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COUNTRY UPDATE REPORT FOR KENYA 1995-1999

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ABSTRACT

The power sector in Kenya has been going through legal, institutional and financial restructuring in order to obtain sufficient funds for the planned investment. The main target is to make the electric power adequately available and reliable in order to revitalize the economy. These reforms stared in the early 1990s. Kenya Electricity Generating Company (KenGen) has continued generating from the Olkaria East power station and carrying out exploration work on behalf of the Kenya Government in several prospects. The power industry was opened to Independent power Producers (IPPs). Two IPPs installed two diesel plants with a total capacity of 87.5MW and two others signed Power Purchase Agreement (PPA) to build a 64MW geothermal power station at Olkaria. Geothermal power is still the cheapest base-load option and 576MW is planned from this resource in the next 18 years. It is anticipated that responsibility for this will be shared between IPPs and the Public sector. However the government will have to find ways of funding the resource assessment programme quickly to avoid slippage in the development plan.

1. INTRODUCTION

The structural adjustment reforms that started in the early 1990s continue to create some changes in the Power sector. These reforms were meant to create a financially stable industry with a sufficient, reliable, quality and cost effective electricity supply to the customers. To achieve this required injection of competitive investment in the sector and the introduction of efficient and cost effective operation procedures. The Government consequently introduced various changes in the sector in order to motivate sustainable growth through participation of both public and private sectors. This paper updates the one presented at the last World Geothermal Congress in Florence, Italy, by Ng'ang'a (1995).

2. RESTRUCTURING OF THE POWER SECTOR

The current power system in Kenya is made up of about 846 MW of installed capacity with effective generation of about 806 MW. Of this effective capacity, 584 MW are hydroelectric, 177 MW thermal and 45 MW geothermal. The thermal generations include 87.5 MW from two Independent Power Producers (IPP) power plants commissioned in 1997. The rest of the generation is owned by the government through regional development authorities (Tana and Athi River Development Authority - TARDA and Kerio Development Authority - KVDA) and companies (Tana River Development Corporation - TRDC and Kenya Power Company – KPC and Kenya Power and Lighting Company - KPLC). These government generation plants have been operated by the only electric utility, KPLC under contract agreements.

Over the next 18 years, an additional 313 MW is expected to be generated from hydro, 576 MW from Geothermal resources, 762MW from Medium Speed Diesel and 250 MW from Low Speed Diesel (Table 1). This generation expansion is estimated to cost about US$ 3351.5 million. This is a huge amount of money, which cannot be expected to come from government investment alone. Consequently, it is expected that in the next 5 years, 271.5 MW capacity of generating plants will be constructed through public sector financing and 249 MW through IPPs. It was with this realisation that it was found necessary to restructure the power industry in order generate enough power to facilitate economic growth to motivate the private sector and also to make the public sector operate more efficiently.

Firstly, a new Electric Power Act was enacted in 1997. In this Act the generation industry was opened to the private sector. The control of the power sector was removed from the government to an independent Electricity Regulatory Board (ERB) that has seven members appointed by the government. The appointment of the ERB members was done in 1998.

Secondly, the power assets were distributed between two companies, one responsible for generation and the other transmission and distribution. All the generation assets were transferred to KPC. The transmission and distribution assets were transferred to KPLC, which is jointly owned by the government and the private sector.

Thirdly, the electricity tariff has been adjusted in various phases to bring prices to the Long Run Marginal Costs (LRMC). Any subsidies in the cost of prices have been removed so that the prices for electricity reflect the true cost of supply. These changes resulted into two companies, Westmont and Aberafrica building two diesel power plants totaling 87.5MW which were commissioned in 1997.

KPC, which was originally managed under Contract agreement by KPLC, received some staff from KPLC and a new Board was established to manage it. In October, 1998 KPC changed its name and identity to Kenya Electricity Generating Company Ltd (KenGen). An interim Power Purchase Agreement between KenGen and KPLC will become effective in August, 1999 and a full PPA by the end of the year 2000.

Unfortunately the restructuring affected the development of the geothermal resources. KenGen is undertaking the geothermal program as an executing agency for the Kenya government. This program has been funded by the Kenya Government support from lending agencies and in particular the World Bank. The implementation of the agreed reforms has caused delays in the disbursement of World Bank's and other donors' contribution to the program for the purpose of resource assessment and Olkaria II power station construction.

Since various least-cost studies (Acres, 1987, 1994 and 1997) have identified geothermal as least cost source of energy for Kenya, there is enough motivation for both private and public sectors to invest in this *green* resource. The latest study of 1997 required a total of 567MW to be generated from geothermal by the year 2017. There are various prospects (Figure 1) from which these resources can be developed.

3. GEOTHERMAL REOURCES UPDATE

Table 2 shows the wells drilled in the last 5 years and Table 3 indicates the total investiment.

3.1.Olkaria

Figure 2 shows the location of the various geothermal fields in Olkaria.

Olkaria East

Olkaria East Power station with its three units of 15 MW each continued to operate very well. By the end of June 1999, a total of 5,501.43 GWh had been generated.

Initially, 23 wells were connected to the three turbines. However, as the exploitation increased some wells decreased in output and one had to be isolated. New make-up wells were drilled to restore generation to the installed capacity. The initial decline in steam was about 7-13% per annum reflecting the reservoir pressure changes. From 1986 to 1994, the steam had reduced considerably due to lack of makeup wells. Generation had fallen to 31 MW. Four make-up wells (OW 27, 28, 29 and 30) were connected in 1995 and 2 more (OW-31 and 33) in 1996 bringing the power station to its full load. Currently 24 of the 29 interconnected wells are producing. OW-05 is being prepared for reconnection after deepening. Two additional wells (OW-32 and 34) are planned to be connected by the middle of 2000 to ensure full load capacity is maintained.

The average availability factor and overall load factor for the period between 1981 and 1997 were 96.8% and 92.8% respectively. As of 30th April 1999 Unit 1 had ran for 145,507.4 hours. Units 2 and 3 had done 131,951.8 hours and 117,171.63 hours respectively.

Machine inspection and servicing have been carried out routinely every year. During this period generator air coolers, switchgears, transformers' tap changers, motors, cooling tower were serviced and turbine blades and condenser inspected for damage. The overhauls are carried out every 5 years. Machine No. 1 has been overhauled twice in 1988 and 1995 after running for 56,699 hours and 107,974 hours respectively and a third is planned for the year 2000. Machine No. 2 has been overhauled once in 1992 after running for 74,223 hours and the second one is planned for August 1999. Machine No. 3 was overhauled in 1991 after running for 52,822 hours and again in 1997 having run for 101,705 hours.

Efficiency tests were carried out on every machine after major overhaul. Values of specific steam consumption are compared with previous measurements. In all cases and for all the machines the values have been close to those obtained at commissioning.

On the whole, the power station has performed very well without any noticeable corrosion in the turbines and the pipelines.

Re-injection

When the third unit was commissioned in 1985, the total amount of separated water from the twenty-three wells in operation was about 66.7t/hr. This water was collected in open channels to a pond, which allowed infiltration into the formation and evaporation. When simulations of the field under exploitation conditions were done, it was shown that substantial benefits could accrue from re-injection. Re-injection could sustain the field pressures, which were already declining, and it would be a more environmentally acceptable way of disposing the brine. Trial experiments were carried out initially using fresh cold water with tracer chemicals. This experiment was successful and cold water was re-injected for several years into OW-12 in the middle of the field. The cold reinjection is currently on hold pending repairs on the pumping station. Thirty tons per hour are also being re-injected hot in another well. The effect of the re-injection has reduced the rate of pressure and well output decline in the field to about 3 % per annum.

Well Deepening

Several of the early wells drilled into the Olkaria East field were shallow (<1200m) and tapped primarily from the steam zone. An attempt was made to deepen some of these shallow wells in order to exploit the deep water zone. This required dismantling the wellhead equipment and pulling out of the slotted liners before deepening. The first attempt to remove the linners from OW-14 failed due to suspected cementation of the casing to the formation by silica as the well dried up. A second attempt was made in OW-05 with success. The well was deepened to 2200m in November 1997. The well increased its output from 1MW before deepening to 4.8MW after deepening. The wellhead gear is currently being reassembled to put the well back into production.

Olkaria North East

Well OW-714 which is the largest producer in this field was retested between May and August 1997. The total power proven from this field is now about 80MW. Further interference tests (Ofwona, 1998). were done simultaneously with seismic surveys (Simiyu *et al* , 1998) in the central part of the field in between September and April 1997.

Unfortunately, the construction of the planned 64MW power station under public investment has still not taken place due to funding delays related to the reforms in the power sector. The construction will be handled under the following six separate contracts:

- OG101 power-station civil works
- OG102 electro-mechanical
- OG103 substations
- OG104 transmission lines
- OG105 steam gathering system
- OG106 Housing

Funding of the first five contracts has support from the World Bank (IDA), European Investment Bank (EIB), Kreditanstalt

fur Wiederaufbau (KfW). OG106 is funded entirely by KenGen. OG103, OG104 and OG105 are on tender and OG106 is under construction and almost 50% complete. It is anticipated that construction of the power station will begin around March 2000 and be completed in January 2002.

Olkaria West.

In June 1997 KenGen completed drilling OW-308 to 2100m the exploration well, which had been top-holed in 1993.

The Kenya Government put out Olkaria West field to international bid in 1996. Two companies submitted responsive bids and after evaluation, one was given clearance to develop a 64MW power station. The company signed a PPA with KPLC in November 1998. KenGen was contracted to flow-test four of the existing wells between March and June, 1999.

Olkaria Central

OW-202, which had been top-holed in 1993, was completed. OW-203, OW-204 were also drilled in this sector. Because of the development of Olkaria West by IPP and Olkaria North East by KenGen, the Central region has been left for the time being as a buffer zone between these two developments until the two stations have been operated for at least five years. This would allow monitoring of any interference between the two stations before any decision is made to develop this sector.

A neighbouring horticultural farm has used OW-101 with an output capacity of 1.28MW (Tables 4 and 5), for direct use in green house heating for flower growing on experimental basis, initially, but this will be on commercial basis subsequently.

Olkaria North West.

One exploration well, OW-102, was drilled in this sector in November 1996. The results were not encouraging and it is unlikely expansion will take place in this direction.

Olkaria South East.

Based on scientific exploration work done in 1993, an exploration well, OW-801 was drilled in August, 1998. The well could not discharge and further geophysical results indicated that this area was unlikely to be productive.

Olkaria Domes

Results of surface exploration of this area in 1993 (KPC, 1994) was used to site three exploration wells which were drilled between September 1998 and May, 1999 each to a depth of about 2200m. These wells are currently under going discharge tests and it appears that Olkaria IV might be developed in this area.

3.2. Eburru

EW-06 which was drilled in 1990 was retested between August and November 1996 (Ofwona, 1997). This is a low enthalpy well producing about 22.9 t/hr of mass with an enthalpy of 453kJ/kg and heat equivalent to 2.9MW thermal.

3.3 Longonot

KenGen conducted surface exploration work in Longonot geothermal prospect in 1998 (Figure 3). Intensive geological, geophysical and geochemical studies were undertaken together with environmental base-line investigations (KenGen, 1998). These results have been used to site the first exploration well south of the volcano in an old caldera. The well will be drilled from about September 1999. If this well is successful, two more exploration wells will be drilled. This development programme is dependent on the availability of the required funds.

4. GEOTHERMAL PROFESSIONAL MANPOWER

Professional manpower allocation to geothermal activities is shown in Table 6. KenGen alone has 41 graduate professionals working on full time basis in geothermal activities. Several others mainly based in Head Office provide services to the geothermal activities at different times. External professional services is obtained through a four-man Board of Consultants (BOC) who meet twice a year.

5. FUTURE DEVELOPMENTS

Out of the planned 576MW expected to be developed from geothermal resources, half of it is expected to be developed by the public sector the rest by the private sector. In order to achieve this target, detailed scientific studies and exploration drilling is required in several other geothermal prospects outside Olkaria in order to prove the resources and prioritize the areas. Scientific exploration work has been done in Longonot and Suswa prospects and exploration drilling is planned to follow in that order. Surface exploration will then be done in Menengai and other fields to the north of Olkaria along the Rift Valley. Experience has shown that production drilling may even have to be done for 30%-50% of the required steam to reduce investment risks before the private sector can become interested in further development.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICTY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (wind)		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	45	366.47	206.5	723.72	598.5	3265.62			0.4	1	850.4	4356.87
Under construction in January 2000			185		140							
Funds committed, but not yet under Construction in January 2000	128		75									
Total projected use by 2005	173	366.47	466.5	738.5	738.5	3265.62			0.4		1378.4	4356.87

TABLE 2. 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)	8				16.535
Production	>150° C	1				1.295
Injection	(all)					
Total		9				17.83

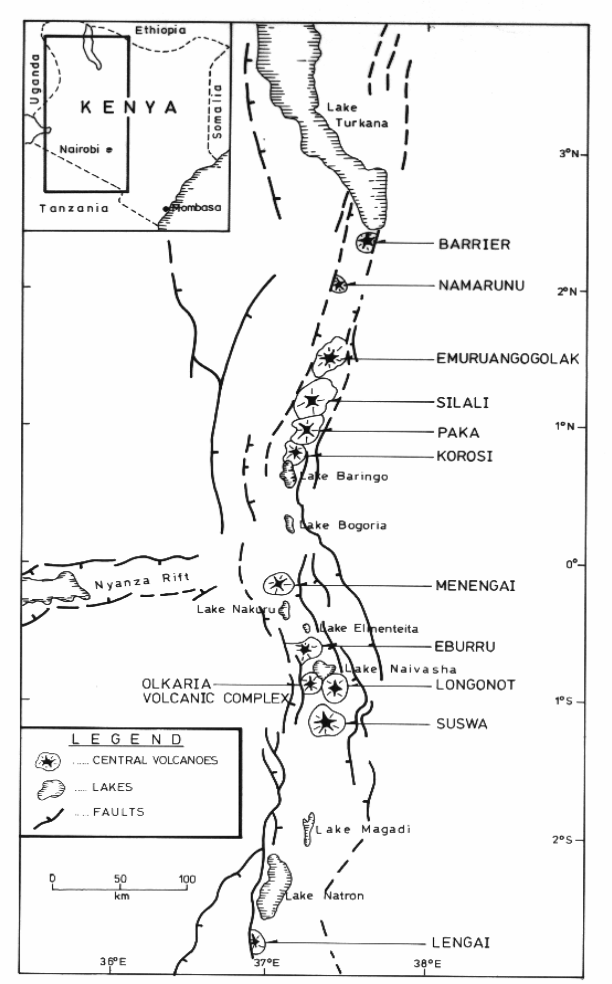

Figure 1. Volcanic Centres with Geothermal Prospects in Kenya

TABLE 3. 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	19.8	63.35		83.15		100
1990-1994	6.4	28.75		35.15		100
1995-1999	8.8	5		13.8		100

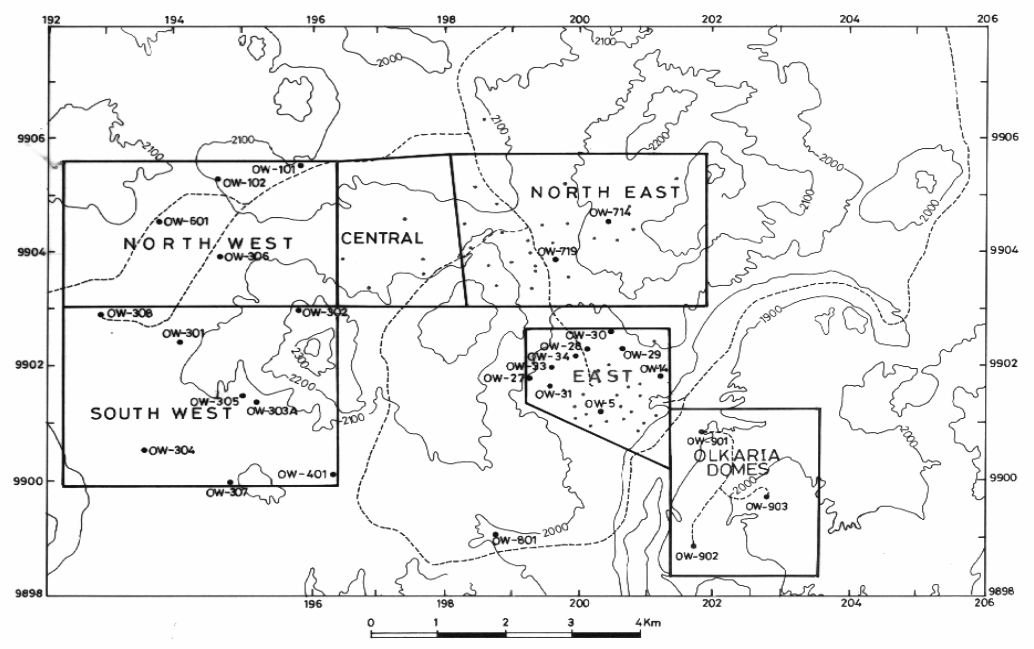

Figure 2. Location map of Olkaria Geothermal Field.

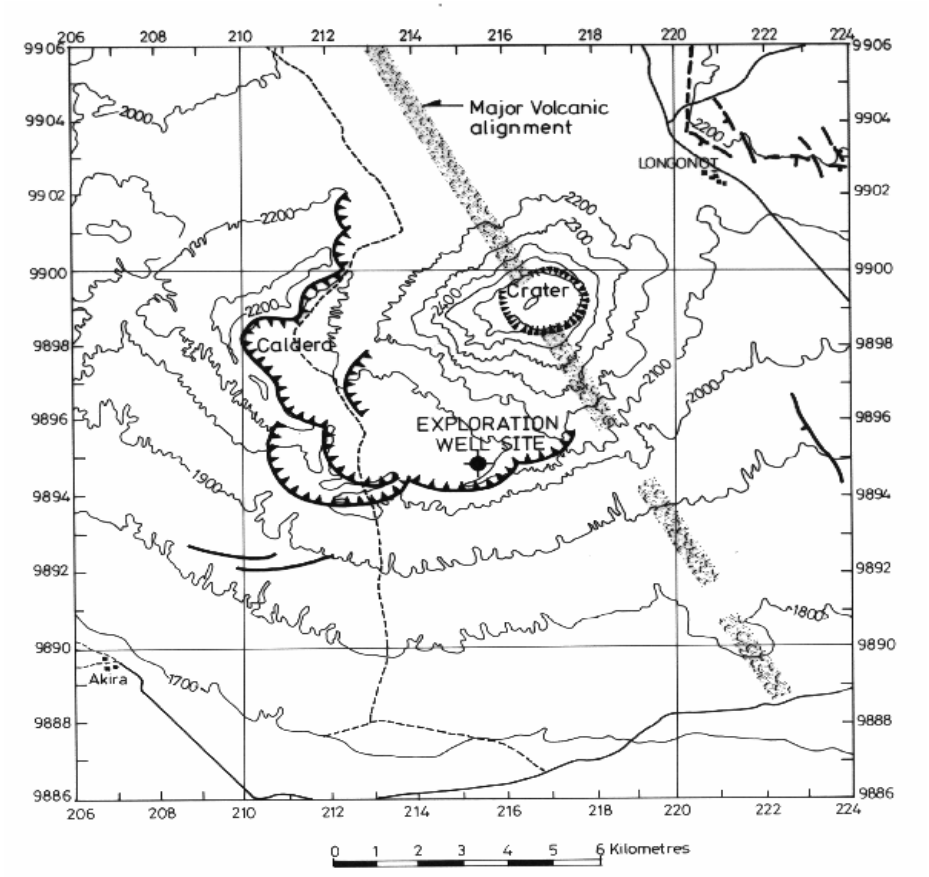

Figure 3. Location map of Longonot Geothermal Prospect.

TABLE 4. 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. (^{o}C) - outlet temp. (^{o}C)] 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. (^{o}C) - outlet temp. (^{o}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

5) Capacity factor = [Annual energy use (TJ/yr) x 0.03171]/Capacity (MWt)
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 (kg/s)	Temperature (^{o}C)		Enthalpy[2)] (kJ/kg)			Ave. Flow (kg/s)	Energy[4)] (TJ/yr)	Capacity Factor[5)]
			Inlet	Outllet	Inlet	Outlet	(MWt)			
Olkaria	G	5	92.0	30.5			1.286	2.5	20.279	0.4998
TOTAL		5					1.286	2.5	20.279	0.4998

Note: please report all numbers to three significant figures.

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. (^{o}C) - outlet temp. (^{o}C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalphy (kJ/kg)] x 0.001

[2] Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}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]			
Air Conditioning (Cooling)			
Greenhouse Heating	1.286	20.279	0.4998
Fish and Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]			
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps			
TOTAL	1.286	20.279	0.4998

[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. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with a University degress)

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

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1995	1	23			0.1	
1996	1	27				0.22
1997	1	28				0.2
1998	1	29				0.4
1999	1	29			0.15	1
Total	5	136			0.25	1.8