THE USE OF LOW-ENTIIALPY GEOTHERMAL ENERGY IN FRANCE

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ABSTRACT

The use of deep groundwater in France started as the result of the two energy crises in the 1970s; its development was very rapid and most operations were completed in the 1980s Because of this, and of the fact that no previous experience was available in this domain, the French geothermal industry had to organize itself very rapidly. developing the necessary techniques, methods and means to make itself into a durable feature. This has resulted in an industry that today is mature and credible.

The past few years have mostly been devoted to the strengthening of geothermics, in particular through the following specific actions:

the implementation of innovative solutions for combating corrosion and scaling:

the optimization of heating networks that use geothermal energy;

the development of specific tools for the prediction and planning of future reservoir exploitation.

I. INTRODUCTION

Over the past thirty years, the French have specialized in the development of geothermal energy using low-enthalpy resources for urban heating. More than 70 such operations were set up, and today geothermal energy is used for heating and hot-water production of around 200,000 housing units. Over 40 of these projects are located in the Paris Basin. where the first installations date hack to 1961 for the Maison de la Radio in Paris, and to 1969 for the heating of 3000 housing units in Melun l'Almont. Both are still in operation.

The 14 operations in the Aquitaine region are smaller and. in contrast to those in the **Paris Basin,** have encountered no major difficulties. Some are used for agriculture (fish farming, greenhouses). In addition, there is a 4.5 MW electric-power station operating in Guadeloupe (French West Indies), and around a thousand operations exploit shallow aquifers with heat pumps for heating and air conditioning.

Most ofthese installations were built between 1981 and 1986 following the second oil crisis, benefiting from the favourable conditions that existed at that time such as.

- ***High energy costs***, and a rate of inflation that favoured investments
- ***Government incentives***, such as the creation of a panel of experts to examine projects and propose financial aid.
- An ***insurance*** covering the drilling phase, accompanied by a 15-year guarantee on the resource. This policy, still in effect, was one of the major determining factors for persuading owners to choose geothermal energy. Within the framework of the Altener Procedure, a proposal has been made to the CEC to study the possibilities of extending this system to all countries of the European Community.
- ***Regulations*** governing the exploitation of the sub-surface, defining the rights and responsibilitiesof all.
- The creation by ADEME, the French Environmental and Energy Management Agency, of a ***remote data-acquisition system*** for all operations affecting the Dogger aquifer. This unique system of reservoir management was a major tool for making optimum use of the geothermal-energy network.

In the Paris Basin, all operations are based on the same design, exploiting the same Dogger aquifer, a reservoir with large quantities of dissolved salts and gases that must be reinjected. Serious technical problems have affected some installations in the Paris Basin. resulting from the corrosiveness of the sulphide-rich geothermal fluid on metal parts of the geothermal **loop.**

Few new installations have been built since 1986, primarily because of the drop in energy prices. The owners of these operations, usually local communities, have encountered financial difficulties since prices were indexed to those of fossil fuels. Since 1989, measures have heen taken to reorganize the finances of operations that were operating at a loss, and to develop techniques for combating corrosion.

To improve the financial situation of the 30 installations in the Paris Basin that showed a deficit. the Prime Minister assigned a prefect the task of finding permanent solutions that would balance the budget of operating installations. Following negotiations with each owner, a protocol was signed with the French Government defining the obligations of all parties (relinancing of debt, lowering of interest rates, financial contribution of cities. etc.). The few operations that could not break even over the medium term were shutdown.

To resolve technical problems, notably corrosion and scaling of metal casings. a two-part technical protection project was set up one programme was devoted to basic research on problems encountered, and a second one consisted of experimentation and the validation of new techniques. Major funding of both programmes was provided by ADEME. Three priority themes were defined: curative techniques for the scouring of wells; preventive techniques to combat corrosion and scaling (injection of corrosion inhibitors); and the use of new materials. The results have been very encouraging and a ten-fold decrease was noted in casing corrosion.

Joint efforts by owners, operators. research institutes, consulting firms and equipment manufacturers have also led to improved performance. Considerable progress has been made in optimizing the exploitation of low-enthalpy heat networks, and the supply rate has increased continuously over the past years to meet demand. However, given current energy prices, there is little incentive to start up new operations without significant French or European subsidies, in spite ofthe fact that a recent feasibility study carried out in the Paris region showed that geothermal enerby is competitive with natural gas. This study took into account all the experience gained in recent years concerning design, exploitation, and legal and financial aspects.

In the absence of an active policy to develop new operations, the effons to optimize and develop existing operations will he continued The potential of hooking up more than 30,000 housing units to existing operations was identified in the Paris region. This mostly concerns new housing units. in which the heating elements will he adapted to low temperatures. In most of these cases, 100% of the heating-energy demand can be covered without any additional investment in heat production.

The average age of most operations is slightly more than 10 years, and a simulation of operating conditions in these installations over the next IS years is in progress. The following points are already clear:

- The heat-transport network associated with geothermal projects represents up to 70% of initial investment. It is therefore necessary to maintain this network under the best economic conditions.
- Investing in a new large-diameter well. protected against corrosion. should be profitable hecaure of the increased flowrate and decreased maintenance costs. Such a well can he designed to operate in triplet, the original wells of the douhlet being transformed into reinjection wells A first experiment will be carried out on the 24-year-old Melun site in November 1994, with funding by the CEC and ADEME.
- New technologies developed by researchers are now operational. A technique for in-situ polymerization of composite casing (Drillflex process) should revolutionize the rehabilitation of highly corroded steel casings. Old oil wells have heen successfully re-lined and an experiment on a geothermal well is planned for 1995.

French geothermal activities, after a difficult phase caused both by the drop in energy costs and the technical difficulties encountered in installations of the Paris region, is again deemed credible. The joint efforts of all of those involved in the exploitation of geothermal energy have led to significant technological advance. Because of acquired experience and know-how, we are now optimistic for this non-polluting energy and foresee a significant renewal of interest during the coming decade under satisfactory technical and economic conditions.

2. CEOTHERMICS OF THE PARIS BASIN

Because of insufficient artesian production from the Dogger aquifer formation in the Paris Basin, when considering the requirements, 87% of the geothermal doublet wells in operation have been fitted with pumps. The geothermal fluid is generally extracted from the production well by means of a submersible pump. On surface, the fluid is kept pressurized, in order to avoid any disturbing degassing effects. It then flows through a heat exchanger that transfers the geothermal energy to the district-heating network After cooling, the fluid is reinjected with a surface pump into the Dogger formation from where it was extracted. The circuit followed by the geothermal fluid is called a geothermal loop.

The difficulties encountered during exploitation can he of three types:

- ***Shutdown of the installation,*** which is generally due to the breakdown of pumps or ancillary equipment; in itself, this is commonly the effect of operation in a highly corrosive environment

  Decreased productivity of wells. shown by a lower tlow rate that is caused by a worsening of the hydrodynamic characteristics of the well. this is commonly caused by restriction or clogging of the production or injection wells.

  Damage to the well, endangering the survival of the installation as a whole: this is the case when the steel casing of wells has been degraded or even holed as a result of corrosion.

To overcome such difficulties, specific techniques of prevention. control and maintenance have been developed for

- discovering the causes of damage or breakdown;
- proposing curative solutions;
- installing prevention procedures

2.1. MAINTENANCE, REHABILITATION AND PROTECTION OF INSTALLATIONS

After the phase during which the installations were created, the passage to industrial exploitation quickly indicated corrosion and scaling problems within the boreholes and the surface loop. At that point. the public authorities started to provide support for finding solutions to these problems, setting up specific R&D programmes that were administered by an ad-hoc organization called IMRG (Mixed Institute for Geothermal Research) that was set up by the AFME (now ADEME) and BRGM. which benefited from CEC support through several R&D programmes.

Helped by this research since 1984, French companies working in geothermics have progressively implemented solutions to the corrosion and scaling problems. These solutions fall into two categories:

- ***Curative methods*** for the elimination of scale and the reconditioning of boreholes, to restore the hydrodynamic well characteristics to a condition that is as close as possible to the initial state; this is the so-called ***rehabilitation*** work.
- ***Preventive methods*** through the application of a treatment that will avoid future corrosion and scaling phenomena. Such methods. which are essentially based on chemical anti-corrosion treatment of the fluid, were first applied as surface treatment, then within the pumping units of production wells, and finally, after 1988, at the bottom of the production wells with the aim of protecting the loop as a whole; this is the so-called ***well-bottom treatment***.

The two methods are complementary, as the efficacy of a treatment with inhibitors will be increased when applied to a perfectly cleaned surface.

2.1.1. Determining the cause of problems

To determine the cause of malfunctioning of an installation, all parameters of the system must he considered, This implies the interaction of various techniques in the fields of geochemistry, corrosion, hydrogeology, electricity, mechanics, etc. Such complete monitoring is based on the on-site collecting of data:

- either periodically, with the help of specific mobile means;
- or continually, by equipping the sites with sensors that measure the basic data. and with the subsequent remote transmission of the data to a processing and storage centre (see chapter on Remote Monitoring).

Specific measuring equipment for geothermal tluids had to be designed, and new measuring methods had to he developed for well characteristics and pump performance The overall brief was that exploitation of the geothermal loop could not be interrupted and that general operations had to remain undisturbed. The newly developed methods and means for measuring and control. were completed hy the training and intervention of specialized teams. as well as by the creation of a specitic organizational structure. The last involves-

- the companies themselves;
- owners and operators, for managing the equipment and exchange of data;
- research teams for the definition of R&D programmes, supported by committees that include representatives of all partners,

- public authorities and companies that contribute to the identification of problems, the search of solutions, and dissemination ofthis information among the profession.

2.1.2. Curative methods and borehole rehabilitation

The rehabilitation of a geothermal well aims at restoring as much as possible the initial production or injection capacity. In the case of doublet wells in the Paris region. most of the damage is caused by major scaling through corrosion of the well casing; below this scale, the corrosion process caused by formation water further develops and advances.

Most wells are deviated and intersect the roof of the reservoir rock at a distance of900 to 1300 m from the collar location. Their depths vary from 1500 to 2500 m and the deviation, which is 30 to 35° on average, can be as much as 60" in certain cases. The wells arc fitted with soft carbon-steel casing that is 9 to 11 mm thick, and has a diameter of 13³/8" (pumping chamber) and 9⁵/8" or 7" (production/injection columns).

Three rehabilitation techniques have been tried, which call upon

- *mechanical cleaning* with a scraping tricone tool hanging from a rod assembly,
- hydraulic *jetting* with a coil-tubing unit of a diameter of 1 1/2";
- a combined *hydraulic-mechanical* process.

To ihe initial objective of restituting the well characteristics. the need was added to restore the surface condition of the casing to a state that would be compatible with an efficient later application of a corrosion/scaling inhibitor that has to deposit a thin film. It was show the third, *hydraulic-mechanical*, process would combine the ***best reliability*** with a ***competitive cost/performance ratio***.

In 1993, the new ***"Soft Acidification"*** technique was introduced, consisting of the injection of acid at a weak concentration over several lens of hours or even several days. with constant monitoring of all parameters. The interest of this method lies in several aspects.

- low cost of the process, i.e. much cheaper than hydraulic-mechanical methods,
- implementation without interruption of the exploitation;
- no surface treatment of gases necessary.

This method is particularly suitable for injection wells. In the case of production wells, it can be used as well, but the question then arises whether or not the submersible pump has to be lifted from the hole.

2.1.3. Preventive methods

The treatment is generally based on inhibitors based on quaternary amines, whose filming capacity ensures an optimum protection of the casing. In addition, a new technique for the fabrication of continuous injection casing as well as new materials for this product were developed. The chemical compatibility of these inhibitors with the other materials used in the well loop, was also tested.

Today, several efficient methods are available from French specialist companies in the geothermal field. Several types of treatment installations and methods are proposed to geothermal operators by these companies Today, the technique of corrosion and scaling treatment by the injection of inhibitors into the well bottom. is backed up by the experience gained on more than 65,000 m installed, which are distributed over about 40 sites in France Such methods have recently been adopted by foreign operators as well, for instance in Switzerland

Continuous work is being carried out on the further improvement of these techniques and products, such as reducing the diameter of injection casing at the well bonom, rapid installation methods, and the type and quantity of inhibitors to be used. At the same time, research programmes continue to explore the domain of corrosion and scaling (work on mineral inhibitors. the role of bacteria, etc.). New materials for installation in such wells are being studied and developed, such as casing of composite materials and the Drillflex process. The last, which is being developed together with oil companies. should contribute efficient solutions for the restoration of damaged casing.

2.2 REMOTE MONITORING AND DATA TRANSMISSION

A network for the remote measuring and transmission of geothermal data, was installed in 1987 by the French Agency for Energy Management (AFME) that since has become ADEME. This network equips 40 geothermal sites in the Paris region and enables the monitoring of the main parameters of this resource. The data acquisition systems installed on the sites, i.e. probes and sensors, are linked by telephone lines to a central computer that manages the system as a whole, which involves data storage, processing and interpretation. The system checks about ten parameters on each site at half-hourly steps; however, it is an open system, as it can handle more parameters and shorter time steps if necessary. which enables the continuous monitoring of specific parameters during work on a site. lor instance.

Custom-designed software is used for filtering, visualizing, storing and processing of the data. The latter are at the disposal of operators, serve to draw up exploitation statistics for the Dogger aquifer, and are used by the research teams that work on the improvement of reservoir knowledge, and on the predictive modelling ofthe reservoir and of the interactions between different wells.

2.3. OPTIMIZING AND DEVELOPING GEOTHERMAL HEAT NETWORKS

The application of geothermal energy to domestic heating through heat networks. has required the development of specilic techniques for making optimum use of this resource. On the design level, this has meant the construction of several distribution-pipe networks; the return flow from installations heated by radiators, generally is still warm enough to be used for under-floor heating. This has meant that a cascading temperature system is used, which requires three or more pipes in the same trench.

Specific research has been carried out on the heat-exchange sub-stations and their control, in order to obtain the lowest possible well-return temperatures. Finally, specific software was developed for operating the installations. which has led to an appreciable further gain in productivity, and opened the way to significant extension of existing networks. This has led to an increase in the usable quantity of geothermal energy, without any investment in new wells. It has been calculated that, in this manner, more than 30,000 new housing units can he hooked up to existing heat networks in the next decade.

2.4. RESERVOIR KNOWLEDGE AND MODELLING

The behaviour of the deep reservoir from which the geothermal resource, i.e. a low-enthalpy mono-phase fluid, can be extracted, is a deciding factor for managing exploitation systems that are based on doublet wells. The main characteristics of this type of exploitation are: reinjection into the original reservoir ofthe fluid after all of it has been cooled an surface; and the exploitation of high flow rates, i.e. 150 to 300 m^3/h). This mode of operation thus cannot he dissociated from the notion of durability of the usable resource, as it is quantified at the production well, either by the start of recycling of the injected cold water (time of thermal recovery), or by an acceptable lowering of temperature (practical life time). This approach, which was started in the 1970s, covers three main aspects:

- data acquisition from measurements made in boreholes;
- characterization of porous matrix and reservoir fluid;
- numerical simulation of reservoir behaviour during production.

These three complementary steps do not necessarily follow each other in time. The progressive improvement of reservoir knowledge, the observation of anomalies or differences from the predicted behaviour, and the constant evolution of simulation requirements related to practical problems, have all led to frequent revisions of earlier steps in this approach. The objective is to ensure, at all times, the coherence of the various components of the overall approach:

- reliability and representativeness of measurements and tests in boreholes;
- identification and quantification of the various physical and chemical phenomena, in terms of their spatial scale and the amplitude of their effects;
- consideration of short- and long-term needs as expressed by the industrial operators, for guiding of the modelling work.

The modelling work on the Dogger reservoir is thus closely linked to the monitoring and prediction of practical problems that affect the system of doublet exploitation in the Paris region. The various phenomena that must be considered for the management of a deep-aquifer exploitation by means of doublet wells, are manifold, complex and constantly changing. The method adopted since the first wells were drilled, has consisted in associating scientific R&D programmes with the constant monitoring of industrial installations. This combined effort, which is carried under the aegis of ADEME, has the following three main characteristics:

- multidisciplinary research programmes investigate aspects of sedimentology, hydraulics, thermics and geochemistry;
- a data network links owners, operators, service operators, public authorities, etc., for the restitution of anomalies (magnitude, frequency, location, etc.) observed on operating installations;
- a centralized remote-measuring system is used for the archiving of the history of such phenomena and of the exploitations themselves. It should be noted here that the dynamics of the general system over time, are practically only governed by the response time of the reservoir.

This scheme is particularly useful for managing reservoir behaviour and the general modelling work, as it provides the necessary data for tackling the two scales of investigation, i.e.: (i) examination of the individual functioning of each doublet, and (ii) study of the interactions between systems for the general management of the geothermal field. In the presence of exploitation anomalies, it was thus possible to take local causes into account, which were the result of the specific functioning of a doublet (decrease in flow rate, scaling in casing, etc.), as well as more regional causes that were related to the amplitude of interaction between systems, such as pressure interference and modifications in the functioning of neighbouring doublets.

2.4.1. The programme of work on reservoir behaviour

Since 1986, when most of the 55 geothermal doublet wells in the Paris region had been completed, three successive 3-year R&D programmes have been implemented, focusing on reservoir behaviour, and with the objectives of understanding the resource and managing its exploitation:

Programme 1986-1989 (ADEME, BRGM, CEC-DGXII)

Objective:	Definition of the geothermal resource in the Dogger of the Paris Basin
Target:	Geothermal domain of the Paris region and the 110 wells drilled
Scale:	90 km x 110 km
Subjects for analysis:	Vertical heterogeneity of reservoir production Lateral variability of fluid and matrix parameters Hydrodynamic coupling

Programme 1990-1992 (BRGM, CEC-DGXII)

Objective:	Understanding the phenomena that define reservoir condition
Target:	The Dogger reservoir at the scale of the Paris Basin
Scale:	400 km x 300 km
Subjects for analysis:	Regional flow and density effects Age and origin of reservoir fluids The porous matrix and permeability

Programme 1993-1995 (ADEME, BRGM)

Objective:	Resource exploitation by means of doublet wells
Target:	The geothermal doublet in its environment
Scale:	10 km x 10 km
Subjects for analysis:	The concept of life time and its characteristics The decline of energy production and its prediction Advance signals of thermal recovery induced by exploitation

These three successive R&D programmes on the behaviour of the Dogger reservoir, have clarified the characteristics of the potential resource, and the main past and present phenomena that govern this behaviour. The main conclusions are:

- The fluid and matrix parameters were recognized to have a strong vertical and lateral heterogeneity. This has led to increasingly reliable predictions concerning the location of favourable areas for the siting of future doublets.
- Coupling was recognized between regional hydrodynamics, and the distribution of thermal and geochemical variables. This confirms the importance of a multidisciplinary approach, and has led to positive exploitation of the coherence between correlated parameters.
- The importance of three-dimensional scale effects on the various phenomena was understood.

After a decade of exploitation and monitoring, the need has now arisen for a better understanding of any divergence from the nominal regime, as well as for a more accurate prediction of the practical life span for an exploitation. This will serve to make a reasoned argument concerning useful or necessary techniques for the next decade, e.g. the adding of heat pumps, or the choice between a triplet or doublet solution.

2.4.2. The three phases in the life of a doublet

The life of a doublet can, schematically and chronologically, be split into three phases, each of which has its own approach and requirements:

- ***Design and construction.*** This is based on a simplified reservoir model with constant parameters. Such modelling generally projects the planned exploitation as well as the so-called normal or reference functioning for a period of 20 years. The design model, which is specific for this initial phase, is based on insufficient data and too restricted hypotheses, to be used afterwards as a tool for managing and monitoring reservoir behaviour.
- ***Reservoir exploitation.*** For numerous reasons, such as flow-rate variations, cleaning operations, or interference between adjacent doublets, the exploitation in practice is rarely managed in the predicted context. This implies a need for periodic updating of the predictive model, to reduce the level of uncertainty in exploitation.
- ***Decline in energy levels.*** This occurs when enough reinjected cold water has closed the underground loop to the production well, to cause a measurable drop in temperature. Knowledge of the detailed behaviour during this phase is still patchy, mainly because of reservoir heterogeneity and the complexity of exploitation at variable production rates.

In addition to the earlier mentioned constraints of three-dimensional scale, study of the problems encountered during the life cycle of a normal doublet shows that a simulation of reservoir behaviour must evolve towards more detailed consideration of the specific phenomena that accompany and condition the decline in energy production of the initial system. This last step of defining the near future, integrates the observed real behaviour and further contributes to the general mastery of low-enthalpy geothermal exploitation from doublet wells

2.4.3. The objectives of the ongoing R&D programme

The work in progress an evaluating the context of a doublet life cycle. comprises two main aspects: (i) an analysis of the evolution of variables that can he measured (i.e pressure and temperature), which condition the operating mode during this period: and (ii) the search for various precursor phenomena (mainly geochemical) of energy decline, for anticipating the choices that will be necessary in about ten years.

The energy decline of a doublet exploitation system is Characterized by a change in well pressure from that of the nominal regime It is necessary to evaluate the amplitude and dynamics of such change Another sign is a drop in production temperature, which is directly related to thermal coupling, exchange and dispersion The main work on this subject concerns.

- Definition and impact of the real reservoir stratification, which affects the amount of thermal exchange through the boundaries of productive layers, as well as the general phenomenon of thermal dispersion.
- Hydraulic-thermal coupling. in particular the impact of the mobile viscosity contrast between reinjected and reservoir fluids, which contributes to slowing down the appearance of cooling in the production well
- Identification and monitoring of the progress of shifting boundaries around the zone invaded by cold injected water, which causes pressure changes in the wells This analysis concerns hoth the feasibility of specific drilling tests. and the detailed interpretation of measurements by the remote-monitoring system.

The study of geochemical precursors of the temperature drop. is based on the fact that migration of a chemical tracer between wells is about four times faster than that of the corresponding thermal front, which can be compared to a piston effect. In this case two types of investigation are used, which are closely related to the work on the impact of dispersion:

- The inventory and practical evaluation of all geochemical phenomena that are induced by exploitation and rehabilitation work, in order to identify the measurable variations in contents of chemical species, such as corrosion of casing, treatment by injection, bacterial development, fluid-rock interaction. etc.
- Evaluation of the practical conditions for artificial tracing through the injection of chemical species that could be considered as perfect tracers, with a minimum impact on the environment.

This ongoing R&D work should lead to a more detailed deiinition of the future context of the temperature drop in doublets. and to the proposal of new investigation methods for predicting the amplitude of corresponding phenomena.

3. CONCLUSIONS

The French geothermal industry, after a difficult phase related to the conjunction of lower energy costs and technical difficulties that affected the operations in the Paris region, now is completely credible. The joint efforts of all organizations involved have led to major technological advance. The experience and know-how thus acquired, show that optimism in this non-polluting energy some is well founded. and that a significant growth in this field is possible over the next decade under satisfactory technical and economic conditions.

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity GWe	Gross Prod. GWh/yr	Capacity GWe	Gross Prod. GWh/yr	Capacity GWe	Gross Prod. GWh/yr	Capacity GWe	Gross Prod. GWh/yr
In operation in January 1995	4	20	23.5	32 800	25	80 000	57.2	341 800	105.7	454 600
Under construction in January 1995							5.8			
Funds committed, but not yet under construction in January 1995										
Total projected use by 2 000	8						62.9			

Locality	power Plant Name	Year Commissioned	Total Installed Cap MWe
Guadeloupe (French Antillas)	Bouillante	1984	4.5

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT IN DECEMBER 1994

1)

I = Industrial process heat	D = Space heating
C = Air conditioning	B = Bathing and swimming (including balneology)
A = Agricultural drying	G = Greenhouses
S = snow melting	O = Other (specify by footnote)
W = Domestic hot rater	hs = Heat Storage (seasonal)
	f = Fish Farming

3) Energy use - mesured (the flowrate and outlet temperature may vary during the heating period, according to the external temperature: certain operations produce Domestic hot water during summer)

4) Fluctuate with the seasons

Locality	Type[1)]	Average Annual Utilization			
		Flow Rate	Temperature (°C)		Energy Use[3)]
		l/s	Inlet	Outlet [4)]	TJ/yr
Paris Basin					
Alfortville	D + W	76	74	47	180
Bonneuil sur Marne	D + W	77	79	49	130
Bruyère le Chatel	D	36	33		16
Cachan Nord	D + W	50	70	40	90
Cachan Sud	D + W	50	70	40	90
Champigny sur Marne	D + W	77	78	45	220
Chatenay Malabry	D	40	68	43	68
Chelles	D + W	77	68	40	140
Chevilly Larue	D + W	80	73	43	200
L' Hay les Roses	D + W	80	70	43	200
Clichy sous Bois	D	50	71	45	130
Coulommiers	D + W	64	83	60	125
Creteil	D	89	74	44	175
Epinay sous Senart	D + W	69	74	44	190
Evry	D	50	72	42	65
Fresnes	D - W	69	72	42	146
La Courneuve Nord	D – W	55	58	40	104
La Courneuve Sud	D + W	50	56	40	75
Le Blanc Mesnil	D + W	50	67	40	112
Le Mée sur Seine	D + W	40	72	40	140
Maison Alfort I	D + W	83	72	42	157
Maison Alfort II	D + W	75	73	42	140
Meaux Beauval 1	D + W	83	78	45	184
Meaux Beauval 2	D + W	83	78	45	184
Meaux Collinet	D	83	78	45	132
Meaux Hopital	D + W	83	78	45	127
Melun L' Almont	D + W	36	71	41	85
Montgeron	D + W	33	72	42	75
Orly I	D + W	50	75	45	122
Orly II	D + W	50	75	45	122
Paris Maison de la Radio	C		26		*b)*
Paris AGF	C		27	18	*b)*
Ris Orangis	D	48	70	40	118
Sucy en Brie	D + W	53	78	50	88
Thiais	D + W	69	76	46	150
Tremblay les Gonesse	D	66	73	43	140
Vaux le Penil	D	36	71	41	75
Vigneux sur Seine	D	61	74	44	50
Villeneuve Saint George	D + W	97	76	46	160
Villiers le Bel	D + W	80	66	40	100
Other Basins					
Begles	hs	10	21		2
Bordeaux Benauge	D	22	44	34	10
Bordeaux Meriadeck	D	25	53	47	20
Pessac Saige Formanoir	D	36	48	30	45
Pessac Stadium	D	11	34	25	8
Merignac BA 106	D	39	52	40	35
Mios le Teich	G	36	73	30	106
Hagetmau	D	11	33	28	5
Mont de Marsan I	D	66	60	54	55
Mont de Marsan II	D	10	56	49	10
Dax		36	47		*Not Use*
Saint Paul lei Dax	B + D		65		*Use 1995*
Blagnac	D	12	58		
Libourne	D	41	23	19	18 *b)*
Chateauroux	D	28	30		*b)*
Lamazere	G	41	57		
Casteljaloux	D	10	43		
Nogaro	B + f	6 *a)*	50	**10**	
Jonzac	B	10	61		
Dieuze	f		31		
Montagnac		41	26		
Total					,5522

a) Total flaw rate 14 l/s, -8 l/s used far Tape Water, and -6 l/s used for Heating
b) With hear pump

TABLE 4. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES

	Energy Use TJ/yr
Space heating	5 200
Bathing and swiming	x a)
Greenhouses	250
Fish and other animal farming	200 a)
Air conditioning	x a) b)
Heat pumps	1 700 b)

a) Detail unknown
Direct use of ground water heat is also that of thermal water This type of use and its medical applications come under the authority of the Ministry of Health More than 900 sources of thermal water exist in France and have temperatures that range from 10° to 80°C . apart from medical utilization, some of these waters are also used for spas and swimming pools and in some place for space heating

b) Estimated - more than 30 000 water/water heat pumps of all capacities have been sold in France
The heat pump projects provide heat for space heating, greenhouses. swiming pools. and are also used for air conditioning

TABLE 5. GEOTHERMAL HEAT PUMPS
Re comments table 4

TABLE 6. INFORMATIONS ABOUT GEOTHERMAL LOCALITIES - Commercial Utilization [1]

1) Only datas from operating operations are available
Datas from Feasibility studies can't be published
Regional assessment are avalaible all over France (also a national assessment and few local assessments exist)

Locality	Location		Reservoir		
	Latitude	Longitude	Rock	TDS g/l	Temp °C
Paris Basin - "Dogger" Aquifer					
Alfortville	48 - 49° N	+ 2 , +3° W	Oolitic limestone	20	75
Bonneuil sur Marne	"	"	"	24	79
Cachan Nord	"	"	"	22	70
Cachan Sud	"	"	"	16	71
Champigny sur Marne			"	13	78
Chatenay Malabry			"	13	67
Chelles		"	"	22	66
Chevilly Larue			"	16	77
L' Hay les Roses		"	"	16	74
Clichy sous Bois			"	19	70
Coulommiers			"	32	[illegible]
Creteil			"	23	78
Epinay sous Senart		"	"	14	74
Evry			"	10	71
Fresnes	"	"	"	14	74
La Courneuve Nord	"	"	"	24	58
La Courneuve Sud	"	"	"	22	58
Le Blanc Mesnil	"	"	"	27	67
Le Mee sur Seine	"	"	"	13	72
Maison Alfort I	"	"	"	22	72
Maison Alfort II	"	"	"	22	73
Meaux Beauval 1	"	"	"	31	77
Meaux Beauval 2	"	"	"	32	77
Meaux Collinet	"	"	"	30	79
Meaux Hopital	"	"	"	32	76
Melun L' Almont	"	"	"	15	72
Montgeron	"	"	"	11	72
Orly I	"	"	"	17	76
Orly II	"	"	"	15	76
Ris Orangis	"	"	"	10	71
Sucy en Brie	"	"	"	26	78
Thiais		"	"	17	75
Tremblay les Gonesse	"	"	"	26	73
Vaux le Penil		"	"	12	71
Vigneux sur Seine	"	"	"	13	72
Villeneuve Saint George		"	"	18	77
Villiers le Bel	"	"	"	27	66
Paris Basin - Other aquifers					
Bruyere le Chatel	48.5	+ 2	Sand		34
Paris Maison de la Radio	"	"	Sand		27
Paris AGF		"	Sand		27
Chateauroux	46 5	+ 1.5	Limestone + Sand		35
Other Basins					
Begles	44 5	- 0.5	Limestone	0.32	21
Bordeaux Benauge		"	Limestone	0 62	45
Bordeaux Meriadeck	"	"	Limestone	0.4	53
Bordeaux Grand Parc		"	Limestone	0.6	48 *(Not Use)*
Pessac Saige Formanoir	44 5	0.0	Limestone	0.36	48
Pessac Stadium		"	Limestone		50
Merignac BA 106	44 5	- 0.3	Limestone	0 11	53.8
Mios le Teich	14 3	- 0.5	Sandstone Limestone	3 7	74
Hagetmau	43 5	- 0.3	Limestone	0 55	32
Mont de Marsan I		"	Limestone		61
Mont de Marsan II	"	"	Limestone	0.08	57
Dax	43.5	- 1.0	Limestone		*(Not Use)*
Saint Paul les Dax	"	"	Limestone		65
Blagnac	43.5	+ 1.2	Sand	1.2	60
Libourne	44 5	- 0 1	Sand	0 25	23
Lamazere	43.5	+ 0.2	Sand	0.4	57
Casteljaloux	44.2	0.0	Limestone		43
Nogaro	43 5	- 0.5	Sand	0.18	51
Jonzac	45.5	- 0.5			62
Dieuze	48.5	+ 6.5			31
Montagnac	43 5	+ 3.5			26
Soultz sous Forêts [2]	48.5	+ 7.5	Granite		160

2) Hot Dry Rock European project - Research Project

Locality	Year Drilled	Well Number	Type of Well 1)	Total Depth m	Max Temp °C
Soultz-sous-Forets	1990	4550	a)	1500	133
" "	1990	4601	a)	1604	130
" "	1988	4616	b)	1414	125
" "	1992	GPK1	EI	3590	160
" "	94 - 95	GPK2	*in progress*	4000	

TABLE 8. WELLS DRILLED FOR DIRECT HEAT UTILIZATION OF GEOTHERMAL RESOURCES FROM JANUARY 1, TO DECEMBER 31, 1994

I - Injection
P = Production

Locality	Year Drilled	Well Number	Type of Well 1)	Total Depth m	Fluid Enthalpy °C	Flow Rate l/s
Melun l'Almont	1990	3	I	1843		
Melun l'Almont	94 -95	4	P			
St Paul les Dax	1993	SPDX1	P	1665	65	42

TABLE 9. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degree)

- Estimated -

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants (Hot Dry Rocks)
(5) Contributed Through Foreign Aid Programs (European Community)
(6) Private Industry

Year	Professional Man Year of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1990	0.5	20	I	0.5	4	16
1991	0.5	17	I	0.5	3	15
1992	0.5	15	I	0.5	3	14
1993	0.5	14	1	0.5	3	13
1994	0.5	7	I	0.5	2	13

TABLE 10. TOTAL INVESTMENTS IN GEOTHERMAL IN (1994) US$

- Estimated -

Period	Research & Development Incl. Surf. Exp. & Exp. Drilling	Field Development Incl. Prod. Drilling & Surf. Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1975-1984	20	320	335	5	80	20
1985-1994	40 (Including HDR Research)	280	290	30	90	10