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Geothermal Exploration and Development in Ethiopia

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ABSTRACT

Ethiopia started a long term geothermal exploration undertaking in 1969. The study has revealed the existence of both low and high enthalpy geothermal resources in the Ethiopian Rift Valley and in the Afar depression, which are both part of the Great East African Rift System.

Over the years, a good inventory of the possible resource areas has been built up and a number of the more important sites have been explored. Of these areas, about sixteen geothermal prospect areas are judged to have potential for high temperature steam suited to electricity generation. A much larger number are capable of being developed for non-electricity generation applications in agriculture, agro-industry etc.

Exploration work peaked during the early to mid-1980s when exploration drilling was carried out at the Aluto-Langano geothermal field. Eight deep (maximum depth of about 2500m) exploratory wells were drilled, of which four are potentially productive. During the early 1990s, exploration drilling was also carried out at Tendaho. Three deep (about 2100m) and three shallow (about 450m) wells were drilled at the Tendaho geothermal field, and proved the existence of high temperature and pressure fluid .

Resource utilization at the Aluto-Langano was delayed until 1998 due to financial constraints. During the year 1998, a new era of resource utilization started by installing the 7.2 MWe net capacity pilot plant at Aluto-Langano. However, the pilot plant has faced operational difficulties that are essentially due to the lack of the appropriate field and plant management skills. With the rectification of these problems, the plant should run more reliably and provide experience that would be useful in the exploitation of the country's extensive resources, to augment power supply from hydro-resources and diversify the energy supply structure.

In the Tendaho geothermal field, a production test and feasibility study is currently in progress. The feasibility study indicates that four productive wells (out of six) of this geothermal field could supply enough steam to operate a pilot power plant of about 5 MWe, and the potential of the deep reservoir is estimated about 20 MWe.

The GSE did detailed geological, geochemical and geophysical studies in the Corbetti (Lakes District) during the year 1985-86 (Kebede, 1986) and Tulu Moye- Gedemsa and Abaya (Southern Afar) geothermal prospective areas during the years between 1998 and 2000 (Ayele et al., 2002). This integrated geoscientific study included drilling of five shallow temperature gradient wells (150-200m) in the Tulu-Moye geothermal prospect area, and has delineated areas for further deep exploration wells. At present, the Survey is carrying out detailed geoscientific studies (geology, geochemistry and geophysics) in the Southern Afar areas (Dofan, Fantale and Meteka). These exploration works of geothermal resources in the Ethiopian Rift are with emphasis on proven sources and systematic detail surveys on target areas delineated during the first reconnaissance investigation (UNDP, 1973).

1. INTRODUCTION

Energy is an important element in Ethiopia's development strategy, because it could be a source of foreign exchange and is a catalyst for industrial progress. Ethiopia has a diversity of modern energy sources (hydro, geothermal, solar, natural gas etc.), but still relies on imported petroleum and petroleum products.

Energy consumption in Ethiopia is made up of less than 1% electricity, about 5.4% hydrocarbon fuels and the balance, traditional biomass fuels (EEPCO Data File). Currently, about 90% of the rural population still relies on traditional biomass fuel (wood) as their primary energy resource. Most petroleum products are consumed in the transport sector and with the low availability of electricity, household energy comprises primarily of biomass fuels (charcoal, firewood and dung). It is estimated that annually 39.4 million tons of fuel wood and 7.6 million tons of agri-residue and animal waste are used for fuel (EEPCO Data File). Fuel wood use has caused the loss of large areas of forest and contributed to environmental degradation (indoor pollution, deforestation, soil erosion etc.). The use of crop residues and animal waste for fuel in rural areas is at the expense of maintaining agricultural soil fertility and contributes to decreasing farm yields.

Rural areas have little access to electricity while petroleum products are somewhat more available and are used in lighting, grain milling and in power generation for rural agro- processing industries. Rural households are predominantly dependent on traditional biomass fuels for cooking and lighting, the main rural energy end-uses.

Considering the shortage of modern energy supplies in the country and environmental degradation of fossil fuel, geothermal energy needs to be developed in Ethiopia to serve as a source of reliable base load power generation to augment its hydro-power generation which relies on highly seasonal rainfall and is subject to the frequent recurrence of drought. Ethiopia being a young geological environment with a high and still rising altitude, its rivers characteristically have high silt loads that adversely affect water storage for hydro-power generation. The diversification of energy sources is essential in order to ensure sustainable energy supply. Therefore, geothermal power needs to be developed (i) to help replace import of fossil fuel; (ii) to provide a major backup to an uncertain availability of hydropower; and (iii) for use in arid and semi-arid areas of the country where hydropower is unavailable.

Electricity generation capacity is presently in the order of 670MW consisting of over 90% hydro power in the Ethiopian Electric Power Corporation's (IPO) Interconnected System (ICS). Additional diesel capacity held in reserve. The self contained system (SCS) has about 30MW capacity of which about 80% is from diesel generating plants and the rest from small hydro plants. Capacity demand is projected to grow from the present about 670MW to about 1,700MW by the year 2025, about 220MW of the additional expected to come from gas turbine driven power plants. Independent Power Producers (IPP) are encouraged to invest in power generation for supply to the grid. In order to facilitate private sector entry onto power development investment, the government has separated operational and regulatory functions by transferring the licensing and regulatory functions from EEPCO predecessor to a newly established regulatory agency, the Ethiopian Electricity Agency (EEA).

2. HISTORY OF GEOTHERMAL EXPLORATION

Ethiopia is among the few countries in Africa with a significant amount of geothermal resources. These resources are found scattered in the Ethiopian Rift valley and in the Afar Depression, which are both part of the Great East African Rift System. The Ethiopian rift extends from the Ethiopia-Kenya border to the Red Sea in NNE direction for over 1000km within Ethiopia, and covers an area of 150,000 Km^2 (Figure 1). Based on the results of the investigations, Ethiopia could possibly generate more than 1000 MWe of electric power from geothermal resources alone. This is substantially in excess of its annual requirement of around 700 MWe from all energy sources for the current Inter connected and Self Contained Systems.

Ethiopia started a long term geothermal exploration undertaking in 1969. Over the years, a good inventory of the possible resource areas has been built up and a number of the more important sites have been explored. Of these areas, about sixteen geothermal prospect areas are judged to have potential for high temperature steam suited to electricity generation. A much larger number are capable of being developed for non-electricity generation applications in agriculture, agro-industry etc.

Exploration work peaked during the early to mid-1980s when exploration drilling was carried out at the Aluto-Langano geothermal field. Eight exploratory wells were drilled, of which four are potentially productive. During the early 1990s, exploration drilling was also carried out at Tendaho. Three deep and three shallow wells were drilled at the Tendaho geothermal field, and proved the existence of high temperature and pressure fluid.

Resource utilization at the Aluto-Langano was delayed until 1998 due to financial constraints. During the year 1998, a new era of resource utilization started by installing the 7.2 MWe net capacity pilot plant at Aluto-Langano. However, the pilot plant has faced operational difficulties that are essentially due to the lack of the appropriate field and plant management skills. With the rectification of these problems, the plant should run more reliably and provide experience that would be useful in the exploitation of the country's extensive resources, to augment power supply from hydro-resources and diversify the energy supply structure.

During the three decades that geothermal resources exploration work was carried out in Ethiopia, a good information base and a good degree of exploration capacity, in human and infrastructure terms, has accumulated, ensuring that selected resources sites can be advanced to the resource development phase much more rapidly than before.

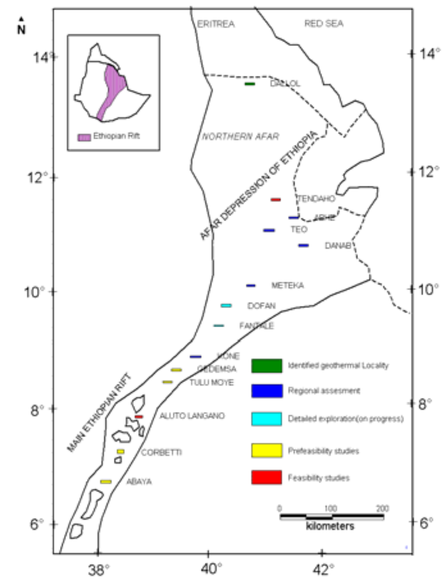

Fig.1 Location Map of the Geothermal Prospect Areas with in the Ethiopian Rift Valley

3.GEOTHERMAL RESOURCES OF ETHIOPIA

The identified "geothermal prospect areas" are widespread in the whole Ethiopian rift valley. Prominent among the geothermal prospect areas are (Figure 1):

(i) Lakes District- Aluto-Langano, Corbetti, and Abaya ;

(ii) Southern Afar – Tulu-Moye, Gedemsa, Dofan, Fantale, Meteka, Teo, Danab ; and

(iii) Northern Afar – Tendaho and Dallol (Danakil Depression).

These geothermal prospect areas are at different levels of study, where the Aluto Langano (Lakes District) and Tendaho geothermal fields (Northern Afar) are at advanced exploration stage including deep exploratory wells. Other geothermal prospect areas have been subjected to detailed geo-scientific investigations including drilling of shallow temperature gradient wells. There are also a number of prospects at reconnaissance level. Data from all these Prospects are outlined below.

3.1 The More advanced Project including Exploration Drilling

Only two Prospect areas have been subjected to exploration drilling to date.

3.1.1 Aluto-Langano Geothermal field

The Aluto-Langano geothermal field is located on the floor of the Ethiopian Rift Valley about 200 km south east of Addis Ababa (Figure 1). In the Aluto-Langano geothermal field, eight deep exploratory wells were drilled to a maximum depth of 2500m, between 1981 and 1985, out of which four are potentially productive. The maximum reservoir temperature encountered in the productive wells is about 350ºC. A feasibility study was conducted by an Italian firm Electroconsult between 1983 and 1986 (ELC, 1986). The study indicated that the resource is capable of generating 30 MWe for 30 years. The feasibility study recommended a three stage development of the field and reviewed the possible use of the Aluto-Lanano geothermal resource for a planned soda ash plant.

With a view to assess the production capacity of the existing production wells, geochemical monitoring, well testing and reservoir engineering studies were carried out since then. However, due to lack of financial resources, further full-scale exploration was halted and the field was handed over to the EEPCO for utilizing the already existing wells and evaluating the reliability of the resource using a pilot plant.

The 1986 feasibility report was reviewed by GENZL (Geothermal Energy development New Zealand Limited Company) in 1995, and recommended to start development of the field by installing a 5 MWe condensing turbine power plant.

A 7.3MW pilot geothermal plant was installed in 1999 utilizing the exploration wells that had been drilled. As mentioned earlier, the plant has not been fully operational due to reasons that have to do with the lack of operational experience. Steps are being taken to identify the problems and then rehabilitate the plant.

3.1.2 The Tendaho Geothermal field

Geothermal exploration was carried out in the Tendaho area with economical and technical support from Italy between 1979 and 1980. Between 1993 and 1998, three deep (to a maximum depth of 2100m) and three shallow exploratory wells (up to 500m) were drilled that found a temperature of over 270ºC. The Italian and Ethiopian governments jointly financed the drilling operation in the geothermal field. A preliminary production test and techno-economic study indicated that the shallow productive wells, which were believed to be drilled along the outflow zone could supply enough steam to operate a power pilot plant of about 5 MWe and the potential of the deep reservoir is estimated about 20 MWe (Aquater, 1996).

Based on this and further studies, the Ministry of Mines is currently in the process of designing a plan to work at Tendaho for progressing it towards development. The recent upgrade of a trunk highway through the Tendaho area will help facilitate such exploration and development. In addition, the Ethiopian government plans to extend the country's main 230 KV transmission line to Semera, which is within ten km of the drilled wells at Dubti.

3.2 Prospects where detailed investigations were carried out

A number of prospects have over the years been subjected to surface investigation: geology, geochemistry and geophysics including drilling of shallow temperature gradient (TG) wells.

3.2.1 Corbetti Geothermal Prospect area

The Corbetti geothermal prospect area (Figure 1) is located about 250 km south of Addis Ababa. Corbetti is a silicic volcano system within 12 km wide caldera that contains widespread thermal activity such as fumaroles and steam vents. Detail geological, geochemical and geophysical investigations conducted in Corbetti area indicated the presence of potential geothermal reservoirs with temperature in excess of 250°C. Six temperature gradient wells have been drilled to depths ranging from 93-178m (Kebede, 1986). A maximum temperature of 94°C was recorded. No further work was carried out since then. The data shows the probable existence of a deep reservoir with temperature in excess of 250 °C.

A 132 KV power transmission line passes within 15 kms of the prospect and is the main trunk line to Southern Ethiopia, to towns along the two branches of the highway to Kenya.

3.2.2 Abaya Geothermal Prospect area

Abaya is located on the northwest shore of Lake Abaya, about 400 kms south by road from Addis Ababa. The Abaya prospect exhibits is a widespread thermal activity mainly characterized by hot springs, fumaroles and altered grounds. Spring temperatures are as high as 96 °C with a high flow rate. Integrated geoscientific studies (geology, geochemistry and geophysics) have identified the existence of a potential geothermal reservoir with temperature in excess of 260°C (Ayele et al., 2002). Further geophysical studies including drilling of shallow temperature gradient wells are recommended here.

The 132 KV transmission line to Arba Minch to the south parts at the Welayta Soddo substation located about 40 kms distance to the NNW of the prospect. This raises the prospect for development of the resource once it is adequately explored, including by drilling.

3.2.3 Tulu Moye- Gedemsa Geothermal Prospect area

The area is characterized by volcanism dating from Recent (0.8 –0.08 Ma) to historical times. Volcanism involved the extrusion of per alkaline felsic lava associated with young tensional and transverse tectonic features dating from (0.1 – 1.2 Ma) with abundant silicic per alkaline volcanic products (Di Paola, 1976) in the Tulu Moye-Gedemsa prospect area Figure 1). This suggests the existence of deep seated magma chamber with long residence time. The area is highly affected by hydrothermal activity with the main hydrothermal manifestation being weak fumaroles, active steaming grounds (60-80°C) and altered grounds. The weakness of the hydrothermal manifestations is explained as being the result of the relatively high altitude of the prospect area and the considerable depth to the ground water table. During 1998-2000, integrated geological, geochemical and geophysical studies including shallow temperature gradient surveys (150-200m) have confirmed the existence of potential geothermal reservoir with temperature of about 200°C (Ayele et al., 2002) and delineate target areas for further deep exploration wells.

This prospect area is located close to the koka and Awash II and III hydro-electric power stations, the associated 230 and 132 KV substations and transmission lines.

3.2.4 Dofan Geothermal Prospect Area

Geological, geochemical and geophysical investigations in the Dofan geothermal prospect (Figure 1) show that the area is characterized by a complex volcanic edifice which erupted considerable volume of pantelleritic lava from numerous eruptive centers between 0.5-0.2 Ma (Cherinet and Gebreegziabhier, 1983). The presence of several hydrothermal manifestations (fumaroles and hot springs) within the graben together with an impervious cap needs to be regarded with high priority for further detail exploration and development. Based on this approach and the estimated reservoir temperature of > 200°C (Teclu, 2002/2003), the Geological Survey of Ethiopia is carrying out detail geological, geochemical and geophysical investigations, in order to delineate and select target areas for deep exploration wells.

The area is located about 40 kms distance from the high voltage substation in Awash town.

3.2.5 Fantale Geothermal Prospect Area

The Fantale geothermal prospect characterized by recent summit caldera collapse felsic lava extrusions in the caldera floor and widespread of fumarolic activity suggesting the existence of a shallow magma chamber. Active tensional tectonics form fissures up to 2m wide nearby the volcanic complex. Ground water discharge to the system is assured by the proximity of the area to the western escarpment. The results of an integrated interpretation of previous data suggest that the area is potentially prospective for future detail geothermal resource investigation. Therefore, due to the presence of an impervious cap rock, especially the western part of the prospect deserves to be investigated in a more detailed geothermal exploration programme. In this view, the Survey is carrying out detail geological, geochemical and geophysical investigations in order to delineate and select target areas for deep exploration wells.

3.3 Prospects at Reconnaissance Level

3.3.1 Kone, Meteka, Danab, Teo and L. Abhe geothermal prospects

During the 1980s, reconnaissance geological, geochemical and geophysical investigations had been conducted in these areas and revealed the existence of young volcanic features and active surface thermal manifestations. Meteka and Teo hold promise for the discovery of economically exploitable geothermal resources at high temperature and warrant detailed surface investigation, followed by exploratory drilling. Detail exploration studies will be conducted in the near future to test the presence of economically exploitable geothermal resources.

4. CURRENT GEOTHERMAL ACTIVITIES IN ETHIOPIA

The status of on-going geothermal activities in the Geological Survey of Ethiopia (GSE) is: **(i)** Monitoring (geochemical and reservoir engineering) of the Tendaho geothermal field (Dubti); **(ii)** Detailed geological mapping, geochemical and geophysical studies of the Southern Afar area (e.g. Dofan and Fantale etc.); **(iii)** Collection of water samples for isotope, chemical and gas analysis from surface geothermal manifestations around Main Ethiopian Rift, Southern Afar and Northern Afar regions.

Isotope Geochemical studies in the Rift System: In order to acquire experience and knowledge in using isotope techniques for geothermal exploration and exploitation, the Geological Survey of Ethiopia (GSE) started a technical Cooperation (TC) agreement, through the Ethiopian Science and Technology Commission (ESTC), with the International Atomic Energy Agency (IAEA) in the year 1993. Since then, the TC projects of IAEA are helping Ethiopia to develop experience and knowledge through training of local personnel, expert advice, and the provision of equipment. Furthermore, water samples from the whole Ethiopian Rift Valley and its escarpments are being analyzed at the isotope hydrology laboratory of the IAEA, Vienna, Austria. This has helped improve the infrastructure and built local capability to study geothermal resources using stable and radioactive isotopes.

5. SUMMARY OF STATUS OF GEOTHERMAL EXPLORATION

Reconnaissance and detail exploration conducted for geothermal resources in the Main Ethiopian Rift and the Afar Depression, since 1969, have resulted in a relatively better understanding of the geothermal resource potential of the country. Consequently, the target areas for further detail exploration and development have been selected. Of these potential geothermal prospects, the Aluto-Langano and Tendaho areas have been promoted to the development and feasibility stages, respectively. Moreover, a preliminary production test and techno-economic study at Tendaho indicated that the productive wells could supply enough steam to operate a power pilot plant of about 5 MWe and the potential of the deep reservoir is estimated about 20 MWe.

Detail integrated geoscientific studies of the Lakes District area, particularly in the Corbetti and in the southern Afar geothermal prospect areas of Tulu Moye- Gedemsa have confirmed the existence of exploitable geothermal resource and delineated target areas for further deep exploratory wells.

Currently, detailed geological, geochemical and geophysical studies are underway in the Dofan-Fantale geothermal prospect areas of the Southern Afar region. Other prospect areas of this region (Kone, Meteka, Teo, Danab and Abhe etc.) and in the Northern Afar (Dallol etc.) are yet to be explored in detail.

Future programs of geothermal exploration and development shall be based on considerations of logistic and socio-economic framework of each prospect. Therefore, each of the prospects is qualified with respect to the probability of having an economically viable geothermal resource. Other than Aluto-Langano and Tendaho geothermal fields, the following are a list of prospects in order of the level of exploration:

- **Advance exploration stage:** Tulu-Moye, Gedemsa and Corbetti
- **Detailed investigation:** Completed: Abaya
- **Detailed investigation-Ongoing:** Dofan and Fantale
- **Reconnaissance Stage:** Kone, Meteka, Danab, Teo and Abhe.

6. FUTURE PLANS TO USE GEOTHERMAL RESOURCES

In Ethiopia, there are limitations of local financing due to the high investment requirement to carry out pre-investment phases (reconnaissance and pre-feasibility studies) and the capital investment phases (geothermal exploration drilling, field development and plant construction) to develop geothermal resources. However, with such high potential to generate power Ethiopia still suffers from occasional power shortages even for the established grid and non grid lines.

Ethiopia could generate a huge amount of energy from geothermal resource which can be used for both local consumption and for export. However, an important constraint, indicated above, is the lack of finance. In this connection, the government is considering various options that could develop the resource while reviewing the overall energy policy of the country. One option would be inviting private investors to participate in the sector. Another option , as was the case in the development of hydroelectric power, would be seek loans and grants from international financial institutions .

In the above perspective, government is planning to increase the country's power generation capacity by developing the identified geothermal resource in the project areas. Consequently, the next five year plan of the government includes:

- the rehabilitation of the Aluto-Langano Geothermal pilot plant;
- work at Tendaho for progressing it towards development; and,
- the completion of detailed exploration works at two more geothermal prospects.

Towards the objective of development of this energy resource, a number of multi and bilateral agreements are underway. Out of which the African Rift Geothermal Development Facility project (ARGeo) is a critical component. This is a 10-year Eastern Africa Regional Geothermal program financially supported by (a) the Global Environment Facility of the world bank, and (b) German Development Bank (KfW). The objective of the project is to promote geothermal resource utilization by removing the risks associated with resource exploration and development and by reducing the cost of power development project implementation. The project's implementation agency is the United Nations Environmental Programme (UNEP). Its executing agencies are the African Development Bank (ADB), UNEP and Kreditanstalt fur Wiederaufbau (KfW). Other institutions that are involved in development financing will also contribute resources, including the Global Environment Fund (GEF) of the World Bank. A total of US$250 million in project finance will be allocated over 10 years.

The countries targeted by the project are Kenya, Ethiopia, Djibouti, Tanzania, Uganda, Eritrea, Malawi, Rwanda and Zambia. For Ethiopia, Tendaho geothermal prospect is considered for further assistance in resource assessment and development.

ARGeo will benefit Ethiopia not only by making the financial resources and know-how transfer that are required to advance geothermal work to the resource utilization stage as well as to finance cost effective power development, but will also open the way for regional collaboration in the spirit of the objectives of the African Union, NEPAD and our other regional affiliations.

Such support for geothermal resource development in Ethiopia will also contribute to realizing the fuller potential of the resource by enabling us to use it for energy supply to a wide range of agro-industrial activities and as a means of microclimate control in high value horticulture, floriculture and animal breeding and growing which are our priority areas of development.

ACKNOWLEDGEMENTS

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REFERENCES

Aquater: Tendaho geothermal project, final report. MME, EIGS- Government of Italy, Ministry of Foreign Affairs, San Lorenzo in Campo. (1996)

Ayele, A., Teklemariam, M. and Kebede, S: Geothermal Resources Exploration in the Abaya and Tulu Moye-Gedemsa Geothermal Prospects, Main Ethiopian rift. Compiled Report. (2002)

Electroconsult (ELC): Geothermal Exploration Project-Ethiopian Lakes District, Exploitation of Langano-Aluto Geothermal Resources, feasibility report. ELC, Milano, Italy. (1986) , 150.

EEPCO Data file: Ethiopian Electric Power Corporation Data File.

Kebede, S : Results of temperature gradient survey and geophysical review of Corbetti geothermal prospect, EIGS, (1986).

Di Paola, M: Geological Map of the Tulu Moye active volcanic area 1: 75, 0000 (Arussi: Ethiopian Rift Valley). CNR, Pisa. (1976).

Cherinet, T. and Gebreegziabhier, Z: Geothermal geology of the Dofan and Fantale area. (Northern Ethiopian rift). Geoth. Exploration Project, EIGS (1983).

Gizaw,B: Hydrochemical and Environmental investigation of the Addis Ababa region, Ethiopia. Ph.D Thesis. Maximillans University of Munich (2002).

Teclu, A: Geochemical studies of the Dofan Fantale Geothermal Prospect Areas. South Africa, Internal Report. GSE (2002/2003).

Teklemariam, M., Amdeberhan, Y., Beyene, K., and Gebreegziabheir, Z: Geothermal Exploration and Development in Ethiopia. Proceedings in the World Geothermal Congress, WGC 2000, Kyushu, Tohoku, Japan (2000).

United Nations Development Programme (UNDP):Investigation of geothermal resources of Power development Geology, Geochemistry and Hydrolog of hot springs of the east African Rift System within Ethiopia. DP/SF/UN 116-technical report, United Nations, New York (1973), 275.

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

	Geothermal		Fossil Fuels*		Hydro*		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
In operation in December 2004			47	12	535	2176	582	2188
Under construction in December 2004			38		584	1987	622	-

** Obtained from EEPCO data file

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

Locality or	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe	Total under Constr. Planned MWe
Aluto-Langano	Aluto-Langano Pilot-power plant	1999	2	N	Binary type	7.28	30
Total							

** Obtained from EEPCO data file

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT

AS OF 31 DECEMBER 2004 (other than heat pumps)

Locality	Type[1]	Maximum Utilization					Capacity[3]
		Flow Rate (kg/s)	Temperature (°C)		Enthalpy[2] (kJ/kg)		(MWt)
			Inlet	Outlet	Inlet	Outlet	
Sheraton Hotel	B						
Filowha	B			58-78			
Ghion	B			44-77			
Hilton	B	0.005		41-50.6			
National Palace	B	0.007		67-75			
Greek Community	B			28			
St. Joseph School	B			35.5			

NB Total Thermal Wells ~ 15.

Discharge rates are by in large pump dependant rather than potential.

Record on thermal wells is unfortunately scarce.

Data obtained from Gizaw, 2002

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)	5*				1
Production	>150° C					
	150-100° C					
	<100° C					
Injection	(all)					
Total						

- Temperature Gradient wells

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

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000	16					
2001	16					
2002	17					
2003	17					
2004	17					
Total	17					