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COMPARISON OF ENVIRONMENTAL ASPECTS OF GEOTHERMAL AND HYDROPOWER DEVELOPMENT BASED ON CASE STUDIES FROM KENYA AND ICELAND

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ABSTRACT

Geothermal power and hydropower are classified as renewable and clean sources of energy. However, only about one-fifth of the world's electricity comes from such sources, while the greatest portion continues to come from fossil fuels which contribute greatly to pollutant gases. In Kenya and Iceland, the balance of energy sources is significantly different with hydro and geothermal supplying the greatest amount of energy for electricity generation. Both countries have regulations, similar yet different, requiring environmental accountability in project development. Though considered benign as energy sources, development of hydro and geothermal resources includes some environmental impacts. However, many of them can be mitigated. Sondu Miriu and Kárahnjúkar are hydropower projects under construction in Kenya and Iceland, respectively. Olkaria 1 and Nesjavellir are geothermal electric power projects in Kenya and Iceland, respectively. A comparison of impacts and management between the two sources of electricity in these two countries indicates both similarities and differences. While the impacts may be similar in nature, their magnitude is determined mainly by location, the technology adopted, size of development and the priority of the country. These factors, in turn, determine the management options adopted. Sometimes priorities and interests may clash, requiring application of special mechanisms and involvement of all stakeholders to reach a solution. Both Kenya and Iceland have great potential for both geothermal and hydro resources, but further development will depend on power plant location, priority by the governments, support of the communities affected, as well as the ability to mitigate environmental impacts.

1. INTRODUCTION

Currently two billion people have no access to modern energy services (Fridleifsson, 2000a) or a third of the world's population. Energy is crucial in economic and social development and as the population continues to increase so does the energy demand. The world population is fast increasing (predicted to double by 2100), and so is the world's energy consumption. A key issue is to make clean and cheap energy widely available and not least to the poor. A greater proportion of electricity is expected to come from renewable sources, including hydropower and geothermal.

Electricity is paramount in industrial development, and therefore a key factor in economic and social development in both the developing and developed world. There are various sources of electricity, each with its unique advantages and disadvantages, depending on various factors. Thus, like any other industrial development project, electricity generation projects also have varying impacts on the immediate and surrounding environment. As much as they are considered clean sources of energy, they also come with their own positive and negative impacts, although many of the negative impacts can be mitigated.

Selecting a source of electricity has to be done carefully because of the environmental and social implications, in addition to the economics. The threat of global warming is in particular causing a lot of concern, and the general consensus as a precautionary measure is to restrain emission of greenhouse gases as much as possible. This should, however, not impede economic development in developing countries and delay fulfilling the basic needs of 40% of mankind without access to commercial energy, and should also not prevent the maintenance of a strong and healthy economy in the industrialized countries. This can be achieved by using energy more efficiently; switching from carbon-rich fossil fuels to low-carbon-content ones; switching from fossil fuels to nuclear power (not approved by the general public) and renewable sources; and capturing and disposing of carbon dioxide to prevent it from reaching the atmosphere. Both hydropower and geothermal are clean energy sources with negligible emissions of greenhouse gases. These, compared to other renewable sources, have mature harnessing technology, although the share of these resources in world energy supply still remains fairly low. If development of these two resources is vigorously pursued, they could fulfil an important bridging function until clean fuel technology and that of other renewable sources have matured enough to provide a bigger share of world energy supply. In two decades, hydro- and geothermal power could reduce carbon dioxide emissions from energy production substantially.

With increasing environmental awareness and the importance of keeping the environment healthy, investors have continually come under pressure to ensure that their undertakings do not pose a threat to the environment. Many nations have passed regulations to safeguard the environment against environmental degradation from industrial and other development activities. As a result, tools such as the Environmental Impact Assessment (EIA) in environmental and related legislation have been evolving. Most power generation facilities fall into the category of activities that require an EIA before implementation.

In light of the above, this report will look at impacts of hydropower and geothermal electric power developments in general, the regulations governing their development, the percentage of global contribution of the two electricity sources, and relative contribution to power needs in Kenya and Iceland. It will focus on one geothermal power and one hydropower project in each country; mitigation measures undertaken; comparisons between the projects; and finally, some recommendations.

2. GLOBAL AND REGIONAL CONTRIBUTION OF GEOTHERMAL AND HYDROELECTRICITY AND FACTORS AFFECTING DEVELOPMENT

2.1 Global contribution

Globally, 38% of all the electricity produced is derived from coal, 18% from hydropower, 18% nuclear, 16% natural gas, 9% oil, and only 2% from renewable sources such as biomass, geothermal, wind, solar and tidal energy. This implies a high emission of undesirable gases from the burning of fossil fuels. By the turn of the century, it is expected that renewable sources will provide 30–80% of total primary energy (Fridleifsson, 2003). The high proportion of global primary energy consumption that currently comes from fossil fuels, is shown in Table 1. Every effort must be made for change if the goal of providing cheaper and cleaner energy is to be met in the near future and a major promotion is needed for use of renewable and cleaner sources, such as geothermal power and hydropower. Unfortunately, most of the industrialized nations derive the main part of their electricity from fossil fuels, with concomitant emission of pollutant gases.

2.2 Main factors affecting development of geothermal and hydropower resources

2.2.1 Cost in relation to other energy sources

When compared to other renewable sources of electricity, the cost is lowest for hydropower and geothermal power, followed by windpower and biomass, as indicated in Table 2. It is predicted that prices for hydropower will remain the same, geothermal power and biomass will fall slightly, while that of solar power will fall significantly in the near future. The cost of production per kWh for hydropower is expected to be slightly higher than that of biomass and geothermal power, but fairly comparable. Hydropower and geothermal power are commercially competitive with fossil fuels. Also, as shown in Table 2, hydropower contributes the greatest proportion of electricity amongst the renewable sources, followed by biomass and geothermal power.

TABLE 1: World primary energy consumption (source Fridleifsson, 2003)

Energy source	**Specific source**	**Primary energy**		**By source (%)**
		(EJ)	**(%)**	
Fossil fuels	Oil	143	36	80
	Natural gas	85	21	
	Coal	93	23	
Renewables	Traditional biomass	38	10	14
	Hydro, geothermal, wind, solar, tidal	18	4	
Nuclear	Nuclear	26	6	6

TABLE 2: Renewable energy sources (electricity) cost per unit in 1998 (source Fridleifsson, 2003)

Type	**Production**		**Investment cost**	**Price**	**Future cost**
	(TWh)	**(%)**	**(US$/KW)**	**(US¢/KWh)**	**(US¢/KWh)**
Hydro	2,600	92.0	1,000 – 3,500	2-10	2-10
Biomass	160	5.53	900 – 3,000	5-15	4-10
Geothermal	46	1.63	800 – 3,000	2-10	1-8
Wind	18	0.64	1,100 – 1,700	5-13	3-10
Solar		0.05			
-photovoltaic	0.5		5,000 – 10,000	25-125	5-25
-thermal el.	1		3,000 – 4,000	12-18	4-10
Tidal	0.6	0.02	1,700 – 2,500	8-15	8-15

2.2.2 Toxic gaseous emissions

Besides cost considerations of energy sources, environmental concerns have become crucial in evaluating alternative energy sources. Of great concern are the emissions of the greenhouse gases responsible for global warming, such as carbon dioxide (CO_2) and methane (CH_4), among others. Other gases from burning of fossil fuels are sulphur dioxide (SO_2) and nitrogen oxides (NO_x). SO_2 is considered responsible for the formation of acid precipitation, while NO_x combines photochemically with hydrocarbon vapours to form ground-level ozone, which harms crops, animals, and humans.

Generation of electricity from hydro, geothermal, solar, wind and other renewable sources results in less emissions compared with coal, petroleum and methane (natural gas). There are fewer and more easily controlled emissions from geothermal power (Hietter, 1995). Hydropower reservoirs, like natural lakes, emit greenhouse gases (CO_2) due to the decomposition of vegetation, but the scale of these emissions is highly variable and more research on a case-by-case basis is needed (Canhydropower, 2003). The emissions depend on the area and amount of vegetation before impounding. Sources such as solar and wind power emit small amounts of CO_2. A comparison of gaseous emissions from different power sources are given in Table 3.

TABLE 3: Comparison of emissions from different power sources (Reed and Renner, 1995)

Emissions (kg/MWh)	**Geothermal**	**Coal**	**Petroleum**	**Methane**	**Hydro**
Sulphur dioxide (SO_2)	0.03	9.23	1.92	0	0
Oxides of nitrogen (NO_x)	0	3.66	1.75	1.93	0
Carbon dioxide (CO_2)	0.48	990	839	540	0.45

Geothermal power plants emit only a small fraction of sulphur compared with fossil fuels. The source is hydrogen sulphide (H_2S), commonly found in geothermal steam, which is oxidized to SO_2 in air. Geothermal power and hydropower stations emit no NO_x. The small amount of ammonia found in geothermal sources is oxidized to harmless nitrogen and water. CO_2 emissions range from zero in binary plants, to 0.48 kg/MWh of electricity produced using flash technology. Hydropower plant emissions range from 0 to 0.45 kg/MWh, while solar and wind power plants emit 0.02–0.29 kg/MWh and 0–0.1 kg/MWh, respectively (after Hunt, 2001).

2.2.3 Land requirement in relation to other energy sources

Land needs for different types of power projects depend on size of the developments and technology used, among others. All the developments need land for powerhouses and associated buildings. For geothermal power, land is disturbed by well-pad preparation, road construction and pipelines (fuel acquisition), in addition to office buildings. However, this is minimal. The average geothermal plant occupies about 400 m^2 per gigawatt hour for 30 years (Reed and Renner, 1995). Land requirements for oil and gas are similar to those for geothermal power. However, nuclear and coal power plants require larger areas for the mining space and safety buffer zones.

Hydropower, in contrast, can occupy large areas where reservoirs are used for water storage, thus displacing people in populated areas. This has partly led to campaigns against such development. The construction of medium-sized plants of the run-of-the-river type without large reservoirs does not create such problems. However, most of the plants are located in remote, uninhabited areas and positive impacts outweigh negative ones.

2.3 Contributions of geothermal power and hydropower in Iceland and Kenya

Hydropower and geothermal power contribute the greatest bulk of electricity in Kenya and Iceland. In Iceland, hydropower contributes 84.1%, geothermal power 15.8%, while only 0.1% comes from fossil fuel (Fridleifsson, 2000b). In Kenya, 74.2% of the electricity comes from hydropower and about 8% from geothermal; while the rest comes from wind, diesel, and thermal (KenGen, 2003). Thus, their importance in the economic and social development cannot be underestimated. There is still a great potential of geothermal resources in Kenya. However, 70% of the Kenyan energy needs come from burning of biomass (Kenya Energy profile, 2003). This leads to degradation of the environment through deforestation, consequent soil erosion and degradation, biodiversity loss and undesirable gas emissions, which cause respiratory problems in the users.

3. ENVIRONMENTAL LEGISLATION AND IMPACT ASSESSMENT

Environmental Impact Assessment (EIA) is a fundamental development component in most countries today, and even in countries that do not have environmental regulations, multilateral financial institutions have made EIA mandatory before lending. Thus, environmental legislation has become a crucial component, alongside finances and other factors in development of projects.

Environmental regulations of different countries are remarkably similar. Most require an environmental analysis of proposed power projects, as well as having specific regulations defining quantities of pollutants that may be emitted to the atmosphere or discharged to land and water. The analysis usually comes with a report referred to variously as Environmental Assessment (EA), Environmental Impact Assessment (EIA), Environmental Impact Statement (EIS), or Environmental Impact Report (EIR) (Hietter, 1995). Major variations exist in terms of agencies involved and time required for the process to be completed.

The purpose of the EIA is to ensure that potential impacts are foreseen and addressed at the earliest possible opportunity. It also provides information that helps in proper planning and should provide an opportunity for stakeholder involvement.

3.1 Environmental legislation of Iceland and its role in power development projects

In Iceland, there are a number of laws addressing geothermal development (Andrésdóttir et al., 2003). These include the following:

1. *Planning and Building Act no. 73/1997.* The Act states that in order to obtain development permits, substantial development projects shall be in accordance with development plans and decisions on environmental impact assessment (EIA).
2. *Research and Use of Underground Resources Act no. 57/1998.* The Act requires the developer to apply for an exploration permit before starting further research and drilling of exploration wells, and utilisation permit before constructing a power plant.
3. *Nature Conservation Act no. 44/1999.* According to the Act, certain landscapes and habitats enjoy special protection. Amongst these are hot springs and other geothermal sources, surface geothermal deposits, volcanic craters and lava fields, all being frequent features of high- temperature geothermal areas.
4. *The Energy Act no. 65/2003.* The Act requires that developers planning to exploit geothermal resources for producing more than 1 MW electric power must apply for operation permits.

The Environmental Impact Assessment Act no. 106/2000 deals with all projects that may have impact on the environment in Iceland and went into effect in June 2000. Legislation on environmental impact assessment was first passed in Iceland in 1993. The main aim of the new Act is to ensure that environmental impacts of projects likely to have significant effects on the environment, natural resources or community are assessed before any permission is given for implementation. High priority is given to public review, unlike the earlier Act, and to cooperation among different groups and the developer. The main changes from the earlier Act are that responsibility for the screening process has been transferred from the Ministry of Environment to the Planning Agency, and a new formal scoping process has been introduced whereby the developer prepares and submits an EIA programme for the proposed project to the Planning Agency as early in the procedure as possible (Thors, 2000). Thus, the Planning Agency (Skipulagsstofnun) monitors the application of law and regulations on planning, building, and EIA.

The Minister for Environment has supreme control of planning and building under the Planning and EIA regulations. The assessment must be part of a planning process. A regulation supplementing the Environment Act lists project categories requiring an EIA. Other projects that may or may not be subject to an EIA depending on their magnitude are listed in Appendix 2 of the regulations. This includes drilling of production and research wells in high-enthalpy fields, and plants for electricity, steam and hot water, hydropower plants with installed capacity of 100 kW or more, or geothermal power exploitation of 2,500 kW or more. When a project falls in one of these categories, the executing party is required to prepare a report, the environmental impact statement, following a detailed procedure, as outlined in the regulations, including a comparison of viable options to inform the Planning Agency of the intended project. After evaluation, the agency decides whether the project is exempted or requires an EIA. Figure 1 shows the process for an EIA in Iceland. If a decision is made that an EIA is required, a licence is issued and the project proponent undertakes the EIA, including all the procedures shown in Figure 1.

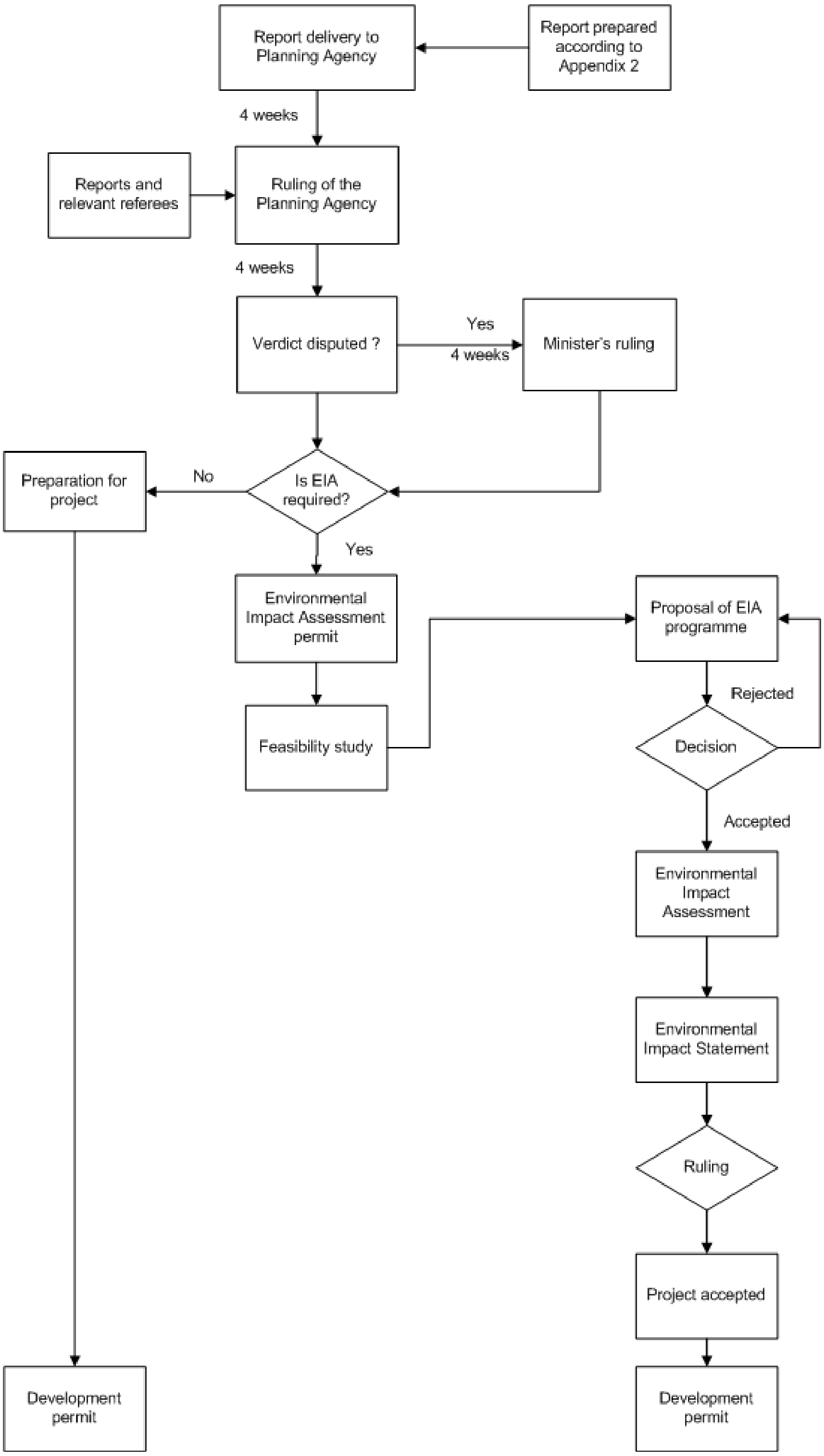

FIGURE 1: Regulatory framework in Iceland

3.2 Environmental legislation of Kenya and its role in project development

The Kenyan environmental legislation is still in its infancy. The Environmental Management and Coordination Act was passed in 1999. Before then, environmental matters were addressed by different Acts in the various sectors, such as agriculture, forestry, physical and land use planning, water and other resources. The 1999 Act deals with environmental matters in a holistic manner.

From the early 1990s, major projects – especially those that relied on financing from multilateral financial institutions such as the World Bank and the International Monetary Fund – were subject to EIA as a primary precondition for funding. Therefore, all power development projects in Kenya implemented after 1991 had EIAs done before implementation. However, the public had little awareness of the process and thus made no contribution. The new Act requires public participation, there is greater scrutiny, and there are well defined implications in case the law is not followed.

The Act contains twelve sections, with section six dealing with EIA. Other sections deal with environmental audit, monitoring, protection, conservation, quality standards, restoration, conservation easements and offences, among others. In addition there are schedules, one of which (Schedule 2) outlines the type of projects for which EIA is mandatory. Thus, any development projects, including hydropower and geothermal power plants, that fit a category listed in Schedule 2 have to be subject to EIA. All the sections affect projects at different stages of implementation and understanding the entire Act is important for project developers.

The National Environmental Management Authority (NEMA) is the body charged with ensuring the proper administration of the Act through supervision and coordination of all environment management activities being undertaken by the lead agencies. NEMA promotes the integration of environmental considerations into development policies, plans and programmes, while ensuring sustainable utilization of resources for the improvement of the well-being of the people. EIA is one of the vital environmental planning and management tools available to NEMA. The EIA application for the licence process is shown in Figure 2.

4. GEOTHERMAL ELECTRIC POWER DEVELOPMENT

4.1 General environmental impacts due to geothermal electric power development

Geothermal power development, though dubbed a "clean energy" source, has some negative impacts associated with its development, although most of them can be mitigated. Most of these environmental impacts are associated with high-temperature systems, but there are potential impacts in both low- and high-temperature systems. While some impacts can be mitigated successfully, others may not, and may be permanent. The impacts shown in this section are based extensively on Hunt (2001).

Destruction of forests and soil erosion. These impacts are due to creation of access and field development. Construction of roads to drilling sites can cause damage to forests and vegetation, which in the tropics can lead to soil erosion and large amounts of silt being washed down by streams and rivers draining the development area. This may in turn affect aquatic organisms downstream in rivers and coastal waters near river mouths. Silt deposits near river mouths may raise the river bed, thus making the surrounding area susceptible to flooding during high rainfall and interfering with navigation.

Noise. Drilling involves noise, fumes, and dust, which can disturb animals living nearby. Site topography and meteorological conditions influence noise levels, which vary from 120 dB(A) for air drilling (reduced with muffling) and well discharge; 70–110 dB(A) for well testing (if silencers are used); 90 dB(A) for heavy machinery during earth movement; 85 dB(A) for well bleeding (reduced by muffling); and 45–55 dB(A) for diesel engines used for operating compressors (if suitable muffling is used). The pain threshold is at 120 dB(A) (at 2 to 4,000 Hz).

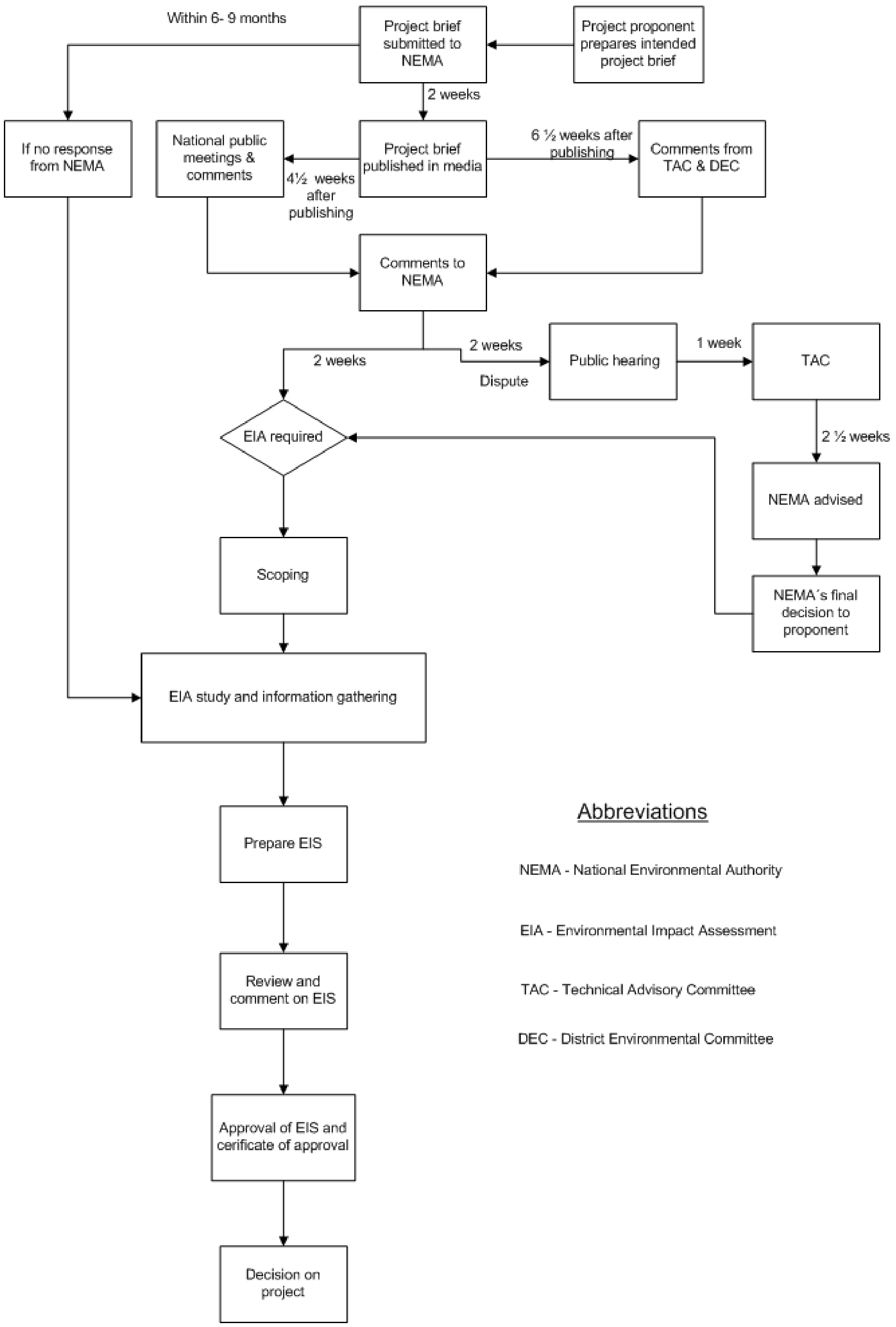

FIGURE 2: EIA process in Kenya

Extraordinary lighting. Continuous drilling activities involve powerful lighting to illuminate the workplace at night. This can disturb local residents and animals (both domestic and wild).

Disposal of waste drilling fluid. During drilling, wastes are produced in the form of drilling mud, petroleum products from lubricants and fuels. Drilling mud is alkaline and can contain chromium and many other chemicals (Brown, 1995). Drilling mud that is not lost in circulation is collected in drilling sumps and requires proper disposal. In the past, it was common practice to discharge waste fluids directly into nearby waterways.

Alteration of thermal features. Many high-temperature geothermal systems, in their unexploited state, are manifested at the surface by thermal features such as geysers, fumaroles, hot springs, hot pools, mud pools, sinter terraces, and thermal areas with special plant species. Most of the features are of tourist and cultural importance. Historical evidence shows that natural thermal features have often been severely affected during the developmental and initial production phases due to decline in reservoir pressure.

Ground deformation. Reduction in reservoir pressure due to fluid withdrawal may result in reduction of pore pressure leading to compaction of rock formations having high compressibility and subsidence at the surface (vertical movement) as well as horizontal movement. This can have serious consequences on the stability of pipelines, drains, and well casings in geothermal fields.

Ground temperature changes. Fluid withdrawal and mass removal from the geothermal reservoir in liquid-dominated systems results in the formation and expansion of a two-phase zone in the upper part of the reservoir which may alter heat flow as a result of more steam formation. This may lead to increased temperature conditions which stress vegetation and sometimes kill it.

Waste liquid disposal. Geothermal energy development brings to the surface a large amount of waste fluids. This is disposed of by putting it into waterways or evaporation ponds or injecting it deep into the ground. The latter method prevents environmental problems unlike surface disposal. Large amounts of hot fluid may cause physiological stress in plants and animals leading to death or displacement. The chemical compositions may affect soil microbes and other small fauna. It may also cause chemical poisoning of species in food chains such as fish, birds, and animals living near water. It may also contaminate ground water. Most of the chemicals are in solution but some accumulate in the river or lake bottom sediments and may be taken up by aquatic vegetation and fish (Webster and Timberly, 1995) and move up the food chain into birds and animals close to the river.

Induced seismicity. Geothermal fields, especially the high-temperature ones, usually occur naturally in areas of high seismic activity. This is because they lie in tectonically active regions where there are high levels of stress in the upper parts of the crust manifested through faults and many earthquakes. Studies have shown that exploitation can increase the number of micro earthquakes.

Waste gases. Normally, low-temperature systems do not produce gases that cause significant effects on the environment. However, in high-temperature fields, power generation from standard steam-cycle plants may release non-condensable gases (NCG) and fine solid particles into the atmosphere (Webster, 1995). The most predominant are CO_2 (greenhouse gas) and H_2S. Besides affecting plants and animal directly, the gases may generally affect the microclimate of the area by increasing fog, clouds, or rain depending on the rainfall, topography and wind patterns. This occurs where there are large power projects in high-temperature fields.

H_2S is a nuisance because of its rotten-egg-like smell. It can cause fatality at high concentrations (700 ppm). When dissolved in water aerosols, it reacts with oxygen to form oxidized sulphur compounds some of which have been found to be components of acid rain.

Carbon dioxide (CO_2) is the most abundant of the NCG gases. It is found in all fields but most prevalent in reservoirs containing sedimentary rocks and especially those with limestone. It is colourless, odourless, and heavier than air and can thus accumulate in topographical depressions where the air is still. It is not as toxic as H_2S, but at higher concentrations it can be fatal due to alteration of blood pH. The amount of CO_2 discharged per unit mass tends to decline with time due to degassing of the deep reservoir fluid and a decline in heat transfer from the formations.

Other geothermal gases are ammonia (NH_3), traces of mercury (Hg), boron vapour (B), and hydrocarbons such as methane (CH_4). Ammonia can cause irritation of nasal passages, eyes and respiratory tract at concentrations of 5-32 ppm. Mercury, if inhaled, can cause neurological disorders. Boron causes irritation to the skin and mucus membranes and is phototoxic at low concentrations. These metals may be deposited on the soil, and leach into groundwater causing contamination. However, they are usually emitted in trace quantities thus not posing any hazard to human health.

Impacts on landscape. Geothermal energy has to be utilised relatively close to the resource to reduce temperature and pressure losses, thus disruption of the landscape is concentrated (Brown, 1995). At the site, land is required for well pads, fluid pipelines, the power station, cooling tower and electrical switchyard. Total area covered by the development is higher than for the individual component requirements. Effects of drill rigs are temporary. Mostly the land between well pads and pipes may continue to be used for other purpose although at some sites the nature of the development may make this impractical. Impact on land depends on type of development and original land use.

Catastrophic events. These may occur during construction or operation of a large-scale geothermal power project. Some of these events are landslides especially in high and steep areas. These may be set off naturally by heavy rains or earthquakes or as a result of construction work. These are rare, but when they occur, then results may be catastrophic. Other events include hydrothermal eruptions, which mainly occur in high-temperature fields when steam pressure exceeds the overlying lithostatic pressure, and then the overburden is ejected resulting in the formation of a crater.

Social impacts. Social impacts are the effects of the society in general and to the host community in particular (De Jesus, 1995): These include the following:

Relocation of affected communities, if the project is located in habited areas, leads to transferring of the people to new environments that may be incompatible leading to lower productivity and destruction of community structures. Increase in local population due to migrant workers coming to the project may cause a strain on the available resources and lead to conflicts.

Due to the constructions, landscape alteration and its effects on hydrology, combined with the influx of migrant workers health of the people may suffer as a result of increased incidences of epidemics and communicable diseases. However, the project may also result in increased job and business opportunities thus making use of the local skills, improving the incomes and improving the living standards of the people. It is thus vital, to avoid conflicts with local communities, by seeking acceptability from the community before the commencement of the project.

4.2 Case studies on geothermal electric power development in Kenya and Iceland

The two case studies are Olkaria 1 in Kenya and Nesjavellir in Iceland. These were constructed at different times and are already operational. Olkaria 1 is located within the East African Rift Valley in Kenya, while Nesjavellir is located in SW-Iceland.

4.2.1 Olkaria 1 geothermal power project in Kenya

Olkaria 1 geothermal power project is located in the Hell's Gate National Park within the Rift Valley which is part of the Great East African Rift Valley as shown in Figure 3. It is within a semi-arid area, 120 km northwest of Nairobi (Kenya's capital city) and 5.3 km south of Lake Naivasha, a water body of great importance. The power station is located in the Olkaria East field which is within the Greater Olkaria high-temperature field. This project is owned by the Kenya Electricity Generating Company (KenGen).

Utilization of the field began in 1981 after studies carried out in the early seventies confirmed that it could support 45 MWe production for 28-32 years. This was followed by exploratory drilling from 1974 to 1977, followed by production drilling. Initially a 15 MWe unit was installed in 1981, a second in 1983 and a third in 1985. The installed capacity of the power project is 45 MWe. The depth of production wells ranges from 1000 to 2500 m and production temperature ranges from 240 to 350°C.

During implementation of this project, there was no environmental law for guidance and no mandatory Environmental Impact Assessment process project proposals. The project activities were however bound by and undertaken in line with a memorandum of understanding signed between KenGen and the Kenya Wildlife Service (KWS), who are custodians of all national parks and nature reserves in Kenya. However, from the early 1990s, most power projects were subject to the EIA process which are a mandatory condition by financiers such as World Bank, International Monitory Fund (IMF) and regional financial institutions.

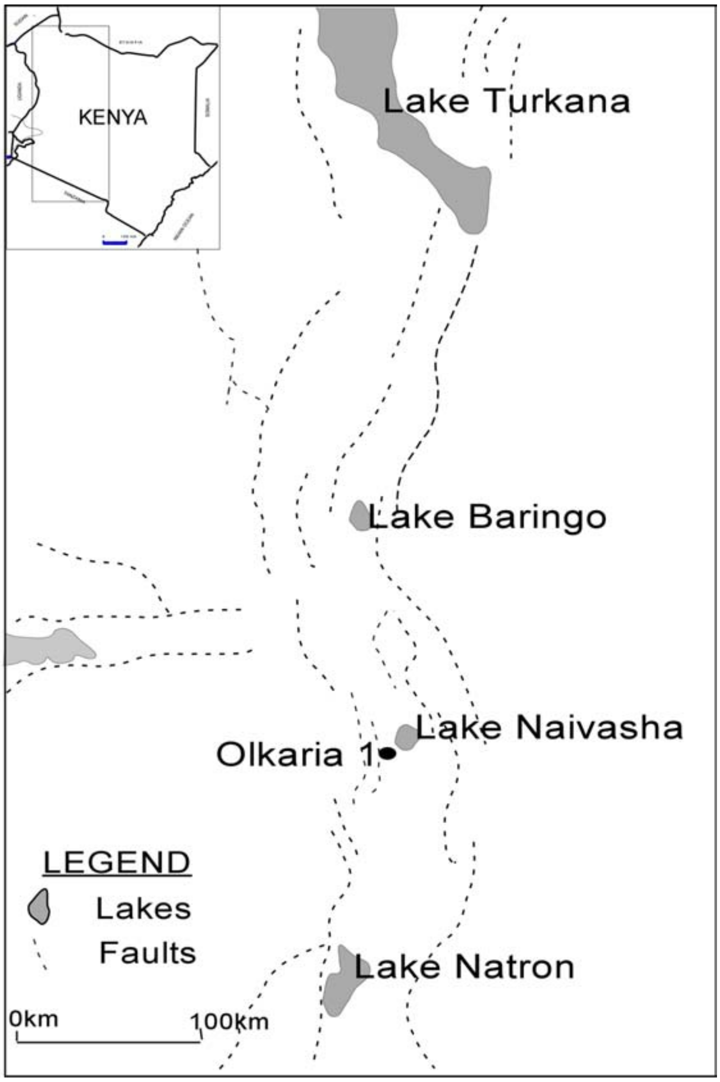

FIGURE 3: Location of the Olkaria 1 power plant in the East African Rift valley

4.2.2 Nesjavellir geothermal electric power project in Iceland

Nesjavellir power plant is located within the Nesjavellir geothermal field, which is along the northern margin of the high-temperature thermal anomaly associated with the Hengil central volcano in SW-Iceland, as shown in Figure 4. The power plant is operated by Orkuveita Reykjavíkur (Reykjavík Energy). Annual precipitation averages 2,780 mm/year and mean annual temperature is 2.9°C. The project is located southwest of Lake Thingvallavatn which is under protection, and activities of the power project may affect the lake since waste brine is disposed of in an open stream which disappears underground and emerges as springs at the lake. The vegetation in the area is characterised by mosses, grasses, shrubs, and woodland in some areas. The vegetation is poor due to over-utilization in the past and soil erosion rampant in the upper areas due to the sensitivity of the soils.

The depth of production wells for electricity production ranges from 1000 to 2200 m and the temperature in the production wells is in the range 320-360°C. The electric power plant has an installed capacity of 90 MWe. Prior to the commissioning of the electric power plant in 1998, Nesjavellir produced 200 MWt of hot water for district heating purposes only for Reykjavík. In 1998, two 30 MWe turbine generators were installed and modifications made to the thermal plant (Gíslason, 2000). Another 30 MWe turbine generator was installed in 2000.

The concept of the plant was to co-generate electricity for the national grid, and water for district heating. Exhaust steam is used to preheat fresh water in condensers. The separated geothermal water is used in heat exchangers to heat preheated water to the required temperatures. The heated water is then treated in de-aerators to suit requirements of the distribution system. Thus, water and steam are used in the most economic way while lowering the temperatures of waste water considerably, reducing thermal impacts on the environment.

It is worth noting that the establishment of the first phase of the electric power plant was not subjected to the EIA process. However, the installation of the additional 30MWe turbine generator in 2000 had an EIA undertaken according to the new EIA Act of 2000. This resulted, among other things, in the implementation of a systematic monitoring system of the impacts of the power station.

FIGURE 4: Location of Nesjavellir power plant and lakeshore springs affected by the plant

4.3 Comparisons and contrasts of impacts of Olkaria 1 and Nesjavellir electric power projects

After critically looking at the impacts of the two power plants and mitigation measures, it is clear that there is a lot of similarity in the two projects especially in the impacts. However, there are differences as well, as discussed below.

4.3.1 Implementation in relation to regulations

The Olkaria 1 power station was constructed long before enactment of the Environmental Management and Co-ordination Act, part of which requires EIA before implementation. It was also undertaken when the financiers were not strict on environmental impacts and did not make EIA mandatory. As such, no EIA was conducted and management practices were guided by the memorandum of understanding between Kenya Wildlife Service (KWS) and KenGen and KenGen's own initiative to undertake suitable environmental practices. The enactment of the Environmental Act in 1999 ensures that any developments thereafter have to be subjected to the new requirements. It is probably out of awareness by the new law that a local community has been raising claims for compensation. In the case of Nesjavellir, the first phase of the electric power station was not subjected to an EIA, however, the upgrading of the power station from 60 to 90 MWe required the undertaking of EIA according to the Environmental Impact Assessment Act no. 106/2000. This has made environmental management easier, more systematic, and clear.

4.3.2 Location and effects on management

The locations of the power stations are in distinctly different settings. The location of Olkaria 1 within a national park poses restrictions and implementation of mitigation measures. Only animals and plants indigenous to the park can be used in rehabilitation or conservation efforts. This presents a major challenge in that some of the species are slow growing compared to the exotics. Local *Acacia spp* and star grass are used in rehabilitation activities (Kubo, 2001). The tree seedlings are raised in the project tree nursery. Any unwanted species introduced into the park due to KenGen's activities have to be removed. These restrictions also mean that future development will largely be controlled by decisions of the KWS due mainly to increase in negative visual impacts. In contrast, the management of Nesjavellir has the discretion to choose what to use in their rehabilitation processes because the power plant is not located in as sensitive an environment and further, the land belongs to the power company. The company has had an annual re-vegetation programme of areas between 150 and 400 m above sea level since 1989 using tree and grass species of their choice. A total of 225,000 tree seedlings have been planted and 240 tonnes of fertilizers used in grassing the area (Thorsteinsson, 2002). Expansion will not be restricted as long as it is within the company's boundaries and the law.

4.3.3 Water sources and usage

Drilling of a typical production well of 2200 m depth requires 100,000 m^3 of water while completion and well testing may require up to 10,000 m^3. In Nesjavellir, in addition to these occasions, water is continuously being used for cooling purposes due to the absence of cooling towers unlike in Olkaria 1 where water for cooling is only used at the initial stages of the cooling process. This requires about 1800 kg/s of cold water. The cooling system recycles the water, thus only little amounts need to be added to the system to make up for the losses due to evaporation. In Olkaria, water is obtained from Lake Naivasha which is also relied upon by many other water users. This led to the formation of the Lake Naivasha Riparian Association (LNRA) to ensure sustainable use of the lake water through adherence of Lake Naivasha management plan by all the members. Nesjavellir obtains its water from boreholes near Lake Thingvallavatn. No problems have been experienced, but ground water levels have to be monitored regularly.

4.3.4 Waste water and thermal effects

In most cases, unless water is used in a cascaded manner, wastewater after electricity generation has temperatures above 100°C. This, in addition to the chemical components of the water, may have detrimental impacts on flora and fauna if released on the surface. In Nesjavellir, waste fluid is disposed of in a surface stream which forms some lagoons and disappears underground to emerge into Lake Thingvallavatn through some springs which, according to some studies, may be affecting the lake biota. Some of the water from the electric power plant is released at 100°C and the rest at 55°C. Studies on thermal effects of wastewater disposal on affected springs emerging into Lake Thingvallavatn have shown a temperature increase of 10 – 21°C in Varmagjá and 13 – 18°C in Eldvík, which may affect the lake biota (unpublished information from Reykjavík Energy). The effects are, however, likely to be localised during calm weather, otherwise wave action will likely mix up the cold and warm water. An ongoing study by Reykjavík Energy is looking into the effects of steam on surrounding vegetation (especially mosses) around the well protection cellars after vegetation changes were noticed after well blowing tests. In Olkaria 1, during well testing, it has been noted that the hot wastewater and steam sprayed on the surrounding vegetation causes physiological stress to the plants due to scalding. Sometimes this is only temporary since the vegetation regenerates once it rains after the testing is over. Where the vegetation does not regrow, revegetation has to be done using indigenous species only.

Studies of chemical composition effluents (1983-1984) by Ólafsson (1992) from four drill holes within Nesjavellir geothermal field indicated high arsenic concentrations (5.6 – 310 μg/l). During the initial thermal plant development (1984 – 1991), arsenic concentrations rose considerably in two exothermally affected springs, Varmagjá (0.6-2.2. μg/l) and Eldvík (0.7-4.7 μg/l). The studies concluded that arsenic was the only element of concern within safe limits for fresh water biota and precautionary monitoring measures were recommended. Other trace elements were low.

According to (Wetang'ula and Snorrason, 2003), arsenic concentrations in Eldvík spring, in summer 2000, were slightly above the recommended 5.0 μg/l Canadian water quality guideline for protection of aquatic life. It was 5.97 μg/l. Other trace elements were below recommended guidelines except for aluminium. Its concentration in separator water was 1670 μg/l and 347 μg/l in the Eldvík spring (above the recommended 5-100 μg/l). Such levels are toxic to aquatic life, but this depends on the aluminium form in solution, Al^{+3} being most toxic. The concentration was also above the lowest biological risk level according to the Swedish criteria of 80 μg/l for protection of some fish such as brown trout (Löfgren and Lydersen, 2002). Other trace element levels were low in biological samples showing no difference between Varmagjá and Vatnskot (control site). In 2000, lead (Pb) in lake sediments was found to be in the significantly high levels of 42 μg/l at the control site which was 20 times the background level. Lead (Pb) was also found in relatively higher samples in the control site in 1995 and 2000. This could be attributed to sources in lead weights and strings of fishing gear left lying or lost at the site. Recommendations for reinjection were made.

In Olkaria, wastewater is easily managed through reinjection thus avoiding environmental problems that would have been caused by chemical components contained in the wastewater. Quarterly monitoring of wastewater, sludge, vegetation and lake water, indicates low concentrations within the following ranges: arsenic (0.01 – 0.0017 ppm) in lake water and sludge; cadmium (0.01 – 0.123 ppm) in lake water and soil; lead (0- 3.05 ppm) in lake water and soil; mercury (0-0.01 ppm) in other samples, lake water and sludge. These elements among others are monitored due to their effects on humans, plants and other animals.

4.3.5 Solid waste

These include drilling mud, sludge, cement waste, wood and maintenance debris (metal). In Olkaria 1 most solid waste is taken to a landfill near well OW–03 which is audited regularly. Household and office wastes are handled by a contracted waste handling company. At Nesjavellir, drilling waste is collected in tanks installed to separate drilling mud from the water after which it is disposed of accordingly. Other solid wastes are stored in special bins and collected regularly by a waste handling company that has been contracted by Reykjavík Energy.

4.3.6 Visual impacts

The visual impacts at Nesjavellir are more conspicuous due to the nature of the landscape, vegetation type and density. The vegetation is comprised mainly of mosses and lichens which provide no cover to the pipeline system. In denser vegetation, pipelines are shielded from public view, especially from a distance, as is the case in most places in Olkaria 1. Colouring of pipes to closely blend in with the surroundings is one way of mitigating the negative visual impacts. In the Nesjavellir case, there is a major contrast between its whitish colour and the blackish surrounding lava; however, the pipelines blend in quite well with the snow covered landscape during the long winters. In Olkaria 1, the colouring is whitish which is a major contrast with the green vegetation, but future changes are towards a dull green colour which will blend better. The design of laying down the pipeline in Olkaria 1 is influenced by migratory routes among other factors so as not to prevent disruption of wildlife migration, unlike in Nesjavellir. Other visual impacts are due to transmission lines and associated structures. In Olkaria 1, prior discussions had to be done to avoid sites of spectacular scenery and birds' migratory routes. Drill rigs cause negative visual impacts in both cases, but they are usually temporary.

4.3.7 Social impacts

There have not been any negative social problems associated with Nesjavellir since the power plant is located on private land which was formerly owned and used by one farmer. Thus, issues of compensation were easily dealt with. The plant provided access to remote tourist sites through road construction, and also provided in itself an attraction (VGK, 2002). In Olkaria 1, to avoid conflicts of interest on the same land, KenGen and KWS have a memorandum of understanding on what should be done and not. Among the issues agreed upon is ensuring that no exotic animals or plants should be introduced into the area, limitation of vehicular speed, ensuring that the project's activities do not pollute the park among others. This however, restricts and defines the management practices KenGen can undertake. In addition, meetings are held regularly between the two bodies to iron out any problems or discuss issues concerning future developments. The other neighbours are flower and horticultural farmers, ranches and other people all depending on Lake Naivasha for their water requirements. All the stakeholders to the lake have formed the Lake Naivasha Riparian Association to ensure proper management of the lake environment using a prescribed management programme. Regular meetings characterise the association to ensure harmony. In recent times, there have occasionally been claims by the Maasai community for compensation for land, but this has been difficult because the land has always belonged to the government body (KWS). However, every effort is being made to get a lasting solution.

KenGen, through the project, has opened up the area in providing access by means of a paved road; provided an additional tourist attraction feature (power plant); provides free piped water to a local community in the neighbourhood (Maasai); and provided health services from the project dispensary and educational facilities to the neighbouring community.

4.3.8 Surface disturbance

These are mainly caused by construction of access tracks to facilitate surveys, studies, and exploration that precede other major exploitation and construction activities. Other disturbances are as a result of clearing and excavation to provide space for drill pads, access roads, steam and power lines, power station and offices. These activities interfere with the aesthetics and species diversity, reduce wildlife food, and facilitate erosion.

To minimise surface disturbance, Nesjavellir has recently adopted directional drilling. This technology allows drilling more than one well from each drill pad. Steam pipes were installed alongside others already in existence (for thermal plant), and conform to the landscape as much as possible to minimise further impact over a larger area. After construction, completion tracks not required were revegetated. In Olkaria 1, area reduction has only been done by reducing the drill pad area from 5,000 m^2 initially to 3200 m^2 currently. Revegetation is done where necessary and proper and careful survey for road construction done in order to prevent haphazard destruction. Roads that continue to be used are either compacted or paved to prevent soil erosion.

4.3.9 Noise

This is one of the main environmental disturbances during construction and operation phases of geothermal development. Noise intensity is measured in decibels (dB(A)). Drilling noise has been found to rarely exceed 90 dB(A), however, because of regulations, those working usually have to wear protective gear (ear mufflers). This is done both at Nesjavellir and Olkaria 1. The loudest noise has been measured from discharging wells during flow tests, sometimes exceeding 120 dB(A). However, silencers can reduce noise levels to about 85 dB(A) which is at acceptable levels. In Olkaria 1, noise has been monitored for thirteen designated stations and measurements taken twice weekly in all the designated stations. Highest levels were from the power station. At Nesjavellir, noise has been monitored in six stations, the highest level of 92 dB(A) being in the valve house. The levels have not been beyond recommended limits for inhabited areas such as the summerhouses, since these are far from the power station and tourist areas are even further away. Those working within or near noise sources are required to put on proper ear safety gear in both Olkaria 1 and Nesjavellir.

4.3.10 Geothermal gases

Main gases of concern are hydrogen sulphide (H_2S), carbon dioxide (CO_2) and methane (CH_4). At Olkaria 1, mean values of H_2S concentrations vary from 0.15 to 1.25 ppm depending on the site (nine monitoring sites) with the maximum being at the power station at 4.40 ppm. These are low concentrations, however, monitoring continues to be done 3 times weekly near the power station and once per week in other areas. There are thirteen monitoring stations. People and animals are kept from areas of danger by fencing. Concentration of carbon dioxide is low in this field, thus measurements are rarely taken except in geothermal water. Vegetation in the project area acts as an effective carbon sink thus ensuring that CO_2 does not rise to levels of concern. Carbon dioxide concentrations from the fluids range between 200 and 300 ppm.

At Nesjavellir, by 2000, the heat and power plant produced 12,000 tonnes CO_2 and 3,400 tonnes H_2S annually according to Gíslason (2000). About 90% of CO_2 and 75% of H_2S are released to the atmosphere. This translates to 7.2 g CO_2/kWh and 1.3 g H_2S /kWh. According to Ármannsson (2003), the CO_2 emission from the power plant is 26 g/KWh. This is considered within acceptable limits as far as the environment is concerned. Monitoring of H_2S in the atmosphere at Nesjavellir (Ívarsson et al., 1993) confirms that the concentration is highest close to the powerhouse, but there is great variation in concentration at some other sites depending on local weather conditions. Aerated shelters are installed over wellheads to prevent the public from entering borehole cellars where the risk of gas poisoning is greatest. The annual re-vegetation programme within the area helps as carbon sinks, prevents soil erosion, and stabilises soil.

4.3.11 Ground elevation

Geodetic and gravity surveys are undertaken yearly since 1990 in Nesjavellir. The geodetic surveys show no significant systematic changes in elevation at the Nesjavellir area that could be associated with exploitation of the resource according to monitoring results of 1998-2002 by Thorbergsson, (2002). However, though not proven by any facts, it is thought that little movements that may have occurred either laterally or vertically may have been overshadowed by the major movements that have occurred in the Hengil area as a result of the 1998 earthquakes. Gravity surveys have shown no significant changes in the Nesjavellir area as indicated by the monitoring survey results of the 2000-2002 by Magnússon (2002). In Olkaria 1, monitoring of elevation has only been done in the recent few years and no changes have been detected, probably due to the existence of a firm cap layer.

4.3.12 Monitoring

Both Nesjavellir and Olkaria 1 have monitoring programmes on aspects such as H_2S, CO_2, chemical trace elements in fluids etc. The only difference is in the methods and frequency of measurements.

5. HYDROPOWER DEVELOPMENT

It is estimated that one-third of the countries in the world currently rely on hydropower for more than half of their electricity supply (Green Nature, 2003). Largely considered a clean renewable energy source, hydropower has provided many economic and social benefits. Many countries have chosen to develop their hydroelectric resources as a means of improving domestic energy security, providing more energy services, stimulating regional economic development and increasing economic growth. The benefits provided by hydroelectric development in the different countries were not achieved without some negative economic, social, and environmental impacts. Economically, most of the large projects have been blamed for increasing the debt burden in developing countries.

5.1 General impacts due to hydropower development

The environmental impacts outlined in the following sections are extensively adopted from the World Bank (2003).

Hydrological and limnological impacts. Damming a river and creating a lacustrine environment has profound impacts on hydrology and limnology of the river system. Dramatic changes occur in the timing of flow, quality, quantity, and use of water, aquatic biota, and sedimentation dynamics in the river basin.

Stream flow: Except for pure run-of-river developments, hydropower projects can cause significant changes in the quantity and quality of stream flow, particularly large impoundment projects. This affects water quality, sedimentation, wildlife, and fisheries; and may limit water use and availability both in the impounded area and downstream. The magnitude of these impacts is largely caused by operational regimes and project design and a diversion scheme can completely stop downstream flow of the dammed river and dramatically increase flow in the receiving water course. For peaking hydro developments, fluctuations of water levels immediately below the dam may be harmful to riverine wildlife or navigation, or it may result in ice jams during wintertime, particularly in cold areas where successful winter operation depends on a solid ice cover.

Groundwater level: Hydropower storage projects can change groundwater levels. The amplitude of change in level decreases with distance from reservoir shoreline, soil permeability, and regional groundwater characteristics. A drop in the water table may be experienced downstream due to reduced aquifer recharge while it may be higher in the vicinity of the foot of the dam as a result of increased hydrostatic pressure. This can affect water availability and quality, vegetation, and land use.

Flood control and hazard: Although a storage hydro development generally improves flood control, there is a risk of flood events in the river and associated safety hazards. This can be due to structural failure and/or leakage in the dam and subsequent release of impounded water; overtopping from a large natural flood inflow; backwater flooding; or a combination of the above. Other potential impacts include floods during construction and prevention of natural floods.

Water quality impacts. A hydropower project on a river may change the physical, chemical, and biological quality of the water flowing in it. The significance of change depends largely on water quality requirements for downstream uses such as protection of aquatic ecology, domestic water supply, irrigation, specific industrial applications (e.g. cooling, food processing, etc.) and recreational use.

In general, most water quality problems are associated with reservoir storage schemes. Impoundment transforms a riverine environment (active) into a lacustrine one (sluggish). These cause changes in water quality.

Chemical changes: Chemical changes in water quality depend largely on the chemistry of the inflowing water, the type of land inundated, the residence time of the water in the reservoir and the reservoir morphology. Increased residence time changes the nutrient content in the water, its mineralization and, thus, the primary biological productivity.

Dissolved oxygen: A sufficient level of dissolved oxygen in river and reservoir water is essential to maintain biological productivity and to prevent anaerobic chemical reactions and decomposition of organic compounds which can lead to the formation of toxic, odorous and corrosive pollutants. Typically, low dissolved oxygen levels can occur in the first few years of operation due to the high oxygen demand due to the decomposition of submerged vegetation and soil but increase rapidly after this demand is met.

Thermal stratification: Thermal stratification in reservoirs is caused by density variations in the water body induced by differences in temperature and other water quality parameters. Water has its maximum density at about 4°C and it decreases at both higher and lower temperatures; the difference causes stratification. Reservoirs tend to undergo stratification if the reservoir depth is more than 10 m and its surface width is less than 30 times the depth, the ratio of inflow to volume is small and the reservoir depth is greater than the light penetration. Thermal stratification affects dissolved oxygen levels, which in turn affects reservoir water quality, functional uses of the reservoir, and flow releases for downstream use.

Pollutants: Pollution of a reservoir by toxic and other compounds depends on many factors. Soil and submerged vegetation become a potential source of heavy metals, pesticides and other pollutants via leaching and decomposition while inflowing water could be contaminated thus polluting the water. Sedimentation (bottom sediments) can be a source of pollution although high sedimentation rates can reduce pollution.

Eutrophication: It is the process of accumulation of reservoir nutrients and resultant changes to the trophic state and biological productivity of the reservoir. There are three principal categories:

- Oligotrophic - poor nutrient content and low biological productivity;
- Mesotrophic - intermediate nutrient content and average biological productivity;
- Eutrophic - high nutrient concentrations and high biological productivity.

Initially, the inundation of a reservoir results in a substantial increase in nutrient and mineral levels, primarily due to decomposition of newly submerged biomass and release from sediments. This can lead to higher biological productivity (beneficial) and/or the proliferation of algae and aquatic plants, reduced water quality, and may cause negative health impacts due to increased disease vector habitat among other effects related to operation of power plant equipment and water flow. Eutrophication is dominant during the early years of the reservoir's lifetime but later stabilisation occurs as the nutrients from this source are utilised.

Sedimentation and ice formation: When sediments flow into a reservoir, due to decreases in flow velocity, the coarser particles deposit first in the upper reaches of the reservoir. Subsequently, the finer materials are deposited further into and along the reservoir bed. Ultimately, such sedimentation will completely fill the reservoir. Sediment deposition into reservoirs leads to loss of storage capacity; damage to or impairment of hydro equipment; bank erosion and instabilities; downstream channel modification; reduced downstream suspended sediment load; upstream aggradation; effect on water quality; effect on waste assimilation; effect on navigation and recreation and on aquatic life.

Ice formation applies to temperate and semi-temperate regions. Three forms of ice can form:

- *Surface ice*, which commonly forms over a reservoir;
- *Anchor ice*, which consists of small ice needles at the bottom of calm shallow open water bodies, and which may form on protective intake screens; and
- *Frazil ice*, which consists of small crystals or needles of ice which can adhere to metal structures that are below 32°F. Ice formation can affect power generation due to reduced flow and structural damage or failure or material fatigue of mechanical equipment due to low temperatures.

Seismic and geological impacts. This affects reservoirs located on geologically unsuitable sites which may also cause landslides around reservoir perimeters. These may be induced by water impoundment and are usually micro in nature. As a result, fault displacements, subsidence or collapse of reservoir floor, creation of new springs and wetlands may occur. The overall effect may be reservoir leakage, reduced reservoir capacity, power generation and downstream water use. Landslides can result from reservoir bank instabilities leading to sudden release of large masses of material into reservoir-generating reservoir waves that overtop the dam, reduce reservoir capacity and interrupt railways and other infrastructures.

Impacts on wildlife and fisheries due to land take. Hydrological projects cause habitat changes, creation and loss of habitat, for terrestrial wildlife, insect life, aquatic ecology and fisheries, reservoir aquatic and down stream aquatic life. Land is taken by submergence, for dam and associated facilities, construction activities and permanently as borrow pits and for human activities such as settlement, cultivation, and industrial development induced by the project. Changes to, or loss of habitat will affect areas used for mating, breeding, nursing, moulting, feeding, and drinking for both resident and migratory wildlife. This may result in significant disruption of ecosystems, causing changes in species diversity and abundance, extinction or reduction of rare species, and proliferation of exotic or competitive species.

Inundation may create wetlands and increase avifauna populations. Reservoir may also provide stable water supply for game and other species, thus increasing species diversity. The new conditions may encourage breeding of certain dangerous insect pests such as mosquitoes, while discouraging breeding of some, such as the river blindness causing black fly.

Impacts of construction. Construction activities during the implementation of a hydro development can result in both temporary and permanent impacts. Typical duration is 5 years, 2 years for mini- and micro-hydro project while mega projects take 6-10 years for completion. Main construction activities include establishing project associated works and supporting infrastructure, construction camps, impoundment, dykes, channels and clearing of vegetation; obtaining raw materials (mining, water abstraction, quarrying and dredging); transporting raw materials, pre-assembled components, machinery and labour to the site; excavation and filling; construction of hydro infrastructure; disposal of construction and domestic wastes; restoration, e.g. resurfacing and replanting of exposed areas. These in turn lead to noise, air, soil and water pollution, visual impacts, health and safety impacts as a result of transmission of communicable diseases and increase of disease carrying vectors due to changed habitat. However, most of these impacts are temporary.

Aquatic ecology and fisheries.
Migratory species: Storage hydro developments alter aquatic environment both in impounded areas and downstream by providing physical barriers in the form of dams to migratory species such as salmon. Run of river developments may also significantly change hydrological flow and present barriers to migration of species. Siting of a hydro development should avoid aquatic resources of high biodiversity value.

Reservoir aquatic life: Key aspects affecting reservoir aquatic life are water quality, reservoir productivity, and turbidity. Changes in dissolved oxygen levels and water temperature are two of the dominant water-quality parameters affecting aquatic species. For example, temperature changes play an important role in the triggering of various stages of metamorphosis (this is also important for other wildlife, particularly insects).

Cold and warm water fish: Cold water resident (non-migratory) fish typically inhabit rapidly flowing streams at relatively high elevations, whereas most warm water fish prefer deep, sluggish streams characteristic of reservoirs, lakes and streams at lower elevations. In general, therefore, the construction of a reservoir at lower elevations will tend to reduce cold water fish habitat, and create habitat for warm water fish. Conversely, high-elevation reservoirs provide good habitats for cold water fish. Some warm water fish consume plants that grow at depths of 3-15 m, depending on the clarity of reservoir water. These plants have a low tolerance to changes in lake depth, therefore warm water fish populations may decline if reservoir water levels fluctuate due to flood control or hydropower requirements. Reservoirs supporting warm water fish must maintain a dissolved oxygen content above about 85% of saturation, and pollutant concentrations must be low.

Downstream aquatic life: Many of the effects on aquatic species occurring in the reservoir are likely to be replicated downstream as the water is discharged. For example, flow changes may alter river bottom habitat and poor water quality may affect particular species directly or indirectly through impacts on food resources. Flow changes may result in a general decrease in species diversity but an increase in the absolute population. During inundation, there will be a period of extremely low flow or even no flow downstream of the impoundment. This will significantly affect or cause complete loss of habitat downstream. Decrease in sediment transport may also have negative impacts on downstream aquatic organisms, through reduced nutrient supply.

Air quality and global warming. Hydropower utilises a renewable and clean resource. If it is used to replace fossil fuel combustion, adverse impacts on local and regional air quality can be avoided. A 1 MWe hydro plant, if operated at a 50 percent plant factor, will reduce combustion of about 2,000 tons of coal annually, with consequent reductions in emissions of carbon monoxide and dioxide; sulphur oxides; nitrogen oxides; particles; metal species and hydrocarbons.

Hydropower development produces less CO_2 emissions. CO_2 emitted from the manufacture of the dam's cement and steel, plus the construction energy is less than 10% of the CO_2 reduction achieved in the first year of generation, compared with a fossil-fuelled equivalent. Greater CO_2 emissions arise from decay of flooded biomass. It is likely that CO_2 produced from large forested hydro reservoirs will be compensated within the first few years of generation.

Social impacts. These are due to displacement due to land take for the project, increased population and competition for resources, danger of increased health problems due to spread of communicable diseases, increased income from employment and increased business opportunities and better living standards.

5.2 Case studies on hydropower development projects in Kenya and Iceland

The two case studies are Sondu Miriu in the western part of Kenya (Nyanza province) and Kárahnjúkar in East Iceland. Both projects are under development at different stages. Sondu Miriu is a medium sized run-of-river type, while Kárahnjúkar is a storage reservoir type. This section will deal with brief descriptions of the case studies, their environmental aspects, and comparisons.

5.2.1 Sondu Miriu hydropower project

Background and features. The Sondu Miriu hydropower project, in Figure 5, is one of the major least-cost projects currently being implemented by the Kenya Electricity Generating Company Ltd (KenGen). It is a run-of-river type and will rely on the flow of the river with only a small storage capacity at the intake (regulating pond). The power is to be fed to the national grid to provide for the country's needs. Construction began in early 1999. Commissioning was to be done by 2003 (KenGen, 2003), but there has been a slow-down in activities due to delayed release of phase 2 funds in relation to allegations raised against the project.

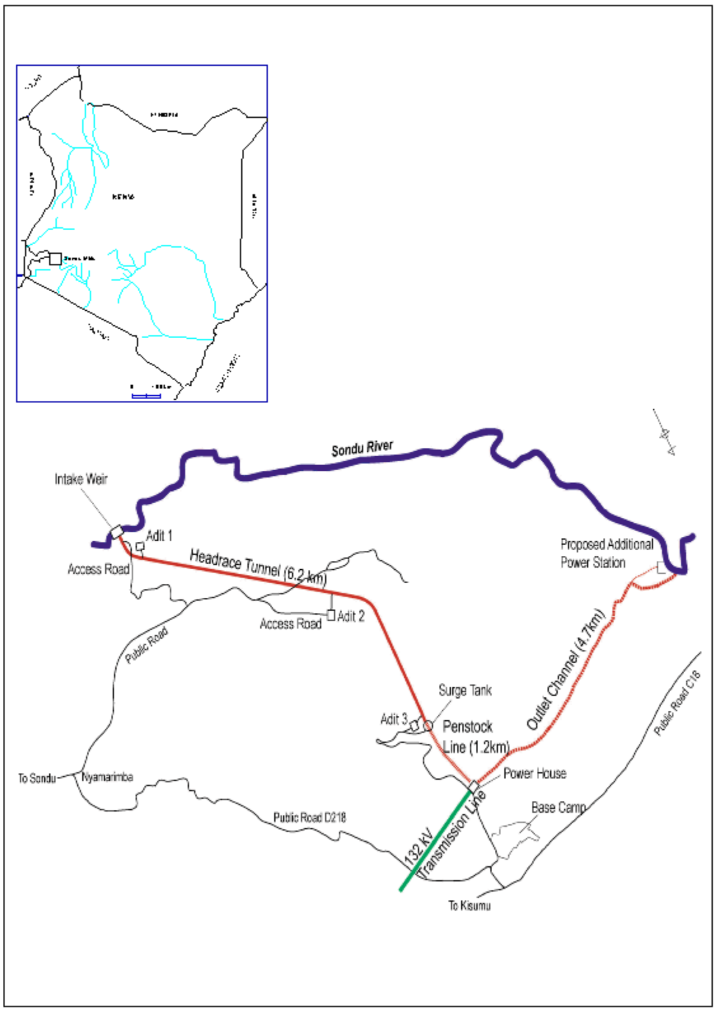

FIGURE 5: Location of Sondu Miriu hydropower project

The project is located in the Nyando district, Nyanza province in West Kenya. It is the first major hydropower project located in Nyanza Province about 60 km south of Kisumu alongside Lake Victoria. When completed, it will have a maximum capacity of 60 MW and a power generating capacity of 330.6 GWh. At the intake, water will be diverted into 6.2 km headrace tunnel at a flow of 39.9 m^3/s, then into a 200 m steel pipeline (penstock), go through the power house and into a 4.7 km open tunnel before rejoining the river course about 13 km down stream of the intake. The electricity will be distributed via a new 49 km transmission line of 135 kV to the Kisumu substation.

The feasibility study for the hydropower project was undertaken in 1985. At that time, it was proposed as a component of an overall basin development programme that included the Magwagwa multipurpose dam and the Kano Plain irrigation project. This multi-purpose programme depended on the construction of a large flow regulating reservoir at Magwagwa, and would have resulted in major changes in the river flow regime, diverting water to another basin. However, this multi-purpose programme was not implemented. Instead, in 1989, Kenya Power Company Ltd (now KenGen) obtained funding from the Japanese government through OECF (now Japan Bank for International Corporation - JBIC) for detailed design work for one component, the Sondu Miriu hydropower project. This component could be implemented independently of the original multi-purpose project, and with fewer negative environmental and social impacts.

JBIC and KenGen are funding the project. In 1997, the first funding block was provided for the initial construction costs and engineering services. The power station was scheduled for commissioning by the year 2003, but there have been some delays. The project is being implemented in two phases in five contracts which include civil works 1, civil works 2, hydromechanical works, generating equipment and transmission line. Work started in March 1999, and construction progressed well to the end of 2000 when some socio-environmental problems arose causing a slow down of the activities. The second funding block to complete the project is yet to be finalized. Work on these contracts was supposed to have started in 2003, but has been delayed.

Residents' attitude towards the project. Prior to the onset of the project, meetings and workshops were conducted for creation of awareness, gauging people's attitude on the project, and educating them on project impacts. These were done in line with World Bank directives to help in making an implementation decision. The overall reaction was very positive. The residents wanted the project, as fast as possible. In general, the residents wanted to stay in the area, in anticipation of the benefits which were expected, particularly in the second phase, with incorporation of an irrigation component. This would also ensure that no conflicts arose due to residents relocating to new areas. Construction started in 1999 and went on well, however, towards the end of 2000, there was a sudden protest against the project by the community and some non-governmental organisations with allegations of environmental pollution, and health problems arising from the project among others. As a result, a technical committee comprising all stakeholders was formed in 2001 to continuously deal with project-related issues and ensure smooth implementation of the project. In the meantime, the financier suspended the disbursement of the phase 2 loan. The technical committee in collaboration with the community has resolved all the critical issues, and a regular environmental impact monitoring programme has been established with reports being prepared quarterly and annually.

5.2.2 Kárahnjúkar hydropower project

Project description and features. The development of the Kárahnjúkar power station entails the harnessing of the glacial rivers Jökulsá á Dal and Jökulsá í Fljótsdal. These rivers originate in the north-eastern region of the Vatnajökull ice cap, and run through the Jökuldalur and Fljótsdalur valleys to their common estuary in the Héradsflói Bay (Landsvirkjun, 2003). The power plant will be located in East Iceland, as shown in Figure 6, and the project developer is the National Power Company of Iceland (Landsvirkjun). Preparatory projects began in September 2002 with the construction of access roads, a bridge, access ramps, and tunnels at the dam site; the construction phase is scheduled for September 2003.

The hydropower station will have an installed capacity of up to 750 MWe, a harnessed flow rate of 126 m^3/s and a power-generating capacity of 5,000 GWh per year. The hydropower project basically comprises the damming of the glacial river Jökulsá á Dal at Mt. Fremri Kárahnjúkur, and the creation of the water-storage reservoir Hálslón (phase 1), which will cover 57 km^2 and hold a usable volume of 2,100 million m^3 based on the lowest water level of 550 m in altitude. Water from Hálslón will be conveyed to the powerhouse through a 40 km tunnel. Another small reservoir, Ufsarlón, will be created by damming the glacial river Jökulsá í Fljótsdal (phase 2). Water will then be diverted from this reservoir through a 13.5 km tunnel to the headrace tunnel coming from Hálslón near Axará river on Fljótsdalsheiði. From the power station, water travels through a tailrace tunnel and canal into the course of the glacial river Jökulsá í Fljótsdal.

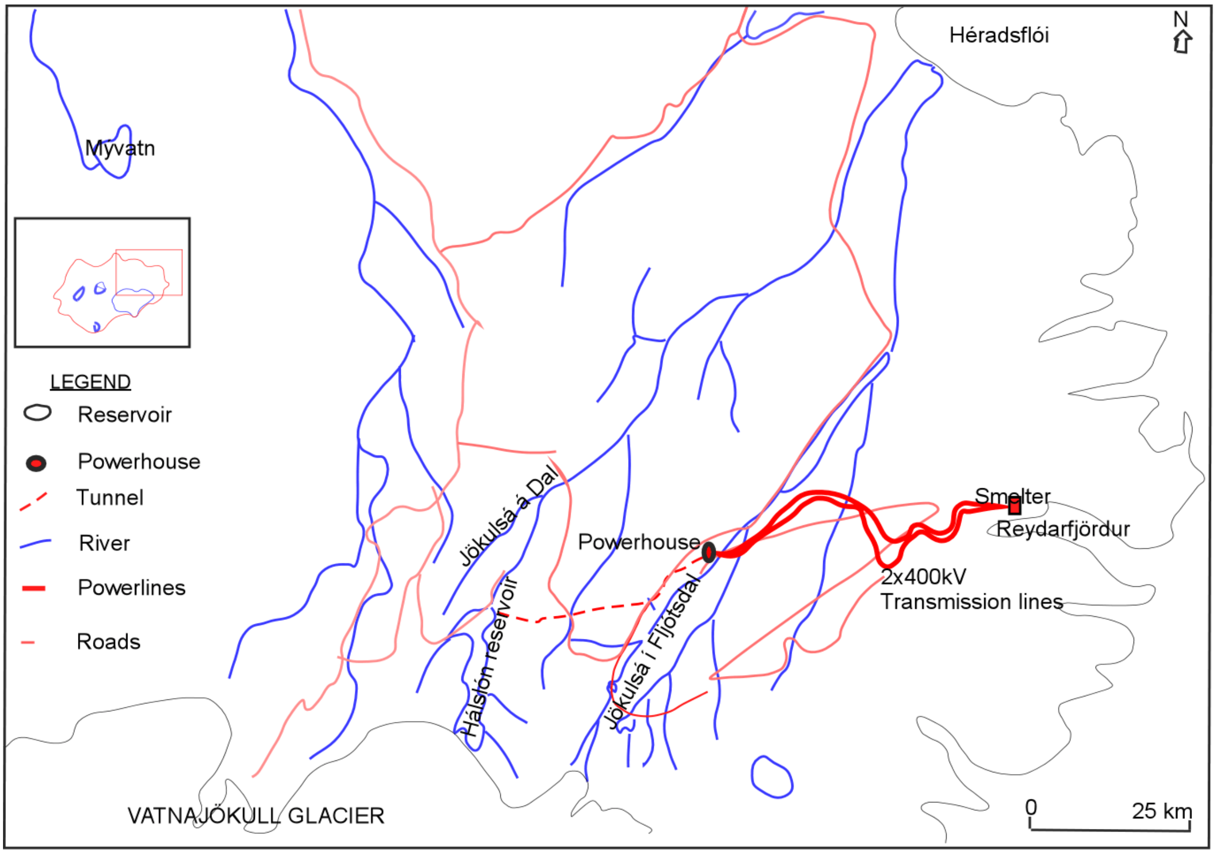

FIGURE 6: Location of the Kárahnjúkar hydropower project

The power plant is mainly being built to supply electricity for a proposed low-emission aluminium smelter to be located in East Iceland. Already a memorandum of under-standing has been signed to this effect between the Icelandic government, Landsvirkjun (The National Power Company of Iceland) and the world's largest aluminium producer, Alcoa. The smelter will have a production capacity of 295,000 tons per year and will receive power from the Kárahnjúkar power station, which will be constructed and operated by Landsvirkjun. The power station will start delivering electricity to Alcoa's aluminium plant no later than 2007. Landsvirkjun had already fulfilled all requirements of an Environmental Impact Assessment in December 2001, and received the required legislative approval for going ahead with the project. A court case was filed in 2001 by the Icelandic Nature Conservation Association and some individuals opposing the project, and the court ruled in favour of the project.

Attitude towards the Kárahnjúkar project. A number of opinion polls have been carried out examining attitudes toward the Kárahnjúkar Hydroelectric Project, the most extensive by the Institute of Social Sciences at the University of Iceland and Gallup. The Icelandic media has also carried out a number of smaller polls. In all the polls, the project received more than 50% support. However, many felt that the project should not be implemented due to what they perceived as negative impacts.

5.3 Comparison and contrasts of impacts of Kárahnjúkar and Sondu hydropower projects

The two projects have similar impacts in general terms. However, there are various differences in nature and magnitude of the two projects, which result in a great difference in impacts. The comparison is based mostly on the impacts as predicted in the EIA reports, EIS, and in part on the experiences so far (in case of Sondu Miriu).

5.3.1 EIA and project implementation

At Sondu Miriu, the EIA was undertaken way before formulation of Kenya's environmental legislation of 1999 and this may have a lot to do with the problems being experienced. An Environmental Impact Assessment (EIA) was done in 1991, and a socioeconomic impact assessment in 1993 under a request by the KPC (now KenGen). The EIA was undertaken according to World Bank directives. The community was given the opportunity to participate in vital issues before implementation began, and they gave overwhelming support for the project to begin as fast as possible. In Kárahnjúkar, the EIA was undertaken and approved under the new legislation (2000). Thus, any objection done came before the implementation began. The assessment deals with direct effects of the proposed project on the natural and human environment. The proposal was presented and introduced in July 2000, investigations and field work carried out the same year, and reports prepared thereafter. The project implementation licence was granted in 2001.

5.3.2 Project location

The location of the Kárahnjúkar project, especially the reservoir (Hálslón), includes areas of special interest such as habitat for reindeer and the pink-footed geese. The nature reserve "Kringilsárrani" will be reduced by a fourth after impounding. Significant geological features and 32 km^2 of vegetation will be submerged by the reservoir. Thorough investigations of geological formations of scientific importance, including sediment banks and crusts of beds of hot springs, need to be done before project implementation. Agreement with land-owners and local authorities will be done regarding appropriate compensation possibly in form of re-vegetation. There is no need of relocating people since the few land-owners are not resident in the area. The Sondu Miriu project is located in the middle of a community, and thus the main effect has been that of relocation and compensation to people for loss of land, crops, property, and business. A small part of Koguta forest (8 ha.) is also affected, much of which has already been rehabilitated by planting 10,000 tree seedlings. There are not any sensitive areas of conservation.

5.3.3 Loss of land, property, and business

Loss of land, property, and business is due to impounding and construction of various structures needed for plant development. Land loss and environmental effects are far much greater in Kárahnjúkar than at Sondu Miriu. However, while a number of people had to be displaced at Sondu Miriu due to high population densities, low population densities in the area affected by the Kárahnjúkar Project resulted in no such displacement. In Kenya populations are scattered in different parts of the country, but in Iceland, on the other hand, the populations are concentrated in towns and scattered farms in the lowlands. The Sondu Miriu project involved relocation of households, three schools and a church. In addition, there was loss of crops and ferry business at certain points of the river due to provision of a bridge. All this was compensated for. At Kárahnjúkar, the dam area had been abandoned many centuries ago so no households or other property will be lost except for land and sensitive habitats for certain animals and plants. Compensation will be made.

The nature of the Sondu Miriu project (run-of-river type) ensures that only a small area is impounded since only a regulatory pond is needed. Thus, only 0.5 km^2 will be covered by the pond with a capacity of 1.1 million m^3 of water after impounding. This area was initially subsistence farmland and compensation was done in cash for land, crops, and buildings. At Kárahnjúkar, a total area of 57 km^2 will be covered by a dam with a capacity of 2,100 million m^3 of water. This will lead to losses of large areas of land, plants, and habitats for some animals.

5.3.4 Carbon dioxide emission

Although the area to be impounded is large at Kárahnjúkar, small amounts of methane may arise due to decay of the relatively scanty vegetation cover. At Sondu Miriu, the gases will be minimal as the area is small and a large part of the area has been cleared of vegetation for the contractors' offices, and by former land owners before relocating. The civil contractor is also supposed to clear the vegetation before impounding, as recommended in the EIA.

5.3.5 Erosion and sedimentation

At Sondu Miriu, sedimentation of the pond may arise from sediments flowing into the river along its course from neighbouring farms which undergo erosion during the rains due to the steepness in terrain and poor farming practices. Frequent flushing of the reservoir will deal with the problem. At Kárahnjúkar, vast amounts of glacial sediments are carried by the river to the reservoir. Occasional flushing is recommended, however, it is estimated the reservoir will fill up in 400 years. Erosion and sedimentation in the banks of the reservoir may result in loess and sand dunes carried by wind off site. Mitigation strategies are being planned. Sedimentation of the seashore from Jökulsá á Dal nearly ceases, and the shoreline is expected to recede by 200 m in 100 years. The sediments need to be rinsed from Ufsárlón every year to prevent it being carried into the headrace tunnel and the power plant. The reservoir will be flushed over a long period of time, if necessary, to limit peak flow in Jökulsá í Fljótsdal during flushing.

5.3.6 River diversion, change in river flow down stream and sediment transport

At Kárahnjúkar, there will be a total diversion of one river and partial diversion of another river; and a number of tributaries into the tunnel and channels. Diversion of Jökulsá á Dal, will cause tremendous reduction of flow downstream of the river while there will be greatly increased flow in Jökulsá í Fljótsdal. It may be possible to control water flows through the spillway when enough water is available for the planned power plant, so as to regulate the flow. Monitoring will be done and landowners and local authorities compensated for raised water levels below the station house. Jökulsá á Dal will be clear of sediment the whole year except in autumn because of the water diversion while increased sediment load will make water in Jökulsá í Fljótsdal and Lagarfljót darker. This will alter habitats and thus lead to deterioration of conditions for aquatic life. Jökulsá á Dal will restrict itself to a more limited course through alluvial floods as the diversion reduces erosive forces. At Sondu Miriu, diversion will be along a 13 km section after which the river rejoins the original course and flows to the lake. It is this section that will be affected, however an environmental maintenance flow as recommended in the EIA will be available always causing minimal changes. According to studies on the river ecology, there are no migratory fish along this section.

5.3.7 Creation of habitat

At Sondu Miriu, the regulatory pond is expected to provide favourable grounds for breeding of some of the fish species found in that section of the river. The residents might also enrich the pond with more fish species for their consumption and income. The pond may provide a good habitat for aquatic birds while the buffer zone to be vegetated may provide good habitat for other types of birds and animals. The pond may also create conditions suitable for breeding malarial parasites causing mosquitoes. Residents have been advised on preventive and curative measures against the problem. At Kárahnjúkar, diversion of Jökulsá á Dal will improve conditions in summer for fish to migrate up the clear water from streams and subsidiaries that will remain untouched. Growth of algae and benthic organisms is expected.

5.3.8 Visual impacts

Kárahnjúkar project dams, reservoirs, channels, quarries, dump sites, altered water courses and roads will greatly affect landscapes and scenery. Open spaces will also be disturbed as a result of all these activities. The river diversions will also have visual impacts on existing features and a number of waterfalls will be affected or lost. Some mitigation will be through regulation of water flow and by spilling when the reservoir is full. Construction structures will be blended into the surroundings as much as possible to minimise negative visual effects. One of the most magnificent canyons in Iceland will be cut by the dam, the upper part filled, but the lower part will lose most of the water. Dump sites have to be organised in consultation with landscape designers. The disturbed areas should be tidied up after development, e.g. through re-vegetation in consultation with specialists. At Sondu Miriu, one waterfall will be affected and the maintenance flow is expected to address the problem. Rehabilitation of spoil banks and affected areas is being done to improve those areas.

5.3.9 Social and economic impacts

Direct employment is provided by various activities during the construction phase of the projects. Indirect employment results from business opportunities to supply goods and services to the increased population in the project areas. At Sondu Miriu, the number of those employed rose to a high of about 1,800 before a decline resulting from a delay of release of the phase two loan. There was a boost in the economy of the area from salaries paid to those employed by the project, and extra income generated by those engaged in increased business activities. The majority of the people working for the project come from within and around the project area and the greater Nyanza province. This has actually led to an increase in income levels and thus improved living standards of the residents. The project will provide improved access. Once the project is complete, the weir will provide a permanent bridge to residents in the area linking the right and left bank roads. During the ongoing construction, the contractor installed a temporary steel bridge which the residents were allowed to use freely. The project improved existing rural access roads that were in a bad state and built new ones. The project would also need to construct bridges where necessary in addition to providing a bridge out of the weir across the intake. This ensures all weather accessibility and connects the area to other areas which had been difficult to access before. Some road sections were paved.

At Kárahnjúkar, a large number of people will be employed during the construction phase. Some of the manpower will be from surrounding areas, some from other areas in Iceland, and a large number from abroad. This will contribute to an increase of income of both local communities and residents of Iceland. Because of these developments, the GDP is expected to increase by 8,000–15,000 million ISK per year. Export income will increase by 14% per year. Transportation will be improved in the highlands due to the construction of new good roads and improvement of the old ones which are to be used during the development of the project. These will be used after the completion of the project. Due to the improvement of access and facilities, a number of tourists will increase and increased need for various types of services will further strengthen the economy of the region.

5.3.10 Water quality

At Sondu Miriu, a waste disposal site is designated, sewage system constructed and hazardous waste disposed in well-lined pits to prevent leakage and contamination of soil and ground water. The concern for water quality is vital in this case because of the dependence on the river by the residents for their needs, and that of their livestock as well as the river ecology. Rural water supply has been improved by the contractor installing a water supply system. The other concern was that of aquatic weeds after impounding in the regulatory pond area. Free-floating aquatic weeds found in the reservoir are to be destroyed before they have time to establish substantial populations. The operation and maintenance manuals will cover the maintenance of the reservoir.

At Kárahnjúkar, water quality may mainly be affected by sediment deposition due to the storage capacity of the reservoir. Concern of quality is for the sake of river ecology rather than humans, since the residents do not rely on the river for their requirements. Waste management problems are currently being resolved.

5.3.11 Safety and health

At Sondu Miriu, the influx of employment seekers may result in increased transmission of communicable diseases and migrant workers become vulnerable to endemic diseases such as malaria. The contractor was advised to employ most people from within the area (especially unskilled) and he provided a health clinic for the workers and their families. Post-construction impacts on health in the project area were likely to be minimal but preventive measures to reduce disease vector breeding sites would be necessary through education and taking necessary action as done before the project began. The safety concern is about people falling into the open discharge channel and regulatory pond, and accidents during construction. Fencing would be done where required.

At Kárahnjúkar, limited health hazards are expected but some accidents are likely to occur in such a large project despite strong preventive efforts. There are few diseases in the area, limited to risks of getting cold and flu and normal diseases.

6. DISCUSSION

The major differences in impacts of the geothermal power and hydropower plants compared are mainly due to the location and size of the projects. These tend to affect the magnitude and type of impacts, as well as the management options to be adopted as shown in all the case studies. For instance, impacts of major concern for the project located in a national park affects mainly wildlife habitats and food sources where clearing is done; high noise levels during construction and drilling since this may scare away the animals; and the visual effects on the beautiful scenery that serves as tourist attraction. This is the case for the Olkaria power plant unlike the Nesjavellir plant. Similar concerns affect the Kárahnjúkar project due to it being located partly in a nature reserve with habitats for important animals and plants of high conservation value. The social impacts in terms of relocation of people are minimal. However, other social impacts such as influx of migrant workers, improvement of people's living standards, and provision of access to the other areas are important positive factors. Location also determines whether there will be conflicts of resources or not. Where vital resources such as water are shared there are bound to be conflicts especially where one player is perceived to be taking too much, thus there will be need for dialogue and systems or mechanisms put in place to address issues arising out of the common resource. If the power plant is located in a densely populated area, a large number of people will have to be relocated even from small areas, thus resulting in major negative social impacts as is the case with the Sondu Miriu hydropower project. However, comparatively, hydropower projects tend to cause more human displacements than geothermal projects because of the reservoirs. On the other hand, hydropower is cleaner when looked at in the context of greenhouse gases which are common in geothermal high-temperature areas.

Technology adopted also affects the impact elicited. For instance, in the absence of a cyclic cooling system such as the use of cooling towers in geothermal power plants, there will always be need for continuous abstraction of water for cooling purposes, as is the case at Nesjavellir.

The size of the power plant is also a large determinant of effects. Bigger power plants will result in greater environmental and social impacts especially where the areas are inhabited. Big hydropower plants will especially cause loss of large areas of land, vegetation, property and change the scenery of the place because of impounding to create dams. The dams may also create avenues for harbouring disease vectors.

In case of geothermal, the large plants result in more wastewater thus greater thermal and chemical contamination effects, production of more gases, thus greater risks of air pollution.

The major environmental impacts of hydropower projects include among others: flooding by storage reservoirs leading to loss of natural features and landscape, vegetation, animal and human habitants, and property; change of down stream flow regimes thus affecting scenic features such as waterfalls; and visual impacts from structures associated with the project. Economically, they involve high financial investment and take long to realise the returns of the project. On the other hand, major impacts associated with geothermal power projects include disappearance of manifestations such as hot springs and fumaroles; localised land subsidence due to long-term production without reinjection; and air and water pollution from dissolved gases and chemical solids from deep-seated geothermal fluids. Some of the impacts of the two resources can be mitigated while some always remain. For instance, reinjection can solve most of the pollution problems associated with geothermal power plants, and also prevent pressure draw down that can be caused by mass withdrawal without replacement thus lengthening the life of the reservoir.

Both resources emit low amounts of greenhouse gases compared to those from fossil fuels, and thus are more environmentally friendly. The two resources save a lot of foreign currency that would have gone into importing fossil fuels. The resources use technologies that are mature, reliable and proven, thus the certainty. The prices are independent of fluctuating oil prices, while the resources are renewable and can be of multiple uses after power production.

7. CONCLUSIONS

In Iceland and Kenya, hydropower and geothermal power resources contribute the greatest portion of electricity that is so vital in economic and social development. In addition, they save the countries some foreign currency for fossil fuels and emit less greenhouse gases than fossil fuels. Just like any other power resource, these resources have environmental impacts of their own, which are similar in the two countries. The magnitude of these impacts, however, varies and is mainly dependent on location, size, and technology adopted in the development of the project. These impacts should, however, not deter the development of these resources in totality. What is needed is thorough research on potential impacts and their magnitude, research that must be carried long before any implementation commences. All this should be done within the local, regional, and international legal framework affecting resource development in the countries involved. Since it is a give-and-take situation, the consequences have to be weighed carefully, and if negative impacts outweigh positive ones, even after considering mitigation measures, then a better alternative should be sought.

Probably the best option may be to develop resources that are located in more remote places rather than heavily inhabited areas, which would imply displacement and relocation of many people especially where hydropower projects are concerned. However, siting projects in remote areas will also mean greater costs due to transmission distances and interference with the natural wilderness. In cases where inhabited areas are to be affected, it is vital to ensure that all stakeholders are involved (through representation) at the earliest time possible so as to ensure full participation in tackling issues that might become obstacles at the time of implementation. Communities to be affected must be fully informed and consulted about the projects, and multiple uses of the water resources considered seriously where necessary. Impacts must be mitigated properly or compensated for.

As a result of the increasing global campaign against construction of large-scale hydropower dams, probably focus should shift to promoting medium-sized dams and geothermal power developments. Development of these resources, due to the financial commitment involved, needs great and sustained support from politicians, governments, and multilateral agencies. This should be done in the light of the increasing global environmental threat to the climate and other factors as a result of emissions of greenhouse gases from the burning of fossil fuels. This will however, depend on individual governments and the residents as a whole. In Iceland, for instance, there are abundant unharnessed hydropower options which could be exploited instead of geothermal sources. However, with growing awareness of the need to maintain inland wilderness (which are greatly affected by reservoirs) for the tourist industry (Gíslason, 2000), the best alternative may be to concentrate more on the development of geothermal power. In Kenya, there seems to be heightened awareness among communities about negative impacts of hydropower on the environment thus leading to major campaigns against hydropower. In addition, there are a few more potential hydropower sites remaining unexploited, mostly in highly populated areas, and sometimes variation of weather has affected reliability of hydropower supply. At the same time, most of the promising geothermal resources are in government-owned lands and thus will present fewer social problems. The best option would probably be to concentrate on the development of the considerable high geothermal potential that is existent in the country. However, it will also be vital to look into the possibility of utilizing the resource more efficiently either by cascading or adoption of technology that uses heat more efficiently.

It is only through vigorous campaigns for development of these resources by governments and other relevant bodies and the acceptance and support of the communities affected that the goal of cutting down emissions of greenhouse gases by substantial amounts can be realized in the near future. Monitoring of a project during implementation should be a crucial tool in the mitigation process. Problems may arise at any point of the development of a project. It is appropriate to ensure a proper mechanism is established early enough to deal with such problems. With a little sacrifice of nature, the two power sources can be developed hand in hand with conservation if all the necessary care is done.

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