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GEOTHERMAL DEVELOPMENT IN HUNGARY COUNTRY UPDATE REPORT 1995-1999

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ABSTRACT

Information is provided on the status of geothermal direct heat use in Hungary, with emphasis on developments from 1995 to 1999.

During the four years since WGC'1995 there have been 6 new geothermal developments in Hungary.

The geothermal energy was utilized in direct use, no electricity has been generated.

Geothermal energy utilization is estimated to be 324.6 MW_t of geothermal capacity and it currently supplies 2804.3 TJ/yr. of heat energy through direct heat application in Hungary, as of January 1, 1999.

Geothermal heat pumps represent 3.8 MW_t of installed capacity.

The quantity of the produced thermal water for direct use in year 1998 was approximately 21.5 million cu.m. with average utilization temperature of 31 ºC.

The main consumer of geothermal energy is in agriculture (64%).

The proportion of geothermal energy utilization in the energy balance of Hungary, despite the significance proven reserves, is low (0.28%).

INTRODUCTION

This paper represents results of the geothermal development in Hungary between 1995 and 1999.

Geothermal development covers the thermal water management and utilization of the geothermal energy represented by geothermal fluids for direct use.

1. BACKGROUND

Hungary is well known as a country of favorable conditions in terms of geothermal gradients that are higher than the World average.

According to the results of different assessments (Boldizsár, 1967 and Bobok, 1988) of the geothermal reserves, Hungary has the biggest underground thermal water reserves and geothermal energy potential of low and medium enthalpy in Europe.

2. GEOTHERMAL UPDATE (Geothermal statistics)

The main data of geothermal energy utilization for direct uses in Hungary by January 1, 1999 as reported by Árpási, 1999 are shown in Table 1.

As a result of the analysis of the geothermal update of Hungary by January 1, 1999 the following conclusions can be drawn:

a) the geothermal energy is utilized in the form of direct use, no electricity has been generated from geothermal energy

b) areas of the direct use (Table 2)
- agricultural utilization
- communal use (space heating and domestic hot water)
- industrial use

The number of geothermal heat utilizing organizations was 124, the number of the settlements utilizing geothermal energy was 42, and the number of spas utilizing geothermal heat for direct use was 4 in 1999.

c) In Hungary geothermal energy utilization is an economically profitable enterprise. With regard to direct heat utilization, according to a survey (Árpási, 1998) the geothermal power was 324.5 MW_t. Concerning the utilized geothermal heat quantity of 2804 TJ/year**,** by comparing it with the World's data of 1995, Hungary is 5th (fifth) in the World's list, while concerning specific geothermal heat utilization, Hungary is 3rd (third) in the World (33.1 W_t/person, 31 Dec. 1997).

As for the agricultural purpose geothermal heat utilization, however, Hungary is the first in the World's list (207 MW_t, and 1786 TJ/year).

d) As was analyzed in a study (Árpási, 1998) the current situation of geothermal heat utilization in Hungary as indicated in Table 2 shows that the quantitative utilization is good in the World comparison, but with respect to efficiency, we lag considerably behind, because:

- the geothermal energy utilization does not have the necessary unambiguous legal basis,
- the thermal water production and direct use are of extensive nature,
- the efficiency of the mostly only seasonal type of geothermal heat utilization is low,
- fundamentally no reinjection is applied.

Fig. 1. shows the geothermal update of Hungary by January 1, 1999.

3. GEOTHERMAL DEVELOPMENTS

The research of new possibilities for the direct use is first of all reasonable due to the fact that it is mostly seasonal in Hungary, too, i.e. traditional applications are mainly used only in the heating season.

Regardless of the fact whether the geothermal energy is utilized in the agriculture, industry or for the district heating, it can be equally stated that the old systems by now have became physically outdated and obsolete.

As indicated in papers (Korim, 1997 and Árpási, 1998) the integrated, multipurpose thermal water utilization in energy cascade use is playing especially an important role.

3.1. Possibility of geothermal based power generation

At the SE part of Hungary (Nagyszénás-Fábiánsebestyén), as defined by oil explorations, there were some high temperature and high pressure indications referring to the existence of geopressured type thermal water reservoir systems. In well # Nsz-3 located in this area, during the formation testing 171ºC wellhead temperature was measured, which is the highest geothermal wellhead temperature measured until now in Hungary. Upon the utilization of such types of reservoirs, it is expedient to use the kinetic and pressure energy of the geothermal fluid in addition to its thermal energy for power production.

Table 3 shows the comparison of the main data of geopressured reservoirs located in Hungary and in USA (Gulf Coast) as indicated in TGC, (1996).

3.2. The problem of reinjection of the spent water

In Hungary both the water management and direct use of thermal waters is implemented in an open drain systems e.g. without reinjection of spent water which is stored in surface aquifers and then drained into surface waters.

The reasons for reinjection of the spent water after the utilization into underground thermal water aquifers or formations being in hydrodynamic connection with them are as follows:

- protection of the thermal water reserves, i.e. stopping the depletion of the thermal water reserves (reserve protection aspect),
- prevention or avoidance of potential environmental pollution of surface areas and surface waters (environmental protection aspect),
- enforcement of the renewable character of thermal water as energy carrier by the creation of the artificial heat extraction–natural reheating cycle.

Under the Hungarian geological and hydrogeological conditions the questions of water reinjection appears in two ways:

- Reinjection into the fractured, carbonated reservoirs of the thermal water is a technically realizable and not too costly solution.
- The experiences of reinjection into porous, clastic (sandstone) formations up to now have indicated that the results were uncertain and could not be regarded to be the preferred basis for commercial application. The technical solution of this question can be obtained by the application of the water disposal experiences obtained from the oil industry. Despite the unfavorable or lacking international experiences, **planning of the pilot application** is providing the basis of the results for commercial application (**Szeged-Felsōváros**).

3.3. The role of the oil industry of Hungary

The Hungarian Oil and Gas Company (MOL Co.) started a program in 1995 to promote the development of geothermal energy (Árpási, 1993). MOL Co. has compiled pre-feasibility studies of the three geothermal pilot projects. The geological-technical data for them are summarized in Table 4.

Fig. 2. shows the process diagram for the cascaded use of geothermal energy at one of the pilot projects, as indicated in Krete-Porció (1996).

3.4. Conception of geothermal energy utilization in Hungary

A conceptual study was undertaken for geothermal development in Hungary (Árpási, 1998), based on the very considerable geothermal reserves in Hungary.

The total energy consumption of Hungary was 1,055 PJ in 1998. The proportionate rate of geothermal energy, based on the status on January 1, 1999, was **2.8 PJ**, which represents a **0.26%** proportionate rate in the total energy consumption of the country.

It is a realistic objective to enhance the proportionate rate of thermal energy in the national energy balance to **1%**, which means **10.5 PJ/year** geothermal heat energy utilization being projected to the total energy consumption of 1998.

The time period of this objective is between **1999-2001** (3 years).

The extension of the utilization to the planned extent can be realized in two ways:

- By the increase of the efficiency of the existing heat utilizing systems,
- By the establishment –by investment– of new geothermal heat utilizing systems.

The total capital cost in the case of new geothermal heat utilization investments is 216 million USD, based on a specific capital cost of 500 USD/kW_t (Árpási, 1999)

The **10.5 PJ** geothermal heat quantity can be produced in the utilization systems with calculated geothermal power of **540 MW.**

The aim to increase geothermal energy use will consequently result in the considerable reduction of air pollution (e.g. reduction of CO_2 emission is 806 kt/year).

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Table 1.: Actual data of the geothermal energy utilisation in Hungary by January 1, 1999

Heat Utilisation area	Quantity of the produced thermal water Mm^3/year	Utilisation heat stage, DT* °C	Utilised heat TJ/year (PJ/year)	Thermal power MW_t
1.	2.	3.	4.	5.
1. Agriculture	12.497	34.1	1 785.8 (1.79)	206.67
2. Communal heating	5.658	26.6	631.6 (0.63)	73.11
3. Other	3.370	27.4	386.7 (0.39)	44.79
Total	**21.52**	**31.1**	**2 804.3 (2.80)**	**324.5**

* Weighted average.

Table 2. Geothermal reserves and utilization data in Hungary

Reserves of geothermal fluids			Thermal water production	Type of thermal Water utilization	Percentage according to the type	Utilized geothermal energy	Percentage in heat content of dynamic reserves
Static volumetric reserves, cu.km	Dynamic reserves, (at ΔT=40 °C) Volumetric Mcu.m/a	Heat content, PJ/a	Mcu.m/a (kg/s)		%	PJ/a	%
1	2	3	4	5	6	7	8
4000	380	63.5	113.15 (3587.9)	1. Balneology 2. Drinking water supply 3. Agriculture 4. Space heating, SHW and industrial	36.7 29.9 29.6 3.8	2.8	3.7

Table 3.: Comparison of the Hungarian (Nagyszénás-Fábiánsebestyén) and (USA) geopressured type geothermal reservoirs

Reservoir Parameters	USA (Texas, Lousiana)	Hungary (Nagyszénás-Fábiánsebestyén)
Depth, m	*4,800*	**3,165-4,034**
Reservoir rock type	*Clastic rocks (sandstone)*	**Carbonate rocks (dolomite) quartz porphyry**
Formation temperature, °C	*150*	**~190**
Reservoir porosity, %	*20-30*	**3-4**
permeability, mD	*20-120*	**11-120**
fluid volume, Mm^3	*10^3*	**10^5**
pressure gradient, MPa/km	*13.5-18.1*	**20.0**

Table 4.: The geological-technical data of the Hungarian geothermal pilot projects

Parameters of projects	Pilot projects		
	"Andráshida-Nagylengyel"	"Mélykút-Pusztamérges"	"Nagyszénás-Fábiánsebestyén"
1. Characteristic of reserves*			
• heat content	low enthalpy	low and medium enthalpy	medium and high enthalpy (geopressured)
• production method	pumping	artesian	artesian
• fluid quantity, cu.m./day, (min)	2600	2650	1891**
• well-head temperature, °C (min)	93	108	171**
• well-head press. during production, bar	–	1-5	450**
2. Number of possible doublets	20	10	5
3.The planned utilization data			
1.1. Potenctial heat capacity of production well, TJ/year	241	289	575*
1.2. Step of heat utilization, °C	63	78	141
of it:			
a) for electric production	-	28	91
b) for direct use	63	50	50
3.3. Installed electric capacity, MW_e	-	1-2	64
4. Planned timelife of projects, years	25		
5. Estimated geological-technical feasibility of project, %	95	80	***

* On base of oil industry measurements

** On base of Nagyszénás-3 well measurements data (July, 1991)

*** It could be estimate after the feasibility period, only

UTILIZATION OF THERMAL WATERS /1995-1997/

(thermal water management and direct use)

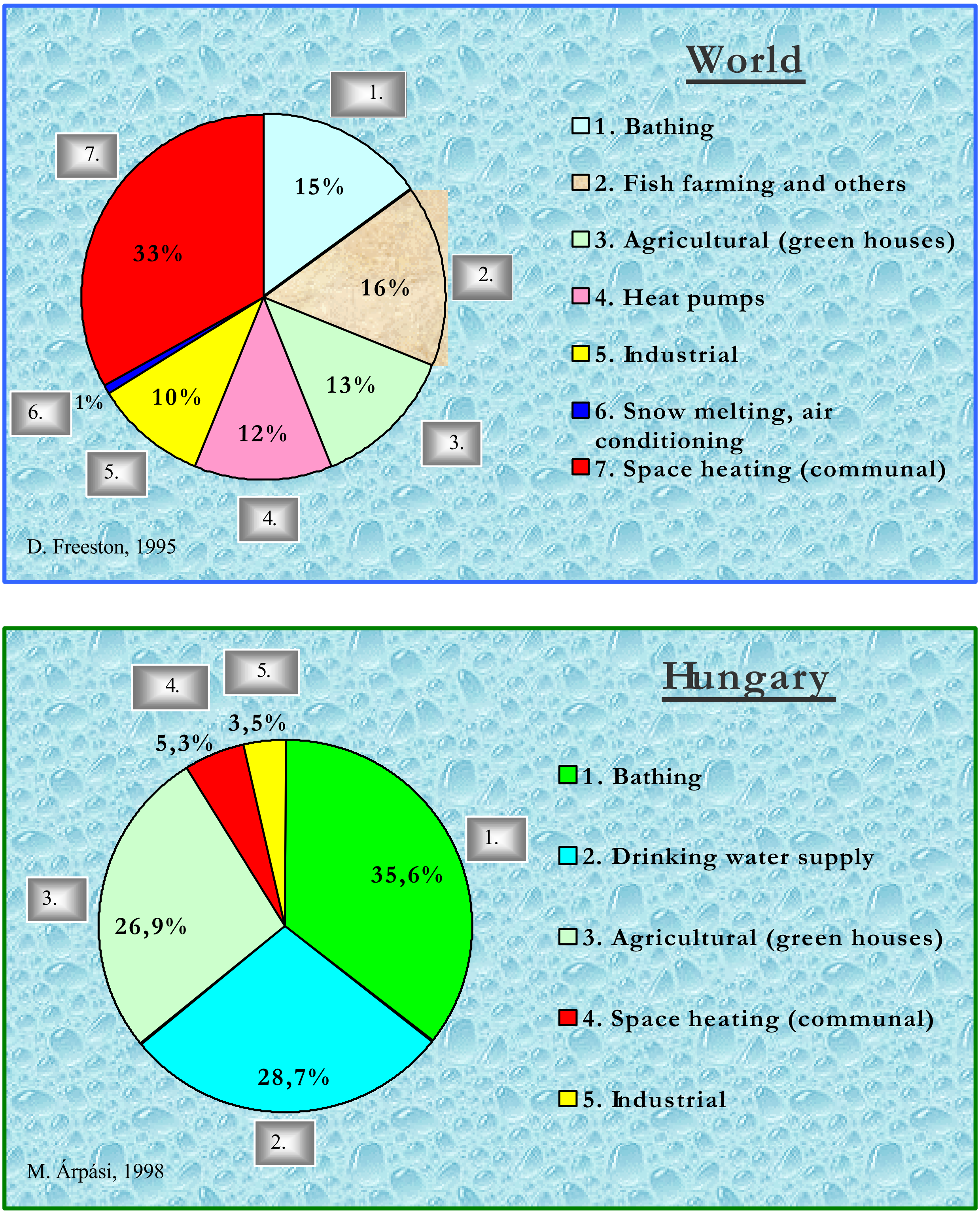

Fig. 1. Geothermal update of Hungary with comparison of World's data (thermal water management and direct use).

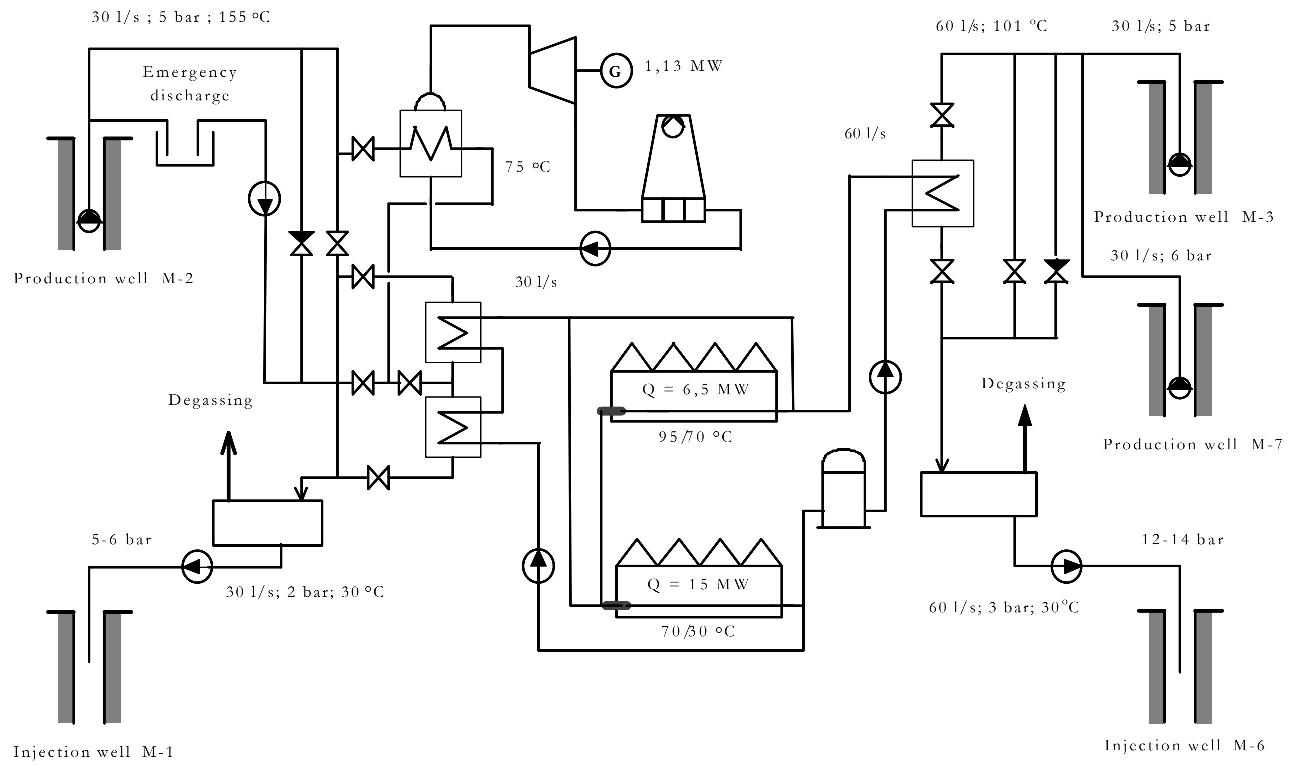

Fig. 2. The process diagram for the cascaded use of geothermal energy (Geothermal pilot project Mélykút, -Pusztamérges Hungary)

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in January 2000	no	no	5172	16588	37	157	1840	13964	no	no	7589	30709
Under construction in January 2000												
Funds committed, but not yet under construction in January 2000												
Total projected use by 2005												

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 1999

1) I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish and animal farming
S = Snow melting
H = Space heating & district heating (other than heat pumps)
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other (please specify by footnote)

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

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184 (MW = 10^6 W)

or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319 (TJ = 10^{12} J)

or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171

Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (^oC)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
124 organisations and persons	G							429,6	1782	0,4
2655 dwellings in 9 cities	D							154,8	636,3	0,5
2 users	I							6,1	28	0,5
4 spas	O*							86,6	358	0,8
TOTAL								677,1	2804,3	

Note: please report all numbers to three significant figures.

***Direct use in the spas (but no bathing and swimming)**

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES
AS OF 31 DECEMBER 1999

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
since projects do not operate at 100% capacity all year

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Space Heating[4]	73,1	636,3	0,5
Air Conditioning (Cooling)	no	no	no
Greenhouse Heating	206,7	1,782	0,4
Fish and Animal Farming	no	no	no
Agricultural Drying[5]	no	no	no
Industrial Process Heat[6]	1,8	28	0,5
Snow Melting	no	no	no
Bathing and Swimming[7]	no	no	no
Other Uses (specify)	42,9	358	0,8
Subtotal	324,5	2804,3	2,2
Geothermal Heat Pumps	no data	no data	no data
TOTAL	324,5		

4) Includes district heating (if individual space heating is significant, please report separately)
5) Includes drying or dehydration of grains, fruits and vegetables
6) Excludes agricultural drying and dehydration
7) Includes balneology

Note: please report all numbers to three significant figures.

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1995 TO DECEMBER 31, 1999

[1] Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)	no	no			
Production	>150° C	no	no			
	150-100° C	no	no			
	<100° C	no	3			
Injection	(all)		1			
Total			4			

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with a University degrees)

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

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1995	no	2	3	no	no	15
1996						
1997						
1998						
1999						
Total	no	2	3	no	no	15

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (1999) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1985-1989						
1990-1994						
1995-1999	0,25	0,1	0,15	no	40	60