ENVIRONMENTAL CONCERNS
FOR GEOTHERMAL DEVELOPMENT IN ETHIOPIA

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ABSTRACT

The Environmental Concerns of Geothermal Development in Ethiopia will fluctuate primarily on the location and geological setting of the geothermal prospect. In Ethiopia the location of the high enthalpy geothermal fields with which this paper is mainly concerned are concentrated in the Main Ethiopian Rift (MER) and the Afar Depression of Ethiopia (AfDE). In the MER the Geological setting of the geothermal fields is near volcanic centres which act as heat sources while in the AfDE it is along axial ranges, incipient spreading zones which also act as heat sources. There are also some geothermal fields associated with volcanic centres in southern Afar. Additionally to these, there will be further variation depending on the types of volcanic centres and axial ranges.

Discussing about Environmental Concerns of Geothermal Development in Ethiopia, this paper mainly refers to those geothermal projects where exploration for geothermal development has been conducted to some degree and with which exploration this author has been involved. Foremost in these explored geothermal areas are the Aluto-Langano Geothermal project, the Tendaho Geothermal project where exploration up to deep drilling has been conducted and in the case of the Aluto-langano Geothermal project a pilot geothermal power plant of 8.2MWe gross was installed, although not operational at present due to some technical troubles which are now under study and in the process of remedial. Then the other geothermal fields referred to are Northern Lake Abaya Geothermal Field, Corbetti Caldera Geothermal Field, Gedamssa Caldera Geothermal field and a number of fields in the Southern Afar Project.

The environmental considerations look into the environmental laws of Ethiopia, the physical environment, the biological environment and the human environment. Considering the initial environment, the high enthalpy geothermal development areas are remotely located and often barren, presently their neighborhood is typically devoid of settlements and also lacking in recreational or tourist facilities. Any Geothermal Development however should conform to the Environmental Policy of Ethiopia issued in 1997 as well as the Proclamation on the Establishment of Environmental Protection Organs, Environmental Impact Assessment (EIA) Proclamation and Environmental Pollution Control Proclamation all issued in 2002.

In the MER the physical environment consists of young rocks and young landform; the soil development is also at a young stage. The topography can vary from flat to mountainous due to volcanic edifices which are in part formed by rock and in part by loose and weak pyroclastic materials which can pose for erosion problems. However the rocks both hard and weak can be used as natural construction materials. The altitude can vary from about 1000 to over 2000 meters. The climate is variable with hot temperatures below the volcanic edifices and cool temperatures on top of the volcanic edifices. There is water available in nearby lakes and rivers in the case of Aluto-Langano, Northern Lake Abaya, Corbetti Caldera and Gadamssa Caldera Geothermal Fields, that can be used for drilling fluid and as part of the natural construction materials. The land-use land-cover is limited. The biological environment does not have abundance of flora and fauna. There are
excepting for bush and rare scattered wood mostly acacia trees. There can occur some wildlife but there are no concentrated wildlife habitats warranting national parks, wild life reserves like at the moment, excepting at the Fantale Geothermal area where there is the Awash National Park. Similarly there are no forest conservation areas. The air quality varies with
ties of H₂S smell near natural geothermal manifestations; noise also varies from quiet to
very high sound levels from fumaroles and other hydrothermal discharges. Aesthetics also
depending on the geological setting and topography although it is generally considered to be
attractive.

In AIDE, where geothermal resources occur the physical environment consists of even younger
and younger land forms in relation to the MER. The land is rocky with lake and Aeolian
deposits covering most parts and with no or very little soil formation. The topography is very flat
at the axial ranges which are represented by ridges. The altitude is in the order of 300 to
800 meters. The climate is hostile with very hot temperatures and very little rain. There are no rivers with
awash and its tributaries being some Kilometers away from the geothermal development site.

is general lack of vegetation including grass due to the very low rainfall and the desert
ation of the area. There is wild life consisting of Gazelle, Antelope, Ostrich, Wild Ass and
og. The Wild Ass and Ostrich population warrant some kind of a wild life reserve. The Wild
is endemic to Ethiopia. Vegetation and wildlife are concentrated near areas of hydrothermal
fissions due to the availability of water there. But the geothermal development areas in
opia do not coincide with the hydrothermal manifestation areas, being some kilometers away
thus would not disturb the flora and fauna existing at the hydrothermal manifestation areas.

As means from the point of the Initial/existing Environment there is a relative ease of adverse
evironmental impacts due to Geothermal Development as a result of the deficiency in human
lement as well as the limited flora and fauna. There will not also be any loss of agricultural land
there is no or limited land use.

The main concerns are then, Geothermal effluents, that is separated brines and non-condensable
gasses including noxious odour emitted from cooling towers and gas ejectors as well as from other
othermal facilities. There is a relatively high concentration of Sodium Bicarbonate (Na₂HCO₃) and
odium chloride-sulphate for example in the Aluto-Langano Geothermal brine. Boron having a high
mpact on vegetation is also of concern. Arsenic which is poisonous is a risk and can pollute water
odies. Among other pollutants to the water and soil are, Ammonia, carbon dioxide and saline bore
aters. Among air pollutants are, Carbon Dioxide (CO₂) which has green house gas effect because it
caps heat from the Sun that is reradiated by Earth; Hydrogen Sulphide (H₂S) which concentrates in
low areas is toxic; Ammonia (NH₄), mercury, radioactive elements and rock dust should also be of
concern. Silica precipitation on vegetation should also be of concern.

To mitigate all the above problems re-injection was found to be the best system in that it meant
getting rid of the effluent quickly by putting it back into the ground. However this was not as easy as
was said. Rather there were some uncertainties about re-injection at the beginning due to lack of
researched data and there was fear that re-injection might cool the system, reduce the permeability,
and so on. Thanks to continued research and growing use of re-injection as well as practical
experience and knowledge in geothermal fields around the world, re-injection was found to reduce
all the pollution concerns of geothermal development besides being advantageous in maintaining the
reservoir pressures and thermally insulting from cold water incursions into the reservoir in some
pects.
Thus pollution from separated brine after extraction of energy can be mitigated by means of injection back into the system. Similarly rejected condensate water can also be re-injected. Sometimes this might have its own problems if the formation lacks permeability or there can occur clogging due to scaling. One can further solve these problems by injecting at higher pressures and higher temperatures (although this can lead to loss of energy), as well as by chemical treatment prior settling of the effluent. If the geothermal setting allows it, discharging the effluents into already saline lakes (as a result of natural hydrothermal discharge into them) and large rivers can greatly reduce the impacts by bringing down the concentration of these elements to ambient levels in the case of large rivers and in the case of Saline Lakes by concentrating the extractable minerals like soda ash which is now being mined in Lake Abiata would be of further economic benefit. However, both these solutions of effluent disposal must be studied in detail for their impact on fish and other aquatic animals.

Non-condensable gases like H$_2$S which pollute the air can be scrubbed before their escape to the atmosphere. It is also these days being considered for commercial extraction of some of these pollutants like for example using CO$_2$ for the manufacture of dry ice, carbonic acid and so on. Similarly adequate ventilation inside the geothermal facilities will protect from poisoning by toxic gases like H$_2$S.

There will also be some environmental concerns due to the construction activity of the geothermal power plant including drilling and construction of buildings and access roads. Erosion, subsidence and settlement could also be a concern during construction and operation, since the foundations of geothermal installations can be accumulations of loose and weak pyroclastic ejecta coming from the volcanoes. The fresh ground water should be protected from mixing with the geothermal fluid. Thus the engineering designs should look into mitigating these problems by including appropriate well construction with concentric casings to prevent mixing of geothermal water with fresh ground water. Blowouts and hydrothermal explosions can occur, thus the engineering designs should provide blowout prevention equipment. Geothermal areas are usually active seismic and volcanic zones. These and initiation of seismic shocks due to withdrawal of geothermal fluid should also be considered and the engineering designs should look into selection of appropriate acceleration factors for the geothermal facilities and buildings. Corrosion protection by selecting appropriate materials and paints should also be examined.

However, on the whole the impacts from the above will be small compared for example with hydropower development where there are usually settlements of people and the hydropower scheme occupy very large areas causing displacement of very large numbers of people especially in the dam site and the reservoir area plus the possibility of greater and more extensive physical environmental problems like erosion and subsidence.

Further the impacts from Geothermal Development would be mainly related to continuous production of steam and brine from geothermal wells and should be negligible and temporary when boreholes are opened only for testing purposes. Finally it is agreed by many that compared to other types of Thermal Plants, Geothermal Plants have relatively little effect on the environment. For example the amount of carbon dioxide released from geothermal plants, is in the range of 4 percent of the carbon dioxide released by an equivalent thermal plant fueled by coal or petroleum. Thus after allowing for the necessary mitigation measures discussed above Geothermal Development is an attractive energy source that is yet to be utilised fully, considering its large resource base compared to oil, coal and nuclear energy.
INTRODUCTION

Background

Geothermal energy resource is said to be only second to hydro-energy resource for generation of energy in Ethiopia. Both Geothermal Energy and Hydro-Energy are renewable resources that proved to be of practical value as energy sources yet to be fully utilized by mankind. They are based on water media. In the case of Geothermal, the water gets its energy from heat derived from terrestrial sources usually magma chamber at shallow depth in the order of 5 to 10 kilometers. The heat source can also be hot dry rock at shallower depth.

Geothermal resources have been used by man perhaps since pre-historic times and certainly in historic times by ancient civilizations like the Greeks and the Romans. Its use flourished with time, being used both for bathing, balneology (medicinal bathing) and also for bottled mineral drinking water. Besides these the other applications were direct heat uses like space heating, food processing, agriculture, refrigeration and so on. In addition minerals and chemicals, like boric acid, sulphur, and calcium chloride are extracted from geothermal resources.

The first successful geothermal power plant for electricity generation was put into service in 1913, at Lardello, Italy. It was a 250 Kw_e power plant using geothermal steam. This was followed by New Zealand about fifty years later with the Installation of 192 Mw_e geothermal power plant using saturated steam from superheated hot water ever-increasing the exploitation possibilities from steam to hot water. United States of America was the next country to produce electricity from geothermal steam. Other Countries like Japan, former USSR, Mexico, El-Salvador, Iceland and Turkey followed. Lately developing countries like Philippines, Indonesia and China have joined in. In Africa, Kenya had been the first country to generate electricity from geothermal energy. Ethiopia joined the club in 1996 by installing the first geothermal power plant of about 8.2Mwe gross.

With the Coming of the African Rift Geothermal (ARGeo) Facility, It is believed that there will be an expansion of the Geothermal Development in Africa as a whole, particularly in East Africa and chiefly in Ethiopia and Kenya. In combination with this sound Environmental Management of the Geothermal Resources at all stages of the Geothermal Development will further enhance the sustainability of the use of this particular energy sector. This paper dwells on environmental concerns for Geothermal Development in Ethiopia.

1.2 Objective

The objective of this paper is to broadly look into the environmental concerns of geothermal development in Ethiopia and to examine which aspects of geothermal development need to have environmental impacts attention and assessment.

2.0 NATURE OF THE RESOURCE AND GEOLOGICAL SETTING

2.1 Geothermal Occurrence

Geothermal comes from the Greek and means Earth-Heat. The earth is broadly divided into the core, mantle and crust. The temperature increases with depth and the heat is generated predominately by radioactive processes. The temperature of the mantle is in the order of 600°C while at the centre of...
the earth the temperature could reach about 6000°c. However to get this heat geothermal development does not have to go to these depths. It is now well known that convection current in the mantle generate drifting of the continents and the phenomenon is known as plate tectonics. As a result there is magmatic up-flow and volcanism at the axis of the spreading zones with the creation of new crust at the surface, while at the other margin of the plate there is collision of the crustal plates. Subduction of the oceanic crust downwards under the continental crust due to the bigger density of the oceanic crust which later melts as it reaches to the high temperature depths and erupts to the surface. There could also be transform zones, were instead of collision there is sliding of the plates against each other.

The plate margins are thus areas of magmatic, volcanic and seismic activity and are now recorded by volcanological and seismological observatories world wide. These processes bring Earth’s Heat up to shallow depth during volcanic activity, in the form of buried remnant magma chambers and/or hot rock. This heat can be picked up by ground water circulating in the subsurface and can further be transported and stored underground in a natural geothermal reservoir at shallower depths in the order of 500m to 3000m where the geological conditions permit and it can be accessed by deep drilling. Some of this fluid can also manifest itself at the surface as hot springs, fumaroles and the like by migrating through fractures and faults from the geothermal reservoir and is known as geothermal manifestation.

It is generally accepted that the ground water is of a meteoric origin and can be recharged continuously by rain, making it renewable. The heat source/magma chamber is believed to have existed for hundreds of thousands of years before it cools. The geothermal resource is thus a naturally occurring heated ground water that is renewable and temperatures can vary from above ambient to superheated in the order of 300°c and more. The lower temperature ranges are used for direct heating purposes, like bathing, space heating, and the medium temperature ranges are used for drying agriculture and mining and process heat in industry etc. while the higher temperature ranges are used mainly for electricity generation.

2.2 Geothermal Resource in Ethiopia

The geothermal Resources in Ethiopia are also related to plate tectonics. The main geothermal Resources of Ethiopia occur in the Ethiopian Rift, which is a result of extension tectonics. The Ethiopian Rift is divided into the main Ethiopian Rift (MER) and the Afar Depression of Ethiopia (AIDE). The MER is characterized by a graben represented by older essentially Northeast-Southwest trending fault blocks and a newer active centre of NNE-SSW trending fault blocks and rift in the east and associated volcanism both basaltic and acid known as the Wonji fault belt Meridiet (1971). The basaltic volcanism is fissural while the acidic volcanism is central forming volcanic edifices. The heat source is related to the volcanic centres, as can be gathered from present knowledge.

The AIDE is an area of incipient spreading zone with accumulations of basaltic volcanism. Some of the basalts are tholeiitic in nature similar to the sea floor basalts. It is this volcanism and the remnants of the buried magma chamber/dykes that supply the heat source for the geothermal energy.

The water recharge comes from rainfalls that originate on the highland plateaus west and east of the Ethiopian Rift Valley as the rainfall within the rift is low and in the case of AIDE it is exceeded by the evaporation, although there could be some infiltration from the rainfall in the MER in some places.
Several geothermal prospects in both the MER and AfDE. Some of these geothermal areas have been explored to varying degrees. A reconnaissance survey has covered the whole of Ethiopian Rift. The exploration included airborne infra-red survey that showed practically all of thermal manifestation areas. After this results areas were selected for further studies and the following table shows the geothermal prospect areas and the geothermal explorations and development undertaken.

<table>
<thead>
<tr>
<th>Geothermal Prospect</th>
<th>Explorations Undertaken</th>
<th>Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, Aluto-Langano</td>
<td>Geological</td>
<td>Geochemical</td>
</tr>
<tr>
<td>2, Corbetti Caldera</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>3, Northern Lake Abya</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>4, Gademessa Caldera</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>1, Tendaho</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>2, Southern Afar</td>
<td>Geological</td>
<td>Geochemical</td>
</tr>
</tbody>
</table>

In addition to the above there were recently conducted geological and geochemical explorations in Moye and Fantale-Dofan in the MER.

The endeavor of all the above explorations is to prove the existence of geothermal resources including its quality and quantity with the ultimate aim of using the resources in electricity generation which needs exploitation of large quantities of geothermal fluids concurrently leading to environmental impacts.

POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK ON ENVIRONMENT IN ETHIOPIA

Although recently, there are environmental laws promulgated in Ethiopia to protect the environment. The following sections briefly point out the environmental policies, regulations, legal and administrative framework existing regarding the environment in the country.

3.1 The Ethiopian Constitution

The constitution adopted on the 21st of August 1995 describes the concept of sustainable development and environmental rights, among others the right to development and the right to live in a clean and healthy environment.
3.2 Conservation Strategy of Ethiopia (CSE)
The Conservation Strategy of Ethiopia (CSE, 1996) which is a policy document recognizes the importance of incorporating environmental factors into development activities as an essential component of economic, social and cultural development.

3.3 National Policies

3.3.1 Environmental Policy of Ethiopia
The Environmental Policy of Ethiopia (EPE) (April 1997) goal is to improve and enhance the health and quality of all Ethiopians and to promote sustainable social and economic development as well as awareness of the essential linkage between environment and development. It also emphasizes the need for participation of the people and their organizations at all levels in environmental management activities.

3.3.2 Sectoral Policies
Several sectoral policies are issued or in various stages of formulation. Of particular note are the following:

- The Water Resource Policy
- Wildlife Policy
- Forest Policy and Strategies
- National Population Policy
- National Policy of Women

Geothermal development should have a good interaction with any of these policies.

3.4 Environmental Framework Proclamations
The following three proclamations are currently issued by EPA:

- Proclamation on the establishment of Environmental Protection Organs
- Environmental Impact Assessment Proclamation and
- Environmental Pollution Control Proclamation

The first proclamation re-established the Federal Environmental protection Authority (EPA), as well as Sectoral and Regional Environmental Units and Agencies respectively. The Sectoral Environmental Units will be responsible for specific Sectoral Environmental Issues while the Regional Environmental Agencies will be responsible in their Region for environmental protection, regulation and monitoring as well as ensuring public participation in the decision making process among other things.

The second proclamation dealing with Environmental Impact Assessment states that projects should first be authorized by the EPA or the relevant Regional Environmental Agency. Licensing agencies should also ensure that projects have the proper authorization from the concerned environmental protection authorities. It also states that the environmental impacts of a project shall be assessed commensurate with its size, location, nature and cumulative effect with other concurrent impacts or phenomena, trans-regional effects, duration, reversibility or irreversibility or other related effects of the project.

The third proclamation dealing with Environmental Pollution Control is concerned with the right of each citizen to have a healthy environment, as well as on the obligation to protect the environment of the country. In keeping with this, regulations are set up to penalize any person violating the law.
Environments are required to be cleaned and put right. Recycling measures are also needed where possible.

**Tenure, Expropriation and Compensation**

Land ownership in Ethiopia is vested on the state, the constitution provides for tenure rights for the leasing of use rights. In addition the constitution states for adequate compensation of property as a result of state programs.

Geothermal Development in Ethiopia shall conform to the Environmental laws of Ethiopia. It require an Environmental Assessment (EA) commensurate with the size of the project and the location. In addition Project Affected Persons (PAP) need be adequately consulted and environmental impacts need to be mitigated to avoid, offset and/or reduce the impacts while at the same time enhancing the beneficial impacts.

**Multilateral Agreements**

Federal Democratic Republic of Ethiopia has ratified several International Conventions and as listed below:
- Convention Concerning the Protection of World Cultural and Natural Heritage, ratified 1972
- International Plant Protection Convention
- Convention on International in Endangered Species (CITES)
- Vienna Convention on Ozone Layer Protection (1990)
- United Convention on Law of the Sea
- Framework Convention on the Law of the Sea
- Convention on Biological Diversity, ratified in 1994
- African Convention on the Conservation of Natural Resources
- Convention on Desertification, ratified in 1994
- Rio Convention on Biodiversity (1997)
- Framework Convention of United Nations on Climate Change (1997)
- Convention on the Control of Transboundary Movement of Hazardous Substance

**4.0 BRIEF DESCRIPTION OF THE PRESENT/EXISTING ENVIRONMENT**

**4.1 Physical Environment**

**4.1.1 Topography**

The topography in the geothermal areas of MER is dominated by hilly terrain formed by volcanic edifices including fault scarps although the geothermal field could be limited to flat areas formed by volcanic depressions like calderas in the case of Corbetti & Gadamssa and summit depressions in the case of Aluto-Langano and escarpments in the case of Northern Lake Abaya Geothermal prospect. The area around the volcanoes is also usually flat. The topography in AfDE is generally flat with southern Afar being hilly including escarpments. The altitude can vary from about 1000 to over 2000 meters at the volcanic edifices in the MER and form about 300m to 500 meters in the AfDE.

**4.1.2 Geology and soils**

The geology in both MER and AfDE is dominated by young volcanic and sedimentary rocks. However it is not the intention here to cover all the geology in the Ethiopian Rift but rather to point out the general geology in the vicinity of the known geothermal areas. The volcanic rocks consist of rhyolitic domes and/or fission basalt while the sediments are lake sediments sometimes called volcano-sediments due to the large proportion of volcano-clastic material that deposited during
pyroclastic eruptions into the lakes created by rifting and subsidence. The tectonics is dominated by extension tectonics with fissures and faults. In both the MER and the AfDE you find faults and grabens of varying amplitude sometimes with enechelon displacements and rift in rift structures as well as tilting of fault blocks. The fissures and faults have acted as passage ways for volcanic material that were eventually the heat sources for the geothermal energy resources.

The soils are young also and there are large areas of bare surface especially in the AfDE. It is again the intention to cover all the soils existing in the Ethiopian Rift valley. The attempt is to describe in general terms the soils existing in the known geothermal prospect areas according to the Geomorphology and Soils Map of Ethiopia (1983). Thus In the AfDE, in the area of the Tenda Geothermal prospect, the dominant soils are orthic solonchaks with sodic characteristics while in the southern Afar Geothermal prospect areas the dominant soils are Lithosols, Eutric Regosols (lithic), Vitric Andosols (lithic) and eutric fluvisols.

In the MER the soils in the Gadamssa Caldera Geothermal Prospect area are Molic Andisols and Eutric Fluvisols and those in the Aluto-Langano Geothermal area are lithosols while those in the Corbetti Caldera Geothermal Prospect Area are mollic Andisols and Lithosols and those of Northern Lake Abaya Geothermal Prospect areas are Chromic Vertisols and Lithosols.

4.1.3 Land Use/land Cover
According to the Land Use/Land Cover Map of Ethiopia the Rift is generally exposed rock, salt flats and exposed land and soil surfaces. These can sometimes have scattered scrub and grass. There are also moderately cultivated lands and grass lands especially in the MER. Acacia trees which had been dense in the past are now very sparse and are the dominant trees especially in the MER. The rift relatively becomes more vegetated as one goes southward and there also occur more moderately cultivated lands. In the Rift valley there also exist agricultural lands limited to the Awash Valley flood plain and its tributaries. The waters of these rivers are used for irrigation and large farms mostly state owned have been developed, that cultivate sugarcane, cotton, fruits and to a lesser extent grain and vegetables. There are also associated agro-industries like food processing and cotton ginning plants as well as settlements forming built up areas around the farms and the Agro-industries like sugar factories. Apart from these the Awash River valley consists of swamps and marshes as well as riverine forest. Similarly in the vicinity of the Northern Lake Abaya Geothermal prospect area there is the Bilate River and Agricultural Development that uses the water of the river for Irrigation. Around Zway Lake which is a fresh water lake, there is also agricultural development using its waters to irrigate flowers and vegetables.

4.1.4 Climate and Water Resources
The rainfall in the Ethiopian rift valley as a whole is low compared to the highlands and the plateau and it also decreases as one goes from the south to the North in the Rift Valley. Briefly, In the MER the Mean Annual Rainfall varies from about 900mm in the Northern Lake Abaya Geothermal prospect area to about 700mm in the Gadamssa Caldera Geothermal Prospect Area. While in the AfDE it varies from 500mm to 300mm in Southern Afar and less than 300mm in the Tendaho Geothermal Prospect area, according to FAO/UNDP-ETH/78/003. Also briefly the mean Annual temperature according to the National Atlas of Ethiopia (1988) in the MER varies from 20 to 25 °C and in the AfDE it varies from 25 to 30 °C in Southern Afar and it is more than 30°C in the Tendaho Area. Isolated temperatures values could be more than 45°C. Thus in Tendaho Area, desert climatic conditions exist and in Southern Afar the climatic conditions vary from desert to hot semi-arid while in the MER the climatic conditions are hot semi-arid. Regarding water Resources there are several fresh to saline lakes namely from North to south, Ziway, Langano, Abiata, Shala, Awasa and Abaya
Geothermal Fluid

Geothermal fluids are saline fluids at high temperature in the order of 330° as evidenced by wells La-6. The geothermal fluid seen on the surface, coming as natural hydrothermal solutions is mixed with shallow fresh ground water and as such is not characteristic of the deep geothermal fluid in the reservoir. Nevertheless there had been conducted deep exploration drilling at geothermal sites namely Aluto-Langano and Tendaho where productive wells have been found and thus it was possible to know the temperature and composition of the deep reservoir. Aluto-Langano Geothermal field having the deepest drilled wells yet has relatively more fluids than at Tendaho. Table 2 below shows the chemical composition and temperature of geothermal fluids from two of the productive wells LA-3 and LA-6, selected for their very high temperatures at Aluto-Langano Geothermal Field, taken from Meseret Teklemariam and Kibret (2001).

<table>
<thead>
<tr>
<th>Well</th>
<th>CO₂</th>
<th>H₂S</th>
<th>He</th>
<th>H₂</th>
<th>N₂</th>
<th>CH₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA-3</td>
<td>320</td>
<td>9.3</td>
<td>1000</td>
<td>228</td>
<td>0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>LA-6</td>
<td>335</td>
<td>8.99</td>
<td>1170</td>
<td>303</td>
<td>0.1</td>
<td>&lt;0.1</td>
</tr>
</tbody>
</table>

As can be observed in the Table 3 above there are high concentrations of the green house gases like CO₂. There are also noxious gases like H₂S.
4.2 Biological Environment
4.2.1 Flora
The flora in the AfDE is scarce often being exposed rock, salt flats and exposed land and surfaces. There are though some scrub and grass around hydrothermal manifestations. In the Northern part there occur open woodland consisting of acacia trees and some grass. Here also occur exposed land and soil surfaces. There are no forests as such.

4.2.2 Fauna
There are birds and wild animals at various localities of the Ethiopian Rift Valley. However, geothermal prospect areas proper are not inhabited except in AfDE where you frequently find life consisting of Ostriches, Wild Ass, Gazelle, Antelope, and Warthog and similarly in the Fantale Geothermal Prospect area in Southern Afar where there is the Awash National park, you find various wild animals mainly antelopes- Sala, Ambaraille, Agazen, Korke, Gazelle with few lions and leopards. The Awash National Park which rests on 756 KM² received legal recognition in 1968 and is reported to be home to 81 species of mammals and 453 bird species. According to the Ethiopian Herald of 11 Oct, 2006, there were about 9068 tourists that visited the park in the 2005/2006 financial year and the revenue for the Fiscal year was Birr 175,714 (about US$ 20,000). And the number of tourists visiting the park increased by about 3400 from the previous year but the revenue doubled. This shows that in the future the revenue from the park could be considerable and that is a reminder that the geothermal development in the Fantale area should be carefully planned so as not to disturb the Awash National Park. Further South near the Corbetti Caldera Geothermal Prospect there also antelopes (kudu, Tragelaphus imberbis.) in Senkale Park.

4.3 Socio Economic Environment
4.3.1 Population
The people living in the geothermal prospect areas of the Ethiopian Rift Valley consist predominantly the Afar people in the AfDE and in the MER are Oromo around Aluto-Langa, Oromia and Sidama around Corbetti Caldera and Wolayita around Northern Lake Abaya.

4.3.2 Livelihood and Economic Activity
The Afar are predominantly pastoralists although this is fast changing with new initiatives taken by both the federal and regional governments to introduce irrigated farming and farming in general. The Kereyu belonging to the Oromo are also chiefly pastoralists with some farming. Large herds of cattle, goats, sheep and camel are common sites in the Afar.

The pastoralists are always on the move in search of grass and vegetation for their animals and it is possible that one way or the other there can occur an encounter with these people including the large herds of cattle. This needs to be given special thought during the environmental impact assessment to offset any impacts that might occur either way. The Sidama and Wolayita are predominantly farmers also with large component of livestock rearing.

Apart from these there are a large number of commercial farm and factory workers in settlements centered around large commercial farms and agro industries as well as towns and villages catering for the large number of transport vehicles going to and forth from the port as well as the Southern, Central and Northern parts of the country on the main highways. The lively hood of the town people is shop keeping of various merchandise as well as running of hotels and restaurants. There are also people employed in cottage industries, garages and workshops in settlements and towns. The towns...
and agro-industries although in the rift are far away from the presently known prospect areas to be affected by environmental impacts from geothermal development.

POTENTIAL ENVIRONMENTAL CONCERNS AND SUGGESTIONS FOR MITIGATION

Physical Environment

Erosion and Land Subsidence

Possible that construction, especially land preparation (excavation, fill, waste disposal, and construction materials) and access road building could initiate erosion and land subsidence. Thus appropriate engineering design standards similar to those used in other construction activities like hydroelectric and road projects should be applied. Land subsidence due to geothermal fluid extraction has been reported to occur in other geothermal areas thus proper engineering considerations should be given including for extraction of construction materials. Re-injection can reduce subsidence due to geothermal fluid withdrawal.

Water Pollution

Harmic which is poisonous to man and animals can occur in geothermal fluids is a risk, and can contaminate water bodies. Among other pollutants to the water and soil are. Ammonia, carbon dioxide, boron, arsenic which is poisonous to man and animals can occur in geothermal fluids is a risk, and can contaminate water bodies. Among other pollutants to the water and soil are. Ammonia, carbon dioxide, boron, and Land Subsidence. Boron having a high impact on vegetation is also of concern.

mitigate all the above problems re-injection was found to be the best system in that it meant re-injection was found to be the best system in that it meant getting rid of the effluent quickly by putting it back into the ground. However this was not as easy as it meant getting rid of the effluent quickly by putting it back into the ground. However this was not as easy as it was said. Rather there were some uncertainties about re-injection at the beginning due to lack of balanced data and there was fear that re-injection might cool the system, reduce the permeability, and so on. Thanks to continued research and growing use of re-injection as well as practical experience and knowledge in geothermal fields around the world, re-injection was found to reduce the pollution concerns of geothermal development besides being advantageous in maintaining the reservoir pressures and thermally insulting from cold water incursions into the reservoir in some respects.

Thus pollution from separated brine after extraction of energy can be mitigated by means of re-injection back into the system. Similarly rejected condensate water can also be re-injected. Sometimes this might have its own problems if the formation lacks permeability or there can occur clogging due to scaling. One can further solve these problems by injecting at higher pressures and higher temperatures (although this can lead to loss of energy), as well as by chemical treatment and prior settling of the effluent. If the geothermal setting allows it, discharging the effluents into already saline lakes (as a result of natural hydrothermal discharge into them) and large rivers can greatly reduce the impacts by bringing down the concentration of these elements to ambient levels in the case of large rivers and in the case of Saline Lakes by concentrating the extractable minerals like Soda ash which is now being mined in Lake Abiata would be of further economic benefit. However both these solutions of effluent disposal must be studied in detail for their impact on fish and other aquatic animals.

Non-condensable gases like $\text{H}_2\text{~S}$ which pollute the air can be scrubbed before their escape to the atmosphere. It is also these days being considered for commercial extraction of some of these pollutants like for example using $\text{CO}_2$ for the manufacture of dry ice, carbonic acid, greenhouse gas supply and so on. Similarly adequate ventilation inside the geothermal facilities will protect from toxic gases like $\text{H}_2\text{~S}$. 


Pollution of water bodies by discharging geothermal effluents into lakes and rivers should be disallowed unless it has been shown that this will not have negative impacts. Similarly mixing of geothermal fluid with the ground water should be prohibited. This could be mitigated by good construction and completion. Discharging waste-water into ponds need protection against use of water by people and animals, this might mean constructing fences or putting a guard.

5.1.3 Air pollution
Among air pollutants are, Carbon Dioxide (CO₂) which has green house gas effect because it trap heat from the Sun that is reradiated by Earth; Hydrogen Sulphide (H₂S) which concentrates in areas is toxic; Ammonia (NH₄), mercury, radioactive elements and rock dust should also be concern. Silica precipitation on vegetation should also be of concern.

5.2 Biological Environment

5.2.1 Flora
It is rather tempting to say that there will be no environmental concerns regarding flora due to scarce vegetation including grass and the occurrence of vast areas of barren rock and soil surface especially in the AfDE. In spite of this any big trees encountered should be preserved and effort should be made to locate boreholes, pipeline routes as well as buildings away from trees vegetation especially endemic and endangered vegetation as much as possible.

5.2.2 Fauna
Some of the geothermal areas are close by to national parks like the Awash and Sinkile Parks in MER. There also exist wildlife in the Afde although there have not been delineated parks. I believed that there could be disturbance to wild animals during mobilization and demobilization well as setting up at well sites. It is likely that the animals could slowly get used to these activities although they may be scared away at the beginning. Thus wild animals should not be hunted and their habitat should be preserved as much as possible. In addition wild life routes should not be obstructed and if crossed by pipe line, the pipe line should be made to overpass by raising it above ground or underpass by going underground along the crossing of the wildlife routes. It is believed that the geothermal facilities will not occupy large spaces and would generally be away from centers of the wild life habitat.

5.3 Socio Economic Environment
The geothermal areas in Ethiopia are generally uninhabited except for occasional pastoralists moving to the area or passing-by with their herds of cattle seasonally. To stop any damage being incurred the facilities and vice versa, fencing of the important facilities could be a simple and cost effective solution. In connection with this creating awareness regarding the geothermal development and use to the pastoralist community would be also useful.

6.0 ENVIRONMENTAL MANAGEMENT PLAN (EMP) AND MONITORING PROGRAM

Environmental management plan is an integral part of the EIA in order to mitigate Environmental impacts. A monitoring program is also required to see the response to mitigation measures undertaken. Monitoring is required to see if there are any changes, especially changes to chemical composition of geothermal fluids with continued exploitation of the geothermal resource.
CONCLUSION

Part of this presentation is not for an all out EIA but rather to point out which aspects of the environment are of concern. As pointed out the existing environment is not sensitive in that it is and does not have human settlement, Flora are also scarce, with no forests, although wild can be encountered in nearby national parks. The main concerns are effluent disposal which achieved by reinjection. Geothermal as energy source is environmentally friendlier compared to energy sources especially fossil fuels.

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