SWISS GEOTHERMAL ENERGY UPDATE 1990 - 1995

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ABSTRACT

The early nineties mark a turning point in Swiss geothermal development. The relatively modest success of deep drilling projects. albeit encouraged by a governmental risk coverage system, gave momentum to countrywide borehole heat exchanger (BHE) installations. Subsequently Switzerland became world leader in the application of this small-scale heat pump-coupled System. well suited to supply heat to decentral objects. Their reliable long-term operation leads to manifold new R&D activities which are further described (BHE groups, combined heat extraction/ storage, energy piles, deep BHE's). Another focus is on the utilisation of warm Alpine tunnel waters and on Hot Dry Rock research. Special governmental programs for research and development promotion to support these activities are outlined. Finally, the geothermal activities abroad by Swiss-owned companies like CALPINE or project financing by Swiss banks are summarized.

Key words: direct use, borehole heat exchangers, doublets, tunnel waters, financing activities abroad.

1. INTRODUCTION

Switzerland is a small country (41'000 km^2, 7 million population) with a remarkably low reliance on fossil fuels for electricity generation (see Table 1). There is no geothermal-based electricity (Tables 2, 4 and 7 are therefore missing).

This is the third update report about geothermal activities in Switzerland. The previous ones (Griesser and Rybach 1985. Rybach and Hauber 1990) presented the geological framework as well as the political and economic background. Since the second report significant steps in the energy policy development towards the utilisation of indigenous and environmentally benign forms of energy have been undertaken: i) acceptance of an energy taw (popular vote, 23 September 1990), ii) initiation of the action plan "ENERGY 2000" (on 14 December 1990; with the aim of producing 0.5 % of Swiss electricity and 3 % of heat supply from renewable sources by the year 2000). and iii) the issuing of the energy utilisation decree (enacted on 22 January 1992) to encourage, by financial support mechanisms, the development of new solutions. To this end, the governmental risk coverage system for deep (>400 m) geothermal drilling, introduced in 1987 and described in detail in Rybach and Hauber (1990) is still effective (see below). A dralt law for a CO_2 tax (which would positively influence the economic boundary conditions of "new" energy technologies including geothermal) is presently in pre-parliamentary discussion.

Besides these events on the federal (country) scene, political entities at lower subsidiary levels (cantons, communities) have started to implement legislative means for promoting novel techniques: for example, the city of Zurich introduced lower electricity tariffs for heat pumps in 1994. Two recent publications (Fehr et al. 1993, Wilhelm et al. 1994) describe these recent developments in more detail.

In the following, the main activity fields in geothermal exploration and development will be summarized. Parallel to these efforts in applied geothermics, the more basic research-oriented topics like lithosphere- scale geothermics receive constant attention (e.g. Čermák and Rybach 1991).

2. EXPLORATION, RESOURCE ASSESSMENT

The compilation and cartographic representation of geothermal data relevant lor resource assessment continues. Here the Swiss input to the Geothermal Atlas of Europe must be first mentioned (Rybach 1991). The updating of Swiss contribution to the EC Geothermal Resource Atlas (Rybach 1988) on the basis of numerous new data from widespread drilling activities (for geothermal, hydrocarbon exploration, radioactive waste disposal site selection, deep tunnel construction etc.) is presently underway, within the framework of the JOULE II program of the European Union. The geothermal potential of the Swiss Moiasse basin (where the majority of the population lives) has been assessed in a special study (Rybach 1992). In order to cover the whole country, the establishment of an extensive geothermal data bank was initiated by the Swiss Federal Office of Energy (BEW, Berne; personal communication by Dr. A. Fehr). Besides the country-scale efforts, local preparatory works (structural geology as well as geophysics, mainly seismic reflection) have been performed to site several deep drillings (see below, especially Table A. The detailed exploration program "GEOTHERMOVAL" 1987-1995, already outlined in Rybach and Hauber (1990), led to the the selection of different drilling targets (cf. Fig. 1). Table 6 lists further localities with identified potential.

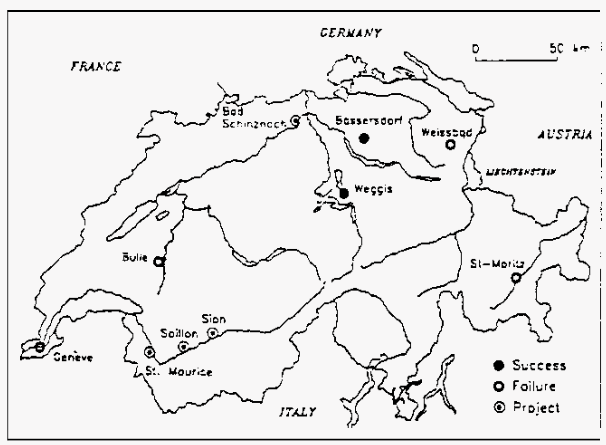

Fig. 1. Location of geothermal deep drilling (>400 m) in Switzerland (see also Table A). The sites St. Maurice. Saillon and Sion result from exploration within the GEOTHERMOVAL project (see text).

3. DEEP DRILLING

The considerable success of large-scale geothermal heating systems in France (based mainly on the "doublet" concept) led to a strong preference on this line of development also in Switzerland. Besides doublets, also the 'singlet' concept has been followed, in cases where the mineralisation of the geothermal fluids is low enough to guarantee surface disposal.

Thank to the risk guarantee of the Federal Government for geothermal production drilling (a total of 15 million Swiss francs to cover activities from 1967 to 1997: for details see Rybach and Hauber 1990) several drilling projects have been initiated. on the basis of intensive, small-scale local exploration for localising the drillsites. Since it is nearly impossible to predict. on the basis of surface measurements alone, the aquifer permeability distribution at depth, geothermal drilling is characterised by inherent risks. This means that the yield of the wells (and thus the useable thermal power) cannot be predicted reliably.

In the late eighties. Several drilling projects were successful (Kloten/ZH, Kreuzlingen/TG, Riehen 1&2/BS; see Rybach and Hauber 1990, Hauber 1991.). In fact. the first Swiss geothermal doublet (geothermal capacity 4.7 MW_{th}, total heating power 15.2 MW_{th}) has started its operation Successfully in fall 1993 (Boissavy and Hauber 1994; Böhi and Huser 1994).

Unfortunately. the activities in the early nineties were less successful (cf. Table A; tor locations see Fig. 1). In general. the flow rate was much less than expected and definitely too low lor a sensible utilisation. Further details are given in Tables 3 and 8.

Table A: Deep (>400 m) geothermal drilling in Switzerland 1990-1995

Locality	Year	Depth (m)	Result*
St. Moritz/GR	1991	1600	F
Bulle/FR	1992	800	F
Bassersdorf/ZH	1992/93	650	S
Weggis/LU	1992193	2300	S**
Thonex/GE	1993	2550	F
Weissbad/AI	1993	900	F

*) S : success. F : failure
**) drilled for a deep borehole heat exchanger

The sobering balance of these drilling endeavours reduces the general Interest for large-scale geothermal development and the preparedness of public authorities andlor prlvate organisations for fundinglsupporting. Some well-prepared projects (e.g. Bad Schinznach/AG, Davos/GR) have already been postponed. On the other hand this Situation creates a favourable atmosphere for other options to use geothermal heat (borehole heat exchangers, tunnel waters; see below).

4. BOREHOLE HEAT EXCHANGERS (BHE)

In view of the modest success in geothermal deep drilling in Switzerland the focus of Interest is now on shallow geothermics. Its depth range can be pragmatically defined to lie between ≈ 15 m and 400 m; the upper limit is given by the depth in which atmospheric surface effects on the temperature field become negligible. and the lower boundary is at the depth from where on the governmental risk guarantee for 'deep" drilling applies.

BHE's are Ideal to make use of ground heat In this depth range. The most popular EHE heating system with one or more boreholes typically 50 - 150 m deep is a decentral, closed-circuit, heat pump-coupled system. ideally suited lo supply heat to smaller objects like single family or multi-family dwellings. They can be installed in nearly all kinds of geologic media (except in materials with low thermal conductivity like dry gravel).

Experimental and theoretical Investigations prove that such systems, if properly designed, operate reliable also on the long term. without negative environmental effects (Rybach et al. 1990, Rybach et al. 1992. Eugster et al. 1992. Rybach and Hopkirk 1994). Although the Installation cost of such a system is some 30 % higher than tor conventional oil-based healing (see Rybach and Hopklrk. this Proceedings), environmental awareness of developers and recent governmental and cantonal subsidy led as Incentives to a real EHE boom in Switzerland. To date there are over 6'000 such systems installed. with a total of 1'300 km EHE length. Areal density (number of BHE's per country area) is highest worldwide (cf. Fig. 2 which shows the Situation in 1992).

Besides these closed-circuit BHE's also numerous open systems are installed (cf. Table 5). The total of EHE heating amounts presently to over 0.8 PJ/a (for comparison: Switzerland used a total of 346 PJ/a lor space heating in 1993). This remarkable

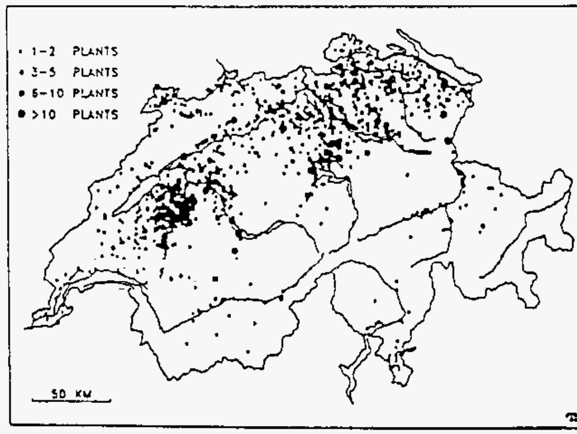

Fig. 2. Location of BHE systems in Switzerland *(situation end of 1992)*. Distribution corresponds roughly *to* population *density*. Areal *density* (number *of* BHES per counlry area) wilh today's *6'000* heating *units* is *highest worldwide*.

development and the considerable EHE potential not yet tapped leads lo manifold R&D activities for new solutions (multiple BHE's, combined heat extraction/storage, 'energy piles'. deep BHE's; see below).

5. FROM RESEARCH TO PILOT & DEMONSTRATION FACILITIES

In Switzerland, the following public and private organisations are funding both geothermal research and promotion (see also Table 10):

- the Swiss Federal Office of Energy (BEW)
- the Swiss Federal Office of Education and Science (BBW)
- the National Energy Research Fund (NEFF)
- the National Science Foundation (SNF).

Occasionally, Cantonal offices (e.g. water management) are supporting specific projects

From the above-mentioned organisations, the most substantial support is provided by the EEW. within the framework of 'Energy 2000'. an action plan already mentioned in the introduction. Two separate programs have been established in 1992; a Research Program and a Promotion Program "Geothermie 2000'. Leader of both programs is H.L. Gorhan.

Besides the risk coverage for deep geothermal production hole drilling (see introduction) the BEW also subsidises 25 % of the actual drilling and testing costs. With respect to the implementation of geothermal pilot and demonstration installations, up to 60 % of the non-amortisable extra costs (relative to a conventional thermal plant) and up to 100 % for studies and heat measurement concepts are eligible for EEW subsidy.

The main targets of the actual research and promotion programmes can be summarised as follows:

5.1 Optimising borehole heat exchangers (BHE)

The most important advance in the increase of economy of EHEs is achieved by developing more efficient types of installations and considering also the local hydrogeological conditions (i.e. open. closed or semi-open circuit EHEs, e.g. the GEOHIL technique). There is a tendency to increase the size of geothermal plants by using a multitude of BHE's. Here, extensive studies are being carried out to determine optimum depths and borehole spacings in order to guarantee an economic life span. It is important lo note that BHE's will not Only serve lor heat extraction but also lot cooling purposes ("free cooling") during the summer. This has the double benefit as the BHE's can be recharged by surplus heat and thus preventing 'heat mining" of the underground. In this regard, several projects are investigating at present the possibility of heat storage by also applying Solar collectors. Furthermore, heat storage is already being used lor keeping roads and bridges free from ice during the winter. This is an interesting technique in order to avoid negative impacts on the environment and on structures due lo road salting.

5.2 Energy piles

Considerable parts of densely populated areas in Switzerland show rather poor foundation conditions and thus require piling for larger construction works. This fact led to the idea to equip these piles with heat exchangers (="energy piles"). Three projects of this type have already been implemented with EEW support and are now intensively controlled by measurements in order to establish heat balances. As for the EHEs. the energy piles are serving a double purpose of heating and cooling. However, temperatures cannot be allowed to drop below 0 °C during heat extraction as this would possibly decrease the safety factor of a pile by reducing friction angles (due to freezing and thawing processes).

5.3 Deep BHES

For oil and gas exploration as well as for the location of radioactive waste disposal sites, a multitude of deep holes have been drilled in various regions of Switzerland. Given a reasonable short distance to potential heat consumers, the idea is to install a deep BHE (e.g. down to a depth of about 2500 m) in these abandoned boreholes. Basically this type of construclion will be Similar to a Shallow BHE. However, due to the considerably higher hydrostatic and ground pressures this will require special construction materials and adequate heat extraction strategies (Hopkirk and Rybach 1994, Rybach and Hopkirk, this Proceedings). At present, two pilot and demonstartion plants of this type are subsidised by the BEW (see also Table 8).

5.4 Geothermal aquifer development and management

Aquifer development can benefit from drilling first with reduced diameter (slim holes), thus having deeper/cheaper holes. Also the well-planned use of geothermal fluids in case of neighbouring utilisers (=aquifer management) needs to be addressed. The latter is especially necessary in Switzerland where stratatype aquifers are often disrupted by faults. Both lines of research are supported by the BEW.

5.5 Tunnel waters

Being a typical Alpine country, Switzerland has several deep road and railway tunnels. Two tunnels of considerable depth and cover are planned to be constructed in the near future (the Gotthard and Lotschberg base tunnels, AlpTransit/NEAT project). Naturally, there is always a good chance to encounter water during tunneling which has to be drained away permanently. Instead of leading this water completely to disposal, considerable energy can be extracted for domestic heating purposes near the tunnel portals. As a matter of fact, a small alpine village is already doing exactly this by using water flowing out of the Furka tunnel and by applying decentralised heat pumps (Rybach and Wilhelm, this Proceedings). Given these promising results, several feasibility studies will be starting soon in order to assess the geothermal potential of all existing and planned tunnels ail over Switzerland.

5.6 Hot Dry Rock (HDR)/Hot Wet Rock(HWR)

Considering the rather high development costs of HDR/HWR projects, R&D activities are only possible within the framework of international cooperation. as already mentioned above. Supported partly by the NEFF and by the BEW, a mathematical simulation model (FRACTure, Kohl et al. 1994) was developed which contribute significantly to the first European HDR pilot project in progress in Soultz-sous-Fôrets, France (Evans et al. 1992). In evaluating the Soultz data, geochemical techniques which were developed partly under Swiss cooperation (Pauwels et al. 1990, 1991) were highly successful.

6. SWISS GEOTHERMAL ACTIVITIES ABROAD

According to old tradition, large Swiss companies and banks are internationally active. Substantial geothermal enterprises abroad make no exception in this respect. In fact. the lack of indigenous high-enthalpy fields is counterbalanced by the development and utilisation of this resource type under Swiss control abroad.

First of ail, the activities of CALPINE (an indirect wholly-owned subsidy of Electrowatt Ltd., a major utility, industrial products and engineering services company based in Zurich) must be mentioned here. CALPINE is the second largest producer of geothermal electricity in the USA, with over 300 MW_e power generating capacity. Negotiations to establish additional capacity of about 290 MW_e are underway.

Swiss banks are well-established project financers in many countries of the world. Whereas Union Bank of Switzerland (UBS) was only active in one development during 1990 -1995 (Santa Rosa/California, USA; 1990). Credit Suisse (CS) demonstrates growing presence on the international geothermal scene. Table E lists the projects financed by CS since 1990

Table B: Geothermal project financing by Credit Suisse

Locality	State/Country	Year	MW_e
Puna	Hawaii/USA	1990	25
Salton Sea	California/USA	1994	80
Upper Mahaio	Leyte/Philippines	1994	119
Malitbog	Leyte/Philippines	1994	216

Finally the manifold involvement of Switzerland in international geothermal research shall be summarised. The participation in R&D activities of the EU (Geothermal Resource Atlas, HDR modelling) has already been mentioned above. New contributions to the German Continental Deep Drilling Project KTB (e.g. Kohl and Rybach 1994) belong here as well as the multidisciplinary project MARMARA which includes geothermal measurements and potential assessment in W. Turkey (Rybach and Pfister 1993).

7. INFORMATION/POPULARISATION

Although geothermal energy is clearly in a leading position worldwide among 'alternative' options (e.g. solar energy) as far as electricity generation is concerned, it is still relatively little known in Switzerland. This applies also to the manifold options for direct utilisation. First-hand inlormation about possibiliities and limitations is essential for decision makers as well as for the general public. Therefore the BEW issued in 1990 a popular, well illustrated information brochure "Erdwärme in der Schweiz - Vorkommen und Nutzungsmöglichkeiten" in a German and French version. It also appeared, in slightly extended form, as a booklet (Weber 1990).

A major step towards popularising and promoting geothermal utilisation was the formation of the Swiss Geothermal Association (SVG, "Schweizerische Vereinigung fur Geothermie") in April 1990. Presently the SVG has over 300 individual and 30 corporate members. It organises well-attended technical meetings. publishes a regular Bulletin, and is presently negotiating affiliation with the International Geothermal Association (IGA).

8. CONCLUSIONS, OUTLOOK

During the period 1990-1995 geothermal energy utilisation in Switzerland proceeded mainly along the general direction set by the countrys energy policy (a.o. promotion of indigenous, environmentally benign energies). Since no high enthalpy resources are known, emphasis was on direct use. However. the lack of suitable resources for electricity generation is compensated by development and financing such resources, under Swiss control, abroad.

The early nineties mark a re-orientation in the direct use philosophy. Since several deep drillings failed to produce sufficient amounts of fluids for district heating, interest and efforts moved to rather small-scale and shallow systems. In fact, within a few years Switzerland became world leader in heat pump-coupled borehole heat exchanger (BHE) applications. This success is backed bv substantial research activities.

For the next years some trends are already visible: novel techniques and solutions gain attention and support, like frontiers in EHE applications (multiple BHE's, combined heat extraction1 storage, energy piles, deep EHEs). utilisation of tunnel waters, and further pursuing HDWHWR R 8 D work.

By all means, Switzerland will continue to take its share, also by intensified international activities and cooperation, in the development and use of geothermal energy.

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TABLE 1: PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Total	
	Capacity MWe	Gross Prod. Gwh/yr	Capacity MWe	Gross Prod. Gwh/yr	Capacity MWe	Gross Prod. Gwh/yr	Capacity MWe	Gross Prod. Gwh/yr	Capacity MWe	Gross Prod. Gwh/yr
In operation in January 1995	-	-	200	1000	11800	36000	3000	22000	15000	59000
Under construction in January 1995										
Funds committed, but not yet under construction in January 1995										
Total projected use by 2000										

TABLE 3: UTILISATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT IN DECEMBER 1994

1) I=Industrial process heat; C=Air conditoning; A=Agricultural drying; F=Fish and Other animal farming; S=Snow melting; D=Space heating; B=Bathing and swimming; G=Greenhouse; O=Other (please specify by footnote)

2) Enthalpy information is given only if there is steam or two-phase flow

3) Energy use (TJ/yr)=Average water Row rate (kg/s)x[Inlet temp (°C)-Outlet temp (°C)]x0 1319

Locality	Type	Maximum Utilisation					Annual Utilisation		
		Flow Rate	Temperature °C)		Enthalpy (kJ/kg)		Average Flow rate	Energy Use	Load Factor
		kg/s	Inlet	Outlet	Inlet	Outlet	kg/s	TJ/yr	
Bassersdorf	D	4.5	23	13			1.1	1.5	
Kreuzlingen	B/D	3.7	30	20			0.9	1.3	
Oberwald	D	90.0	16	6			22.6	29.9	
Riehen	D	20.0	65	33			5.0	21.1	
Weggis	D	1.5	40	10			0.4	1.0	
Total								54.7	

Locality	Heat Source °C	COP-Factor	Heat Pump Rating MWth (Output)	Thermal Energy Used TJ/yr
closed circuit borehole heat exchangers –6000 installations with a total length of 1'300'000 m	11	–3 0	98 0	775
Open circuit borehole heat exchangers (GEOHILL) 132 installations with a total length of 32'350 m	15	–3 7	4.1	25
Energy piles ~ 28 installations with a total length of 28'150 m	9	~2.9	2.1	20
Total			104.2	820

TABLE 6: INFORMATIONSABOUT GEOTHERMAL LOCALITIES

1) Main type of reservoir rock

2) **Total** dissolved solids (TDS) in water before flashing. Put v for vapor dominated

3) N= Identifiedgeothermal locality. but no assesssment information avaiable
R= Regional assessment
P= Pre-feasibility Studies
F= Feasibility studies (Reservoir evaluation and Engineering studies)
U= Commercial utilisation

Locality	Location 'o Nearest .5 Degrees		Reservoir		tatus in lanuary 1995	Reservoir Temp. (°C)	
	Latitude	Longitude	Rock	Dissolved Solid: mg/kg		Estimated	Measured *
Bovernier	46.0 N	7.0 E	Metamorphite	300	R	35-40	
Brigerbad	46.0 N	8.0 E	Metamorphite	1300	R	110	52
Combioula	46.0 N	7.5 E	Metamorphite	2900-5200	R	35	28
Epinassey	46.0 N	7.0 E	Metamorphite	700	R	30-40	
Furka tunnel	46.0 N	8.5 E	Metamorphite	150	U	25	22
Gotthard tunnel	46.0 N	8.5 E	Metamorphite	<3000	R	30-40	
Lavey-les-Bains	46.0 N	7.0 E	Metamorphite	1400	R	100	
Leukerbad	46.0 N	7.5 E	Metamorphite	2000	R	60	
Lötschberg tunnel	46.5 N	7.5 E	Metamorphite	<3000	R	30-50	
Rawyl tunnel	48 0 N	7.5 E	Metamorphite	400	R	35-40	30
Saillon	46 0 N	7.0 E	Metamorphite	1400	R	30-40	24
Saxon	46.0 N	7.0 E	Metamorphite	700-3200	R	35-40	25
Simplon tunnel	46 0 N	8.0 E	Metamorphite	1500-7900	R	60-80	57
Val de Bagnes	46 0 N	7.0 E	Metamorphite	1000	R	25	
Val d'Illiez	46.0 N	7.0 E	Metamorphite	1800	R	35-40	
Total							

* outflow temperalure

TABLE 9: ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted lo **Personnel** with a University degree)

1) Government
2) Public Utilities
3) Universities
4) Paid Foreign Consultants
5) Contributed Through Foreign Aid **Programs**
6) Private Industry

Year	Professional Man Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1990	2		2			2
1991	2		2			2
1992	2		2			2
1993	2		2			3
1994	2		2			3

TABLE 8: WELLS DRILLED FOR DIRECT HEAT UTILISATION OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1990 TO DECEMBER 31. 1994
(Do not include thermal wells less than 1000 m deep)

1) Type or purpose of well and manner of production
Use one symmbol from Column (a) and one from Column (b)

(a)	(b)
T= Thermal gradient or other scientific **purpose**	A=Artesian
E= Exploration	P=Pumped
P=Production	F=Flashing
I= Injection	

2) Total now rate at given wellhead pressure (WHP)

Locality	Year Drilled	Well Number	Type of Well	Total Depth m	Max Temp	Fluid Enthalpy	Well Output Flow Rate kg/s	Well Output WHP ba
Bassersdorf	92/93	1	P/P	583		[illegible]	4.5	
Bulle	1992	1	failure	800			<5	
Saillon	94195	1	planned	1000	~		?	
St. Moritz	1991	1	failure	1800			0.7	
Thônex (Geneva)*	1993	1	failure	2530	43	180	3	
Weissbad **	1993	1	failure	1600	25	105	1 5	
Weggis ***	9293	1	PIP	2304	49	205	1 5	
Total				10417		992		

* borehole length 2690 m
** deep borehole **heat** exchanger, 1213 m active
*** deep borehole heat exchanger. full length utilized

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

Period	Research & Development Incl Sufi Exp & Exp Drilling	Field development Incl Prod Drilling & Surf Equipment	Utilisation		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US16 **	Million US$	Million US5	%	%
1975-1984	2 5	28 5	31.0	-	95	5
1985 - 1994	6 5	80.0	88.5	-	85	15

** Geothermal **wells** and borehole heal exchangers