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Country Update Report for Kenya 2000-2005

Martin Mwangi

Kenya Electricity Generating Company Ltd, P.O. Box 785, Naivasha, Kenya

mmwangi@kengen.co.ke

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ABSTRACT

Electricity generation from geothermal in Kenya has increased by 82 MWe over the last five years. Construction of 2 x 35MW Olkaria II geothermal power station, started in August 1999 and was commissioned late 2003. The completion of this plant makes the total geothermal output in Kenya to be 127MW which is about 11% of the effective capacity. The independent power producer, Orpower 4 Inc, a subsidiary of Ormat International, commissioned a 12 MW binary pilot plant for Olkaria III in the year 2000. Simultaneous to power plant construction, 9 appraisal and production wells were drilled phases. From the results of these wells, the field was assessed as capable of supporting 48MW over a period of 20 years. The proposed Olkaria IV development continued to suffer from lack of funding. Oserian Development Company, a flower growing company, installed a green house heating system in May 2003 using a 1.28MW steam well leased from KenGen. Oserian has also constructed a 1.8 MWe binary plant for use at the flower farm. A prefeasibility study for multiple uses of geothermal for generation and water production for agriculture and domestic use was carried out at Eburru geothermal field. Detailed surface exploration work at Menengai geothermal prospect was completed.

1. INTRODUCTION

Kenya relies on three major sources of energy. These are biomass (68 %), petroleum (22 %) and Electricity (9 %). On the other hand hydropower (57 %) dominates the electricity sub-sector, followed by fossil- based thermal (32 %) and then geothermal (11 %). The other forms of renewable energy (wind, solar, biogas, micro hydro etc) account for less than 1 % (Table 1). Due to unreliable rain patterns, and the fact that Kenya depends highly on hydropower, the electricity supply has becoming unreliable especially during the dry seasons. An example of such scenario was experienced in the year 2000. This was a great drawback to the economy as industries suffered luck of electricity for long hours. Development of geothermal energy, which is indigenous, low cost, environmentally benign and reliable, seems to be the long-term solution to this problem. The least cost power development plan for the year 2004 (KPLC, 2004) has considered geothermal energy as a least cost source of electrical power in Kenya to replace the medium diesel plants which were in the earlier plans.

The electrical power demand in Kenya has been having an increasing trend over the last five years. This is expected to rise even more with the improvement of economy. More attention should therefore be focused on geothermal power development.

The government of Kenya has demonstrated a great commitment to exploration and exploitation of geothermal energy. About 8 million US dollars will be set aside, every year for the next five years, for geothermal exploration in the Kenyan Rift Valley. More funds are being sought from development partners for exploitation of the already proven geothermal resources i.e Olkaria IV, and Eburru, Suswa, Longonot and Menengai.

2. GEOLOGICAL BACKGROUND

Geothermal activities in Kenya and Africa in general are concentrated in the East African Rift Valley which extends from the Triple junction to the north and Malawi to the south (Figure 1).

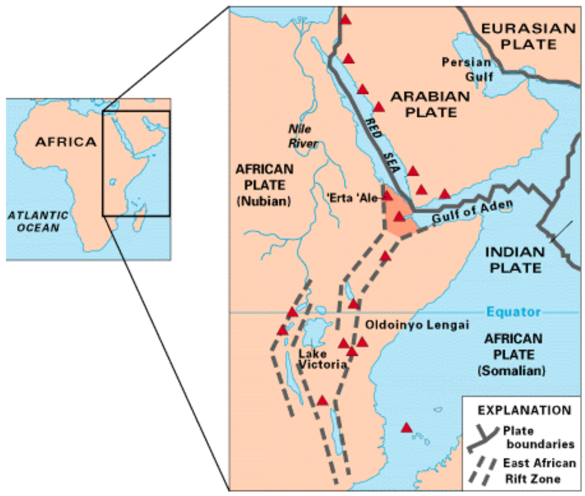

Figure 1: The East Africa Rift System.

The East African system, although intracontinental, is clearly associated with the worldwide rift system, originating in the Early Mesozoic and now responsible for the present pattern of continents and oceans. It is a divergence zone which is widening at a rate of about 1cm/year. The rifting in the East African rift system has been accompanies by intense volcanism. Faulting has occurred so frequently in the eastern rift zone that it is difficult to separate distinct phases. A summarised structural sequence can be presented as follows:

- Domal uplift caused by convective currents accompanied by extensional crustal thinning;
- Down warping and major boundary faulting accompanied by powerful basaltic and trachy-phonolitic volcanism;
- Closely spaced pararell faults across the whole width of the rift valley floor accompanied by volcanism of the trachytic ignimbrites; and

- Faulting in a narrow central belt accompanied by intense central volcanic activity which gave rise to a number of calderas.

Volcanism associated with the central rift zone started in Miocene and continued upto the Late Pleistocene. The Late Pleistocene volcanism has a lot of significance for the geothermal activity in the central rift, in that it indicates the presence of at least partially molten chambers beneath the rift floor. The magma chambers are presumably the heat source for the geothermal systems in the rift valley (Nyambok, I. O, 1979).

3. GEOTHERMAL RESOURCES AND POTENTIAL

About fourteen (14) geothermal prospects have been identified in the Kenyan Rift valley (Figure 2).

Figure 2: Geothermal prospects in the Kenyan Rift valley

Their geothermal potential is estimated to be in excess of 2000 MWe. Wells have been drilled in only two of these sites , Olkaria and Eburru but exploitation is only at Olkaria geothermal field.

The Olkaria geothermal system

The Olkaria geothermal system is located on the floor of the East Africa Rift valley in Kenya about 120 km North West of Nairobi. The resource is associated with the Olkaria volcanic complex which consists of a series of lava domes and ashes, the youngest of which was dated at 200 years ago (Clarke et al., 1990). The geothermal reservoir is considered to be bounded by arcuate faults forming a ring or a caldera structure. A magmatic heat source might be represented by intrusions at deep levels inside the ring structure. Faults and fractures are prominent in the area with a general trend of N-S and E-W but there are also some inferred faults striking NW-SE. Other structures in the Olkaria area include the Ol'Njorowa gorge, N-S and NW-SE faults, the ENE-WSW Olkaria fault and WNW-ESE (Fig. 3. (Muchemi, 1999)

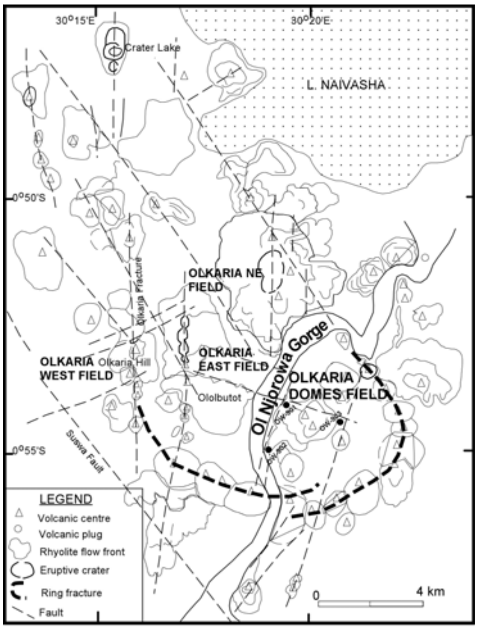

Figure 3: Volcano-Tectonic map of Greater Olkaria Geothermal Complex

Faults are more prominent in the Olkaria East, Northeast and West fields but are scarce in the Domes area, possibly due to a thick cover of pyroclastics. The NW-SE and WNW-ESE faults are thought to be the oldest and are associated with the development of the rift.

The most prominent of these faults is the Gorge Farm fault, which bounds the geothermal fields in the NE part and extends to the Domes area (Lagat, 1995)

For the sake of development, the Greater Olkaria geothermal area which is about 80 km2 has been divided into seven sectors namely Olkaria East, Olkaria West, Olkaria Northwest, Olkaria Northeast, Olkaria Central, Olkaria Domes and Olkaria Southwest (Figure4).

Currently, three of the sectors namely Olkaria East, Olkaria West and Olkaria Northeast fields are generating 127 MWe. In Olkaria Domes field, which is the forth field targeted for development, three exploration wells were drilled between 1998 and 1999 and plans for appraisal drilling are at an advanced stage. Exploration drilling has also been undertaken in the other sectors of Olkaria but has shown poor results.

Detailed surface exploration was concluded in Suswa and Longonot prospects and deep exploration wells sited. Currently, surface exploration is going on in Menengai – Olbanita prospect. With availability of funds, exploration drilling will commence in these prospective areas.

There is need to accurately assess power potential in all the remaining prospects within the Rift Valley in order to properly rank them in terms of priority for further exploitation. More surface exploration work will therefore continue in the other prospects

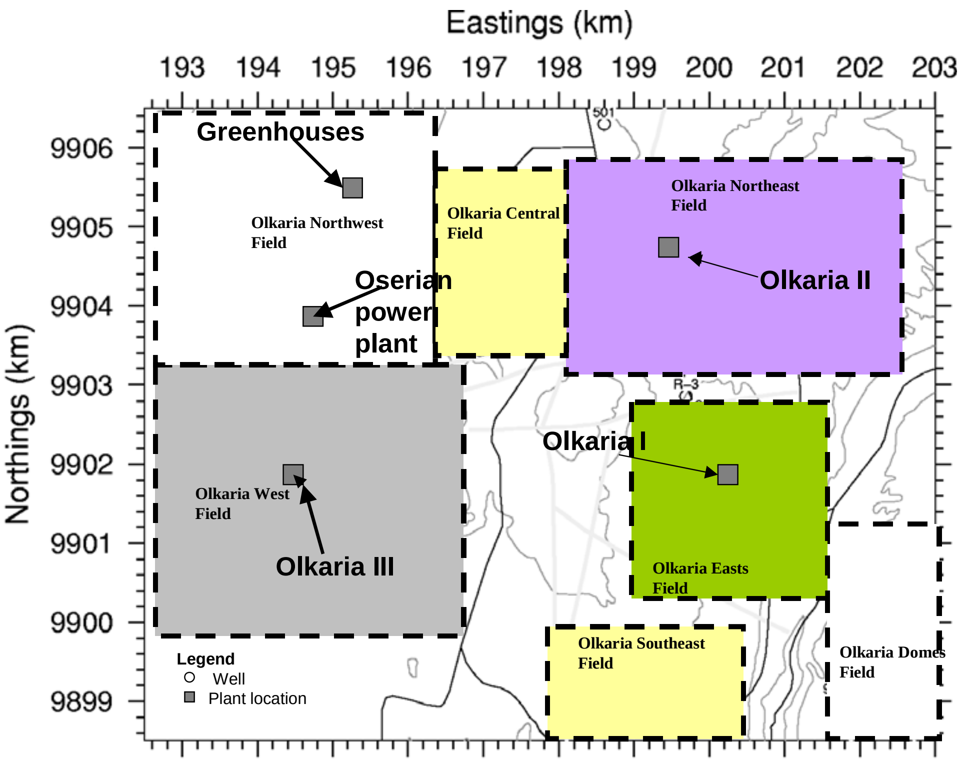

Figure 4: The Greater Olkaria Geothermal Area

4. GEOTHERMAL UTILISATION

4.1 Geothermal energy for Electricity Production

Currently, utilisation of geothermal energy is only in the Olkaria field. Three of the seven fields namely Olkaria East field, Olkaria West field and Olkaria Northeast field are generating a total of 127 MWe.

4.1.1 Olkaria I Power Plant

The Olkaria East field has been supporting the three 15 MWe each turbo generating units of Olkaria I power plants which were commissioned in 1981, 1983 and 1985 respectively. The plant therefore has been generating 45 MWe over the last twenty three (23) years.

Thirty three (33) wells have been drilled in this field and thirty one (31) of them connected to the steam gathering system. Currently, twenty six (26) of them are in production while the rest have become non-commercial producers due to decline in output over time and some of these are earmarked to serve as reinjection wells. Nine (9) of the wells were drilled as make-up wells.

Connection of make-up wells OW-32 and OW-34

The last two make up well, OW-32 and OW-34, were connected to the steam gathering system in the year 2001. This involved putting up a 600 mm diameter, 7 km long pipeline to carry about 130 t/hr of steam from OW-32 to OW-34 wellpad. The steam from the two wells is combined and piped from well OW-34 well pad to the power station through a 700 mm diameter, 9 km long pipeline. These two wells have enough steam to generate 15 MWe.

In 2002 however, well OW-34 had a sudden decline in steam output from 42 t/hr to 7 t/hr. This behaviour had not been encountered before in Olkaria. Investigations showed existence of a thick layer of silica deposition in the pipeline leading to and from the separator with the thickest deposition being in the two-phase pipeline. The well was therefore disconnected from the steam gathering system to give time for investigations into the causes and possible solutions to this unique problem. Discharge tests carried out in this well in 2003 showed that the mass flow from the well had actually increased possibly due to improved permeability (Ofwona and Opondo, 2003). Currently, studies are being carried out to investigate the possible options that exsist to inhibit the scaling.

4.1.2 Olkaria II Power Plant

Construction of 2 x 35MW Olkaria II geothermal power station started in August 1999 was commissioned in October and November 2003, respectively. The project which is publicly owned by Kenya Electricity Generating Company Ltd (KenGen) also included construction of 116km of 220kV from Olkaria to Nairobi and 3.5km 132kV transmission line connecting Olkaria I and II station.

The initial design had suggested 64 MWe but since the plant was build 10 years behind schedule, it took advantage of the latest technology. The plant is more efficient than the Olkaria I plants with a specific steam consumption of about 7.2 t/hr per MWe as opposed to the 9.2 t/hr for the Olkaria I plant. As a result of the efficient machines there is excess steam available in this field.

4.1.3 Olkaria III Power Plant

Olkaria III project is the first private geothermal power plant in Kenya. A 20 year Power Purchase Agreement (PPA) was awarded by Kenya Power and Lighting Company (KPLC) under a world Bank supervised international tender for the field development of up to 100 MWe.

The first phase of the project included drilling of appraisal wells and construction of a 12 MWe which is owned by ORMAT and was entirely financed from ORMAT's own funds. The first 8 MWe was put on commercial operation on September 2000 and the other 4 MWe in December 2000. The appraisal Drilling which commensed in February 2000 was completed in June 2001 having drilled 5 wells. 4 wells were drilled as production wells (Table 6) and by March 2003, 48 MWe and 30 % reserve was proven.

KenGen was contracted to do completion and heat-up tests in these wells. Both vertical and directional wells were drilled for appraisal as well as production with depth ranging between 1850 m – 2750m. All the nine (9) new wells were drilled on only 3 well pads. Production success rate of 100 % of the new wells was achieved. The 36 MWe power plant is expected in 2006 (Reshef and Citrin, 2003).

<u>4.1.4 Oserian Plant</u>

Oserian Flowers company has constructed a 1.8 MW binary plant Ormat OEC utilising the fluid from leased well OW-306. The plant, which is supposed to provide electrical power for the farm's operations is expected to be commissioned in June, 2004.

4.2 Geothermal energy for Direct Uses

The only commercial application of geothermal energy for direct use in Kenya is at Oserian Development Company, a flower growing company neighbouring the Olkaria geothermal fields. The company installed a green house heating system in May 2003 using a 1.28MW steam well leased from KenGen. Heating green houses help to reduce humidity and consequently decrease deseases. The carbon dioxide from the well is also useful for the flowers photosynthesis. The system started off by heating 3 hectares of green houses and is being expanded to 30 hectares. Oserian is therefore planning to lease more wells from KenGen for this purpose. Oserian has also constructed a 1.8 MW binary plant Ormat OEC for use at the flower farm.

Hot springs have been used to heat spas in tourist hotels for example in Borogia hotel which is located near the Bogoria prospect

The Local community at Eburru geothermal resource condenses the steam from fumarole and uses the water for domestic purposes. They also use geothermally heated driers to dry their pyrethrum.

5. DISCUSSION

Due to unreliability of hydropower during prolonged dry seasons, the country has been forced use of expensive and environmentally unfriendly fossil fuels. Exploitation of the large geothermal potential present at the Kenyan Rift can make geothermal energy the leading source of electrical power and hence avoid such negative effects in future. More attention should therefore be focused in development of this large resource.

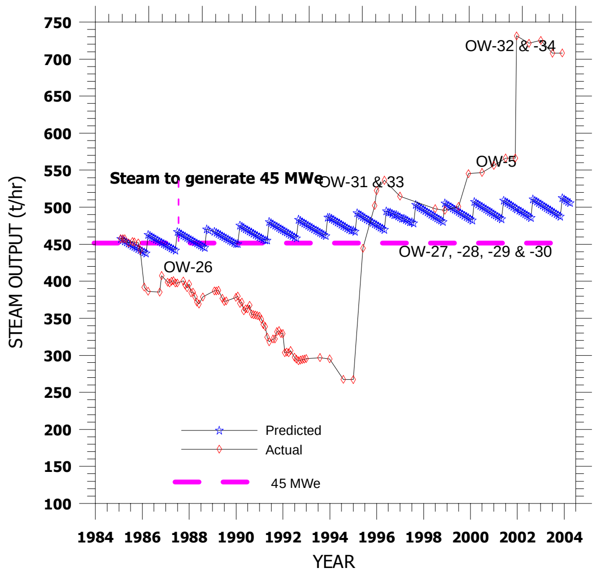

Figure 4: Steam output at Olkaria East field for 23 years

The acceleration of geothermal power development has been hampered by lack of funds. The Olkaria II power plant, for example, was supposed to come online in early nineties but it did not until 2003, about ten years behind schedule. More power plants were expected to be commissioned by this time. There is however more commitment from the government to accelerate this indigenous, low cost and environmentally benign source of energy.

The Government of Kenya has proposed creation of a special purpose geothermal development company (GDC), fully owned by the government. The company will be mandated to explore and develop geothermal energy for electricity generation and other uses. By so doing, the government will have taken the risks associated with geothermal exploration and hence KenGen or other private developers will be shielded from these risks.

There is very little application of direct uses of geothermal energy in Kenya (Table 3). Applications of this resource for example in swimming pools and Spas, balneology, drying of farm produce and greenhouse heating will be encouraged through the geothermal development company.

The professional manpower allocation to geothermal activities is shown in Table 7. KenGen alone has 40 graduate professionals working on fulltime basis in geothermal activities. Several others mainly based in Head Office provide services to the geothermal activities m at different times. During the period 2000 to 2004, expertrites assistant was sought during the construction of Olkaria II power plant and steamfield development. About 3 persons per year were engaged on fulltime bases (Table 7). As can be seen, 75% of the professionals are in the public sector. And 16 % are in the private sector, mainly due to the construction of a privately owned Olkaria III power pilot plant. Between 2000 and 2004, two power stations, Olkaria III and II were constructed (Table 2). Also drilling at Olkaria West was done between 2000 and 2003. This called for involvement of between 3-5 expatriates per year.

In the past geothermal development was solely being funded by the government using public funds, but between 2000to 2004, about 13% funding is from private sector

((Table 8). This is mainly due to liberalisation of power sector by encouraging Independent power producers (IPP). Oserian Flowers Company has also invested in geothermal exploitation (Tables 3 and 5). This is a positive step in geothermal development and with more and more private involvement geothermal exploitation will be accerelated.

6. FUTURE DEVELOPMENTS

6.1 Electricity generation in Olkaria Fields

The Olkaria I power plant which is supported by Olkaria East field has been in operation for the last 23 years. The initial design had proposed a life of 25 years for the plant. In two years time, the plant will have exhausted its initial design life. The current study shows that the plant and the reservoir are in good condition, and as a matter of fact the field is having more steam than what is required to generate 45 MWe (Figure 5). KenGen is planning a proposal for life extension of this plant.

The performance of early geothermal fields in the world shows that with good reservoir management practices, a geothermal reservoir is sustainable. Also with good maintenance practices, some power plants have been is relatively good condition after being in operation for over 50 years for example Wairakei, NewZealand has been in operation since 1958.

A proposal to install a third unit of 35 MWe in Olkaria II to utilise the excess steam from Olkaria East and Olkaria Northeast fields is being evaluated. With availability of funds, the plant is expected to be commissioned in the year 2007. The 36 MWe plant in Olkaria III is expected to be online by the year 2006.

KenGen, which operates Olkaria I and Olkaria II Power plants completed surface exploraion in the Domes field in 1993. Three deep exploration wells were drilled between September 1998 and May 1999. This field is designated for development with expectation it can generate 70 MWe for 25 years and will be the site of Olkaria IV power plant. Plans are at an advanced stage to drill six (6) appraisal wells in this field.

6.2 Direct uses

Oserian Development Company, which is a flower growing company installed a green house heating system in May 2003. The company expanded the heating system from the initial 3 hectares to more than 30 hectares.

6.3 Other Geothermal Prospects

A prefeasibility study for multiple use of geothermal for electricity generation and water production for agriculture and domestic use was also carried out at Eburru geothermal field. Detailed surface exploration work at Menengai was started in January, 2003 and is expected to be completed in the next six months.

The future of geothermal energy in Kenya is bright. There is fresh commitment from the government to exploit the large resource at the rift valley. In the next several years, massive exploration drilling will be undertaken in Suswa, Longonot and Menengai prospects where detailed information is already available.

7. CONCLUSIONS

- For the last five years, geothermal energy exploitation has increased by 280% from 45 MWe in 1999 to 127 MWe in 2004.
- In the Power development plans of year 2003 - 2004 geothermal energy has been considered as least cost source of electrical power.
- Surface exploration of geothermal energy in the Kenyan Rift is going on and the government of Kenya is committed to finance the work.
- Oserian Development Company, which is a flower growing company has started utilising geothermal steam for greenhouse heating. Oserian has also constructed a 1.8 MW binary plant Ormat OEC for use in the farm activities.
- Since 2000, OrPower 4 Inc. have been generating 12 MWe from an early generation Ormat plant in Olkaria West field. They have drilled more wells and obtained enough steam to generate 36 MWe over the next 25 years. Plans are underway to construct the additional power plant.
- There is enormous amount of geothermal energy in the Kenyan Rift valley which should be exploited to replace the fossil fuel plants.
- Geothermal energy is indigenous, low cost, reliable and environmentally benign source of energy and should be given the first priority wherever it occurs.
- Creation of a special purpose geothermal development company by the government will be a useful milestone in geothermal energy exploitation and is expected to accelerate geothermal development in Kenya to achieve the least cost development plan.

ACKNOWLEDGEMENT

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY (Installed capacity)

	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 December 2004	127	1088	348	461	654	4125	0	0	0.4	3	1129	5677
Under construction in December 2004	0		0		60	378	0	0	0			378
Funds committed, but not yet under construction in December 2004	0		0		0		0	0	0			
Total projected use by 2010	268				714							

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2004

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash
2F = Double Flash
3F = Triple Flash
D = Dry Steam
B = Binary (Rankine Cycle)
H = Hybrid (explain)
O = Other (please specify)

3) Data for 2004 if available, otherwise for 2003. Please specify which.

Locality	Power Plant Name	Year Commissioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe	Annual Energy Produced 2004[3)] GWh/yr	Total under Constr. or Planned MWe
Olkaria	Olkaria I	1981, 1982, 1985	3		1F	45		
	Olkaria II	2003	2		1F	70		35
	Olkaria III	2000	2		B	12		36
	Oserian Plant	2004	1		B	4		1.8
Total						127		72.8

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2004 (other than heat pumps)

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

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

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

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

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.

Note: please report all numbers to three significant figures.

		Maximum Utilization					Capacity[3)]	Annual Utilization		
Locality	Type[1)]	Flow Rate	Temperature (^{o}C)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Olkaria	G	10					10			
TOTAL										

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2004

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] 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. (^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

[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

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]			
District Heating [4]			
Air Conditioning (Cooling)			
Greenhouse Heating	10	79.14	2.509529
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]			
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps			
TOTAL			

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2000 TO DECEMBER 31, 2004 (excluding heat pump wells)

[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)					
Production	>150° C	9	_	_		22
	150-100° C					
	<100° C					
Injection	(all)					
Total		9				

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with 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)
2000	1	37		3		3
2001	1	37		3		9
2002	1	37		3		9
2003	1	37		3		9
2004	2	37		5		9
Total	6	185		17		39

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2004) 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$	%	%
1990-1994	6.4	28.75	0	35.15	0	100
1995-1999	8.8	5	0	13.8	0	100
2000-2004	0.125	20	8	194	13	87