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ENVIRONMENTAL MANAGEMENT IN GEOTHEMAL DEVELOPMENT: CASE HISTORY FROM KENYA

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ABSTRACT

In Kenya, all the geothermal power is currently exploited from Olkaria geothermal field on which Kenya's geothermal experience is based. Electricity generation from geothermal in Kenya started in 1981 with construction of Olkaria I (45 MW) geothermal station. The current output from geothermal in Kenya is 130 MW, which is about 11% of the country's effective capacity. However, there is a plan to increase generation from geothermal by an additional 576 MW by 2026.

The experience gained in Olkaria for the last 26 years has showed that geothermal energy is an indigenous and a relatively clean alternative source of power. The potential negative impacts of geothermal developments have been mitigated to a large degree through establishment and implementation of sound environmental management and properly designed operation systems. These management methods can be applied in any other geothermal field with modifications based on, among others, site conditions, laws and regulations and availability of resources including manpower.

1. INTRODUCTION

Kenya relies on three major sources of energy. These are biomass (68 %), petroleum (22 %) and Electricity (9 %). 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 %. Due to unreliable rain patterns, and the fact that Kenya depends highly on hydropower, the electricity supply has become unreliable especially during the dry seasons. An example of such scenario was experienced in the year 2000. This affected 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. Several recent least cost power development plans (KPLC, 2005) has considered geothermal

energy as a least cost source of electrical power in Kenya. There is a plan to increase generation from geothermal by 576 MW by 2026.
The electrical power demand in Kenya has had an increasing trend over the last five years. This is expected to rise even more with the improvement of economy. With the commitment the government of Kenya has demonstrated to exploration and exploitation of geothermal energy, geothermal energy is expected to meet a large percentage of this demand. It is also anticipated that the commencement of African Geothermal initiative (ARGeo) project together with other funding agents will assist in development of the already proven geothermal resources i.e. Olkaria IV, and Eburru, Suswa, Longonot and Menengai. This will result in huge savings normally incurred from use of fossil fuels as well as address the environmental issues.

Most of the geothermal resources in Kenya are located in environmental sensitive regions. Olkaria and Longonot geothermal fields are located in National Parks. Lake Bogoria and Lake Baringo geothermal prospects are located in Game Reserves. The rest of the prospects are either in public (Gazetted forest land), communal or private land. The development of geothermal resources at these sites, particularly in Olkaria geothermal field, has created environmental challenges and also inspired vibrant economic activities in the region particularly from Kenya Electricity Generating Company (KenGen's) corporate social responsibility initiatives.

This paper discusses the experiences gained in the management of environmental and social issues during development of geothermal resources in Kenya.

2. GEOTHERMAL RESOURCES POTENTIAL IN KENYA

Geothermal activities in Africa are concentrated in the East African Rift system (Figure 1). It is a divergence zone, which is still active. The rifting in the East African rift system has been associated with intense volcanism and faulting. Volcanism associated with the central rift zone started in Miocene and continued up to Holocene. 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).

The high temperature geothermal resources of Kenya are in the Kenya Rift, which is the eastern segment of the East African Rift. There are about 14 known geothermal sites many of which are associated with central volcanic centres. The geothermal resources at these sites manifest themselves in form of steam jets, hot springs, geysers and altered hot grounds. Their geothermal potential is estimated to be in excess of 2000 MWe. Wells have been drilled only in Olkaria and Eburru but exploitation so far has only been done at Olkaria geothermal field.

Comprehensive exploration of these geothermal resources commenced in 1970 and currently Kenya generates about 130 MW of power, which accounts for about 11% of the effective installed capacity. KenGen has two power stations (Olkaria I and II) with a total capacity of 115 MW. Orpower 4 Inc (Olkaria III) and Oserian Development Company have 13 MW and 2 MW binary power stations, respectively. KenGen, which is a public-private company, generates 80% of Kenya's power. Orpower4 is an Independent Power Producer (IPP) while Oserian is a farming company that generates power for its farm use.

Other than producing power for farm use, Oserian Development Company is a leader in the region for growing cut flowers. Currently Oserian is using geothermal heat and CO_2 in 50 hectares of green houses for production of cut flowers for export market.

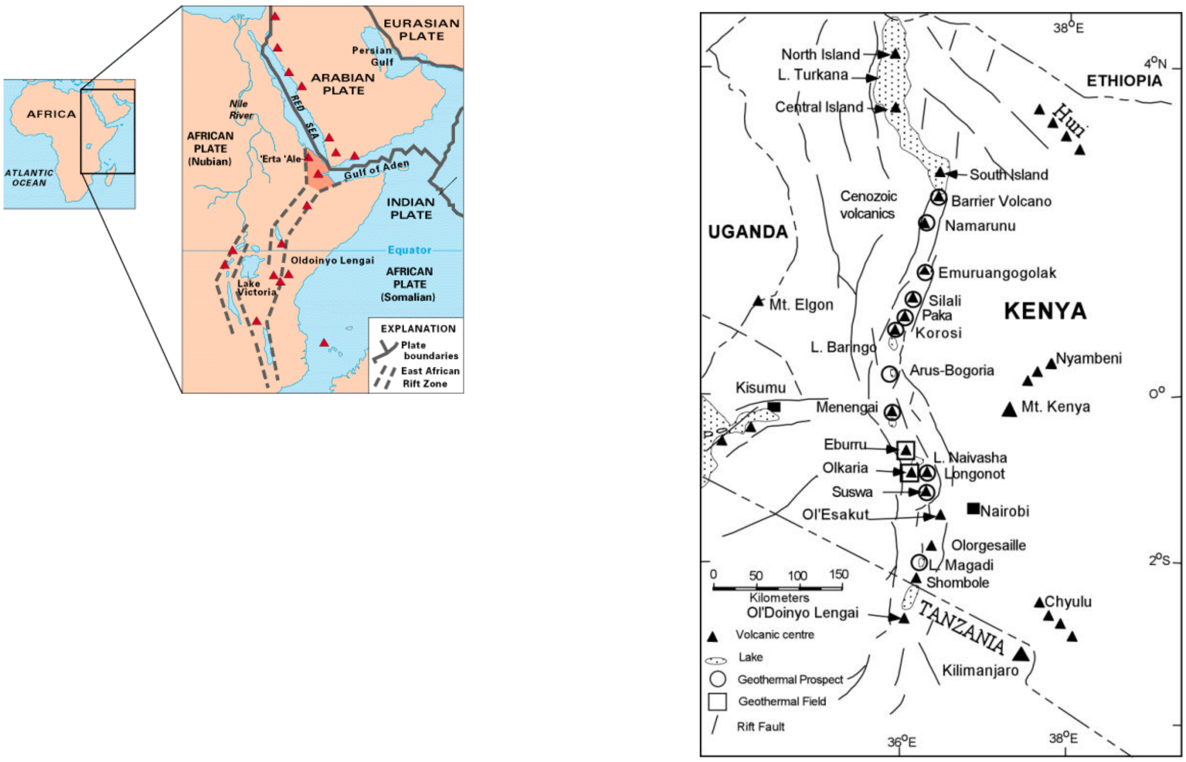

FIGURE 1: African Rift system and geothermal prospects of Kenya

Currently all the geothermal power is exploited from Olkaria geothermal field on which Kenya's geothermal experience is based. The Greater Olkaria geothermal area, which is about 80 km^2, is located within the axis of the central segment of the Kenyan Rift. For the sake of development, Olkaria area (Figure 2) has been divided into seven sectors, namely, Olkaria East, Olkaria West, Olkaria Northwest, Olkaria Northeast, Olkaria Central, Olkaria Domes and Olkaria Southwest The Olkaria I, which is the first geothermal power station in Africa, with an installed capacity of 45 MW, was commissioned in 1981 and 1982 and has been operating in the Olkaria East field for over 25 years. In the Olkaria Northeast field, is the 70 MW Olkaria II geothermal power station, which was commissioned in 2003. In Olkaria Domes field (Olkaria IV), which is the forth field targeted for development, three exploration wells were drilled between 1998 and 1999. Appraisal drilling is currently in progress in Olkaria IV. Exploration drilling has also been undertaken in the other sectors of Olkaria but has shown medium temperature reservoirs.

Outside of Olkaria Geothermal field, exploration drilling has been undertaken in Eburru geothermal field, which is located some 50 km north of Olkaria. A prefeasibility study for multiple uses of geothermal for electricity generation and water production for agriculture and domestic use has been carried out for Eburru geothermal field (WestJec 2003). The first phase of this project, which is the construction of a 2.5 MW binary plant, is in the bidding stage and is planned to be commissioned at the end of 2009. Detailed surface exploration works at Suswa, Longonot, Lake Bogoria, Lake Baringo, Korosi-Chepkuk and Paka have been completed and deep exploration wells sited. Surface exploration is about to commence in Silali. Exploration drilling is planned to be done in Longonot in 2008 and Menengai in 2009.

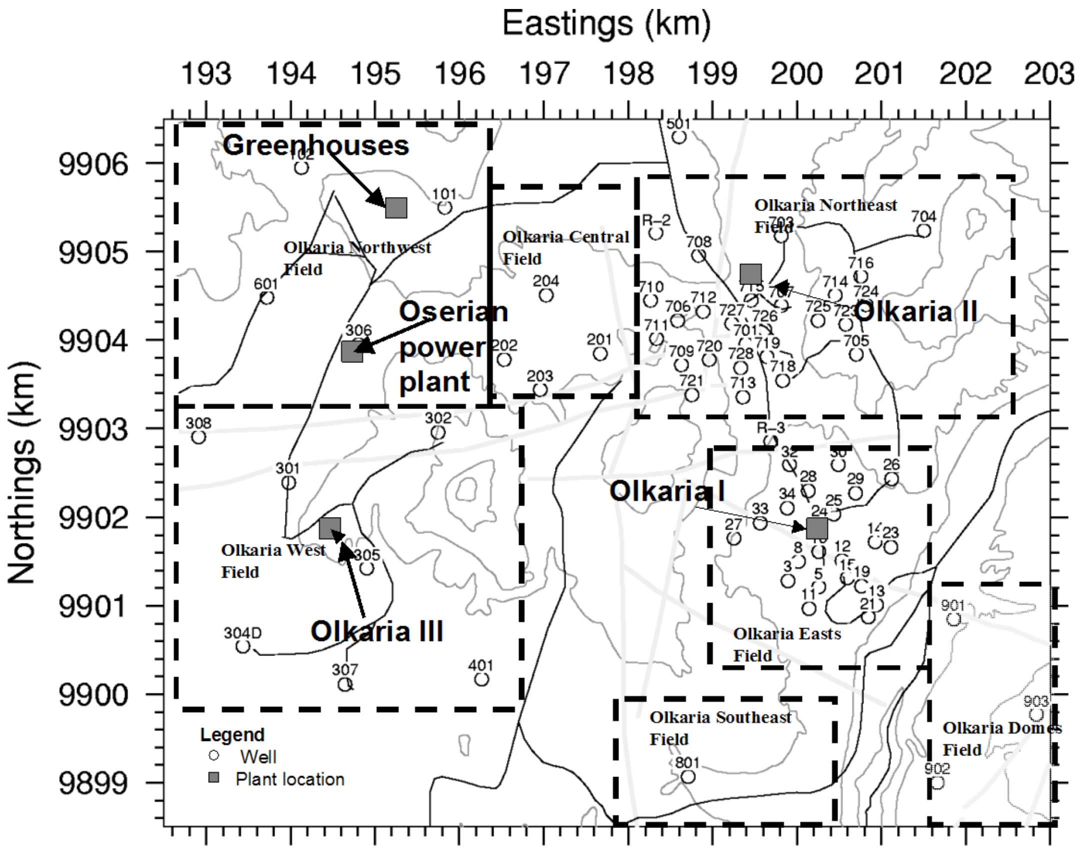

FIGURE 2: Olkaria Geothermal Field showing location of development sectors and power stations

3. ENVIRONMENTAL ISSUES AND MANAGEMENT TOOLS

3.1 Background

As mentioned above, Kenya's experience in geothermal development has been concentrated around the development of Olkaria Geothermal field and to some less extent in Eburru. Some experiences have been obtained during the detailed surface scientific studies in about 6 geothermal prospects beyond Olkaria and Eburru. This paper will therefore detail experiences gained in Olkaria and which are intended to be replicated in other regions with modifications based on local settings and improved experiences along the way.

Environmental management initiatives undertaken by KenGen were triggered by the fact that Olkaria geothermal field was declared a National Park by the government in 1984 when Olkaria I power station was already commissioned. At the same time, the World Bank became interested in the further development of Olkaria geothermal resources and was lending funds for further exploration and development. Under the lending terms, the World Bank required that future developments use OP 4.00 environmental guidelines (World Bank, 1989). Based on these two aspects, KenGen decided to create a section in its geothermal project development department to deal with environmental management in its daily activities. Subsequently, as environmental management developed in the project, the results are found in the design differences between Olkaria I and Olkaria II power stations. KenGen is currently in the process of implementing and establishing and maintaining an Environmental Management System under the ISO: 14001.

The environmental impacts associated with Olkaria geothermal project are typical of any geothermal resources found elsewhere in the world but the manner in which they are addressed differ from magnitude, location, knowledge base, laws and regulations.

3.2 Laws and regulations

In Kenya there are several Acts of Parliament that work together to regulate and guide geothermal and natural resource use in a sustainable manner. Two laws, which specifically deal with geothermal development, are the Geothermal Resources Act of 1982 and supplementary legislation of 1990 and the Environmental Management and Co-ordination Act (EMCA) of 1999. Other regulations do not directly refer to geothermal but due to their implications affect geothermal development at various stages and in various ways. These include among others Electric Power Act, Forest Act, Water Act, Factories and Other Places of Work Act, Wildlife Conservation and Management Act. Besides these legislations, there are Kenyan and international policies and regulations that govern the development of geothermal resources, more especially those tied to conditions on funding geothermal projects, for example the World Bank operational directive OP 4.00.

Initially, KenGen based its environmental management initiatives on the World Bank's operational directive OP 4.00 for the development of Olkaria II. The directive requires that a fully-fledged environmental impact assessment (EIA) be undertaken for a power station development. Such an assessment was therefore undertaken in 1992-4 for Olkaria II development. Based on the results of the EIA, a Memorandum of Understanding (MoU) was signed between KenGen and Kenya Wildlife Service (KWS) for the development of geothermal resources within the Hell's Gate and Longonot National parks. Other processes, for example, the use of Lake Naivasha water, have driven other initiatives.

EMCA of 1999 came late in the development of geothermal in Kenya. It is an overall legal instrument for managing environmental issues and created several institutions for its management the key one being the National Environmental Management Authority (NEMA) including Provincial and District Environmental Committee and Public Complaints Committee. This provision of the law therefore gives the public voice and a chance to participate in matters related to environment. NEMA requires that all power projects, among others, undergo an EIA and conduct a public discloser involving all the stakeholders before a licence is issued. In addition, an Environmental Management Plan together with regular environmental monitoring and audits and associated costs of implementation are required.

Under the Act, the Energy Regulatory Commission (ERC) is recognised as the lead agency for the enforcement of environmental and safety regulations in the electric power sub-sector, the functions of which are conferred by the Energy Act of 2005.

EMCA requires ERC to take into account the need to protect the environment, conserve natural resources, and protect the health and safety of service users and the public at large, among other things when appraising applications for licences.

3.3 Environmental aspects of geothermal development

3.3.1 Surface disturbances

Olkaria geothermal field is located within gently rolling hills and ground. Unfortunately most of it is covered by a thick cover of pyroclastics and volcanic ashes deposited from the numerous volcanic eruptions of the area. The ground is covered by grass, which has a poor cover and appears to be dead during drought. Bushes are made primarily of short Leleshwa with occasional short acacia thorn trees. These volcanic ashes are very venerable to water erosion when the ground is opened for drilling pads, roads and power stations. In order to mitigate these impacts, the infrastructure sizes are controlled and only what is absolutely necessary is cut. Rehabilitation is also done quickly using local grass and bushes as soon as the equipment is removed. If roads have been discontinued for any reason, then topsoil is returned and rehabilitation is done otherwise roads for developed fields are tarmaced to minimize erosions.

During well drilling, care is taken to avoid oil spillage. Otherwise, spillage is collected in trays into drums for resale. Use of water instead of mud chemical additives and drilling detergent particularly aerated water is preferred during drilling. Any rubbish generated during drilling or any construction activities is transported off site for disposal through burning and carefully selected metal dumpsite for scrap resale.

3.3.2 Noise

Sources of noise in geothermal development include operating drilling rig, well testing and power station operation. Only few instances do operating rig equipment noise exceed 85 dB(A). The highest noise of up to 120 dB(A) occurs during vertical discharge of wells during start-up before they are horizontally discharged through a separator. The period of vertical discharge has been reduced to not more than 30 minutes to clear cuttings and other debris in the well. Horizontal discharge through separators reduces noise to < 85 dB(A). Initially wells were put on horizontal discharge for periods of about one year. Wells are now discharged for short periods not exceeding two months. Also better-designed separators are in use, which dump noise more effectively and also reduce water carry-over. The water carry-over which would inhibit plant growth.

Noise around Olkaria power stations is associated with Non Condensable Gases (NCGs) gas ejectors, air filters and turbines. Because of this noise, the NCGs for Olkaria II station are designed to discharge through the cooling towers, which dampens the noise. The turbines have fairly low noise levels by design specifications and much of the other noise is generally trapped by the inclusion of the turbines in a building instead of being in the open.

3.3.3 Waste geothermal brine

Olkaria wells produce 75% steam and 25% water and dry up as the well continue to discharge. The brine component has harmful chemical substances as shown in Tables 1 and 2 below. From a study done by Wetang'ula and Snorrason (2005) from some wells of Olkaria I, the trace elements concentration levels in wastewater from most wells are within the international water quality criteria for protection of plants and animals (mammals) against any potential ecotoxicological risk except for As, B and Mo in wastewater from a few wells. Geothermal wastewater could be a potential ecotoxicological hazard due to these trace elements if proper disposal strategy is not used. The fluoride level in the wastewater of all wells is high which is typical of Kenyan rift waters.

TABLE 1: Trace elements levels (μg/L) in wastewater of selected Olkaria I field wells for 2000 (Wetang'ula and Snorrason 2005) and permissible limits (CCME, 1999)

Trace Elements	Al	As	B	Cd	Co	Cr	Cu	Hg	Mo	Ni	Pb
Average Olkaria I (8 wells)	947	1192	6694	0.09	0.046	1.42	4.967	1.71	257	1.47	
Livestock Limits	5000	25	5000	80	1000	50	500-1000	3	500	1000	50000
Plant water limits	5000	100	500-6000	5.1	50	4.9-8	200-1000		10-50	200	1000-5000

Recent speciation modeling studies of trace elements in spent geothermal fluids by Were (2007) predicted occurrence of labile and toxic Cd in spent geothermal fluids, Cu, Pb, and Zn species in acidic to neutral geothermal fluids and non-toxic aqueous Al, As, and Hg species in spent geothermal fluids. Cd concentrations were, however, below detection levels and in all probability low.

Initially, Olkaria I brine from wellhead separators was collected in open concrete channels into fenced-off conditioning ponds, which allowed the silica to polymerise and precipitate as it cooled down. The conditioned brine from these small ponds was collected from various wells into a large pond that then infiltrated into the ground and the rest evaporated. Later, the conditioned water has continuously been reinjected cold into disused well(s). In another part of the Olkaria I field, the separated hot brine is being reinjected before cooling. The cooling tower blow down water is also mixed with the separated water from the wellheads and reinjected. Ponds are generally fenced off to keep away both wild and domestic animals from entering them to drink water and possibly drown. Alternative fresh drinking water is provided at strategic points for this purpose.

TABLE 2: Contaminant concentrations in selected geothermal fluids and in world average in mg/kg (Wetangula, 2001; Opondo 2002)

	Li	**B**	**As**	**Hg**	**H_2S**	**NH_3**
Fresh Water	0.003	0.01	0.002	0.00004	<dl	0.04
Deep well water						
Salton sea, USA	215	390	12	0.006	16	386
Ceero Prieto, Mexico	-	19	2.3	0.00005	0.16	127
Waireki, (NZ)	14	30	4.7	0.0002	1.7	0.2
Reykjanes, Iceland	4470	8.7	0.1	0.0000087	1.9	1.61
Olkaria, Kenya	1.6	4.6			5.3	

<dl: Below detection limit

Based on reinjection experiences from Olkaria I, all the separated water from Olkaria II field is reinjected hot in 4 wells located in the field. The power station blow down is reinjected in two wells located some distance outside the producing field to avoid adverse cooling of the reservoir.

In 2001, during the construction of Olkaria II and after twenty years of Olkaria I operation, KenGen received complaints from the local pastoralist people that the brine was killing their cattle and making their women miscarry. The community disrupted regular work but not the operation of the station. They complaints were also sent to the local press and created bad publicity for KenGen. No one could prove this. It was later learnt that the complaints had no basis and was meant to bring attention for more jobs and some mode of compensation. Some activists had instigated the complaints.

3.3.4 Gas emissions

Olkaria steam has 1% NCGs. Of these NCGs, 92% is CO2, 3% H_2S and the rest methane, nitrogen and hydrogen (Opondo 2002). Well under test discharge emit these gases over a limited period of time. However, there is a continuous emission from the power station ejectors at Olkaria I station at the top of the station building. In Olkaria II the NCGs are exhausted through the cooling towers and therefore ascending very high in the atmosphere where it is effectively dispersed. The main gas of concern because of its potential to form acid rain is H_2S but the amount produced from the field is relatively small. However it is a nuisance to human beings because of bad (rotten egg) smell.

When Oserian farm started the business of growing flowers, the farmer accused KenGen of discharging gases that affected his flower crop. Fortunately, this happened only in one season. It was later discovered that a disease that the farmer had not known about, because at that time he was inexperienced in growing flowers, had affected the crop. In order to address this matter conclusively, an experiment was jointly conducted by KenGen and the farmer (Kollikho and Kubo 2001) whereby flowers were grown at two plots located 600m and 1200m from Olkaria I station in the most direction of the wind at the same time similar flowers were grown in the main farm about 7 km away as a control. The trials were done over a period of one year in 1994 and it proved that the gases did not affecting the flowers because the concentrations were too low (<1ppm).

Currently Oserian Development Company is actually using geothermal gases in the green houses particularly CO_2 to boost growth of roses. In the green houses, fresh water heated with geothermal water through heat exchangers keeps the temperatures at night high and therefore reducing humidity to below 85%. This reduces the need to use chemicals for spraying some types of diseases and consequently reducing the production cost. The heat and the CO_2 also increase the rate of flower growth resulting into a better crop.

3.3.5 Steam gathering system

In the National Park or a ranch, the cross-country steam lines or hot water gathering systems can affect the free movement of animals. In order to overcome this problem, the animal routes are mapped before the lines are constructed and taken into consideration during the design. In some cases bridges or loops are created for this purpose. The color of pipes is also selected to march the environment.

3.3.6 Power transmission lines

Transmission lines require EIA in order to avoid visual impact and collision of birds. The Olkaria II 220kV line was routed with the help of Kenya Wildlife Service personnel to avoid crossing scenic Hell's Gate gorge and collision of birds, which airlift over the gorge.

4. SOCIAL ISSUES AND MANAGEMENT

4.1 Water

Olkaria area depends solely on Lake Naivasha as its only source of water. For a large distance south of Lake Naivasha boreholes drilled are either dry or discharge steam. Coupled with the fact that rainfall is low, the local pastoralists suffer a lot from lack water for domestic and animal use. KenGen therefore provide water pumped from Lake Naivasha at about six points through out the year to the local community. Some other water is provided to KWS staff and wild animals. Water is also provided to the Eburru community who were originally depended on rainwater or condensed steam from the naturally occurring steam jets. During severe drought KenGen also supplies water in water bowsers to communities much further from Olkaria.

4.2 Roads

Between 1985 and 1990, KenGen decided to tarmac Olkaria- Naivasha road (40 km) and the bore field access roads. The tarmacing of this road opened the entire area for agriculture, tourist hotels and assisted easy access into Hell's Gate National park. The horticultural industry consequently created a lot of jobs in the areas. Some of the large farms employ about six thousand people of different professions. Flower industry along this road is the second to tea as a foreign earner. Several new hotels have been built and more and more people now visit Naivasha and Hell's Gate National park for business and recreational purposes. The area supports directly and indirectly over 500,000 people.

4.3 Labour

The power stations employ about 425 staff permanently. However, services like cleaning and guarding are sourced through contracts to local communities. A large portion of labour is also sourced from the communities on casual basis during power station construction and maintenance.

4.4 Education

KenGen constructed a Nursery and Primary schools to cater for its employees and the local community. Currently these two schools have 480 pupils and more than half of them are from the local community. The company bus brings in the pupils from local communities leaving more than 15 km.

KenGen, under its social responsibility programmes have for the last three years sponsored six students into secondary schools and eight students into National universities and plan to increase these numbers in future.

KenGen, Orpower4 and Oserian have assisted the construction of some classrooms in some schools further away from the Olkaria. Orpower 4 has provided some teachers to some schools. KenGen is currently planning to spend about US$ 900,000 from Community Development Carbon Fund (CDCF) for this purpose. The funds will also be used to expand the water supply and dispensary initiatives.

4.5 Health

A dispensary constructed for KenGen staff is open to the local community for some limited treatment. KenGen and Orpower4 have continued to organise some Health camps, which take the services closer to the communities around Olkaria.

4.6 Transport

The area south of Olkaria Project has no public transport. For this reason, KenGen and Orpower4 provide free rides to the community. In particular, Kengen provide a bus on Saturdays throughout the year to the local community for shopping. Transport is also provided during inoculation or other government health or education initiatives to the local communities.

4.7 Public complaints

Even with this level of community assistance, the local communities continue to demand more assistance. Some of these communities reside in land owned by others. Although KenGen would be willing to assist these communities the company would not want to be involved in land disputes, as land issues in Kenya are sensitive. KenGen would only want to be involved in community projects located in areas without disputes.

4.8 Social afforestation

KenGen's tree nursery was initially meant for germinating seedlings for rehabilitations within the geothermal projects. Currently, about 100,000 seedlings are either issued to staff, churches, schools, universities or the general public under social afforestation programme. Environmental Scientists are also involved in training community groups or schools that would like to start their own tree nurseries.

5. CONCLUSION

It is now accepted that geothermal energy is a relatively clean source of energy. The utilization of geothermal energy saves Kenya's foreign currency and emits less greenhouse gases. In this regard, Kenya would like to take full advantage of its large geothermal potential.
The potential negative impacts of geothermal developments can be mitigated to a large degree through establishment and implementation of sound environmental management and operation systems and taking due regard for the local communities. The many social and economic benefits associated with the geothermal development should benefit these communities in which they are located to a large extent in order for the projects to be accepted. Olkaria geothermal project offers an excellent case history of a geothermal project developed in a fragile environment given that it has been developed in a National Park for the last 26 years. KenGen is confident that the experience gained in Olkaria can successfully be replicated in other geothermal resources areas.

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