in 1962 at Carrières-sur-Seine west of Paris. "The well," wrote Dr. Pierre Ungemach, Chairman of GPC Instrumentation Process, a French company, "was abandoned due to highly mineralized brine unsuitable for disposal in a surface stream[4]." The question of disposal was solved in the next attempt begun in 1969.

"That year," Dr. Ungemach continued, "a



Some geothermally heated buildings in the city of Sucy-en-Brie, 18 km from Paris. REPRINTED WITH PERMISSION. FROM: "*LA GÉOTHERMIE, QUELLES TECHNOLOGIES POUR QUELS USAGES?*" © VILLE DE SUCY-EN-BRIE.

Paris-Orly Airport

In December 2010, the new geothermal heating system at the Paris-Orly Airport began operating with 74 °C waters extracted from the Dogger reservoir. The hot water flowing up the wells goes to a titanium heat exchanger at the surface where the heat is extracted and transferred to the airport hot-water circuit. The cooled water is returned to the Dogger. By 2020, the geothermal system, coupled with the Rungis waste incinerator, will supply almost half of the airport's heating water and almost half of the heating water needed for the future Coeur d'Orly business park at the airport. A clever website animation shows project details. Find it at: www.aeroportsdeparis.fr.

private joint venture (Cgc, now DALKIA, operator, and Laurent-Bouillet) commissioned the first field application of the 'geothermal-doublet' concept of heat mining, combining a production well with an injection well for returning cooled brine to the reservoir. The doublet—two deviated, 7" cased wells produced in a self-flowing mode—went on line in 1971 at the Melun l'Almont site south of Paris, supplying heat and hot water to a local residential dwelling compound. New titanium-alloyed, plate heat exchangers were installed to handle the corrosive geothermal fluids.

"Today the original doublet has been replaced by three wells, called a 'triplet array'—two injection wells and a new, innovative-production well with steel casings and a freely suspended, un-cemented, fiberglass liner. The liner, designed as a materials solution to corrosion damage, was completed in 1995.

"Regarded at the time as a technological curiosity, this 1971 project still operates satisfactorily and has been extended and replicated, not only throughout the Paris Basin but throughout other geothermal basins in France (map two). Today over 34 space-heating systems operate in the Paris Basin alone—with hot waters from the underlying Dogger limestone. Each has unique arrays of wells and the main challenges remain constructing and managing the systems and financial competition from conventional fossil fuels," Dr. Ungemach said.

Mr. Vernier said it first was thought the hot waters in the Paris Basin would last for 20 years, but now, 40 years later and with temperature decreases around a degree in just one or two wells, it is clear the model was too conservative. New modeling shows additional years—or decades—of heat; of course, no one is sure the new model is correct.

Over time in every project, new wells have been drilled and older wells modified. Models of the Dogger reservoir show how closely wells can be drilled. The geothermal heating systems are often owned by French town councils, which earn profits from them.

Injection wells may have shorter life spans than production wells because injection waters can deposit particles—making the source rock impermeable and reducing injection over time. Production wells have more problems with corrosion because the water is hotter; well corrosion is avoided by using chemicals.

In the future, Mr. Vernier noted, heating and cooling operations will be undertaken in shallower parts of the Dogger reservoir because modern buildings are more energy efficient and cooler waters can be used to heat and cool them. In addition, people are looking at the hotter, deeper strata—with temperatures up to 100 °C (map two). After electricity is generated from the hotter waters, the heat at the end of the cycle can be used for projects like heating buildings; the hotter waters also can be used to replace heating plants in industrial complexes.

Eventually, strata shallower and deeper than the Dogger will be tested further in the Paris Basin and techniques devised to exploit them. For now, Mr. Vernier said it remains easier to return to the Dogger reservoir—except for some parts of the Paris Basin where no room exists for additional projects. BRGM geologists continue to characterize strata in geothermal basins throughout the country for future development.

EGS at Soultz-sous-Forêts

At the Enhanced Geothermal System (EGS) Geothermal Pilot Project in Soultz-sous-Forêts, France, near the German border, over 20 years of research and development have occurred under auspices of French, German, and Swiss governmental and European funding programs. The pilot geothermal-power plant, seen in the accompanying photograph, was built by a French-German consortium. Most of the following information is from an interview with (and a published paper by) Dr. Albert Genter, Scientific Manager of the Soultz project, formally called *GEIE Exploitation Minière de la Chaleur Route de Soultz*.

The Soultz geothermal power plant. At the back of the project site is the Organic Rankine Cycle power unit; in the middle of the site are the three geothermal wells; at the front is the cooled geothermal loop. The town of Soultz-sous-Forêts is in the background, about a kilometer away. CAPTION COURTESY OF A. GENTER; PHOTO COURTESY OF GEIE.

At the Soultz site, wells GPK2 and GPK4 are production wells and well GPK3 is an injection well. These three deviated wells are drilled into fractured granite from the same well pad. Today a second injection well, GPK1, is used because operating two injection wells simultaneously helps minimize microseismicity and because no additional power or monies are needed—the injection occurs by gravity alone. Well GPK1, which is only 3.6 km in depth, was the first well drilled at Soultz and is closest to the project office. The other three wells are about 5 km deep, aligned along natural fractures and the maximum horizontal-stress field, and have bottom-hole temperatures of about 200 °C. They are cased from the surface to depths of about 4.5 km, leaving an open-hole section of about 500 m. The maximum capacity of the geothermal power plant is 2.2 MWe, gross, and the performance is about 1.5 MWe, net.

Two types of well pumps are used at Soultz. One, an electro-submersible pump, can be placed at any well depth and the one at Soultz was installed in well GPK4 at a depth of 500 m in November 2008. The pump, designed for high temperatures, worked for about 4,000 hours and was used for 13 periods over an expanded lifetime. It is no longer working and can't be pulled out and repaired. The problem has been adapting the pump to geothermal conditions: the high operating temperatures, metallurgy, and corrosion. Plans exist to remove the pump and continue using well GPK4, with a line-shaft pump.

The line-shaft pump currently at Soultz is in well GPK2—with the pump mechanism in the well and the motor at the surface. The pump was installed in well GPK2 in April 2008 at a depth of 345 m. After some trouble with scaling, anti-scaling chemicals were added and today the pump works properly, reinstalled at a depth of 250 m. The Soultz technical team can remove the pump from the well, clean it, and replace it. There are no plans to drill new wells or deepen current wells. However well GPK4 may be reentered and perforated to improve flow.

"The Rhine graben is a high-fault system with low permeability. Each time we drill into the granite, we find brine trapped in fractures with about 100/grams per liter of total dissolved solids (three times more than seawater)," said Dr. Genter. "We only use water from the earth

during circulation. The Rhine graben has natural, large-scale circulation—the origin of the water isn't clear. We stimulate the wells and drain the natural water in the faults. Today we pump out hot water, extract the heat, and inject all the cooled water. The project is a kind of surface closed system connected, at depth, to a large-scale fracture system. We are developing natural circulation and increasing permeability: first by hydraulic and chemical stimulation and then by forced hydraulic circulation. The Soultz project has no circulation losses because we are continually draining natural water from the far field," he said.

At Soultz, fluid injection is much more expensive than fluid extraction. Injection pressures are carefully watched, as too much pressure can result in earthquakes. Two scientific teams monitor seismicity at Soultz. Scientific and technical monitoring for the project, in general, is undertaken by the industry and by the French and German Governments.

Dr. Ungemach said the Soultz project is not undertaken for commercial viability, although the electricity generated there goes to the grid. The importance of the project is what it can tell us about an EGS project. "We need 10 pilot plants in the Rhine graben, where the Soultz plant is located—and at other European sites, to define uniform EGS technology and learn about the lifetime of the system," he concluded.

Of the four other geothermal projects in the Rhine graben today, operating or under construction, three are in Germany and located 40 to 60 km from Soultz. These are Landau and Bruchsal (generating electricity) and Insheim, which will generate electricity in the future. The fourth project, Rittershoffen, is in France, about 10 km from Soultz. Here the energy will be used for drying cereals. The same people who created Soultz work at these other industrial projects.

New Project near Soultz

On January 12, the European Commission (EU) authorized France, under EU state-aid rules, to provide a €25.3 million grant to construct a heating boiler operated with geothermal heat extracted from the Rhine graben in the village of Rittershoffen, less than 10 km from Soultz-sous-Forêts. The aid will be granted to a joint venture of Roquette Frères, Groupe Electricité de Strasbourg, and Caisse des Dépôts et Consignations. The joint venture will sell the produced geothermal heat to the industrial site operated by Roquette Frères in Beinheim, enabling the company to partly replace its existing gas-fired heating boilers.

Dr. Albert Genter says the geothermal water is expected to be highly saline. Therefore a heat exchanger at the well will be used to heat "fresh" water that will be transported to the boiler at Beinheim through 15 km of horizontal pipeline.

"We have no current plans to expand the Soultz project," Dr. Genter said. "In fact, the pilot plant phase is almost over. We have produced electricity since June 2008. In 2010 we began a new, three-year scientific and technical monitoring phase with the help of industry and French-German public funding. We are concentrating on reservoir studies (temperature, fluid, geochemistry), environmental consequences (microseismicity, noise, radioactivity), and technical challenges (pumps, corrosion, heat exchangers)."

Community communication is an important issue. The Soultz project is about a kilometer from the nearest town, Kutzenhausen. In early June 2003, the largest earthquake at Soultz occurred at a time when a well was shut in. After the quake, many community meetings were held in Kutzenhausen, where the Soultz project was explained. Since 2007, over 7,000 visitors have come to Soultz. Educational tours of the power plant are offered to everyone, building trust. "People are encouraging us to continue the project," said Dr. Genter. "Communication is very important."

Geothermal Politics, Finance, Goals

Christian Boissavy, the founding president of the European Geothermal Energy Council, lives in Paris and works for G^{2}H Conseils, a French

1334, The World's First District Heating System

Although Chaudes-Aigues (showeds-egg), France, is home to fewer than 1,000 people, it is unique in the annals of geothermal history. Here the world's first geothermal district heating system began at least 677 years ago, with waters piped to buildings and baths from a hot spring called *le Par*– at 82 °C, one of the hottest in Europe (map two). The system dates at least from 1334, when it was entered on the village register of real property and the local lord received payment from his vassals using the hot waters.

In the 1700s, the system was expanded and upgraded into a series of channels cut along the streets. The hot spring waters flowed through the channels and in and out of the houses and buildings along them—the same heating system used today. (The Romans heated baths and occasional villas with geothermal waters, but not towns.)

How did/does the system work? If a house is too cool, someone goes outside and raises a metal plate by the doorstep. Inside there is a pipe filled with hot spring waters—flowing by gravity alone. A plug is pulled out of one hole in the piping and put into another, redirecting the hot waters into the house. The waters flow beneath the floor through very narrow channels and a few larger warming basins—circling until they reach the outside and pass again into the main pipe. When a house feels warm enough, someone goes outside and returns the plug to its original position. Now the hot waters bypass the house entirely. One winter day I entered the house at the bottom of the system, the last to receive the hot waters. It was a warm and toasty place.

Today fewer houses in Chaudes-Aigues are heated with this system than in the 1990s and those that are have the metal plates at the front doors. More details on the Chaudes-Aigues district heating system—and all early uses of the hot waters—are in an essay by Gibert and Jaudin.[2]

For a geothermal visit ... In Chaudes-Aigues, the Office of Tourism—where English is spoken—offers helpful visitor information (www.chaudesaigues.com). First, ask for the schedules of the geothermal walk and the geothermal museum—and plan everything else around them. Next reserve a meal in the Michelin-starred restaurant, Serge Vieira, in the remains of the chateau overlooking Chaudes-Aigues (www.sergevieira.com). Here is where the lord received payment from his vassals for using his geothermal waters. A final pleasure could be swimming in these waters in the spectacular pool at the Brit Hotel du Ban—at the foot of the road to the chateau.

View of Chaudes-Aigues, France. Le Par *hot spring and the geothermal museum are about one third up the left-hand side of the picture, near the tiny house with a chimney in the middle of the roof. The Office of Tourism is near the middle of the photo and remains of the chateau stand on the hill behind the photographer.* PHOTO BY S. HODGSON.

Le Par *hot spring flows from this original basin into channels of the district heating system. The geothermal museum, at the back, is filled with interesting and imaginative displays, many with captions in English.* PHOTO COURTESY OF THE OFFICE DE TOURISME.

The metal plates in the sidewalk of this ancient, Chaudes-Aigues street show these buildings are part of a geothermal district heating system—one of several small systems now operating. PHOTO BY S. HODGSON.

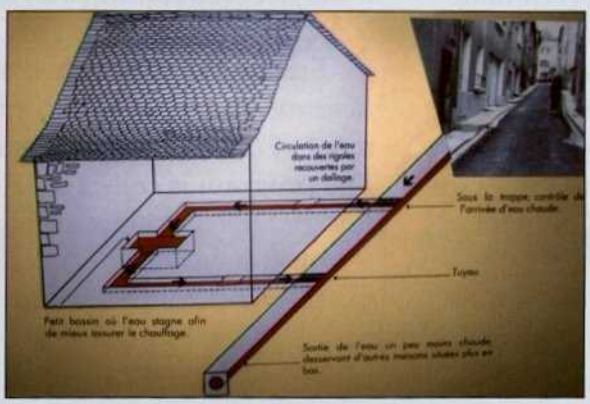


Diagram of the hot waters from le Par *spring flowing down the street (upper right corner of the photo), entering a house, and passing beneath the floor. The large basin retains heat.* REPRINTED COURTESY OF GÉOTHERMIA, MUSÉE EUROPÉEN DE LA GÉOTHERMIE ET DU THERMALISME.

Only a plug controls the entrance of hot waters under the floors of each building in the district heating system. PHOTO BY S. HODGSON.

Today PVC pipe is used, but in 1334 the pipes were made of hollowed-out pine trunks. PHOTO BY S. HODGSON, COURTESY OF GÉOTHERMIA, MUSÉE EUROPÉEN DE LA GÉOTHERMIE ET DU THERMALISME.

geothermal consulting company. A geothermal expert for the European Geothermal Commission, Dr. Boissavy works on geothermal issues and the politics of geothermal energy in Europe, especially France. The following comments are based on our interview and his publications.

"Thirty years ago," Dr. Boissavy said, "no one was interested in having a French geothermal society. But times have changed." On June 15, 2010, he founded the French Association of Geothermal Professionals—becoming its first president. The organization has about 100 members—all established French companies: thermal engineering firms; underground engineering companies; drilling contractors; heating and cooling installers; heat-pump manufacturers; operators and

developers of heating networks; and utilities. Member activities fall into four geothermal sectors: power generation, direct use, heat pumps in large buildings, and heat pumps in private dwellings.

The association hopes the geothermal industry can present to others—especially the French Government—a united, independent voice on important issues. These include increasing governmental subsidies; accelerating and refining the project-permission process in terms of time and paperwork; and helping the industry to become a private partner of the French State.

For the last 30 years, the French Government has offered risk-guarantee programs to developers of deep-geothermal resources. The programs were updated in 2006, when a financing fund was reconstructed to cover geological risks. The program's *Short Term Procedure* guarantees the results of the first well of a geothermal doublet and covers geological risks in case of total or partial well failure—success is measured by flow rates and temperatures. Once a geothermal facility begins operation—the well doublet has been installed and the geothermal characteristics are known—a *Long Term Procedure* kicks in, insuring for 15 years of operation against the risk of total- or partial-depletion stemming from temperature and/or flow rate decreases and from corrosion and/or scaling in the wells.

Since 1985, the French Government has offered a risk-guarantee program to developers of shallow-geothermal resources. The program targets plants (not private houses) using heat pumps of over 30 kW. The program's *Research Guarantee* is similar to the *Short Term Procedure* just described for the initial drilling of deep-resource projects. However, for shallow-resource projects—once drilling is finished and exploitation begins—a *Long Term Productivity Guarantee* will cover for 10 years the risks of resource decrease or deterioration and equipment deterioration. The shallow, geothermal-resource program has been successful, overcoming many obstacles to geothermal development, including psychological and financial barriers.

Regarding private homes, French citizens receive a deduction of 40% for investing in geothermal installations. The Association of Geothermal Plant Owners has obtained a reduced VAT tax—5.5%—the same VAT tax received by natural gas long ago. Geothermal now stands on an equal playing field with natural gas and has a commercial advantage of 14.4% over other fossil fuels.

Every renewable-energy source has a different feed-in tariff in France. On July 24, 2010, the French feed-in tariff for geothermal electricity was increased to 20 cents per kilowatt hour. In the French overseas departments, such as the island of Guadeloupe, the geothermal feed-in tariff is 13 cents per kilowatt hour. The tariff is upgraded if the heat remaining after electrical production is used.

France has established a new, €1.35 billion *Renewable Energy Fund* to support the development of cutting-edged, clean-energy technologies. The program is called the *Renewable and Green Energy Demonstration* and will offer €450 million in subsidies and €900 million in low-interest loans over the next four years for new-technology projects. The new governmental initiative will focus on financing emerging technologies facing high startup costs—including geothermal projects.

June 30, 2010, was the deadline for all 27 EU Member States to hand in a *National Renewable Energy Action Plan* to the European Commission, under the *Renewable Energy Directive*. In France, Jean-Louis Borloo, Minister for Ecology, Energy, Sustainable Development and Town and Country Planning, unveiled *La Strategie Nationale du Développement Durable 2010-2013*. Among the 2020 strategy goals are a 20% reduction of French greenhouse-gas emissions compared to 1990 levels and a 23% target for renewables in French national-energy consumption.

Minister Borloo has asked the French Association of Geothermal Professionals what is needed to facilitate increased geothermal development. It is important to note the position of Minister Borloo in the French Government is secondary only to those of the Prime Minister and

the Minister of Defense, marking the first time the topics of energy and the environment have been at the top of the French national agenda.

Acknowledgments

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BRGM publications: Although BRGM is not directly a public service, communications is one of its public missions. At the ADEME-BRGM website, you can download several French geothermal publications and newsletters, many translated to English. (ADEME is the French Environment and Energy Management Agency.) The website itself offers a great deal of geothermal information with English translations. Find it at: www.geothermie-perspectives.fr.

Soultz-sous-Forêts publications: Much literature is available about the Soultz-sous-Forêts project. Forty-one Ph.D. theses have been written on the topic and about 230 papers published in peer-review journals. The June 2010 special issue of *Comptes Rendus Geoscience*, a journal published by Elsevier, contains 18 papers about Soultz. Several papers presented at the 2010 Annual Meeting of the Geothermal Resources Council and the 2010 World Geothermal Congress in Bali cover the Soultz project (and other geothermal activities in France). ■