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ENVIRONMENTAL AND SOCIO-ECONOMIC ISSUES OF GEOTHERMAL DEVELOPMENT IN KENYA

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ABSTRACT

Geothermal energy currently plays are very important role in clean energy supply in the world. The impacts of geothermal development are often positive. A range of socio-economic effects is also important especially on the neighbouring communities. However, it is imperative that environmental issues associated with the development are identified and addressed very early in the development and during the operation. The use of Environmental Impact Assessment methods and the establishment of an Environmental Management System are useful in this regard. Kenya has now developed about 130MW of geothermal power most of which is located in a game park. The environmental and socio-economic issues that have to be managed in this development are discussed in this paper.

1. INTRODUCTION

Geothermal resources of Kenya are associated with the Great African Rift system that transects the eastern part of African continent. There are about 14 known geothermal sites many of which are associated with central volcanic centres (Figure 1). The geothermal resources at these sites manifest themselves in form of steam jets, hot springs, geysers and altered hot grounds.

Comprehensive exploration of these resources commenced in 1970 and currently Kenya generates about 130MW of power, which accounts for about 12% of effective installed capacity. Kenya Electricity Generating Company (KenGen) has two power stations with a total capacity of 115 MW (Olkaria I and II) while Orpower 4 (Olkaria III) has 13 MW and Oserian Development Company has 2 MW. KenGen is a public-private company and generates 80% of Kenya's power. Orpower4 is an Independent Power Producer (IPP) while Oserian is a farming company that also generates power for its farm use. Currently all the geothermal power is exploited from Olkaria geothermal field on which Kenya's geothermal experience is based.

FIGURE 1: Olkaria Geothermal field (red triangle) and other potential geothermal prospects in the Kenyan Rift

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 (Figures 2 and 3).

FIGURE 2: Oserian green house project

FIGURE 3: Geothermal heating and CO_2 utilization in Oserian greenhouse

Olkaria geothermal field is located in the central part of the Kenya Rift Valley to the south of Lake Naivasha, 120 km northwest of Nairobi. The field is divided into seven sectors namely; East field, Northeast, Northwest, Southwest, Southeast, Central and Olkaria Domes fields for management purposes (Figure 4). Geothermal exploration work started in the early 1950s when two wells were drilled at Olkaria. Olkaria East field supports a 45 MWe Olkaria I geothermal power plant fully commissioned in 1985. An important aspect of the environmental management of geothermal development in this area has been the existence of Hells Gate National Park gazetted in 1984 which supports wildlife species such as Buffalo (*Syncerus cafer*), Zebra (*Equus burchellis*), Grant's gazelle (*Gazelle grantii*), Thomson's gazelle (*Gazelle thomsonii*), Coke's hartebeest (*Alcephalus buselaphus*), Maasai giraffe (*Giraffa reticulata*) among others.

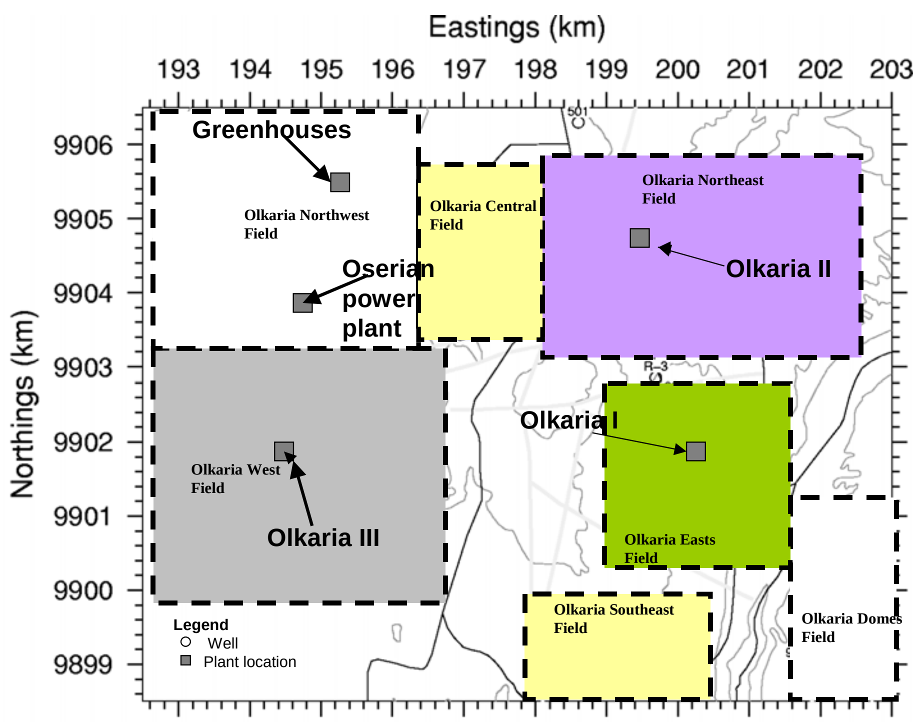

FIGURE 3: Seven sectors of Olkaria Geothermal field and location of geothermal power

Outside of Olkaria Geothermal field, exploration of drilling has been undertaken in Eburru geothermal field (Figure 1), which is located some 50km north of Olkaria. In that field, one exploration well is suitable for generation of power and currently KenGen is tendering for installation of a pilot binary plant from which in addition to generating power will produce water for agricultural use by the local small-scale farmers.

Geothermal development at Olkaria has created environmental challenges and also inspired vibrant economic activities in the region particularly from KenGen's social responsibility initiatives, which form the subject matter of this paper.

2. ENVIRONMENTAL ISSUES

2.1 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 in surface exploration during the detailed 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 setting and improved experiences along the way.

Environmental management initiatives undertaken by KenGen were triggered by the fact that Olkaria Geothermal Field was gazetted as Hells Gate National Park by the government in 1984 when Olkaria I power station had already been 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 its Operation Directive OD 4.00 - Environmental Assessment guidelines (World Bank 1989). Based on these two aspects, KenGen decided to create a section in its geothermal project organisation 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 establishing an Environmental Management System under the ISO14001.

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.

2.2 Laws and Regulations

In Kenya there are several Acts of Parliament that work together to regulate and guide geothermal and environmental 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. The listed legislation may not be exhaustive, but gives some of the important legislation affecting geothermal development in Kenya. Besides the legislation, 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 OD 4.00.

Initially, KenGen based its environmental initiatives on the World Bank's operational directive OD 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 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. Olkaria III and Oserian power stations were developed much later when EMCA was already in force.

EMCA of 1999 came late in the development of geothermal development 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). The Act provides for the establishment of an appropriate legal and constitutional framework for sustainable management of the environment and natural resources in Kenya. The Act outlines environmental impact assessment procedures, environmental audits, monitoring procedures, transmission and environmental quality standards. The government enacted the Act to Address the ever-growing negative environmental concerns of human activity on the environment, conversion and use of energy being one of the those factors contributing to atmospheric pollution, land degradation, global warming among others.

It also provides for establishment of provincial and district environmental committee and Public Complaints Committee. This 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 are required.

Under the Act, the Electricity Regulatory Board (ERB), 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 Electric Power Act of 1997. EMCA requires ERB 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.

2.3. Environmental Impacts

2.3.1 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 topography of the area is quite diverse with various volcanic masses and scarps formed by both faulting and erosion. The Njorowa Gorge has sheer faces carved from sheets and plugs of intrusive commendite, and volcanic masses of the central and Fischer's towers. Small patches of plains exist to the Northeast. The landscape is not uniform most of it being hilly. Three major landscapes exist depending on terrain, vegetation and wildlife use (Kenya Wildlife Service, 1992).

The plains are part of the Njorowa gorge with dominant plant species being *Cynodon dactylon, Digitaria scalarum,* Leleshwa *(Tarchonanthus camphorates)* and *Acacia shrubs*. Hill and mountain encompasses the geothermal development area towards the Olkaria gate. Olkaria hill with an elevation of 2240 m.a.s.l is within this region. Dominant vegetation association are *Tarchonanthus/Acacia shrubland and Cymbopogon/ Themeda / Digitaria* which do not constitute important food source for the animals hence low concentration. Cliffs, main wall and towers consist of the main walls of the gorge and the Fischer’s and central towers. The area is rocky with scanty vegetation.

Soil parent materials are predominantly volcanic in origin. They are porous volcanic ash derived from lava, pyroclastic rock and lacustrine lake deposits (Clarke, 1990). These volcanic ashes are very venerable to water erosion when the ground is opened for drilling pads, roads and power stations construction. In order to mitigate these impacts, the infrastructure sizes are controlled and only what is absolutely necessary is cut. Rehabilitation is also done by planting star grass, Leleshwa and *Acacia Sp*. The steam pipelines are often painted to blend into the landscape. If roads have been discontinued for any reason, then top-soil is returned and rehabilitation is done otherwise roads for developed fields are tarmaced to minimize erosions.

2.3.2 Solid waste management

Geothermal development produces significant amounts of solid waste, therefore suitable disposal methods need to be found. Because of the heavy metals particularly arsenic, which are contained in geothermal waters, these solid wastes are often classified as hazardous waste. Geothermal drilling produces waste in form of drilling mud, petroleum products from lubricants, fuels and cement wastes. Drilling mud are either lost through circulation in the well or end up in the drilling sumps as solid waste for disposal. Since a lot of fuel and lubricants are used when drilling a single well, storage and transport of these products usually follow sound environmental practice as stipulated in the new KenGen Environmental Policy. Cements are not normally considered hazardous, although some constituents like silica may be hazardous. During plant operation phase KenGen has special provision for safe storage of lubricants and fuels.

Other principal solid wastes are cooling tower sludge (may contain mercury), construction and normal maintenance debris. All these are transported safely to designated disposal site or landfill which are periodically monitored and audited for environmental compliance.

2.3.3 Noise

Sources of noise include, operating drilling rig, well testing and power station operation. Only few instances do operating rig equipment noise exceed 85dBs. The highest noise (up to 120dB) occurs during vertical discharge of wells during start-up before they are 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 less than 85dB. 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 covers plants with solids from the well which affects their growth temporarily.

Noise around Olkaria power stations is associated with non condensable (NCG) gas ejectors and air receivers 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. So even with good designs for noise reduction workers must use ear protectors both during drilling, discharge tests and plant operation.

A number noise monitoring sites were selected after carrying out an extensive survey to determine the potential noise sources in the project area (Kubo 2001). Thirteen (13) sites were designated as noise monitoring sites or stations. The noise level measurements are taken twice a week in all the monitoring sites or stations. Noise occupational health and safety criteria in Kenya, regardless of hearing protection is 85dB (A) in a work place for an employee working 8-hour day. Other than the power station and the N370 rig during drilling which have levels above Occupational exposure limit noise level at other stations are below the recommended exposure limit.

2.3.4 Brine

In 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 table 1 and 2 below. It is also hot and can easily burn both humans and animals. From a study done by Wetang'ula and 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 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) ppb	947.3	1192.8	6693.8	0.09	0.046	1.42	4.967	1.71	256.85	1.47	
Livestock Limits (ppb)	5000	25	5000	80	1000	50	500-1000	3	500	1000	50000
Plant water limits (ppb)	5000	100	500-6000	5.1	50	4.9-8	200-1000		10-50	200	1000-5000

Initially, Olkaria I brine from wellhead separators was collected in open concrete channels into fenced-off conditioning ponds which allowed the silica to polymerise on cooling 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 blowdown water is also mixed with the separated water from the wellheads and reinjected into deep wells. Ponds are generally fenced off to keep away both wild and domestic animals from entering to drink the water and possibly drown especially during the dry spell when water is scarce in the park. Alternative animal water drinking points have been provided at strategic locations for this purpose.
The reinjection of waste water is an environmentally friendly of managing the waste water and also artificially replenishes the reservoir and thus increases its life.

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	bld	0.04
Deep well water						
Salton sea, USA	215	390	12	0.006	16	386
Cerro 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	

Based on reinjection experiences from Olkaria I, all the separated water from Olkaria II field is reinjected hot in 4 wells located infield. The power station blowdown 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. The complaints were also sent to the local press and created bad publicity for KenGen. These allegations could not be verified by the complainants. It was later learnt that the complaints had no basis and was meant to draw some attention for more jobs and some mode of compensation. Some environmental activists had instigated the complaints.

2.3.5 Gas emissions

Olkaria steam has 1% non-condensable gases. Of these non-condensable gases, 92% is CO2, 3% H_2S and the rest methane, nitrogen and hydrogen (Opondo, 2002). Wells under discharge test 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. At Olkaria II, pumping these gases to the cooling tower and releasing them at high upward velocity through the cooling tower fans achieve more effective disposal.

Hydrogen Sulphide gas emission is the major gas of concern due to its unpleasant smell and toxicity at moderate concentrations. Measurements done at the Power plant have recorded 1-minute concentration not exceeding 1.25 ppm. Monitoring is done three times in a week for most locations around the power station and at least once in a week for those sites further away. There are a total of ten main monitoring sites distributed to cover residential areas, occupational workplace areas and entry points Olkaria. The occupational exposure limit (O.E.L) of H_2S in work places is 10ppm for an averaged 8-hour day. It is important to note that H_2S levels at Olkaria are far below the occupational exposure limit. The maximum value recorded was 4.40 ppm at the power station.

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 7km away as a control. The trials were done over a period of one year in 1994 and it proved that the gaseous emissions were 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 the 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.

2.3.6 Steam gathering system

The cross-country steam lines can affect the free movement of animals in the park. In order to overcome this problem, the animal migration routes are mapped before the lines are constructed and taken into consideration during the design. Sections of the pipelines are raised to a height suitable for giraffes to comfortably pass under. Giraffes are the tallest animals in this area. In some areas pipes pass in underground culverts so that animals can pass over the pipes. The colour of pipes is also selected to march the environment.

2.3.7 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 cliffs, the Hell's Gate gorge gorge and the Fischer's and central towers which form important breeding and nesting grounds for various bird species such as the verreaux's eagles, ruppell's vulture and the rare lammergeyer (bearded vultures). This has avoided collision and electrocution of birds by power transmission lines.

2.3.8 Use of water

The water used for both domestic and geothermal development comes from Lake Naivasha. It has been designated as a Ramsar site under the Ramsar Convention due to national and international interest in the ecology of lake environment as a wetland habitat. There is a high demand for lake water for the ever-expanding flower growing business, human settlement in Naivasha town and other upcoming shopping centres, tourism and pastoralists. Geothermal development uses fairly small amounts of water for power station startup drilling and domestic purposes. Drilling operation has practised recycling to minimize this use.

KenGen is a member of Lake Naivasha Riparian Association. (LNRA) whose membership are all stakeholders who own riparian land, and a community based management plan (The Lake Naivasha Management Plan) for sustainable use of the Lake. Lake Naivasha Riparian Association involved all the stakeholders of lake Naivasha to develop a management plan. In the management plan various stakeholders have developed codes of conduct to govern their activities with respect to the Lake. For the energy sector, KenGen has developed a comprehensive code of conduct and all power producers operating in the vicinity of the Lake are expected to adhere to it. The association also self regulates in the use of riparian land which have potential for polluting the lake.

3. SOCIO-ECONOMIC ISSUES

3.1 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 of water for domestic and animal use. KenGen therefore provides 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 rain water 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.

3.2 Roads

Between 1985 and 1990, KenGen decided to tarmac Olkaria- Naivasha road (40km) and the borefield 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 in Kenya. 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.

KenGen also assists KWS in the maintenance of roads in the Hell' Gate National Park. There are also a large number of tourists that enter the park to visit Olkaria Geothermal stations. The geothermal development has therefore been one of the major tourist attraction sites in Hells Gate National Park.

3.3 Labour

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

3.4 Education

KenGen constructed a Nursery and Primary schools to cater for its employees and the local community. Currently these two schools have 480 pupils more than half 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 has for the last two years sponsored four students into secondary schools and four students into National universities and plan to increase these numbers in future.

KenGen, Orpower4 and Oserian have jointly assisted the construction of some class rooms in some schools further away from the Olkaria. Orpower 4 have provided some teachers to some schools. KenGen is currently planning to spend the money from Carbon Credit fund for this purpose. The funds will also be used to expand the water supply and dispensary initiatives.

3.5 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.

3.6 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.

3.7 Complaints

There are some local communities very close to the project that complaint that KenGen is not doing enough for them. These are some communities that reside in land owned by others. Although KenGen would be willing to assist these communities, KenGen would not want to be involved in land disputes as land issues in Kenya are sensitive. It would only want to be involved in community projects located in areas without disputes.

3.8 Social Afforestation.

KenGen's tree nursery was initially meant for germinating seedlings for rehabilitation 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.

4. CONCLUSIONS

Geothermal energy is relatively clean energy source. The possible environmental impacts from its exploitation include surface disturbance, physical effects due to heat effects, emission of chemicals and socio-economic effects. All these impacts can be minimized. Putting in place monitoring and control programmes can check the unforeseen impacts that only appear during operational phase of geothermal development. Olkaria geothermal project has not led to environmental degradation of Hells Gate National Park. Socio-economic impacts are also important and can be optimized through the involvement of local communities through effective corporate social responsibility policies.

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