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ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR A MODULAR POWER PLANTS PROJECT IN MENENGAI, NAKURU COUNTY, KENYA: IMPACT IDENTIFICATION, EVALUATION AND RISK ANALYSIS

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ABSTRACT: *This paper is an extract from the Environmental and Social Impact Assessment report for the Menengai modular geothermal power plants projects for Geothermal Development Company Limited. Geothermal Development entails exploration drilling, steam collection, construction of power generation units and power transmission lines. Preliminary phase of land acquisition, vegetation clearing, construction and power generation is likely to cause environmental disturbance. Integrated resource utilization and environmental conservation needs an effective and efficient environmental and social management plan in order to facilitate sustainable implementation of the proposed project. Impact identification and risk analysis for any proposed project, are key for they provide useful information to decision- makers. This paper aims to provide a valuation's perspective on how to best design and execute the impact identification and risk analysis to achieve results that align mitigation with identified potential impacts of the proposed project activities. The process involved identifying where the interactions were likely to occur between the proposed project activities and the receiving environments. A modified Leopold Matrix (LM) integrated with Lohani & Thanh methods were used to identify and estimate the magnitudes and importance of the potential impacts. Cumulative impacts were estimated using consequence and probability ranking model adapted from the South African Department of Environmental Affairs' guideline document on EIA regulations of 1998. The model predicts the significance of impacts by considering magnitude, duration, spatial scale and factoring in probability of the impact to occur. Based on results of analysis, the cumulative impacts ranged from minor to moderate and can be mitigated.*

KEYWORDS: Modular Geothermal Power Generation Technology, Cumulative Impact, Risk Analysis, Impact Assessment, Society, Environment.

INTRODUCTION

Geothermal Development Company (GDC) is one of the key organizations entrusted with power sector promotions in Kenya. GDC has a plan to develop the Menengai Geothermal Field in Nakuru County, Kenya, by installation of 3 modular power plants of 30MW each. Therefore an Environmental and Social Impact Assessment study was carried out for this proposed project. The study was aimed to document the findings in reports that would be submitted to NEMA in compliance with the Environmental (Impact Assessment and Audit) Regulations, 2003. This paper is an extract of the study report focusing on impact identification, evaluation and risk analysis.

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LITERATURE UNDERPINNING

Geothermal energy as defined by Meyers (2016) is energy derived from the heat of the earth. Heat from the centre of the earth conducts outwards and heats up the outer layers of rock called the mantle. When this type of rock melts and becomes molten it is called magma. Magma can reach just below the earth's surface. During precipitation, water infiltrates and percolates down through geological fault lines and cracks becoming super heated by the hot rocks below. The super heated water may rise back to the surface of the earth where it emerges as hot springs or geysers; however, if the hot water is trapped below the surface it constitutes a geothermal reservoir (Williams, 1984). Such a resource can be exploited through exploration drilling, installation of steam collection pipes and electricity generation turbines or installation of modular Well head generation units in case of early generation of electricity to augment energy supply required for accelerated exploration drilling.

Geothermal Energy Development project falls in Schedule 1 developments project for which an Environmental Impact Assessment (EIA) must be carried out (NEMA, 2003; Friend of the Earth, 2005). Environmental and Social Impact Assessment (ESIA) is a process of evaluating the likely environmental impacts of a proposed project or development, taking into account inter-related socio-economic, cultural and human-health impacts, both beneficial and adverse (Mebratu, 1998). It is the systematic identification and evaluation of the potential impacts of proposed projects, plans, programs, or legislative actions, relative to the physical–chemical, biological, cultural and socioeconomic components of the environment (Council on Environmental Quality, 1993).

METHODOLOGY

The Kenya government policy on all new projects, programmes or activities requires that an Environmental & Social Impact Assessment (ESIA) be carried out at the planning stages of any proposed undertaking to ensure that significant impacts on the environment are taken into consideration during the design, construction, operation and decommissioning of the facility. This ESIA Report has been prepared in accordance with the Environmental (Impact Assessment and Audit) Regulations of 2003 (revised in 2013). It is also guided by other environmental and social safeguards such as the World Bank's requirements for industrial projects and International Finance Corporation's (IFC's) Environmental Health and Safety (EHS) Guidelines for Geothermal Projects.

The study methodology for the proposed project comprised the following activities:

Preliminary meetings

a) Document review
b) Site inspection and discussions with site personnel
c) Baseline condition survey
d) Public consultation
e) Air and Noise Dispersion Modelling
f) Impact identification and assessment
g) Data analysis and report preparation

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This paper however, focuses on the Impact Identification and Assessment stage. The ESIA Report has confined itself to the construction of three (3) 30MW modular power stations and associated infrastructure, including the transmission lines from Menengai to Olkaria-Lessos line through Rongai.

The anticipated impacts were identified using checklists and matrices. Impact assessment was carried out in order to identify where the interactions are likely to occur between the proposed project activities and the receiving environments (Canter, 1999). Checklists of project activities were used and impact scores were assigned through consultative approach including public participation such as chief's meetings (barazas), stakeholders' consultative meetings and focused group discussions. A modified Leopold Matrix (LM) developed by Leopold *et al.*, (1971) was used to estimate the magnitudes and importance of the potential impacts.

RESULTS AND DISCUSSION

The diagonal lines in Tables 1 and 2 illustrate identified interactions between the environmental components and project activities. The interactions were described in terms of magnitude (M) in the upper section and importance (I) in the lower section. The magnitude of interaction was described by assigning values ranging from 1 (for small magnitude) to 10 for large magnitude. (Petra, 2009) explains a Modified Graded Matrix (MGM) with reference to the interaction environmental impact assessment (EIA) matrix as developed by Lohani and Thanh (1980) in which relative weights are assigned to each activity of the project. Relative priority of the development activity was determined based on a scale of 1 to 10. The total value of a particular activity is the vertical sum of product of magnitude (M) and importance (I) on each environmental component interacting with that particular activity. The horizontal total value is the sum of product of magnitude (M) and importance (I) on each environmental resource interacting with a particular activity, multiplied by the respective priority value (Table 2).

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Table 1: Leopold Impact Identification Matrix Showing Magnitude and Importance Values

		Phases of the Project											
		Construction					Operation				Decommissioning		
Environmental Aspects	Project Activity / Resource	Transportation of Power plant parts and construction materials	Power house	Brine sump and store	Transmission lines	Power substation	Steam abstraction	Waste handling	Electricity generation	Fluid Management	Dismantling of generator	Well capping	Wellpad rehabilitation
Physical	Water resources		1/9	2/5		2/6	4/7		3/8	4/7	1/7		
	Geology/Soil			3/4	2/5	2/4	4/5		4/5	5/6			
	Vibration	1/6					5/8	4/8		6/7	3/6		
Biological	Flora				5/8				4/8				5/9
	Wild Animals	1/6			2/7	2/6		3/5	2/6		2/8		6/8
Socio-economic	Employment/ Economy	2/6	4/4	2/3	3/5	4/3	2/4	8/8	2/4	1/3	1/4	1/3	2/3
	Health	2/6	5/7	3/6	2/6	4/7	2/4	1/7	5/6	6/5	2/6	1/4	4/5
	Infrastructure	1/6	4/8		2/8	2/9		8/8			4/8		
	Local Culture	2/4			2/3	2/2		5/4					2/4

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Table 2: Modified Leopold Matrix Showing Incorporating Lohani and Thanh Priority Values

		Phases of the Project													
		Construction					Operation				Decommissioning				
Relative Priority	Project Activity / Resource	Transportation of Power plant parts and construction materials	Power house	Brine sump and store	Transmission lines	Power substation	Steam abstraction	Waste handling	Electricity generation	Fluid Management	Dismantling of generator	Well capping	Wellpad rehabilitation	Leopold Methods	Lahani & Thanh
6	Water resources		1/9	2/5		2/6	4/7		3/8	4/7	1/7			17/49	624
1	Geology/ Soil			3/4	2/5	2/4	4/5		4/5	5/6				20/29	100
4	Noise/ Vibration	1/6					5/8	4/8		6/7	3/6			19/35	552
5	Flora				5/8				4/8				5/9	14/25	585
7	Wild Animals	1/6			2/7	2/6		3/5	2/6		2/8		6/8	18/46	861
9	Employment/ Economy	2/6	4/4	2/3	3/5	4/3	2/4	8/8	2/4	1/3	1/4	1/3	2/3	32/50	846
10	Health	2/6	5/7	3/6	2/6	4/7	2/4	1/7	5/6	6/5	2/6	1/4	4/5	37/69	2160
3	Infrastructure	1/6	4/8		2/8	2/9		8/8			4/8			21/47	480
2	Local Culture	2/4			2/3	2/2		5/4					2/4	13/17	92
3	Religion/ Historical Sites				4/7	3/9								7/16	165

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Lohani & Thanh	50	92	46	141	112	104	202	126	133	99	7	127		

Project Activities and Environmental Parameters of Importance as Depicted from Analysis

Based on the analysis in Table 2, the activity that is of relatively high priority is waste handling both gaseous and brine and transmission lines that had Lohani and Thanh value of 202 and 141 respectively. Health and wild animals issues also depict somewhat pronounced Lohani values (2160 and 861 respectively). The health impacts may be due to emission of gases (H_2S) and noise, while negative impacts on wild life could be attributed to disturbance of habitat due to noise and increased human activity. Health and wild animal are major environmental and socioeconomic parameters of concern and therefore need priority in environmental management action plan.

Cumulative Impact and Risk Analysis

For purposes of the ESIA, the cumulative impacts were assessed by considering effects of various planned activities of the project. The Leopold, and Lohani and Thanh methods (Table 1 and Table 2) assisted in identifying major activities and in defining areas where attention is mostly needed. That information together with information available from the baseline data and professional judgment of the assessment team, constituted the basis for cumulative impact and risk analysis. The ranking scale is given in Table 3. Example of Consequence and Probability Ranking (Table 3) was used to quantify the significance of the impacts. The risk assessment model is adapted from the 'South African Department of Environmental Affairs' guideline document on EIA Regulations, April 1998. The consequence of impacts was derived by considering the following criteria:

i. Severity/magnitude (how severe the impact would be);
ii. Duration of the impact (how long the impact may be prevalent for); and
iii. Spatial extent (the physical area that would be affected by the impact).

The overall probability of the impacts is regarded as the likelihood of impact occurrence based on professional judgment and guided by weighted indicators in Leopold/Lohani and Thanh methods. The overall risk from the impact is determined by multiplying the consequence by the probability of occurrence thus:

Significance of Impact = Consequence (magnitude + duration + spatial scale) x Probability.

The probability value criterion is based on subjective informed judgement regarding the likelihood for the impact to occur.

Table 3: Example of Consequence and Probability Ranking

Residual Magnitude / Severity	**Duration**	**Spatial Scale**	**Probability**
10 – Very high / Don't Know	5 – Permanent	5 – International	5 – Definite / Don't know
8 – High	4 – Long-term (impact ceases after operational life)	4 – National	4 – Highly probable
6 – Moderate	3 – Medium-term (5-15 years)	3 – Regional	3 – Medium Probability

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4 – Low	2 – Short-term (0-5 years)	2 – Local	2 – Low probability
2 – Minor	1 – Immediate	1- Site only	1 – Improbable
0 – None			0 – None

Significance of Impact = Consequence (2 + 4 + 2) x 4 = 32

A case in the provided example can be noise from power plant and also from the cooling towers. The impacts are considered long-term but localized.

The maximum sum of potential cumulative impacts (SP) is 100. Environmental and social effects are rated High, Moderate, Low or No Impact accordingly, based on the following criteria:

- SP>75 indicates **high** environmental and social significance
- SP 50 to 75 indicates **moderate to high** environmental and social significance
- SP 30 to 50 Indicates **moderate** environmental and social significance
- SP<30 Indicates **low** environmental and social significance
- SP = 0 Indicated **no** environmental or social impact

The cumulative impacts, possible mitigation and ranking for the various activities are summarised in Table 4.

Table 4: Cumulative Impact Assessment, Possible Mitigation and Risk Ranking for the Various Activities

Parameter	Likely Impact	Mitigation	Residual Impact	Risk Ranking
Wildlife Habitat	Habitat integrity degradation due to noise scare Degradation of habitat with surface disposal of geothermal water Built structures altering natural environment	Development structures to be camouflaged to suit the surroundings. Muffle the sound during power generation to reduce noise. Geothermal waste-water to be re-injected	If measures are taken impacts can be mitigated	48 [(4+4+4) x 4 =48] Indicates moderate environmental and social significance
GHG and H_2S gas	Contributes to global warming (Climate change Contributes to acid rain. Respiratory diseases	Choice of technology that minimizes fluid interaction with the atmosphere	Impacts mitigated during power generation	30 [(2+4+5) x 4= 30] Indicates moderate environmental significance
Vegetation Clearance	Clearing of vegetation to give way for transmission	Reforestation of cleared sites	Regenerated when trees are planted	32 [(4+2+2) x 4 = 32]

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	lines and construction of sub-station			Indicates moderate environmental significance
Aesthetic and Scenic	Construction of structures results in cut and fill slopes and alteration of natural sceneries	Camouflaging buildings, and Landscaping to avoid interfering with scenic sites	Restored following the prescribed measures and adds tourist attraction	16 [(4+2+2) x 2= 16] Indicates low environmental significance
Socio-economic and cultural	Settlement of foreign workers; Increased disease such as HIV/AIDS Acculturation	Provide health facilities Education awareness	Highly achievable with correct mitigation measures considering that the area is metropolitan	16 [(2+4+2) x 2=16] Indicates low environmental significance

Parameter	**Likely Impact**	**Mitigation**	**Residual Impact**	**Risk Ranking**
Waste generation	Wastes oils, metal scraps generated from power house	Skim off oils from wastewater effluent, used oils repository sites and scrap metal storage and re-use	Manageable with adherence to mitigation measures	16 [(2+4+2) x 2=16] Indicates low environmental significance
Water resources	Interference with hydrology of the project area Contamination of underground and surface water bodies	Monitor changes in the area ecosystem Pump acceptable daily rates from the bore holes and balance the rest with surface water Acquire permit from WARMA Discharge drilling effluents in lined ponds	Impacts minimized with adherence to permitted abstraction rates and adherence to mitigation measures.	30 [(4+4+3) x3=33] Indicates moderate environmental significance

Cumulative Impacts Depicted from the Analysis

The cumulative impacts for the proposed Geothermal Modular power generation unit in the project area would range from low to moderate (Table 4) and could be mitigated. No adverse cumulative impacts were expected from implementation of the project in the area if the generation technology would minimize release of H_2S into the atmosphere. Besides, with geothermal water re-injection, no adverse effect was expected from geothermal brine. However, given that no development can take place without impacting on the environment, this paper outlines potential negative impacts that are expected to occur to the bio-physical and socio-economic environments as depicted in the impact identification and risk analysis matrix.

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Negative Physical Impacts
i) Air quality and dust impacts

Aerosol contribution to the atmosphere may occur during excavation for construction of roads and buildings; and during use of fuel-run equipments including vehicles, generators and compressors. The proposed site, located close to discharging wells, would be impacted with H_2S smell. However this would be short leaved since productive wells would be sealed and connected to steam collecting pipes for generation of electricity. Besides, workers and permitted persons in the project site are provided with relevant Personal Protective Equipment (PPE) part of occupational and public safety and health.

ii) Noise and Vibrations

Noise and vibrations would occur during transportation and installation of equipment and the power generation process. Table 5 shows noise levels from these operations, which may have risen up to 120 decibels (dB). For comparison, noise levels in quiet suburban residences are of the order of 50 dB, noise levels in noisy urban environments are typically 80–90 dB, and the threshold of pain is 120 dB at 2,000–4,000 Hz. The Menengai wells are in a more or less secluded area, where the natural level of noise is low, ranging from 37.7 to 67.2 dB. As a result of drilling, a slight change in noise is detectable. With best practices, for example, installation of portable barriers to shield noisy equipment where necessary, noise levels can be kept to below 65 dB, and therefore construction noise should be practically indistinguishable from other background noises at distances of one kilometre. Furthermore, turbine-generator buildings, should be well-insulated acoustically, and equipped with noise absorptive interior walls thereby keeping noise within acceptable limits. Existing company environmental policy also ensures that site workers are protected by wearing ear mufflers.

Table 5: Geothermal Exploration and Construction Noise Levels by Operation

Operation	Noise Level (dB)
Discharging wells after drilling (to remove drilling debris)	Up to 120
Well testing	70–110
Diesel engines (to operate compressors and provide electricity)	45–55
Heavy machinery (e.g., for earth moving during construction)	Up to 90

iii) Liquid Waste

i) Storm Water

Compaction of surface on well-sites, in roads and campsite construction would create impervious surfaces (slab environment). There is a likelihood of increased storm water runoff from these sites, which result in gully erosion with time. In addition to creating unattractive terrain, this may cause flood incidences along streams downhill during high rainfall times.

ii) Oil Spills

The machines at site and project vehicles required oils during maintenance. The oils would be transported and stored at project site. Any major accidental oil spill would impact negatively on the environment as a whole. Cumulatively, small releases of oil would also impact negatively on the environment. Such impacts include creation of new sceneries due to

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destruction of biological diversity and pollution of water and soil. But these dangers are contained by maintaining the machinery in specific areas designed for this purpose.

iii) Geothermal Waste Water

Geothermal waste water occurs at the well sites as steam condensate and also from the power plants. Depending on the cooling system, geothermal waste water is discharged at the cooling towers. The geothermal waste water contains pollutants including heat, ammonia, CO_2, H_2S, CH_4, silica and toxic heavy metals such as lead, cadmium, arsenic and mercury. Re-injection of spent geothermal fluid is recommended and if disposed off on the surface, it should be in lined ponds, to prevent infiltration and percolation into the ground water.

Impacts on climate change

Geothermal energy is considered as green energy resource and as such generation of electricity from geothermal energy is an integrated cleaner production technology. The environmental benefits of the proposed project are realised in terms of reduction of greenhouse gas emissions hence contributing significantly to reduction of global climate change. Indeed cumulative impact analysis indicates no significant impact on the local climate. An equivalent amount of electrical energy delivered by a coal-fired power station would result in the emission of approximately much higher tonnes of carbon dioxide while the quantities of these gases emitted from a fuel-burning power station of a similar capacity would even be much higher.

Solid waste generation

During construction solid waste is generated. These include cement bags, plastics and timber remains among others. Dumping within the site would interfere with the aesthetic status of the area. This has a direct effect to the surrounding community. Disposal of the same solid waste off-site could also be a social inconvenience if done in the wrong places. The off-site effects could be aesthetic, pest breeding, pollution of physical environment, invasion of scavengers and informal recycling communities.

Negative Biological Impacts

i) Vegetation

Vegetation would be interfered with during construction of substation, office buildings, transmission lines and roads. However, this impact is short-term and not significant because the spatial extent would be minimised by ensuring that vegetation disturbance is confined to constructed sites. Further, the project sites can be re-vegetated with the same species after construction.

ii) Fauna

The project area is a protected forest housing wildlife such as monkeys, leopards, several bird species and reptiles. The most significant effect of geothermal power plant operation on the environment is noise, power transmission cables and air pollution. These may disturb the habitat, interfere with breeding and displace the animals thus increase animal-human conflict especially from monkeys that may resort to farm crops as alternative food.

If animals graze at the contaminated sites, the chemical might accumulate in the animal body and cause side effects such as mineral imbalances leading to anemia (Suttle, 2010). However,

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geothermal effluents from the proposed project would be re-injected and sites fenced off. Ultimately animals' access to contaminated sites would be minimal and therefore potential impacts are unlikely to occur.

iii) Health

Negative health impacts that are associated with geothermal power generation include respiratory diseases, nausea and headaches due to inhalation of gases such as H_2S and ear defects due to noise. Although the level of H_2S from geothermal plants is low and within acceptable occupational limits thus of low health risks, the odour can be a nuisance. Loss of life and impairment can occur as a result of accidents from excess exposure to H_2S during repair of confined section of power plants and even the steam systems such as the silencers. Other sources of accidents may occur during machine operations, electrocution and transport. Installation of automated H_2S detectors within working spaces is necessary to mitigate potential impacts. Adherence to 8 hour working shifts reduces exposure and hence mitigates potential health risks associated with H_2S.

IMPLICATION TO RESEARCH AND PRACTICE

The study applied numerical methods in evaluation of potential environmental impacts. Weighted quantification of impacts helped to explain extent of magnitude and thus making impact significance credible. The study has identified potential impacts namely waste handling, health and interference with wild animals' habitat as negative impacts that need to be given priority in environmental and social action plan during the implementation of the project. Importantly the numerical impact evaluation approach has provided quantitative facts that can be relied upon by over-side authority, National Environment Management Authority (NEMA) in this case, to make an informed decision on the proposed project. The study findings enhances approach to impact identification and evaluation for informed decision making on proposed projects.

CONCLUSION

Results from the modified Leopold Matrix (LM) integrated with Lohani & Thanh approach for identification and estimation of impact magnitudes and significance indicate the cumulative impacts for the proposed Geothermal Modular power generation unit in the project area would range from low to moderate and can be mitigated. No adverse cumulative impacts were expected from implementation of the project in the area. Based on this impact evaluation study findings, it was concluded that the proposed modular power plants project was suitable to the ongoing geothermal power development at Menengai Caldera.

RECOMMENDATIONS

Recommendation is made for application of the modified Leopold Matrix (LM) integrated with Lohani & Thanh methods for identification, evaluation and analysis of risks when carrying out Environmental and Social Impact Assessment for geothermal power development projects.

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Licensing of the project was recommended to allow for speedy implementation of the project as an initial stage towards increasing the geothermal development in Menengai Caldera and increasing electricity production in Kenya, towards attaining vision 2030.

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