ELSEVIER

Energy Policy 30 (2002) 1119–1128

ENERGY POLICY

www.elsevier.com/locate/enpol

The impact of large-scale renewable energy development on the poor: environmental and socio-economic impact of a geothermal power plant on a poor rural community in Kenya

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Abstract

The article assesses the local environmental and socio-economic impact of geothermal power plant on poor rural community in Kenya. The country's geothermal resources are located in the Rift Valley region—an environmentally and culturally fragile part of the country. Kenya's main geothermal plants are located in the middle of one of Rift Valley's major wildlife parks—a major tourist attraction. Over the last two decades, the surrounding area has also become a major centre for Kenya's flourishing commercial flower farming, which is now partially powered by geothermal energy. This article examines environmental and socio-economic impacts on the nomadic low-income rural *Maasai* community of the simultaneous development of geothermal energy, flower farming and wildlife/tourism industry. While the near-term environmental impacts have been minimal, the article warns of significant adverse impacts in the future if the competing demands of the fast growing geothermal energy, flower farming as well as wildlife/tourism sector are not adequately addressed. In the short-term, however, the socio-economic impact of geothermal energy development is likely to be the main source of conflict. The article ends by proposing policy and institutional measures that would ensure that the local *Maasai* community enjoys a wider range of socio-economic benefits as well as mitigate long-term adverse environmental impacts associated with geothermal energy development.

Keywords: Poor; Geothermal; Kenya

1. Introduction

Geothermal energy is the natural heat from the earth's interior stored in rocks and water within the earth's crust. This energy can be extracted by drilling wells to tap concentrations of steam at high pressures and at depths shallow enough to be economically justifiable. The steam is led through pipes to drive electricity-generating turbines. Geothermal fields are fairly widespread in the world and are exploited in Italy, the USA, New Zealand, Japan, Mexico, El Salvador, Iceland, the Philippines and Turkey (Fridleifsson, 2001; Milford, 2000). Kenya is the first African country to tap power from the crust of the earth in a significant fashion (Karekezi, 1997; Johansson et al., 1993).

Olkaria is an area located within the southern part of the Kenya rift from Lake Naivasha in the north to the Suswa volcano in the south (see Fig. 1).

In this area, extensive igneous and volcanic activity has occurred in the recent geologic past (Clarke et al., 1990; Omenda, 1994; Muchemi, 1994; Mungania, 1995). The area contains three large volcanic fields, Longonot, Suswa and Olkaria, each with a significant caldera.

At Olkaria, geothermal investigations started as long ago as 1956 when exploratory drilling was undertaken by a consortium of companies that included the then East Africa Power and Lighting Company Limited and Balfour Beatty and Company. Two wells were drilled without any marked success. It was not until the end of the next decade that interest in geothermal power revived.

Between 1970 and 1972 investigations were undertaken at Olkaria, Lake Bogoria and in the Eburru area,

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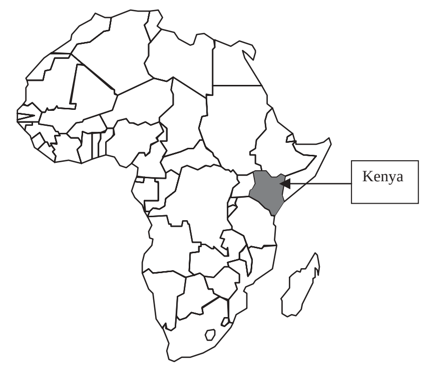
0301-4215/02/$ - see front matter
PII: S0301-4215(02)00063-0

north of Lake Naivasha (Ewbank Preece Limited, 1989). Further work that produced positive results was carried out on the two exploratory wells drilled at Olkaria in the 1950s.

Brief Country Profile: Kenya



Kenya: Selected Indicators

Population (million): 28.7 (2000)
Area (km^2): 580,000
Capital City: Nairobi
GDP Growth Rate (%): 0.4 (2000)
GNP per Capita (US$): 350 (1998)
Official Exchange Rate: KShs. 78.56 = 1 US$ (Jan 2002)
Economic Activities: Tourism, agriculture, forestry, manufacturing, mining, construction, commerce
Energy Sources: Geothermal, hydro, solar, biomass, imported oil, imported coal
Installed Capacity (MW): 1,173 (2001)
Electricity Consumption per Capita (kWh): 122.1 (2001)
Electricity Generation (GWh): 4,081 (2001)
System Losses (%): 21.5 (2000)

Sources: Business in Africa (2001); AFREPREN (2001); EIU (2001)

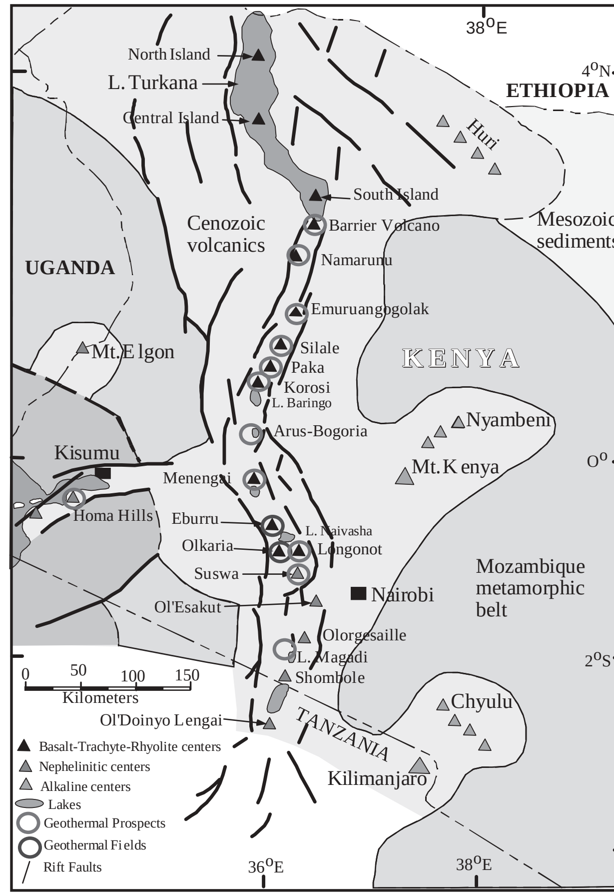


Fig. 1. Simplified geological map showing locations of geothermal areas in Kenya. *Source*: Mariita, 2000.

On that basis, drilling started in earnest in 1973 and by 1975, four more wells had been drilled in the area. A feasibility study was then undertaken to evaluate Olkaria's potential for generating electricity from geothermal steam. The study found that the Olkaria geothermal field covered some 80 km^2 and steam for 25,000 MW years. The present production area, which covers 11 km^2, was estimated to have steam for 400 MW years (UNEP, 2001; Daily Nation Correspondent, 1995; Muna, 1998; Omondi, 1987).

Geothermal power is being tapped by the Kenya Electricity Generating Company, KenGen, a public utility at Olkaria East and by OrPower 4, an independent power producer, at Olkaria West. Both companies use superheated water and steam to generate a total of 57 MWe of electricity (KPLC, 2000; Bronicki, 2001). The Power, which currently meets about 5.5% of the nation's electricity consumption (Omenda, 2001), had its first phase connected to the national grid system in 1981, initially with 15 MWe by KenGen (Dickson and Fanelli, 1988; Kenya Electricity Generating Company (KenGen), 1999). Table 1 summarises the installed capacity by the Kenya Electricity Generating Company Ltd.

Table 1
KenGen Co. Ltd.'s installed electrical capacity

	Installed capacity (MWe)	Percentage
Hydro	681.28	74.00
Thermal	197.80	21.00
Geothermal	45.00	5.00
Wind	0.35	0.04
Total	924.43	100.00

Sources: Kenya Power and Lighting Company Ltd. (1998/1999;2000).

The frequent drought experienced in Kenya has clearly demonstrated the dangers of heavy reliance on hydropower. In recent years, poor precipitation in the central Kenya region resulted in very low inflows into the River Tana where most of the hydropower plants are situated, leading to halving of hydropower electricity generation. Load shedding (power rationing) became inevitable which adversely affected national economic performance. To keep the economy running, power has had to be produced expensively on an emergency basis from hired diesel fired stations. During this time, the two geothermal power plants at Olkaria offered continuous base-load power with almost 100% availability, unaffected by the prevailing weather conditions (KenGen, 2000). If more geothermal energy had been available, the electricity supply would have been insulated from the high cost and environmentally unsound fossil-fuel fired power generation.

Three newly installed independent power producers (IPPs) contribute 90 MWe from thermal and 12 MWe from geothermal bringing the total electrical power installed in the country to about 1026 MWe. This figure excludes the small isolated diesel plants run by the Rural Electrification Program (KPLC, 2000).

Presently four potential areas have been identified within the Greater Olkaria Volcanic Area that are earmarked for separate development: East Production Field (EPF), North East Field (NEF) and Olkaria West Field (OWF). The EPF is generating 45 MWe (Johansson et al., 1993). A second 64 MWe power station in the NEF to be managed by KenGen is now under construction and is expected to be working by the end of the year 2002. OrPower 4 is expected to increase its output from the current 12 MWe to 64 MWe in the next couple of years. This will bring the total power generated from Olkaria to 173 MWe. Additional geothermal stations of 64 MWe each will be in service in the years 2005 and 2006, thus bringing the total power generated from Olkaria by the year 2006 to 301 MWe (Mariita, 2002).

The national energy sector master plan has identified the generation of electricity from geothermal sources as the least cost source of energy. It is expected to meet an increasingly larger proportion of the country's power needs in the years ahead. A total of 448 MWe of additional geothermal energy is envisioned up to the year 2012. This will represent about 30% of Kenya's power requirement. The development of this resource will mark a significant step in Kenya's technological and economic development (UNEP, 2001).

Kenya's major, sustainable, and clean energy resource—geothermal energy—lies beneath the vast, but environmentally and culturally sensitive East African Rift Valley. The exploration and exploitation of this resource should be done in a way that does not have negative impacts on the environment and human life.

Kenya's geothermal resources are located in the Rift Valley region—an environmentally and culturally fragile part of the country. The Rift Valley is home to a large number of world famous wildlife parks that contain some of the world's most endangered animal species. The unique wildlife found in the Rift Valley region attracts a large number of tourists to wildlife parks and has contributed to developing Kenya's tourist sector into a major source of employment and convertible currency for the country. For the last four decades, Kenya has been one of the leading tourist destinations in the world. The main attractions are the wildlife, lakes, and vegetation within the rift valley where the flora and fauna has been preserved because there had been very little human socio-economic activity. Kenya's main geothermal plants are located in the middle of one of Rift Valley's major wildlife parks.

Over the last two decades, the surrounding area has also become a major centre for Kenya's flourishing large-scale flower farming sub-sector, which is now partially powered by geothermal energy. The last 10 years have seen this region of Kenya emerge as one of the leading cut flower exporting regions of the world. Flower farming has done well in the Rift Valley due to volcanic soils around the volcanic centres. This is also where the geothermal resources are. One of the flower farms (Oserian Development Company), now uses the geothermal steam and water from a well leased from the KenGen Company for soil fumigation and greenhouse heating.

The Rift Valley is also home to one of the country's poorest rural communities, the *Maasai*, a conservative nomadic community that has over the last centuries developed low-impact nomadic practices that allowed peaceful and environmentally sound co-existence with the local wildlife. The development of geothermal energy, large-scale flower farming and wildlife/tourism has gradually taken over the ancestral rangelands of the nomadic *Maasai* community. This article examines environmental and socio-economic impacts on the local *Maasai* community of the simultaneous development of geothermal energy, large-scale flower farming and wildlife/tourism industry.

This study was designed to assess the environmental and socio-economic impacts brought about by the development of the Olkaria East geothermal plant, which has been operated by KenGen for the last 20 years (KenGen, 2000). The operations of the new geothermal installation, OrPower 4 have not been considered because it has been online for a period of <3 years (KPLC, 2000). The study included assessments of geothermal resource, land, and water use prior to the production of geothermal energy.

2. Study approach

KenGen Co. Ltd has a full time environmental management unit that deals with all environmental aspects pertaining to the development of geothermal energy. Discussions were held with this group to obtain background information as well as going through the literature at the Olkaria library. This was followed by direct field surveys, visiting the *Maasai* villages and interviewing the people found there. Community elders as well as the administrative chief of the area were interviewed. Of paramount importance was the identification of those *Maasai* who formerly lived in the park. An attitudinal survey of the *Maasai* community on visitors to the park and the power station was conducted. From this survey the project development impact assessment was conducted.

The first step was to characterise the existing environmental and socio-economic setting of the area. Estimates of the impact were to be deduced from a comparison of this base-line data with information and data collected during geothermal exploration, project construction or operation. The *Maasai* population within 10 km radius of Olkaria power plant was studied and interviewed. Data was collected in order to assess positive and negative impacts. The data was to be used to establish:

- Population size and growth rate.
- Provision of public services such as schools, water and hospitals.
- Improvement in infrastructure such as roads, water and power supply, etc.
- Employment rate.
- Average size of families and educational achievement.
- Patterns and rate of migration.
- Effects of geothermal activity, e.g., noise, hydrogen sulphide (H_2S), cultural disruption, tourism and recreation.
- Collection of adequate background information on the previous condition of the area and to collate the findings from the time the Olkaria project was started.

The study included the assessment of:

- The beneficial impacts of the project, e.g., employment, provision of water, infrastructure, etc.
- The negative impacts of the project, e.g., displacement, noise, etc.

Specifically, the study addressed the following issues that directly affect the *Maasai* community:

(1) Environmental
- To what extent did the development of the Olkaria Geothermal project adversely affect the land used by the local community, e.g., acquisition of grazing land?

(2) Operations
- Have gas emissions and waste brine contaminated the environment?
- Have the domestic livestock been affected by drinking waste brine?
- Has the noise associated with the power station and drilling been a nuisance?
- Has any member of the family or domestic livestock been injured by anything related to geothermal energy development?

(3) Socio-economic and cultural factors
- Was any provision made for housing or transport when families were displaced?
- Has the project contributed in any way to the economy, e.g., employment, business?
- Has the project assisted the *Maasai* community with infrastructure such as water, hospitals, roads, electricity, etc. and do they actually use them? Are they reliable?
- Do they benefit from tourists visiting their cultural centre?

(4) Health impacts
- Did the project create any health problem, e.g., from noise, H_2S?
- Has the project educated the *Maasai* on the dangers of geothermal wells?

(5) General attitude
- What is the overall attitude/perception towards the project?
- Are the regular meetings between the *Maasai* community and KenGen beneficial?
- What were their reactions towards being relocated from the Park?
- Will they oppose any future expansion of the project?
- The *Maasai* homesteads are kilometres apart with very few motorable roads. Data collection involved trekking long distances on foot. Data was collected using a questionnaire, an interview schedule, personal observation and a checklist for group discussions. In total 48 respondents were interviewed: 43 around Olkaria and 5 from Suswa area for comparison (Mariita, 2002).

3. Existing conditions of the Maasai community

3.1. Social organisation

The findings of this study revealed that the total population of the *Maasai* in the vicinity of the project was approximately 2000. The average family size of the community was 19 family members, which comprised of 3 wives and 6 children per woman on average. The majority of the population was in the 20–30 age bracket. Many respondents regarded the present location of residence as their permanent home, though they sometimes migrated to some other areas in search of pasture.

The community members had organised themselves into self-help groups, which included a women's group, a water development group, a cultural centre group, a wildlife committee, and youth and church groups. The women group had 25 members, the cultural centre group 67, the water development group 25 members and 12 members in the wildlife committee. Membership was, however, not restricted to only one group. The membership fee of each group was based on each individual's capability (Mariita, 2002).

Some of the cultural activities involving community members included circumcision, naming ceremonies, weddings, burials, religious ceremonies and sacred rituals to their gods. These activities were, however, performed when the need arose. The community members would also perform their traditional songs and dances at the nearby cultural centre.

Neighbouring the geothermal project, the *Maasai* run a cultural centre where tourists who visit the adjacent Wildlife National Park come for entertainment and purchase artefacts. Brief cultural studies were carried out. A large part of the *Maasai* community as a whole is still entrenched in their traditional way of living; many of their traditional practices are largely intact and the cultural transformation has been slow. Change has occurred in those *Maasai* communities who have come into contact with other communities from other parts of the country, schools, missionaries and development projects. Alteration or destruction of a cultural resource may impair its value. Since cultural resources are unique and non-renewable they require some level of protection. This study assessed how the geothermal project has contributed towards the transformation of the *Maasai* community's way of life.

3.2. Amenities and quality of life

About half of the families visited had one or two houses with mud walls and corrugated aluminium sheets. The other houses were the traditional all mud-type dwellings, which had to be redone every year. Two families had brick/stone walled houses.

Most of adult family members who were interviewed looked well dressed and clean, alternating between traditional and 'modern' modes of dressing. However most of the children were partially dressed and not so clean which was an indication of a certain level of water scarcity. Over 90% of the community members got their water from two water tanks provided to them by the Kenya Electricity Generation Company (KenGen) (Mariita, 2002).

Casual observation of the interviewees and their members indicated a well-fed community. Meals taken by the respondents were both traditional and 'modern' diets largely comprising of milk. The only setback was the thousands of flies on people and especially children's eyes due to the close proximity of livestock sleeping/resting dens. Most of the homes did not have pit latrines and used nearby bushes as toilets—a practice that contributes to the communities' poor health.

The facilities found in the community included one primary school (Inkorienito primary school which is about 15 km away). No High School or college exists in the nearby area. Three quarters of the interviewees said that they had at least one child going to either Inkorionito or KenGen's Muvuke primary school. The majority of the households interviewed did not have any form of formal education, though five respondents said they had had secondary school education.

The study located one traditional healer. The health centres visited by the community were the Naivasha and Maela district hospitals, which were approximately 50 km away.

3.3. Economic activities

The community members did not have title deeds to the land on which a large majority had been born to, but only had numbers and sketch maps. The average land size held by the community members was 100 acres per family.

The *Maasai* have lived in the Kenya Rift for many years, well before Europeans moved in and occupied most of it. Modern *Maasai* still live in game parks and the geothermal areas where they graze their livestock. They believe that land is a resource meant to support the human race and one cannot therefore claim ownership to it, have titles or sell it. During the first half of the 20th century, the then colonial Government of Kenya took their land, sub-divided it and issued titles to colonial land settlers thus systematically marginalised the *Maasai*.

The predominant land use is pastoralism, which involved the rearing of cows, sheep, goats and donkeys. On average, each family had about 70 cows, 200 sheep and goats and 11 donkeys. During the wet season (March–August), the men migrate to the higher grounds with their cows looking for pasture. The women were left behind with the children, to look after the home and the remaining livestock. The men would then return during the dry season from August to February. However, during prolonged drought, men would move the livestock to 'far-northern-away lands' such as Gilgil and Nyandarua in search of pasture.

Farming is practised in the highland areas of Suswa and Maela and also in the lowland areas of Naivasha. The crops grown are maize, beans and potatoes, which are cultivated using hoes. Some respondents had large farms of up to 300 acres on which they planted wheat as a cash crop.

The community members sold or bought their cows, sheep and goats at an average price of Ksh. 7000 and 1500 respectively, mainly at the local Suswa market. An average of 15 animals were sold per year. Milk was sold at an average price of Ksh. 15 per litre (1 US$ = KShs 78.54 in January, 2002). The community members also sold to tourists at the cultural centre, necklaces at Ksh. 2800, bracelets between Ksh. 300 and 600, Ksh. 250 for shoes, cloth decorated with beads at Ksh. 1500 and swords and knives at Ksh. 3000 each. Daily household requirements were bought at either Inkorionito market or KenGen employee shops. The average monthly income of the community members was Ksh. 4000, which they revealed was not enough (Mariita, 2002).

A few of the community members were employed as watchmen, cleaners, drivers, and office messengers at either KenGen or OrPower 4. They complained that the two companies had not done enough in terms of employment. The study identified five high school leavers who said they had tried to secure jobs at either OrPower 4 or KenGen but in vain. However, some of the community members were self-employed as carpenters and blacksmiths.

The community members revealed that their living standards and quality of life were very low, because they were struggling to meet their basic daily needs of food, clothing, health care and housing.

3.4. Infrastructure

The type of infrastructure found in the community included both tarmacked and all weather roads which were built by KenGen and Kenya wildlife services (KWS). No public transport was available near their homesteads. The community members have to walk for about 10–15 km to the nearest public transport point. Once in a while, they secured lifts on KenGen or KWS vehicles. A few had bicycles.

The community did not have any telecommunication services like telephone booths. There were no telephone facilities nearby except those at KenGen premises. Use of this service was rare. Five of the respondents said they had made calls using the public telephone facility at KenGen. However, one person possessed a mobile phone. Most homesteads had portable radios. As mentioned earlier, five families have pick-up vehicles.

The centres used by the community members were those in Naivasha and Maela, which were approximately 50 km away. The community members also used the shopping facilities of KenGen.

3.5. Energy services

The energy demand and supply for the *Maasai* around Olkaria was found to be similar to that of other rural communities in Kenya. Fuel wood and charcoal were the main sources of energy used for cooking and warming the house, which they obtained from nearby bushes. Effects of this could be seen from the large tracks of bush that have been cleared near the homesteads, the bare ground left vulnerable to soil and wind erosion. Women are gradually being forced to travel longer and longer distances in search of the commodity.

As can be seen from Table 2, fuel wood contributes almost all the energy requirements of the interviewees. There is concern, however, that over-reliance on wood will impact negatively on the environment resulting is deforestation. This is a serious problem as Olkaria is located in a semi-arid area with a mean annual rainfall of less 1000 mm, reducing chances of timely rejuvenation of the bushes once they have been cleared for fuel wood in order to ensure a sustainable supply.

Table 2
Primary energy supply and usage. Total number of respondents = 48

Type of usage	Source of energy	Respondents	% Usage
Cooking and warmth	Wood	48	100.0
	Paraffin	6	12.5
	Gas	2	4.2
Lighting	Paraffin	48	100.0
	Solar	2	4.2
	Gas	0	0.0

Source: Mariita (2002).

Most homesteads rely on paraffin lamps for lighting. Only six households have paraffin-cooking stoves. Two respondents said they used natural gas for cooking and solar for lighting. Though electrical supply is gradually reaching rural areas in Kenya through the Government's Rural Electrification Program, the number of households already connected is dismally low. The community around Olkaria is not yet electrified, in spite of being next door to the Olkaria Power station.

From the interviews, most of the respondents indicated that they had never considered connecting electricity from the Olkaria power plant to the houses. When asked why, they indicated that they considered electricity as 'something for the rich'. They further said that their Member of Parliament has not initiated such a project. From these answers it would appear that the high cost of electrification and local political leadership were some of the main bottlenecks to bringing electricity to the *Maasai* community.

4. Socio-economic and environmental impacts of the geothermal project

Five families said that they used to stay in the area now occupied by the geothermal project and National Park and were simply asked to move without any compensation being given. They further said they do not understand why they are prohibited from grazing within the game park. However they appreciated the permission to use some of KenGen facilities such as transport, schools, and shops.

On whether the geothermal project has had any impact on their lives, many respondents mentioned the positive benefits such as water, shops and school. They strongly felt that the project should have economically empowered them by providing employment. The majority of respondents said that the project should remain. A few were non-committal.

On their relationship with the geothermal company employees many were non-committal. They praised a few staff for occasional offers of lifts in company vehicles. A few said that they had been offered a vehicle during an emergency illness. In spite of this, many respondents felt that most company staff looked down upon them.

They were especially grateful to KenGen for providing them with piped water, which has reduced cases of water borne diseases such as cholera and typhoid. Most respondents said that the noise or gas emissions did not discomfort them in any way. Neither as far as they know have any of their livestock been hurt by the project facilities. Some claimed that bathing in the KenGen effluent waters has assisted them in managing some skin ailments.

Other concerns raised included:

- The increasing dust levels and smell the project could bring if it expands towards their homesteads.
- A possible rise in respiratory diseases like asthma, eye problems, colds and flu.
- Displacement/ resettlement from their present homes.
- The reduction in their land size(s) as the project expands.
- The reduction in grazing land for their livestock.
- A reduction in family size due to the gradual decrease in land size.
- An increase in miscarriages or children being born with deformities or retarded if the projects expands.
- Their cultural values being eroded by outsiders.

Table 3 summarises the socio-economic impacts on the *Maasai* as a result of the Olkaria Geothermal Project. It is evident that the greatest benefits of the project have been the provision of shopping centres, water and sale of souvenirs to tourists at the cultural centre. This has resulted in increased income levels and subsequent rise in living standards and quality of life. In terms of employment, the impact is negligible. The company employees do, however, provide some market for sale of livestock products.

5. Employment opportunities

The Olkaria New Geothermal Project employs 493 persons comprising of:

Scientists	15
Engineers	21
Technicians	82
Artisans/Craftsmen	175
Support staff	200

Of these 493, only seven come from the *Maasai* community comprising of one copy typist, one clerk, one driver, one office messenger and three watchmen, i.e., 1.4% of the work force at Olkaria East are *Maasai*. Three of them are from a different district (Narok District). This poor representation is due to several factors. The main one is the general low level of education of the *Maasai* and the other is their hitherto nomadic way of life.

Table 3
Socio-economic impact resulting from the presence of the geothermal project

Facility	Respondents who enjoy facility	
	Number	Percentage
Entertainment centres	9	18.75
Cultural centres	17	34.40
health centre	4	8.30
Water pipeline	41	85.40
Employment at power project	4	8.30
Telephone	10	20.80
Tourism	19	39.60
Small shops	43	90.00
Small businesses (sale of milk/ livestock products)	14	29.10
KenGen Co. Ltd. schools	3	7.00

Source: Mariita (2002).

6. Conclusions

Preliminary analysis of the data indicates that the general environment of the community around Olkaria has not been significantly affected by the power project. Proper operational management by the geothermal plant operators is in place to stem any possible conflict with the surrounding community. This includes the fencing of the plant premises to prevent injury to the community and their livestock and the holding of regular meetings between the project management and *Maasai* elders.

The study shows that although the area surveyed has very low rainfall, loose soils and high ground slope, it is well preserved by a light vegetative cover. Drilling activities have the potential of degrading the quality of the environment if not properly handled. Care has had to be taken during road construction, drill-site preparation and effluent disposal to avoid soil erosion. The results show that further geothermal energy development, if properly executed, will not adversely affect wildlife. All the envisaged environmental impacts can be mitigated. Contamination of groundwater is unlikely since the water table is very deep and the wastewater is being re-injected. Care will therefore need to be taken during road construction, further drill-site preparation and effluent disposal to avoid soil erosion.

Since the flower farming, geothermal energy development, wheat farming, dairy, tourism and wildlife conservation, all use water pumped directly from the adjacent Lake Naivasha or wells drilled within the Lake Naivasha groundwater basin, co-ordination is necessary. This enclosed lake has only one small river flowing into it and the lake level has been going down over the last 20 years (Njenga, 1994). At the moment, irrigation farming in this arid region has the largest impact on the water level. Most of the irrigation water evaporates, so very little of it gets back into the ground water system. Although all these activities depend on water from the lake basin, the amount of pumping from the Lake and drill holes has not been evaluated and is not controlled. This needs to be done. Flower farming and geothermal production are the fastest expanding industries in the area and are increasing the pressure on the lake water. At the current rate of expansion, the lake environment might not be able to sustain a reasonable water level for balanced future development.

The Olkaria geothermal project has, to some extent, improved the living standards of the *Maasai*. It is hoped that with better utilisation, management and conservation of the available resources, an example will be set to similar undertakings and lead to a rejuvenation of the Kenyan economy. To a large extent the project has opened up this community "to the outside world" by the construction of infrastructure such as roads and telecommunication, making access to markets and other facilities possible. It was noted that a number of visitors to the power plant visit the *Maasai* Cultural Centre to admire and buy *Maasai* artefacts as well as watch traditional dances for a modest fee.

None of the *Maasai* interviewed complained of health problems relating to either the noise or the H_2S gas or the geothermal wastewaters. This is likely due to the long distance between the homesteads of the *Maasai* and the geothermal power plants as well as the general favourable wind directions.

While many of the respondents had favourable comments about the project and were specifically appreciative of the provision of water, shopping facilities and occasional lifts in company vehicles, many felt that the project could do more to the local community. Job opportunities for them could be much higher than they currently are. There was a general feeling that the project employees, many of whom are from other parts of the country, never make any effort to socialise with the local people.

Many of the interviewees also wondered why the company, and for that matter the Government, could not provide them with electricity now that it is being produced from what they consider their former lands. However, they would rather have more of their people employed at the power plants than have the electricity. When asked what their reaction would be if the power plants were translocated elsewhere, they said they would use any possible means to block the move. It would, therefore, appear that despite the complaints from the local community around the Olkaria Geothermal Power Plant, the project is nevertheless viewed as beneficial.

7. Recommendations

7.1. Socio-economic issues

The nomadic way of life of the *Maasai* ensured harmonious co-existence with wildlife. The open areas that remained at independence, on which they now live and graze cattle, were declared government land. This land was initially reserved for wildlife and game parks that include Olkaria (Hell's Gate) and Longonot. This was done without considering the needs of the *Maasai* who were living on it, thus in effect, the *Maasai* ended up living illegally on land, which was actually their ancestral land. Over the years, this reserved land was used for other development purposes thus further reducing the size of available grazing land. At present, the available grazing area for the *Maasai* and wildlife is too small to sustain both. There is therefore a direct conflict between the *Maasai* people, geothermal development and wildlife conservation. It is necessary to develop ways of extracting the geothermal resources without adding pressure on the remaining land.

Although socio-economic impacts are inevitable in any development of geothermal power, holding consultations with the affected residents and taking their interests, fears and concerns into consideration can minimise them. For example, Tole (1997) has shown that long-term monitoring of the welfare of displaced residents worked. He also suggested that for residents who remain in the vicinity of a project it is essential for them to be provided with social amenities so that they can identify with the project. This is important because the land on which the projects stand was their only ancestral inheritance.

In Olkaria's case, ways have to be found to assist the neighbouring *Maasai* acquire electrical power. Emphasis should be placed on integration of electricity power use for income generation into the overall project planning and implementation. A fund could be set up to channel financial support to community based projects, involving community members, NGOs and of course the government whose role should be restricted to regulatory functions.

Electrification of *Maasai* homesteads is likely to spur non-formal industrial activities, which in turn tends to stem migration to urban centres in search of job opportunities. Secondly, it could reduce over-reliance on wood as a primary source of energy. Other positive benefits that might also result from the provision of electricity include the, provision of more reliable water supply services and more employment opportunities.

Findings of this study also agree with those of Sinclair Knight (1992), who carried out an interview with the *Maasai* around the power plant to find out their attitude towards the geothermal project. The interviewees exhibited a generally favourable and positive attitude towards the project. Even those members of the community who were relocated to areas that are outside the national park without any compensation being advanced to them were not bitter. Their presence in the project area had been seen as an environmental threat in terms of outstripping the ecological capacity of the area coupled with the region's soils which are highly susceptible to erosion (Omondi, 1987). The *Maasai* now reside outside the park, mostly on the land between the southern boundary of Hell's Gate National Park and Suswa. It is the view of this study that this goodwill should be reciprocated by offering appropriate jobs to more of the local *Maasai*. This is especially true for those who have had secondary education. The current number of members from the local community who work at the two power plants is not equitable and could be a future source of friction.

Occasionally, the project does involve the community members, through their recognised leaders to address some conflict of interest, however, there is need to involve them more in the decision making process for activities that may have adverse impacts on the community. The geothermal project should participate more actively in community development activities (e.g., regular donations in cash or in kind) to the self-help groups in order for the community to identify with the project. Finally the community members need to be educated on general safety measures in order for them to protect themselves.

The active participation of KenGen and OrPower 4 in the activities of some of its concerned stakeholders has resulted in improved relations with some local stakeholders. It provided a forum to correct information to local stakeholders and created goodwill. A public relations environmental officer should be appointed to participate in the enhancement of the project activities and image in its vicinity.

7.2. Environmental issues

The project needs to periodically contract an independent person or group of persons to evaluate their environmental management systems according to the ISO 14001 and 9001 certificate principles and guidelines. The operational directives of World Bank funded projects need to be followed in order to ensure that there is proper management of the immediate and surrounding environment.

The geothermal project should first focus its efforts and resources on the installation/formalisation of an Environmental Management System (EMS). The EMS is expected to protect the companies of liabilities environmental risks, and to assist in sustaining project operations through environmentally sound and socially acceptable practices. Once the EMS is installed, the ISO 14001 accreditation can be easily attained.

Surface disposal of waste water which is discharged from well pads during drilling and well testing phases should be avoided as much as possible because this can also lead to gully erosion. Once gullies develop, they are difficult to control. The best disposal method is to re-inject all the wastewater into the deepest reservoir so that it does not get into shallow water aquifer.

The prevalent form of erosion is water whose erosion potentials are evidently great. This can be attributed to the loose physical nature of the soils that consist mainly of volcanic ash. The area is a semi-arid zone. Erosion by water only occurs during rainy seasons and affects almost the entire area to varying degrees. All run-offs from stabilised roads (murram or tarmac) through culverts should be handled in the best way to avoid gully erosion. New run-offs can be diverted at regular intervals before it accumulates to problem levels.

Bush fires regularly occur in Olkaria. A Fire Control Plan is recommended, possibly in conjunction with the Kenya Wildlife Service, to minimise recurrence of these fires. The plan has not yet been prepared, due to the concentration of the small KenGen Environmental staff on the Environmental Assessment and Monitoring Programs. That is why the streamlining and downsizing of the monitoring workload are recommended by the author, so that other equally important concerns, such as Fire Control Plan, can be attended to.

It is anticipated that further geothermal development may lead to noise levels that are above the permitted dB level especially near the power plants. The noise control measures that should be taken include the following:

- The control room and general powerhouse design should be made in a way that reduces the emission and propagation of noise as part of the noise control program. These should include vibration control within the original design of the equipment in order to avoid generation and structural transmission. Where it cannot be incorporated in the original design, then acoustic barriers and silencers can be used.
- Starting from 85 dB, the allowed exposure to workers should not exceed 8 continuous hours. This will mean worker's rotation on shifts, use of hearing protection and rest booths (Hills and Ramani, 1990).
- Analysis of geothermal emissions of H_2S and CO_2 at Olkaria show that they are below the World Health Organisation harmful levels (Sinclair Knight and

Partners, 1994). While the results of air monitoring indicate compliance with occupational standards, there are secondary environmental standards on the length and peak of exposure to H_2S emissions that should be adhered to. It is also worthwhile to check the sensitivity of the automatic H_2S equipment to low concentrations, because the equipment might not have the capability to measure ambient H_2S with accuracy, resulting in misleading zero values.

KenGen together with the Oserian Development Company (ODC) that owns the nearby flower farms carried out a study on the effect of H_2S and CO_2 gases on the performance of flower growing (El-Hinnawi, 1981; Pasztor and Kristoferson, 1990). They found that flowers that were exposed to geothermal emissions did better than those that were not (Muna, 1998). Scientific long-term studies should be carried out to determine whether this phenomenon is long lasting or temporary.

The ODC started as a purely horticultural farming enterprise. The company has now combined flower farming with wildlife conservation with remarkable success. ODC has in its sanctuary large animals such as buffalo, lion, rhino and giraffe. It has managed to do this by controlling human activities, especially the number of tour vehicles that enter into their park. It has also engaged indigenous Maasai in the conservation efforts by having them work alongside formally trained personnel and contribute their traditional expertise. In some respects, the ODC initiative should provide a model for combining development with local participation and environmental protection that Kenya's geothermal industry could emulate.

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