Environmental and Social Considerations in Geothermal Development.

ODUOR Jennifer A., Kenya

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SUMMARY

Geothermal energy is the natural heat stored within the earth's crust. The energy is manifested on the earth's surface in the form of fumaroles, hot springs and hot and altered grounds. To extract this energy, wells are drilled to tap steam and water at high temperatures and pressures.

Geothermal resources in Kenya are mainly located along the Kenyan Rift, which is part of the eastern arm of the African Rift. Olkaria, in Hells Gate area south of lake Naivasha, is the main source of geothermal electricity in Kenya. The terrain is irregular and is characterized by volcanic hills, valleys, gorges, bolders and weathering rocks.Vegetation is mainly shrubs and short trees .The land is mainly used for geothermal activities, wildlife conservation and ranches. There are spontaneous settlements by the Maasai, a pastoral community, who are the indigenous inhabitants of the land and private land owners whose interest is mainly ranching and conservancy.

In view of the background given above, this paper discusses environmental and social considerations in geothermal development.

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ABSTRACT

The pressure to shift from energy sources causing global warming and ozone depletion is top agenda on the global environmental debate. As a result, geothermal energy is among the underexploited options under consideration due to its controllable environmental impacts, un-fluctuating fuel (steam) prices and fluctuating weather conditions associated with thermal and hydro. Social and environmental considerations and applicable laws in geothermal utilization should therefore be clearly understood for it to effectively compete with other alternative sources especially in developing countries that have not met their energy requirements and have a reserve of the resource. The overall project development benefits would be realized if the local communities are integrated from initial stages and have clear knowledge of what they can accrue from such projects.

1. INTRODUCTION

Geothermal energy utilization as an alternative source is gaining momentum in both developed and developing countries around the world in the age of higher environmental awareness. Though biological and physical impacts of geothermal siting are well understood, socioeconomic impact is still the missing link. In order for geothermal resource to achieve popularity, as a renewable energy alternative, there is need to clearly identify the social and environmental impacts of its development. This is achievable through environmental and social impact assessments/monitoring from project initiation to operation phase. The integration of social concerns into the decision making, planning and management of any geothermal project is required by international agreements/protocols, national laws, policies of bilateral agencies and international financing institutions. Internalizing the cost of social and environmental benefits in the overall project cost would be one way of enhancing the competitiveness of geothermal energy against other alternative sources.

Most geothermal resources in the world are located in remote scenic, wild and protected areas. The key socioeconomic impacts associated with developing these resources include opening up and modernization sites, loss of wildlife habitat, visual intrusion in scenic tourist areas among others. The sub-Saharan African countries depend on their immediate environments for economic and social needs than any other parts of the world. Due to this dependency, public awareness and concern on how new projects are impacting on the socio-economic environment is becoming an important factor among decision makers. Though geothermal energy is relatively new to most countries in the continent, it is not an exception to this rule. In Kenya, geothermal development at Olkaria has resulted in greater environmental and social benefits to the local communities and the region as a whole due to manageable environmental and social impacts.

2. LEGAL ENVIRONMENTAL FRAMEWORK

Before implementation of any project, the national and international environmental legislation relevant to its implementation must be understood. In geothermal power development, it is important to understand these legislations in relation to exploration, drilling, power plant construction, operations and decommissioning. These legislations often specify standards with which the project must comply and sometimes may delay implementation due to lengthy licensing process or public consultation requirements. Implementing agencies should guard against any environmental liabilities as they may have adverse financial implication on the total project cost. Some of the legislations that must be understood include;

- **Environmental Impact Assessment regulations** (*National legislation and guidelines, WB Operational policy* **(OP) 4.01**, **OP/BP/GP 4.02**, *Environmental Action Plan;* **OP 4.07*)*.**
- **National and donor emission standards for air, noise and water quality requirements** (*WB guidelines on air and Noise emissions, WHO water quality requirement, National and local bylaws requirement, Water Resources Management; OP 4.09, Conventions on climate change*)
- **Local and international legislation in relation to biodiversity conservation** incase the project is located in the park**. (WB OP/BP/GP 4.04,** *Natural Habitats,* Convention on Biological Diversity.
- **National and international policy on resettlement/relocation and compensation** of people if necessary. (**WB OP/BP 4.12,** *Involuntary Resettlement, National Resettlement Policy.*
- **Identification of key stakeholders and public consultation and disclosure** methods within the national environmental legal framework (**OD 4.20,** *Indigenous Peoples*; **and OPN 11.03,** *Cultural Property, National disclosure methods)*.
- **Occupational health and safety rules related to geothermal development.**
- **Local council bylaws.**

In developing countries, there is limitation in institutional and financial capacity of enforcing government agency to implement these requirements. This is not to say that the developer should take advantage of the situation and implement the project, but should, where necessary, uphold environmental ethics and applicable laws.

In the case of Olkaria, three geothermal power projects', the development took place before the enactment of the Environmental Management and Coordination Act (EMCA), 2000. They were however implemented and have been operating in line with the legal requirements of the World Bank, World Health Organization (WHO) and other existing legislations. Full EIA's were undertaken and appropriate environmental management plans put in place. The first experience in application of the national law on geothermal projects in Kenya is Olkaria II Unit 3 that is currently being subjected to the EMCA 2000 process.

While most national legislations like the EMCA, 2000 encourage use of local resource persons in EIA's, it may be necessary to have a mix of both local and international experts with some experience. This is important in countries where the resource has never been developed because each geothermal field has its own unique challenges, which may require specialized expertise from people with vast experience in the field.

3. ENVIRONMENTAL CONSIDERATIONS AND BENEFITS OF GEOTHERMAL DEVELOPMENT.

Environmental benefits of geothermal against other conventional energies

Compatibility with other land-uses. Geothermal power plants require relatively little land. The installations don't require damming of rivers or harvesting of forests, and there are no mineshafts, tunnels, open pits, waste heaps or oil spills. They can be sited in farmland and forests and can share land with cattle and local wildlife.

Renewability of the resource. Geothermal energy has been classified under clean and renewable resource. The resource can be described as renewable only if the rate of extraction is less than the recharge rate. Sustainable use of the resource can be attained through reinjection and reservoir flow monitoring.

Minimal solid wastes. Geothermal power plants do not generate appreciable wastes during operations. However, some geothermal fluids contain by-products, which most often have valuable minerals that can be recovered and recycled for industrial use. These include salts that can be crystallized and used while silica solids can be used in cosmetic production as is done at the Blue lagoon of Iceland. Some of the dissolved minerals can have negative impact to the environment if not re-injected back into the reservoir.

Separated and condensed thermal water from the plants is routinely reinjected to the ground minimizing the release of steam and thermal water to the environment. Unlike fossil fuel, geothermal steam does not need storage or transportation facilities nor is there necessity for waste (fuel) disposal.

Gaseous emissions. The increase in deployment of geothermal energy will have a large net positive effect on the environment in comparison with the development of fossil fuels. This is in accordance with the Kyoto resolutions on global climate change. During production, geothermal power plants emit insignificant amounts of CO_2, SO_2 and absolutely no nitrogen oxides in comparison to thermal plants. These small quantities from geothermal plants are not emitted during power production as a result of combustion but are natural constituents of a geothermal reservoir. The gases would eventually vent into the atmosphere under natural conditions although at much lower rates (Goff, 2000).

According to survey done by IGA, CO_2 composition in sampled geothermal power projects in the world, range from 4 g/kWh to 740 g/kWh with the weighted average being 122 g/kWh. The estimates from the data collected gives an of average CO_2 content in the NCG at 90.46%. A comparison of CO_2 emission data for fossil fueled power plants and geothermal power plants based on the weighted average above is shown on **table 1** below:

Table 1: Comparison of CO_2 Emission by Power Source

Power source	**CO2 Emissions (g/kWh**
Geothermal 35% efficiency	122/kWh (weighted average)
Coal @ 35% efficiency	915/kWh
Fuel oil @ 35 % efficiency	760/kWh
Natural Gas combined cycle @ 60% efficiency	315/kWh

Source: International Geothermal Association (IGA), 2002

The amount of Non Condensable Gases that may be released into the atmosphere is determined by the nature of the reservoir and the type of technology. For instance, binary plants emit virtually no gases because it's closed loop system using heat exchange method. Dry steam and flashed steam plants emit water vapor containing these gases. However, the process of reinjecting the geothermal fluids back into the reservoir diminishes the possible release of gases into the atmosphere.

In low temperature utilization, CO_2 found in geothermal fluids could prove beneficial in direct use greenhouse applications as a growth stimulant. Studies have shown that increase in CO_2 from normal level of 300ppm to approximately 1000ppm can raise crop yields by up to 15% (Dunstall and Graeber, 2004).

As a result of these environmental benefits, geothermal energy easily qualifies as one of the candidates for Clean Development Mechanism (CDM) of the Kyoto protocol, which would be an added incentive to the development of the resource. The CDM concept allows developed countries to offset their GHG emissions by investing in emission reduction projects in developing countries. It enables emission reduction targets to be achieved cost effectively while developing countries receive sustainable development and technology transfer benefits (Michaelowa, 1997).

Minimal surface and ground water pollution. Unlike most fossil fuel plants that release waste heat into water bodies, geothermal power plants use cooling towers to emit heat into the atmosphere.

The technology for harnessing and utilizing geothermal energy has carefully been developed to minimize possible ground water pollution. Production and injection wells are lined with steel casing and cement to isolate fluid from environment and ground water resources. Continuous sonic logging measurements done on casing and cement ensure that no leakage occurs.

Geothermal plants have no fluid disposal problems as it can all be reinjected back to replenish the reservoir. The recycling of wastewater for extending the life of geothermal reservoir helps conserve water too.

An overview of environmental impacts of geothermal development.

Air emission. Though geothermal energy is rated highly in terms of air emission in comparison to thermal sources, its impact on air quality cannot be underestimated at a local level. In Olkaria geothermal power plants, monitoring of gas emissions is routinely conducted. Air emission from drilling is minor and mainly caused by fumes from diesel generator and dust from vehicular movement. During well testing, the hot steam released has a temporary impact on nearby plants and air quality with respect to emission of H_2S. Impact assessment concentration of gases during operation should be done using air pollution modeling. This helps in monitoring ground concentration levels of the gases to minimize health and nuisance impacts.

The most significant geothermal gas is hydrogen sulphide (H_2S) with a range of 0.03 – 6.4 g/kWh from power plants. The gas creates an offensive pungent rotten – egg like smell. The range of H_2S emissions from geothermal plants is 0.03–6.4 g/kWh (KAPA systems, 2000). Some of the possible impacts of H_2S are described in **table 2**.

Table 2: Effects of H_2S on Human and Wildlife

Effect of Hydrogen sulphide on human beings	
Concentration in ppm	**Effect**
1-10	Offensive odour
10-20	Occupational exposure limit
20-100	Ceiling of occupation exposure limit. Worker must wear breathing apparatus
100-200	Loss of sense of smell in 2-15 minutes. May burn throat and chest. Causes headache and nausea, coughing and skin irritation
200-500	Loss of reasoning and balance. Respiratory disturbance in 2-5 minutes. Prompt resuscitation required.
500-700	Immediate unconsciousness with one sniff. Causes seizures, loss of control of bowel and bladder. Breathing stops and death will result if no resuscitation is done
700-1000	May immediate unconsciousness. Death or permanent brain damage may result unless rescued promptly
1000-2000	Immediate collapse with respiratory failure

During operation, these gases are monitored by (a) measuring the fraction of non-condensable gases in the steam flow, and (b) sending samples of non-condensable gas for analysis at the KenGen Olkaria laboratory. In a typical geothermal field, gas analysis will be conducted frequently in the early years of the project, and less frequently in the later years, as the reservoir becomes stabilized. In many classical reservoirs, the non-condensable gas fraction declines over time. The average emission levels in Olkaria in the ambient air at 1- 10ppm (below the WHO limits).

Noise. Possible sources of noise in a geothermal power development include; noise from heavy earth moving machinery during construction, well testing, cooling tower complex, gas ejectors, main powerhouse.

During well testing, high pressure steam is released through a silencer with a roaring noise similar to a large jet engine. The cumulative impact of noise is therefore dependent on the number of wells under testing that takes about 60 days and therefore has a temporary impact on the surrounding (Ogola, 2004). Construction noise is mainly generated by bulldozers, graders, trucks and cranes for the duration of power plant construction (KPLC & Sinclair Knight Merz, 1992). Noise during operation is from cooling towers, gas ejectors and powerhouse. To mitigate noise levels, use of silencers and earmuffs to workers is enforced. Indicative noise level is described on **table 3**.

Table 3: Indicative noise levels during drilling and construction

Operation	**Noise Level (dB)**
Air drilling	85–120
Mud drilling	80
Discharging wells vertically (to remove drilling debris)	Up to 120
Normal well testing through silencers	70–110
Diesel engines (to operate compressors and provide electricity)	45–55
Heavy machinery (e.g., for earth moving during construction)	Up to 90
Power plant operation (Olkaria II)	65 - 70

The world-bank noise level requirements are shown in table 4 below.

Table 4: World Bank requirements on Noise Level (World Bank, 1998)

World Bank maximum allowable ambient noise level		
Receptor	Maximum allowable limit (hourly) in dB (A)	
	Day time (0700-2200hr)	Night (2200-0700
Residential. Institutional and Education	55	45
Industrial and Commercial	70	70

Waste water. The main geothermal wastewater is brine. In Olkaria I, the disposal of brine was via gullies and natural drainage, but in Olkaria II, wastewater disposal is done by deep reinjection. Though brine is not considered toxic by any standards, it may pose health risk depending on the geothermal fluid chemistry. The brine also poses risk on water pollution if it has heavy metals like As, B, Hg, Zn, Pb, Cl, Li. Some of the international standards (WHO) that may be used in monitoring these heavy metals and other pollutants in geothermal and other projects are listed on table 5.

Table 5. WHO limits for processed water.

Wastewater Parameter	**Maximum Concentration (mg/l)**
Biological Oxygen Demand (BOD)	**50**
Chemical Oxygen Demand (BOD)	**250**
Total Suspended Solids (TSS)	**50**
Oil and Grease	**10**
Heavy metals (Total)	**10**
Total Chromium as Cr	**0.5**
Total Copper as Cu	**0.5**
Total Iron as Fe	**1.0**
Total Zinc as Zn	**1.0**
Total Chloride as Cl	**0.2**
Total Arsenic as As	0.1
Total Lead as Pb	0.1
Total Mercury as Hg	0.01
Total Nickel as Ni	0.5
pH	**6 – 9 unit less**

During drilling, drilling mud, additives, cuttings, cement, oil and grease are passed through a sump system where drill cuttings and mud particles settle down and the viscous drilling fluid is recycled back into the system. Deep reinjection, proper well casing and cementing are a one-stop solution to preventing geothermal wastewater from entering the shallow water table. Other wastewaters and oils resulting from power plant operations are managed through proper drains with separators.

Land subsidence. If the rate of fluid withdrawal is greater than natural reservoir recharge during power plant operations, the net outflow can cause rock formations to compact especially in areas of clay and sediments. The main cause of subsidence includes;

- Pressure drop in the reservoir due to excessive fluid withdrawal
- The occurrence of a highly compressible geological rock formation above the reservoir
- The presence of high-permeability paths between the reservoir and the formation, and between the reservoir and the ground surface

Subsidence is common in liquid dominated reservoirs and can affect the stability of pipelines, drains, and well casings. It can also cause the formation of ponds and cracks in the ground and, if the site is close to a populated area, it can lead to instability of buildings. Cases of subsidence are limited to a few geothermal fields. The best example of ground subsidence was in Wairakei in New Zealand with a maximum-recorded rate of 13 meters per year (KAPA systems, 2000), in Icelandic field of Svartsengi and Reykjanes, averages of 10mm/yr and 6mm/yr have been measured respectively (Eysteinsson, 2000) while in Olkaria no subsidence has been observed. Little is currently known on how to mitigate the impact of ground subsidence. Subsidence prevention is achieved by maintaining pressure in the reservoir by reinjecting hot fluids at some distance from production wells to avoid cooling.

Soil and Vegetation. The geothermal activities mostly affect vegetation by gaseous emissions, physical removal of vegetation to pave way for roads, drilling pads, and buildings and hot or cold geothermal brine flowing on the surface.
Disposal of geothermal water on the surface can cause high metal concentrations in soils and vegetation. In Olkaria I for instance, the wastewater is stored in conditioning ponds before it is reinjected. Plants and soils around the conditioning pond have a high concentration of trace elements like Pb, Zn, Cu, Cd, Hg, Ni and B. Direct reinjection is the best method or completely isolate the conditioning ponds from plants and animals.

To mitigate against removal of vegetation to pave way for drill sites, roads, steam pipe lines and powerhouse, site rehabilitation is done followed by grassing and planting of trees.

Well blowout. "Blow-Out" is an uncontrolled escape of fluids from a drilling well when high formation pressure is encountered. This can explosively blow out of the well during drilling. This is prevented through proper cementing and pressure monitoring. Blowout preventers and related well control equipment are normally used with a reliable supply maintained until drilling operations are completed.

4. SOCIOECONOMIC CONSIDERATIONS

Expectations of local communities, governments, development organizations, non-governmental organizations (NGOs), and other stakeholders have risen significantly regarding how effectively companies should mitigate environmental impacts of their activities. These expectations have been explicitly expanded to include social issues and impacts, which are often not seriously discussed in environmental impact assessment reports. In developing countries, expectations have been made complex by the challenges associated with sustainable development. To meet these challenges, governments through their legal systems must develop regulation on creation of a level field for industrial competition and investment without jeopardizing the needs of the local communities and other affected parties.

- **Role of stakeholders in project impact assessment.**

In project development, national policy and legal framework for public consultation must be understood before project implementation. The Task Team and the Client Government must consult relevant stakeholders during scoping, before the Terms of Reference (TOR) for the EA are finalized (OP 4.01, s. 15)(World Bank 1989). In some countries an adequate PC (Public Consultation) legislative framework may be lacking, but there may be other cultural or informal ways in which citizens participate in decision-making (Vanclay, 1999).

In Kenya, the EMCA, 2000 and Regulations make public consultation a pre-requisite for all projects. Any developer is required to make available information upon public requisition. Each institution is now accountable for its actions on environmental performance. The EMCA provides for the right of every person to a clean and healthy environment. It also makes it the obligation of every person to protect and manage the environment. The developer is therefore expected to adhere to the three principles of sustainable development; polluter pays principle and precautionary principle (Republic of Kenya, 1999). Evidence of the developer's good intentions and environmental governance can be made known through public consultation and disclosure. This is done during EIA, environmental audits and monitoring during project implementation and operation.

All stakeholders should be identified and consulted at the initiation stage of the project. Means of contacting influential stakeholders and the non-influential ones should be devised and the effectiveness of the consultation process evaluated.

- **Socioeconomic impacts of developing geothermal projects – The Olkaria experience.**

The Greater Olkaria Geothermal Area is influenced by historical factors, which has influenced its current socioeconomic set-up. The area has undergone tremendous land use changes with accelerated changes experienced in the last decade. Unlike many parts of Kenya where the stakeholders are local communities bound by similar culture, language and race, this area is cosmopolitan. Therefore the socio economic impact of development would not be a typical reflection of what happens in any rural set-up in Kenya. Some of the key socioeconomic impacts as experienced in Olkaria are discussed below;

Tourism and Wildlife Conservation. There is a debate as to whether geothermal resource development and wildlife conservation are compatible. The Olkaria power plants located in Hells gate National Park are a classic example of such compatibility of the two land uses. This area was gazetted as a park in 1984 after construction of Olkaria I power plant. This has been perceived as the best decision made by the conservationist at that time in view of the fact that the area was going to be opened up following the construction of a power plant. Since then, Kenya Wildlife Service (KWS) and KenGen developed a Memorandum of Understanding (MoU) to govern geothermal power operations within the park. The MoU also covers Orpower 4 (an independent power producer). The KWS and KenGen are currently working on the revision of the MoU following the commissioning of Olkaria II in 2004, which is also within the same park. The main concerns of the Kenya Wildlife Service and other conservationists include; effluent disposal, emissions, animal accidents (traffic), loss of habitat, harassment of animals, blockage of seasonal animal migration routes, noise and odour.

In order to minimize impacts caused by geothermal development activities in the park, several studies were carried out. These studies included establishment of animal migratory routes, breeding grounds, tourist circuits and protected plants and wildlife species. The plant operations have maintained conservation of unique scenic features and wildlife species within the park. Steam pipelines on major animal routes were looped to provide easy movements for the wildlife such as giraffes within the park.

High voltage lines and silencers are a potential danger to birds and as such they were constructed to avoid right angle crossing of known bird flying routes. To avoid animal accident in the park, a speed limit of 40km/h is observed while game proof fencing is done to keep the animal away from brine pools.

Education. The implementation of Olkaria I project came with the construction of the Mvuke primary and nursery schools. The school infrastructure financed by KenGen is open to the local community and the teachers provided by the government. However, the nursery school is fully funded by KenGen.

Despite the increase in flower farms and associated population, the government has not been able to meet the need for more schools. Some flower farms have responded to this need by constructing schools to meet the demand brought about by their large labour force.

Agriculture. In the late 1970s, horticultural farming was introduced around the lake and has since grown to large commercial farming for export. Before independence and shortly after, the irrigation-based agriculture around the lake was mainly food and fodder crops for the local market and minimum export. The farming is presently oriented for the European market and has led to heavy growth and a complete change in land use from ranching and wildlife grazing to commercial irrigated agriculture. This industry has been attracted by availability of abundant fresh water from the Lake Naivasha, large tracks of land (which can be leased), favourable climatic conditions, cheap labour and proximity to Nairobi.

Increase in agricultural activities in the area is also attributed to opening up of the Southlake road, which was done under the implementation of Olkaria I power plant. The construction of this road improved access into the then remote area and opened up opportunities for agricultural development. Kenya has currently overtaken Israel as a world leader in cut flower export and horticultural products. Naivasha supplies about 75% of the total export and earns the country approximately USD 110 million per annum (CBS, 2002).

Several studies and farm experiments were done on trial basis by KenGen to assess the impact of cooling tower plume and gas ejectors on the flowers. The results of the study indicate that the plume and especially H_2S does not cause any hazard to the flowers and horticultural crops. This has been confirmed by activities in places like Iceland where geothermal water is used in greenhouses for heating. The Oserian flower farm has developed a system for utilizing geothermal heat and gases to heat > 30 hectares of greenhouses as a means of controlling temperatures and humidity to stop fungus growth and reduce the use of fungicides and subsequently meeting the stringent European market standards on residual plant chemicals. The farm is also injecting the geothermal CO_2 into the greenhouses increase the rate of photosynthesis and production with much success.

Indigenous community and culture. The indigenous community of the Olkaria area are the Maasai´s who are less than 100 people. The community lives in the vicinity of the park on surrounding private farms and therefore have no firm legal rights of occupation. The development of the power plants did not displace or directly affect any indigenous community and their culture. Though there is very limited interaction with the community in-terms of project operations and maintenance, methods of ensuring that they benefit from the project have been devised. Some of the benefits the Maasai´s community has enjoyed from the project include provision of piped water at the Kedong and Narasha, access to Mvuke primary school, transport provision for shopping every weekend and assistance to put up a new primary school called Iseneto.

The expansion of geothermal development in the areas immediately outside the park may however affect the Maasai's if KenGen was to acquire the land from the private farms.

Aesthetics and visual impact. The construction of geothermal plants in a tourist set up can cause visual intrusion if not carefully planned. The Visual Absorption Capacity (VAC) of an area should be clearly understood right from the planning stage. The Olkaria area has a high visual absorption capacity due to topographical nature of the area. Using equipment with neutral, non-reflective colours that blend with the surrounding rocks or trees have reduced the visual impacts. For instance, the Olkaria II powerhouse is coloured in light brown and green to blend with the surrounding environment. In Olkaria II, separated water is not released into the atmosphere like in Olkaria I hence have no visual impact of plumes.

During drilling and construction of powerhouse, the visual impact may be temporary, though notable. Costs and means of minimising these impacts must be determined prior to implementation.

Labour. Just like any development project, geothermal development stimulates creation of additional economic activities, indirect jobs and generates tax and revenue. The geothermal industry provides a wide range of employment opportunities from exploration, drilling, manufacture of turbines and operations. Through the economic multiplier effect, salaries earned generate additional incomes and jobs in the local and regional economy. A general rule of thumb is to maximize the use of local labour.

During the plant construction stage, there is an influx of workers that require camping facilities such as X2 camp during Olkaria I construction. Other social impacts relate to the interaction of locals with the construction workforce. The construction phase of a geothermal plant involves far more workers than the operation maintenance stage, and because appropriate infrastructure and management procedures are often not in place, the impacts at this time can be higher than during the operation stage. Though the construction of Olkaria II came with an influx of construction workers, the plant operational staff were internally relocated from Olkaria I and Kipevu thermal. The increased labour force requires an increase in transport, rental houses and leads to pressure on existing social infrastructure. The temporary labour force during construction of Olkaria II was estimated at 920. It is however important to note that this increase cannot be matched to the phenomenal increase in permanent labour force brought about by expansion in flower and horticultural farming.

Energy and economy. Energy is a means to development. The increase in energy leads to growth of development activities and eventually poverty alleviation. Currently, only 15% of Kenyans have access to electricity from the country current installed capacity of 1218 MWe. Geothermal only contributes 11% of the total with an installed capacity of 129 MWe. The gross revenue generated from geothermal in 2004/2005 was about Kshs 1.7 billion. In most African countries, the local communities especially in the rural areas do not directly benefit from the electricity generated as it is taken to the national grid.

Some of the local economic benefits include increase in trade and business, income from rent and transport services, improved access to essential services etc.

Health. While it is commonly believed that that health impacts are social impacts, a qualified health impact assessment expert is needed to thoroughly examine the health impacts that are likely to occur as a result of a geothermal project implementation and operation. It is also important to do a baseline survey of local health and disease incidences before the project to avoid speculation during and after implementation. The main health impact related to operating geothermal is occupational exposure to geothermal gases like H_2S. The health impacts during construction are accident related and are reported in the monthly progress reports. During construction of Olkaria II, a new dispensary was constructed to meet the health requirements of the construction workers and KenGen staff on site. The main public health facility is in Naivasha town while other existing facilities are owned and run by commercial farmers in the area.

The health benefits of geothermal brine are known worldwide. The local Maasai´s community and some workers use the brine for skin ailments. Having some third party liability insurance cover to guard against unforeseen external costs should be considered.

Water requirements. The source of water in Olkaria is Lake Naivasha, which is a Ramsar site due to its unique hydrological conditions and being home to hundreds of bird species. Though the lake has no visible surface outlet, it has not become saline despite the high evaporation rates. This indicates a subsurface outflow that has been a major subject of speculation. Ground water resources include the deep geothermal aquifer, which is not directly linked to the lake, and the upper aquifer, which is believed to have a direct link to the lake. The lake is like a small pan several kilometers above the geothermal resource and are recharged by different hydrological systems.

Water requirements for the power stations, residential houses, and other occasional activities like construction and drilling must be established before resource exploitation. Currently, the water use for KenGen is mainly for power plant operations and domestic. KenGen also supplies Orpower 4 (IPP) and the Maasai´s with piped water as a Corporate Social Responsibility. The total water consumption for KenGen is 59,000-m^3/year/station use and about 1000 m^3 of water per day during drilling. However, drilling is an activity that happens in one year of a decade or more and cannot make significant difference in the lake level. Water consumption for powerhouse uses are negligible compared to the 300,000 m^3 used for irrigation per day by the commercial farms. The water used for drilling is also recycled. KenGen may supplement the water with geothermal brine during drilling of Olkaria IV.

There is a possible risk on water pollution from heavy metals like As, B, Hg, Zn, Pb, Cl, Li etc from geothermal fluid. Water quality monitoring is done more regularly and consistently by all stakeholders to determine its quality and impacts of surrounding agricultural activities on its ecosystem. The impact of these pollutants on availability of water for domestic and livestock use should be determined and prevented.

In order to limit degradation of the deep geothermal aquifers, reservoir performance at different exploitation capacities by simulation studies carried out. Sustainable management of the reservoir by maintaining adequate balance between geothermal fluid withdrawal and recharge of disposed fluid is done once operation begins.

Road and Transport. Moi South lake road is a class D loop road providing access to Olkaria geothermal power plants, flower/horticultural farms, hotels, Hells Gate National Park and other residential areas. KenGen constructed the road under the World Bank fund in 1990. Stakeholders under the LNRA body of which KenGen is a major contributor do road maintenance.

The impact associated with the development was an increase in labour and service transport vehicles to and from site. The increase in vehicular and pedestrian movement increased the number of accidents. To avoid the above impacts;

- The traffic should abide by the speed limits and by laws of the area.
- Movement of heavy construction traffic should be planned appropriately
- Prevention of soil erosion during upgrading and use of access road and regular watering should be done to avoid impact of dust.
- Establish maintenance responsibilities and ensure that road rehabilitation takes place as soon as possible (Ogola, 2004).

5. ENVIRONMENTAL MONITORING PLAN

An environmental monitoring plan is normally designed and included in the EIA report. Monitoring is done to identify and mitigate changes in the environment brought about by geothermal project development. This is done during exploration, drilling, construction and operation. The monitoring plan has all the identified possible impacts, their mitigations and the person responsible for implementation. A cost is also attached to all mitigation measures and possible alternatives analyzed.

Participatory approach is encouraged in monitoring social issues (World Bank, 1994). Table 6 highlights some of the key environmental and social issues that are monitored in geothermal development.

Table 6: Social and environmental monitoring parameters in Geothermal

Social Monitoring Parameters	**Environmental Monitoring Parameters**
Land use changes	Soil and vegetation elements concentration
Public health and safety	Water elements concentration
Water use and consumption	Ecosystem (plants & animals both aquatic and terrestrial)
Community complaints	Noise level
Employment and income	Air pollution and Precipitation chemistry
Resettlement (if application)	Soil erosion and control
Traffic volume	Subsidence
Business and services	Water and gas chemistry
Demographic changes (wildlife and human)	Ground water chemistry and levels
Tourism (if applicable)	Seismic monitoring
School enrolment and facilities	Geo-hazard monitoring

6. CONCLUSION

The development of geothermal energy does not cause adverse impacts to the environment compared to other conventional energy sources. All the known environmental impacts resulting from geothermal development can be mitigated against. However, in developing geothermal projects, the costs of environmental and social mitigation measures should be factored into the total project cost. All the national and international legal requirements should be used to benchmark environmental management. Ultimately, the need is to balance between development that is brought by the energy resource and conservation of the environment.

Most African countries have not met their energy requirements despite the vast resources in the continent. The countries with geothermal potential should seek for funds to develop these resources. There is also great need to have receiving communities identify with the projects from initiation stage to decommissioning and to ensure that they accrue direct benefits from such projects. Otherwise, if not involved, the communities can reject the project and blame all environmental degradation on the developer.

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CONTACT

Jennifer A. Oduor
Kenya Electricity Generating Co. Ltd.
P. O Box 47936-00100. Nairobi
KENYA.
Tel +254 722 740095

joduor@kengen.co.ke