Cover Page

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ENVIRONMENTAL IMPACT ASSESSMENT FOR SUSTAINABLE GEOTHERMAL ENERGY DEVELOPMENT

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SUMMARY –Both the developed and developing countries would like to move to the position of sustainable geothermal development while the restoration of natural resources and improving the quality of existence environment. Generally the impacts of geothermal energy development are positive but still there are some negative impacts. It is important, to consider, the association of positive and negative impacts in all development stages of geothermal projects including exploration, drilling and utilizations in the standard format of Environmental Impact Assessment (EIA) method. A drafted early in the project planning stage and well-prepared EIA report can significantly add to the quality of the overall project. In the most countries, the role of EIA, customarily ends with the decision making to proceed the project but in the case of geothermal projects with the target of sustainable development the environmental impacts analysis process could be more effective if regular monitoring and mitigation plans detail in the EIA, continues during project implementation. In other words, geothermal development EIAs should be analytic rather than encyclopaedic (1). Air quality, water resources and quality, geologic factors, and socioeconomic issues will invariably be the most important factors. The EIA should be intended to help public officials to make informed decisions that are based on an understanding of environmental consequences and take proper actions. The EIA process has been defined in different ways throughout the world. In fact, it appears that no two countries have defined it in exactly the same way. This study tries to find or prepare a guide that presents a comprehensive discussion of the environmental impacts and suggests mitigation plans which associated with geothermal development projects as a standard EIA format by reviewing the methods. Finally, the report of the EIA and executive summery should be well written and present the significant impacts, clarifying which are unavoidable and which are irreversible; the measures which can be taken to mitigate them; the cumulative effects of impacts; and the requirements for monitoring and supervision.

1. INTRODUCTION

Geothermal power is a relatively benign source of energy. There are, however, certain negative impacts that this development could have if there are not appropriate mitigation and monitoring plans in place. The environmental assessment process has been defined differently everywhere. In fact, it appears that no two countries have defined it in exactly the same way. General blanket statements are often made that the developing countries are all behind the industrial countries in terms of environmental issues. It is interesting to note that the Philippine has required EIAs for certain projects since 1977. The Federal Republic of Germany started to do so nearly a decade later (Biawas, 1991). In addition to the different approaches to the process are the wide variety of formats for EIAs that are available.

EIA and GIS are becoming more and more extensively used in the world. EIA is an aid system to decision-making and to the minimization or elimination of environmental impacts at an early planning stage. The EIA process is potentially a basis for negotiations between the developer, public interest groups and the planning regulator. There are many techniques used in EIA, such as matrices, checklists, overlay maps, and networks. This study has been undertaken to determine which information is needed to establish baseline environmental conditions including surveys of geology and land, weather, noise conditions, ecology and socio-economic conditions. This paper presents popular EIA methods and the elements that should be included as part of a comprehensive EIA report of geothermal development project. The goal is the establishment of an international standard method.

2. ENVIRONMENTAL ASSESSMENT

2.1. What is EIA?

EIA is a relatively new planning and decision-making tool first established in the United States in the National Environmental Policy Act of 1969. It is a formal study process used to predict the environmental consequences of any development project and its environmental management.

The EIA tool assists decision-makers in considering the proposed projects environmental costs and benefits. Before starting a major project, it is essential to assess the present environment without the project, and the likely impact of the project on the environment, when it is completed. For analysis of environmental impacts, many professions and disciplines have to be involved. Like economic and engineering feasibility studies, EIA is a management tool for officials and managers who make important decisions about major development projects.

2.2. Definition

EIA can be defined as a process of identifying, predicting, evaluating and mitigating the biophysical, biological, hydrological, ecological, meteorological, noise, economical, social, and other relevant effects prior to development, then using the conclusions as a tool in planning and decision-making (Yousefi, 2004).

2.3. Purpose and Scope

Environmental Assessment enables us to carry out an Environmental Cost-Benefit Analysis of projects at an initial stage. Based on Environmental Assessment, the regulatory measures can be identified and the roles of agencies concerned defined for achieving more efficient environmental management. EIA is a process with several important purposes. Its general purposes are (IAIA.1999):

- To ensure that environmental considerations are explicitly addressed and incorporated into the development decision making process;
- To anticipate and avoid, minimize or offset the adverse significant biophysical, social and other relevant effects of development proposals;
- To protect the productivity and capacity of natural systems and the ecological processes which maintain their functions; and
- To promote development that is sustainable and optimizes resource use and management opportunities.
- To help public officials make informed decisions that are based on an understanding of environmental consequences and take proper actions.

2.4. EIA framework

Several countries have over 20 years experience in applying EIA (e.g. USA, Australia, Canada and New Zealand). Recently, the number of countries with an active EIA process has increased rapidly, possibly to more than 100 countries. The environmental assessment process has been defined differently in different countries. In fact, it appears that no two countries have defined it in exactly the same way. In addition to the different approaches to the process are the wide varieties of formats for EIAs that are available. Generally, studies of physical, chemical, biological and socio-economic impact are carried out for an EIA. These parameters are differently defined in different countries. For these parameters some countries use different EIA evaluation criteria. Matrices, Checklists, and flow charts are the most commonly used technique for impact identification. But Geographical Information System (GIS) has improved quickly in the world. Therefore, overlay maps can give a good evaluation of environmental impacts. In addition, monitoring is important for checking the results of an EIA, but it is very difficult to develop for economical and technical reasons. Nowadays both the developed and developing countries would like to move to the position of sustainable geothermal development during the restoration of natural resources and improving the quality of existence environment they believe that the sustainable production is essential and for sustainable production monitoring and modeling as a part of an strong EIA can determine the sustainable production rate. A general framework process of EIA is shown in Figure 1.

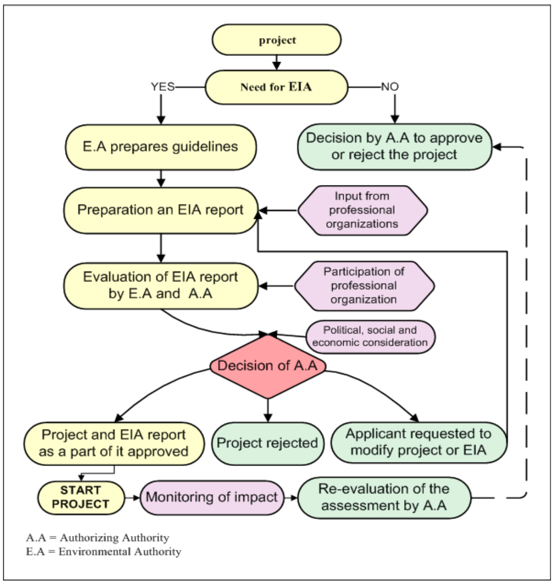

Figure 1: International process of EIA (UNEP 1999)

2.5. EIA methods

2.5.1. Ad Hoc Method

Ad hoc methods are not really methods as they do not structure the problem, so it is more amenable to systematic analysis. A good example of an ad hoc method is a team of experts assembled for a short time to conduct an EIA. Each expert's conclusions are based on a unique combination of experience, training and observation. These conclusions are assembled into a report. Sometimes this is the only required or possible approach.

This method is very easy to use, but does have a few drawbacks (Lohani and Kan, 1983):

- It may not encompass all the relevant impacts;
- Because the criteria used to evaluate impacts are not comparable, the relative weights of various impacts cannot be compared;
- It is inherently inefficient as it requires sizeable effort to identify and assemble an appropriate panel of experts for each assessment; and
- It provides minimal guidance for impact analysis while suggesting broad areas of possible impacts.

Environmental impact assessment usually requires the collection and analysis of considerable information about the economic, social, and biophysical environment. Methods are needed to organize this information for analysis and presentation — ad hoc methods fail to do this in any meaningful way.

Ad hoc methods, usually the collective opinion of a group of experts, are used throughout the EIA process. Often panels of experts are asked to help developer for EIA reports. Experts are almost always consulted during the review of the EIA report. In most cases, the analyses that support the preparation of the EIA report should be undertaken using systematic methods. Experts need to be able to back up their conclusions.

2.5.2. Checklist

Checklists are standard lists of the types of impacts associated with a particular type of project. Checklists methods are primarily for organizing information or ensuring that no potential impact is overlooked. They are a more formalized version of ad hoc approaches in that specific areas of impact are listed and instructions are supplied for impact identification and evaluation. Sophisticated checklists include:

1) scaling checklists in which the listed impacts are ranked in order of magnitude or severity, and 2) weighting-scaling checklists, in which numerous environmental parameters are weighted (using expert judgment), and an index is then calculated to serve as a measure for comparing project alternatives. There are four general types of checklists: Simple (Table 1), Descriptive, Scaling, Scaling Weighting Checklists.

Varying levels of information and expertise are required to prepare checklists. Simple checklists may require only a generalized knowledge of the environmental parameters likely to be affected, and access to an information base. Alternatively, simple checklist methods can be used to summarize the results of an EIA. Scaling weighted checklists are likely to require more expertise to prepare. There are several major reasons for using checklists:

- They are useful in summarizing information to make it accessible to specialists from other fields, or to decision makers who may have a limited amount of technical knowledge;
- Scaling checklists provide a preliminary level of analysis; and
- Weighting is a mechanism for incorporating information about ecosystem functions.

Westman (1985) listed some of the problems with checklists when used as an impact assessment method:

- They are too general or incomplete;
- They do not illustrate interactions between effects;
- The number of categories to be reviewed can be immense, thus distracting from the most significant impacts; and
- The identification of effects is qualitative and subjective.

2.5.3. Matrices

Matrix methods identify interactions between various project actions and environmental parameters and components. They incorporate a list of project activities with a checklist of environmental components that might be affected by these activities. A matrix of potential interactions is produced by combining these two lists (placing one on the vertical axis and the other on the horizontal axis). One of the earliest matrix methods was developed by Leopold et al. (1971). In a Leopold matrix and its variants, the columns of the matrix correspond to project actions (for example, flow alteration) while the rows represent environmental conditions (for example, water temperature). The impact associated with the action columns and the environmental condition row is described in terms of its magnitude and significance.

Most matrices were built for specific applications, although the Leopold Matrix itself is quite general. Matrices can be tailor-made to suit the needs of any project that is to be evaluated. They should preferably cover both the construction and the operation phases of the project, because sometimes, the former causes greater impacts than the latter. Simple matrices are useful: 1) early in EIA processes for scoping the assessment; 2) for identifying areas that require further research; and 3) for identifying interactions between project activities and specific environmental components. However, matrices also have their disadvantages: they tend to overly simplify impact pathways and they do not explicitly represent spatial or temporal considerations, and they do not adequately address synergistic impacts.

Matrices require information about both the environmental components and project activities. The cells of the matrix are filled in using subjective (expert) judgment, or by using extensive data bases. There are two general types of matrices: 1) simple interaction matrices; and 2) significance or importance-rated matrices. Simple matrix methods simply identify the potential for interaction (Table 2). Significance or importance-rated methods require either more extensive data bases or more experience to prepare. Values assigned to each cell in the matrix are based on scores or assigned ratings, not on measurement and experimentation. For example, the significance or importance of impact may be categorized (no impact, insignificant impact, significant impact, or uncertain). Alternatively, it may be assigned a numerical score (for example, 0 is no impact, 10 is maximum impact).

2.5.4. Networks

Networks are an attempt to systematically and comprehensively identify, through sequential cause/effect linkages, the series of impacts (primary, secondary, tertiary) that may be triggered by project activities (the initial impacts). There are two types of networks: those which trace the progression of causes and effects of various project actions i.e. stepped matrices and flow diagrams; and systems diagrams which trace higher order dependencies among the components of a defined system. The development of the network diagram is usually based on experience with similar projects. The method appears to have been developed by the Travellers Research Corp. in 1969, but the best known approach is probably that developed by Sorensen (1971). The advantages of the approach include the fact that the importance of indirect effects is recognized, the interrelatedness of environmental components is recognized, it may facilitate the examination of alternative project designs through experimentation with different combinations of elements and it may be a useful tool to communicate complex information in a visually understandable form.

The disadvantage is that the network developed depends on the knowledge of the network designer and some effects can be missed. Where cause effect linkages are less clear (especially social effects the approach may be less useful). Screening is essential otherwise the network becomes too complex and dominated by trivial effects. The importance of the approach is in identifying cause effect relationships at different levels but is rarely used because of its complexity (for examples of its application see, for example, Biswas and Geping, 1987).

2.5.6. Overlays

Overlays are a system of representing information in graphic form as series of individual themes (overlays) that provide information on individual topics (data bases) and which are subsequently displayed as a "composite" or "aggregate" map which is capable of telling a "bigger" story. This traditional geographic technique was developed by McHarg (1969) as a land use planning tool. A set of transparent overlay maps, each displaying information about environmental or social components were produced. The overlaid maps can show overlaps or conflicts between projects and environmental factors. The method does not guarantee that all potential impacts will be identified but it can show the potential spatial extent of impacts. For example, mapping the reservoir of a proposed dam would show the spatial extent of flooding; this can be overlaid with maps of animal habitat, human occupation, etc. Areas can be weighted to illustrate their relative importance. The advent of GIS techniques allow this approach to go several steps further. Additional spatial data files can be incorporated and a much broader range of questions can be asked.

2.6. APPLICATION OF GIS IN EIA

Geographical information systems can be applied at all EIA (EIA) stages. EIA is a decision process, which aims to both identify and anticipate the impacts on the natural environment. The interface between these two components produces several effects, which will generate specific impacts and also, GIS can be explored within the EIA process to improve different features, which are mainly related to the data storage and access, to the analysis capabilities and to the communicability of the results. The development of such a system will allow a more realistic approach to the environmental descriptors and a better understanding of their interrelationships. GIS will bring to the EIA process a new way of analyzing and manipulating spatial objects and an improved way of communicating the results of the analysis, which can be of great importance to the public participation process.

The use of GIS in the EIA process, where public participation is of great importance, requires the development of applications allowing a better understanding of spatial phenomena. The EIA process involves the consideration of many different variables and phenomena presenting complex interrelationships, which vary in space and time. These procedures involve technical analysis that includes changing assumptions and priorities and descriptions of significant visual and audible impacts.

In summaries the capabilities of GIS in EIA are:

- In this context, it is possible to store large amounts of different kinds of data. The access to these richer databases allows the performance of dynamic queries based on real world representations.
- Concerning the analytical capabilities, some potential functionality can be added such as the use of interactive video and digital sound associated with maps of zoning, to help planners and decision-makers to visualize and better evaluate the impact of a new infrastructure. Other capabilities are related to the integration of spatial simulations associated to real images and to stereoscopic aerial photographs in order to get an improved visualization of the phenomena and its evaluation in real time.
- The results of an EIA correspond to compressed information for which it is intended to synthesize in a small number of descriptors the complex and diversified universe that has been analyzed. In a GIS, the improvements in the communicability of the results are associated with the use of images, which represent information in a compact way, and of easier comprehension.

The development of GIS for EIA requires the analysis of this process in order to identify the tasks that will be of benefit. To better understand the study area it may be necessary to view it from several different perspectives: aerial views, static and dynamic ground views. The aerial view corresponds to combination of a flight through the aerial photographs or the satellite digital photograph, which gives a perspective of the study area. This representation can be associated with the correspondent route of the flight over a map, allowing the interrelationship between the two spatial representations.

2.7. Environmental impacts of geothermal projects

Environmental impacts from geothermal development vary during the various phases of development. Geothermal development can be described as a three-part process: exploration, drilling and utilization. This section describes the typical operations for each phase of development and the impacts that can be expected during each phase.

Preliminary exploration is usually the least expensive exploration operation with the least environmental effect. There are usually no environmental effects of geologic mapping as it only involves walking or aerial reconnaissance across the exploration area. Sampling procedures carried out during this phase are also benign. In geothermal projects most land effects occur during drilling. Each drill site is usually between 200-2500 m^2 in field. The soil in these fields is compacted and changed, and close to the drill site there is also deposition of waste soil and drill mud. To transport the drill rig and other instruments road construction may be needed and this affects the land. Construction of roads, well pads, and power plant sites results in cut and fill slopes that reshape the topography of the fields, but the effect on the field's topography is not significant. During installation there is some effect on the land from soil movement for construction of pipelines, power plant and other buildings. During plant operation subsidence, induced seismicity and effect on hot springs are the main possible effects on the land of the power plant and surrounding areas zones.

Exploration (geology, geochemistry, and geophysical exploration) during geothermal projects does not affect atmospheric air. During drilling and utilization air pollution can result from non-condensable gas (especially H_2S and CO_2) emissions, exhaust smoke from generators, compressors and vehicles. Combustion of diesel fuel in the drilling rig produces NOx, CO, SO2 and hydrocarbons, but the amount of these gases is not significant and does not have an important effect on the atmosphere. During well testing, steam and spray can have an adverse effect on the local vegetation with trees and grass being scalded. Fugitive dust is generated by several activities scheduled during construction, operation and decommissioning. The principal source is dust generated by travel on unpaved roads, dust generated by earthmoving activities during construction and reclamation on the power plant site and well pads, and dust carried by wind blowing across exposed surfaces (Yousefi, 2004).

3. THE QUALITY OF EIA

Unfortunately the EIA is often undertaken to satisfy the requirements of banks and donor agencies. Thus, the EIA gets done, but has only a minor role in improving environmental conditions of projects (Flynn et al, 1991).

The environmental impact assessment process will only be effective for sustainable development if there is regular monitoring during project implementation and operation so that appropriate environmental impacts can be identified and measured.

EIAs should be prepared using an inter-disciplinary approach to insure the integrated use of the natural and social sciences. The disciplines of the preparers must be appropriate to the scope and the issues identified in the scoping process. The EIA should list the names and qualifications of the persons primarily responsible for preparing the EIA or significant background papers. Where possible the persons who are responsible for a particular analysis, including analyses in background papers, are to be identified. Following these guidelines will insure that appropriate standards will be applied and carried out with reasonable safeguards. This is particularly important to ensure quality, especially when consultants and contractors subcontract out the work. Another quality improvement for EIA preparation is that any methodologies used should be referenced, by explicit reference, to the scientific and other sources relied upon for conclusions in the EIA (Goff, 2000). Discussions of the methodology should appear in the appendix. In addition, the EIA should contain an executive summary which adequately and accurately summarizes the EIA. Often decisions makers may read only this summary; therefore it must present the significant impacts, clarifying which are unavoidable and which are irreversible; the measures which can be taken to mitigate them; the cumulative effect of the impacts; and the requirements for monitoring and supervision.

Geothermal sites and volcanic regions often exhibit significant landslide hazard. Such sites are typically characterized by sloping, hydrothermally-weakened, saturated ground, and substantial volcanic activity. Engineering works associated with geothermal sites, including wells, pipeline networks, and modification of ground by cuts and fills, may also contribute to landsliding. It is imperative that a standard EIA format include some discussion of the impacts of landslides and

suggested mitigation options for landslide hazards (Goff, 2000).
The authors by using their long term experience, tiring to prepare a guide with the purpose of providing tools for integrating geothermal environmental factors into the plan, design and operation of projects. The guide will present comprehensive discussions of the environmental impacts associated with geothermal development projects and suggest monitoring and mitigation plans by using GIS environment.

4. WORLD BANK PROCESS

The World Bank has recognized EIA including monitoring and modeling as one of the most important tools to ensure environmentally sustainable development. In 1989, the Bank first adopted operational directives (OD) 4.00, which later on was amended as OD 4.01 in 1991, where environmental assessment became a standard procedure for the projects financed by the bank. An environmental assessment should be carried out early in the project cycle during project conception and design stage in order to identify its direct and indirect impacts on physical and social environment and establish linkages. Various steps to be followed during identification, preparation, appraisal, negotiation, implementation, and evaluation of the project, as recommended are given in the World Bank guidelines. The target of this guide is shown in Figure 2. Components of an EIA report for World Bank include an executive summary; a policy, legal, and administrative framework; project description; baseline data; impact assessment; analysis of alternatives; a mitigation or management plan; an environmental monitoring plan; and public consultation.

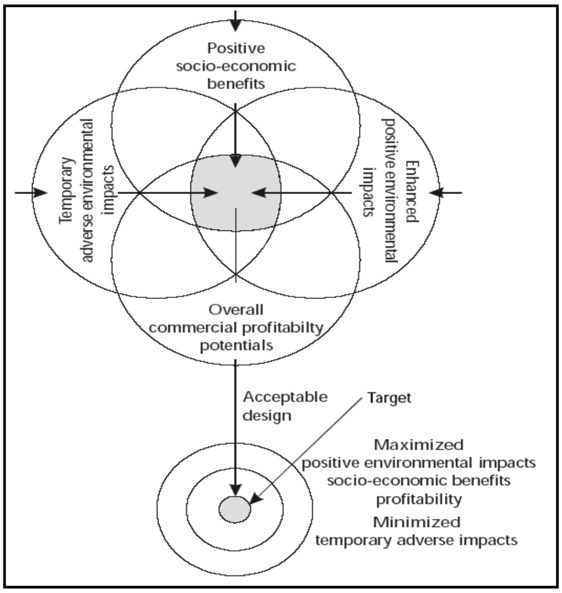

Figure 2.The target of EIA process

5. DISCUSSIONS & RECOMMENDATIONS

A well-prepared EIA report for geothermal development can add significantly to the quality of the overall project.
A standard format should be a required part of a geothermal plan (Goff, 2000). Utility companies should consider that the EIA cannot progress individually and it is necessary to assembling a local team to prepare EIAs by consultations with other organizations such as universities, other ministries, and private companies or senior experts.
Utility company representatives or appropriate governmental personnel should understand the essence of an EIA. This requires learning how to do a comprehensive review; having the team putting the EIA together spend adequate time in the field assessing the environmental conditions at the development project; knowing the qualifications of those preparing the document and the disciplines that will be represented; spending time with the team preparing the EIA; and requiring status reports as part of the overall bid specifications (Goff, 2000).
The Geothermal Environmental Impact Assessment (GEIA) should concentrate on impacts most closely associated with energy sector development. Air quality, water resources, geologic factors, and socioeconomic issues will consistently be among the most important factors. If working near protected area, national park or natural resource areas, biological/ecological factors will increase in importance. The positive impacts that energy development projects could have on ecological issues could be stressed by including a reforestation, revegetation program affiliated with the development component. This will not necessarily be costly and will add to the overall improvement of environmental quality in the country. It is also essential to establish environmental control procedures and standards to ensure that program activities are carried out with reasonable environmental safeguards.
The process should be intended to help public officials make decisions that are based on understanding of environmental consequences and take proper actions. It is especially important that public opinion be taken into consideration. Finally, to develop a sustainable geothermal energy resource, it is highly recommended to accomplish a standard format of GEIA process to the program before starting exploration drillings.

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Table 1: Simple checklist developed for the Huasai-Thale Noi Road Project

Items	Nature of likely impacts									
	Adverse						Beneficial			
	ST	LT	R	IR	L	W	ST	LT	SI	N
Aquatic ecosystems		×		×	×					
Fisheries		×		×	×					
Forest		×		×	×					
Wildlife		×		×		×				
Endangered species		×		×		×				
Surface water hydrology		×		×		×				
Surface water quality		×								
Groundwater										
Soils										
Air quality	×				×					
Navigation		×			×					
Land transportation								×	×	
Agriculture							×			×
Socioeconomic								×		×
Aesthetic		×			×					

legend						
	×	Indicator	ST	Short Term	LT	Long Term
	R	Reversible	IR	Irreversible	L	Local
	W	Wide	SI	Significant	N	Normal

Source: National Environment Board, 1980

Table 2: Simple environmental impact matrix for the Phoenix Pulp Mill

Environmental components	Project Activity								
	Plant constriction	Farming of kenaf	Pesticide fertilizer	Transport of row materials	Water intake	Solid waste	Effluent discharge	Emissions	Employ-ment
Surface water quality			×			×	×		×
Surface water hydrology					×				
Air quality				×				×	
Fisheries			×				×		
Wildlife habitat	×								
Terrestrial wildlife	×								
Land use pattern		×							
Highways				×					
Water supply			×				×		
Agriculture		×							
Housing									×
Health						×	×	×	
socioeconomic									×

Source: Lohani and Halim, 1983