UNITED NATIONS UNIVERSITY
GEOTHERMAL TRAINING PROGRAMME
Orkustofnun, Grensasvegur 9,
IS-108 Reykjavík, Iceland

Reports 2012
Number 33

COMPARATIVE STUDIES OF EIA REVIEW FOR PAPUA NEW GUINEAN AND ICELANDIC PROJECTS WITH A FOCUS ON GEOTHERMAL UTILISATION

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ABSTRACT

Geothermal energy resources are abundant and can be utilised in many different ways to benefit society and the people living in it. However, the legal environment has placed legal and regulatory challenges on the progress of geothermal utilisation in many countries. Permit processes and Environment Impact Assessments of geothermal projects are parts of the important regulatory framework that all developers should be subject to before carrying out preparatory work. Well-defined and stable legal and regulatory frameworks are important to geothermal developers to ensure that the planning stages of geothermal development are carried out stepwise for the benefit of a country and to motivate the promotion of geothermal projects. Iceland and Papua New Guinea are countries that operate legal and regulatory frameworks in relation to geothermal development. Both countries have regulations, similar yet different as regards to permissions and EIA processes for geothermal development. Interestingly, Papua New Guinea is new to the geothermal arena and additional geothermal development is likely to take place. Iceland is one of the top geothermal producing countries with several major geothermal power plants. A comparison of legal and regulatory frameworks between the two countries shows both similarities and differences. While the geoscientific and geothermal engineering work may be similar in nature, their regulatory frameworks and preparation of geothermal projects may be compared on the basis of EIA, exploration, permit policies and utilisation. These factors, in turn, provide practical experience and obstacles for Papua New Guinea which is emerging to become a promising country with a geothermal potential of about 3000 MW. Papua New Guinea does not have a regulatory framework for the exploration and development of geothermal energy. Hence, a set-up of a regulatory framework including EIA and permitting processes is proposed.

1. INTRODUCTION

The demand for electricity in the world is increasing at a growing rate in light of increased economic growth and increased population. Of 6 billion people, 2 billion do not have access to modern energy services and still depend on the use of fire to cook and for light (Fridleifsson, 2002). The world´s population is likely to double and is going to place huge constraints on the provision of reliable electricity. Hence, more demand will be expected from energy resources to meet those power needs, and more people will rely on energy resources to make ends meet.

Coal, hydropower, nuclear power, natural gas, oil, biomass, geothermal energy, wind, solar energy and tidal energy are the main electricity resources but on different scales and magnitude. Table 1 shows the division of the world´s electricity sources in 2010, showing coal, hydropower, nuclear power and natural gas, as the main sources of electricity production. Coal is causing an increased level of carbon dioxide emissions leading to changes in climate and affecting ecosystems.

TABLE 1: World electricity share per energy source (IEA, 2012)

Electricity	**Share (%)**
Coal	41
Hydro	16
Nuclear	13
Natural gas	22
Oil	5
Biomass, geothermal, wind, solar, tidal	4

New emphasis has been placed on the use of renewable energy resources to provide clean energy in the light of increased world demand for electricity and the increased level of carbon dioxide emissions. Clean energy is the key to improving the living standard of the poor so that they can access energy at affordable prices (Fridleifsson, 2002). Fridleifsson further added that there is an expected increase in the share of electricity coming from renewable resources. Hydropower and traditional biomass are renewable resources that are already being increasingly utilised, with the former supplying 16% of the world´s energy needs (Table 1). New renewable resources and biomass account for a 4% share of the world´s electricity, including geothermal energy, wind, solar energy and tidal energy.

Geothermal energy is an emerging activity and is considered to be a sustainable and renewable resource. The geothermal energy resource is considered an alternative source of energy to replace fossil fuels. Geothermal development is slowly expanding and has brought considerable benefits to the people and the environment. Geothermal energy is needed for many reasons, the main reasons being to provide reliable and cheap electricity and to replace fossil fuel resources. There are now twenty-four countries generating electricity from geothermal resources with the USA, the Philippines and Indonesia being the top three countries (Beltane, 2010). Papua New Guinea is a new potential geothermal country, ready to exploit and utilise resources in the near future. More and more countries are emerging as more research and training promote geothermal energy in the world (Figure 1).

However, the production capacity is the main concern that determines the level of recharge to the system, controlling the geothermal system by reservoir pressure decline (Axelsson, 2008b). Hence, geothermal resource management plays an important role in planning and identifying risks and how to avoid problems. Utilisation of geothermal resources is favourable but legal and regulatory issues need to be reviewed to encourage the growth of geothermal utilisation (Haraldsdóttir, 2010). The issues focus on government management of regimes where resources are to be utilised, by whom and how, both on private and public land. A regulatory framework must not be a barrier to geothermal development (Haraldsson, 2012). Legal and regulatory frameworks need to be set up in such a way that they address all aspects concerning utilisation of geothermal energy resources.

Haraldsdóttir (2010) said the key to addressing regulatory setbacks are long term planning and advanced rules on access to resources, whereby utilisation of geothermal resources is restricted by environmental, economic and technical constraints.

In light of this, this report will focus on: the geothermal development and experience of Iceland and Papua New Guinea (PNG); mitigation measures undertaken; a comparison between projects; and finally, some recommendations. This report is divided into three main parts. The first part describes the characteristics of geothermal power and the main regulatory framework in Iceland and Papua New Guinea, respectively. It also outlines the legal and regulatory framework governing geothermal in Iceland and Papua New Guinea, respectively. The second part describes the case studies on EIA experiences of geothermal development in PNG and Iceland. The third part of the report explains the main regulatory framework that can be applied in PNG and how it can best help PNG using Iceland´s practical experiences.

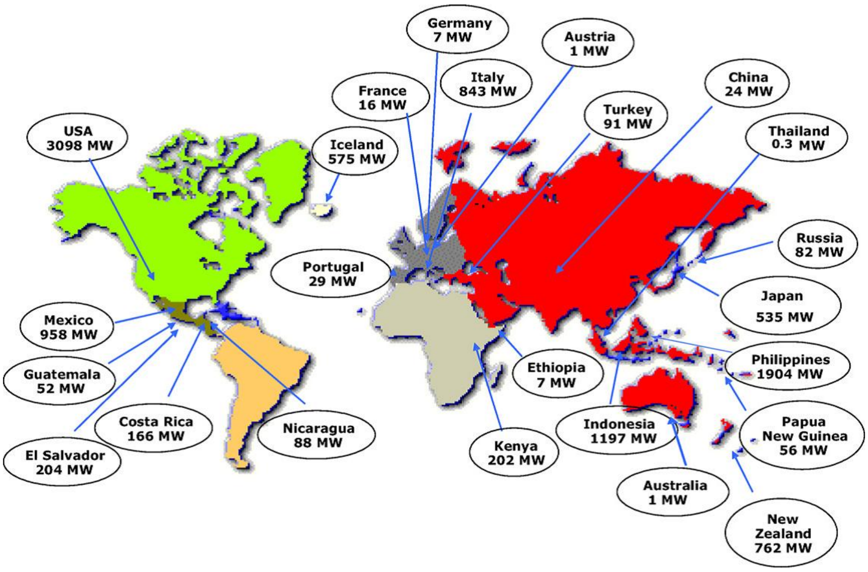

FIGURE 1: Geothermal-producing countries and installed capacity (Bertani, 2010)

2. LEGAL ENVIRONMENT AND EIA

EIA is an important part of any legal and regulatory framework. EIA and a legal environmental regulatory framework play important roles in the conservation of protected areas and the minimisation of adverse environmental risks while ensuring the promotion of economic viability and social prosperity. Technically, regulatory framework ensures that environmental permits and EIA licences are fulfilled so that permit/licence holders are held responsible and mitigation plans are adhered for both construction and operation phases.

Geothermal development is no exception and requires a regulatory mechanism. The utilisation of geothermal resources cannot be free of environmental risks as there are possible consequences of geothermal development (Ármannsson and Kristmannsdóttir, 1992). It is for this reason that geothermal resource management has put emphasis on the need for an effective legal environmental regulatory framework. Legal and regulatory frameworks reflect the significance of geothermal resource management. Key management issues need to balance environmental and energy interests, sustainable utilisation and how to ensure that resources are utilised for the benefit of the nation (Haraldsdóttir, 2010).

The changes in the environment brought about by geothermal developmental projects are as follows (Ármannsson and Kristmannsdóttir, 1992):

- Surface disturbances
- Physical effects due to fluid withdrawal
- Noise
- Thermal effects
- Emission of chemicals

Hence, geothermal exploration and developmental projects should be subjected to legal environment regulations.

2.1 EIA

EIA is an important part of the preparation for the development of projects, including geothermal projects and it is now the norm to subject all major developmental projects to an EIA. According to the Icelandic National Planning Agency (NPA, 2005), EIA is a process that identifies not only environmental impacts but also social and economic impacts. It is a process whereby possible impacts are evaluated and examined, the significance of the impacts is analysed, and then mitigation measures are introduced to minimise possible negative impacts. While evaluating and analysing the significance of the project's impacts on the environment, EIA also determines its methodology and ideology in order to consider the balance of economic, social and technical factors against environmental risks (NPA, 2005). Such an estimation of other holistic factors determines the significance of the project and how the project benefits the people and the environment. EIA helps to make right decisions on projects by promoting economic viability and social prosperity while promoting environmental sustainability.

The consideration and evaluation of possible impacts, their significance and recommendations to minimise negative impacts are important in the early stages of planning a project and can be used to achieve numerous objectives. According to NPA (2005), an EIA for a development project can:

- Avoid possible disturbance and facilitate a response to foreseeable damage at the design phase of the project;
- Minimise adverse and serious environmental risks caused by the project;
- Ensure that the environment and natural diversity are considered before final decisions are made;
- Increase the likelihood that the parties and the stakeholders involved in the matter will agree upon the implementation of the project;
- Promote greater public participation including the landowners in decision-making concerning projects that affect the environment;
- Increase the likelihood that the negative environmental impact of the projects that are carried out will be kept to a minimum level;
- Promote sustainable development.

2.2 Why compare?

Comparative studies benefit PNG in distinguishing the practical experience and obstacles in a regulatory framework and in preparation for geothermal development. PNG intends to harness its geothermal energy resources with its huge geothermal potential of 3000 MW (Bertani, 2010). However, PNG does not have a regulatory framework for geothermal projects. There are several applications being put on hold pending the setup of a proposed regulatory framework. For this reason, comparative studies are desirable as is finding out from Iceland, Kenya and El Salvador how EIA can be formulated for the geothermal projects in PNG and how permit processes are carried out in fulfilment of respective legal and regulatory frameworks.

2.2.1 Global

The EIA process is to some extent different in geothermal energy producing countries (Haraldsson, 2012) like Kenya, the Philippines, Iceland, USA, New Zealand, and El Salvador although effective in all. PNG has a legal and regulatory framework including EIA for developmental activities concerning exploration, land, water, mining, oil and gas, forestry and others. EIA in PNG is administered under the Environmental Act 2000, a general Environmental regulatory system. However, geothermal energy utilisation is a new activity that is mostly lacking within the regulatory framework and this needs to be changed.

The EIA methods used in the fast-growing geothermal producing countries, El Salvador and Kenya, are presented in the study to introduce an EIA preview and to understand and compare the methods, processes and legislation before focusing on Iceland´s basic structure for EIA and the relevant regulatory protocols concerning geothermal project development in Iceland.

2.2.2 El Salvador

The EIA process in El Salvador is controlled by the Ministry of Environment and Natural Resources (MARN) and geothermal development is expanding fast. It has been reported that additional geothermal drilling has taken place recently, especially in two major geothermal fields, Ahuachapán and Berlin (Bertani, 2010). However, the EIA process is in the early stages and MARN is now improving its environmental law to legalise and integrate geothermal development within the legal jurisdiction (Arevalo et al., 2011). Figure 2 shows how the EIA process is administered in El Salvador. The process is simple whereby an Application for an Environmental Permit is required to be submitted to MARN stating the intention to develop a geothermal area.

MARN will review the submitted environmental permit and visit the site for technical appraisal (Arevalo and Franco, 2011). MARN, in consultation with the relevant authorities, will then determine and evaluate whether an EIA is required or not. If an EIA is necessary, based on the significance of environmental risks, the developer would have to publish a notice of his intention to develop the geothermal area by inviting stakeholders and the general public and by facilitating a public hearings involving affected communities in order to gauge the views regarding the project. Once the final EIS has been evaluated and approved under the Environment law, the developer would be notified of the requirements to produce an Environmental Management Program that eventually serves as the basis for granting an Environmental Permit for the preparatory work.

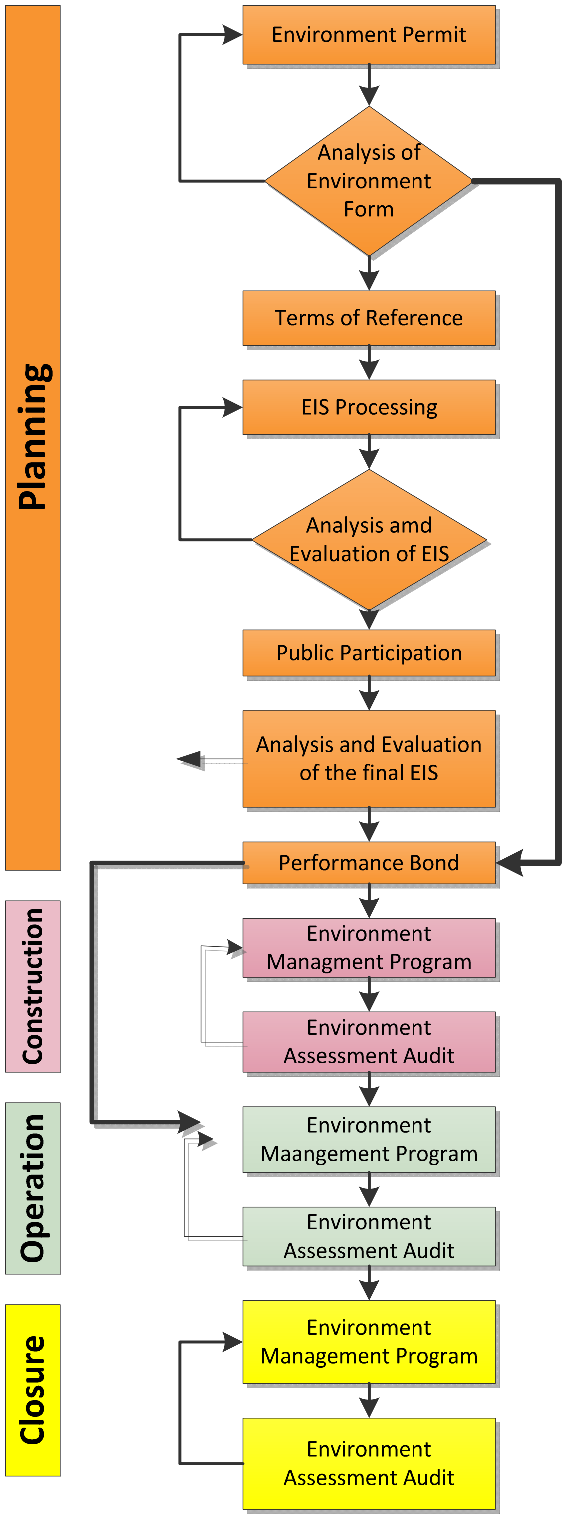

FIGURE 2: El Salvador EIA process (Arevalo and Franco, 2011)

2.2.3 Kenya

Kenya is a country where geothermal energy is utilized and is preparing to construct three new geothermal power plants at Olkaria, producing 330 MW of electricity (Bertani, 2010). Unlike most geothermally developed countries, Kenya has a principal act dealing with geothermal matters which is the Geothermal Resources Act 1982 (Mwawughanga, 2005). The act also deals with geothermal exploration and the issuance of geothermal exploration licences which is authorised by the Ministry of Energy.

The EIA process in Kenya falls under the Environmental Management and Co-ordination Act 1999 (Mwawughanga, 2005). The responsible body is the National Environmental Management Authority (NEMA) which administers EIA procedures. The EIA procedure is explained in a summary in Figure 3. The developer of a geothermal project is required to submit an EIR to NEMA, and NEMA will confirm whether an EIA is necessary to be carried or not (screening). NEMA will also need to confirm the following requirements that payment amounting to 0.1% of the project cost must be made, that the lead expert preparing the EIA report is registered and that the correct administrative protocol is followed before confirming the EIA report.

NEMA reviews the EIA report based on guidelines and makes a decision based on an ecological approach, using a hierarchy to mitigate expected impacts, applying a precautionary principle, ensuring equitable sharing and the consideration of risk assessment (NEMA, 2012). The decision of NEMA will decide whether a project is approved and an EIA licence will be issued, the time limits for the developer to submit additional information and whether the application will be rejected.

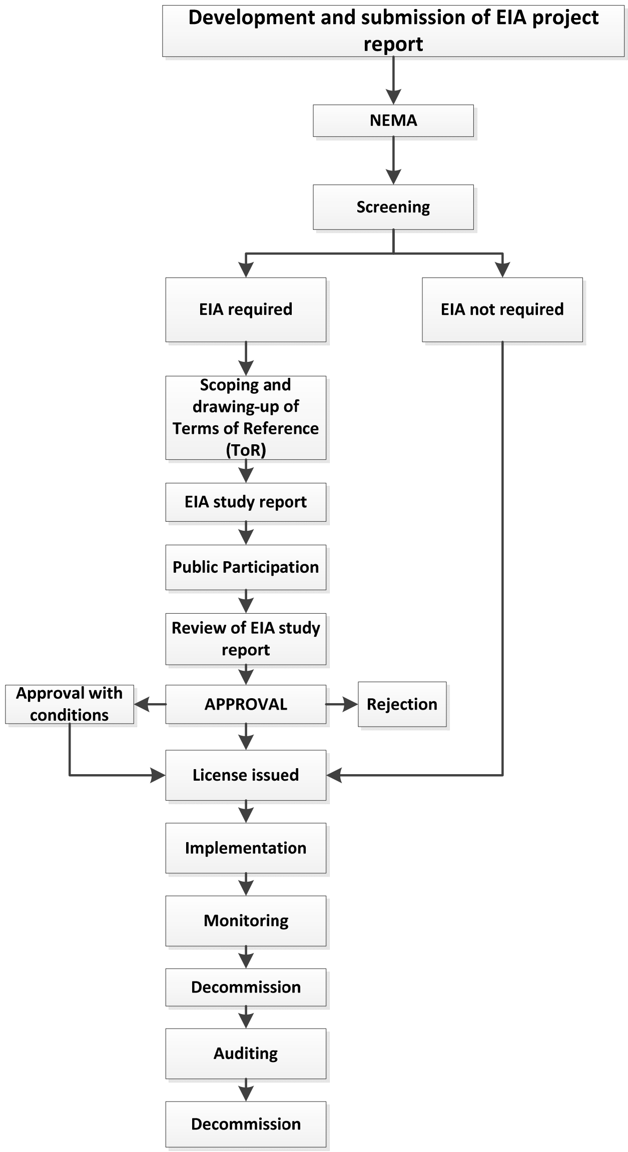

FIGURE 3: Simple EIA process in Kenya (modified from NEMA, 2012)

3. GEOTHERMAL ENERGY

Geothermal energy is considered to be a clean, efficient, environmentally friendly and renewable resource. It meets all criteria of an energy assessment and is proven to have significant potential for the provision of energy, especially for developing countries (Ofwona, 2012). Geothermal energy is a promising energy source that can transform the lives of poor people in developing countries as it provides relatively cheap and reliable electricity for their needs. The availability of geothermal resources is immense and utilisation possibilities are favourable for the improvement of living standards and for economic development.

In classifications of geothermal systems high temperature geothermal systems are associated with volcanic systems. Thus, several geothermal systems in PNG can be classified as high temperature geothermal systems. The general conceptual model of a high temperature field is shown in Figure 4. The heat sources of a volcanic systems are hot intrusions from beneath; they are often located close to the caldera or the spreading centres (Figure 4). The hot intrusion heats up groundwater, causing the hot water to rise to the surface.

A high-temperature geothermal resource can be either a dry-steam, vapour-dominated resource or a hydrothermal, liquid-dominated resource. In PNG there are several active volcanoes, as the country is located along the Pacific Ring of Fire.

It is important that the resource be utilised in a sustainable manner. This has been defined as follows, with reference to Figure 5: For each geothermal system, and for each mode of production, there exists a certain level of maximum constant energy production, E_0, below which it will be possible to maintain constant energy production for a very long time (100-300 years). If the production rate is greater than E_0 it cannot be maintained for this length of time. Geothermal energy production below or equal to E_0 is termed sustainable production, while production greater than E_0 is termed excessive production (Axelsson et al., 2001).

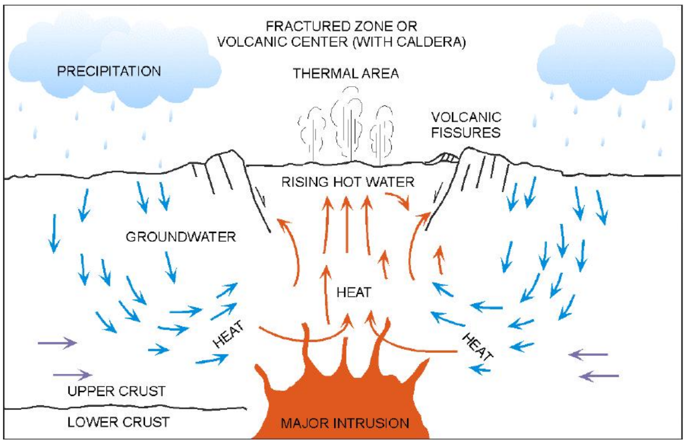

FIGURE 4: A general conceptual model of a high temperature field (Steingrímsson, 2012)

Geothermal resource management is needed to ensure long-term utilisation which involves a close examination of a reservoir production scheme, avoidance of over-exploitation, application of step-wise development, minimizing environmental effects, minimizing costs and maximizing revenues and the avoidance of operational problems (Axelsson, 2008a).

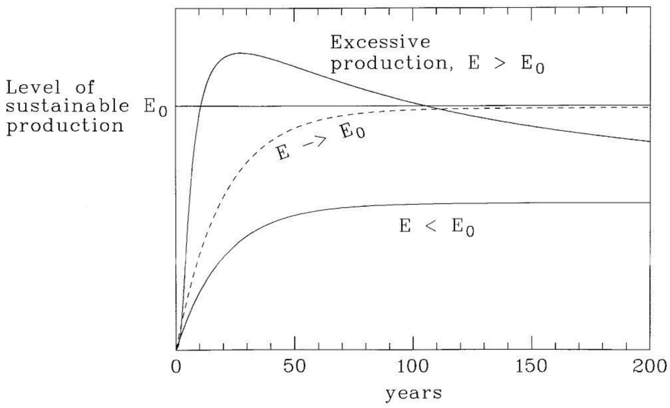

FIGURE 5: Sustainable production from a geothermal system (Axelsson et al., 2001)

This is also a rationalisation for an effective legal and regulatory framework to be developed to set policy for successful geothermal development. There are certain issues to be considered, especially for developing countries who could learn from other countries´ backgrounds on exploration and the development of a geothermal resource. The issues include regulation, ownership and fiscal regimes over which resources are to be utilised, by whom and how within the land (Haraldsdóttir, 2010). Thus, the importance of a regulatory framework is emphasized.

3.1 Iceland

Iceland, located on the Mid-Atlantic Ridge, hosts several active volcanoes and has huge geothermal potential. Iceland is among the world´s top eleven geothermal electricity producing countries and its share of geothermal energy utilisation in the country's energy budget is the second biggest in the world, accounting for 26% of the nation´s use of electricity (Fridleifsson, 2002).

Iceland has several high temperature fields and numerous low temperature fields in most parts of the country (Figure 6). There are currently 7 major geothermal power plants in Iceland with 3 plants being used to provide both heat and electricity (Table 2). The Hellisheidi geothermal power plant is the largest plant with an installed capacity of 303 MWe and 133 MW thermal energy (Orkuveita Reykjavíkur, 2012).

TABLE 2: Main power plants and generation in Iceland (Enex, 2012)

Power plant	Year operation started	Power generation	Hot water production
Bjarnarflag	1962	3.2 MW	Only electricity
Krafla	1977	60 MW	Only electricity
Svartsengi	1977	76 MW	150 MWth
Reykjanes	2006	100 MW	Only electricity
Nesjavellir	1990	120 MW	300 MWth
Hellisheidi	2006	303 MW	303 MWth
Húsavík	2000	2 MW	Only electricity

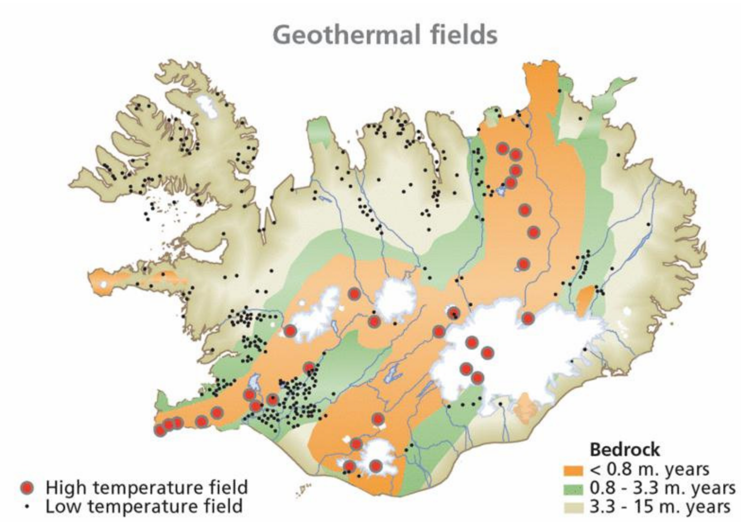

FIGURE 6: Geothermal fields in Iceland (Orkustofnun, 2012)

Space heating is the most common direct geothermal utilisation in Iceland; about 90% of the population of Iceland has access to district heating. The Reykjavík district heating system, which is operated by Reykjavík Energy, provides space heating to more than 200,000 people in the capital area (Ragnarsson, 2010).

The legal and regulatory framework has been reviewed in the past, some of it to take into account the development of geothermal utilisation. The abundance of geothermal resources has drawn the Icelandic government´s attention to coming up with policies about the exploitation of geothermal resources for heating and electricity uses (Haraldsdóttir, 2010). Successful research and drilling has been on-going in several high and low temperature fields (Figure 6). Furthermore, the need for sustainable energy utilisation was further strengthened with the Icelandic government's decision in 1997 to prepare a Master Plan for geothermal and hydropower development, to identify the most sustainable energy sources, and to maximise the production of energy from renewable energy sources. According to Björnsson et al. (2012), the purpose of the Master Plan was to promote sustainable development and to prepare a matrix for various potential energy projects both in geothermal and hydro sources throughout Iceland. This, in turn, would identify and evaluate projects according to their economic significance and environmental sustainability as well as promoting social prosperity for the wellbeing of the Icelandic people. Björnsson et al. (2012) pointed out that according to the final scientific proposal for a Master Plan in 2010, geothermal potential in Iceland is about 35,000 GWh/a with 9,000 GWh/a considered appropriate for development.

3.2 Papua New Guinea

PNG is located on the Pacific Ring of Fire and is a host to several volcanoes (Table 3) from the southeast to the northwest of the country with several known geothermal areas (Figure 7 and Table 4). Geothermal utilisation is insignificant in PNG but will become a new player in the field of energy in the near future.

According to REEP (2012), the total installed electricity capacity in PNG was 582 MW in 2010. Hydropower accounted for about 40%, diesel 37%, and natural gas 14%. Only 9% was accounted for by geothermal energy. About 90% of the population has no access to electricity. Most of the electricity

TABLE 3: Major active volcanoes in PNG (Volcano live, 2012)

Name of volcano	Province	Category	Last eruption	Summit elevation	Type
Bagana	North Solomon	Active	2007-2008	1750 m	Lava cone
Rabaul	East New Britain	Active	1994-2010	668 m	Caldera
Manam	Madang	Active	1974-2012	1807 m	Strato
Karkar	Madang	Active	1979	1839 m	Strato
Lamington	Oro	Active	1951	1680 m	Strato
Langila	West New Britain	Active	2009	1330 m	Complex
Ulawun	East New Britain	Active	2010	2334 m	Strato

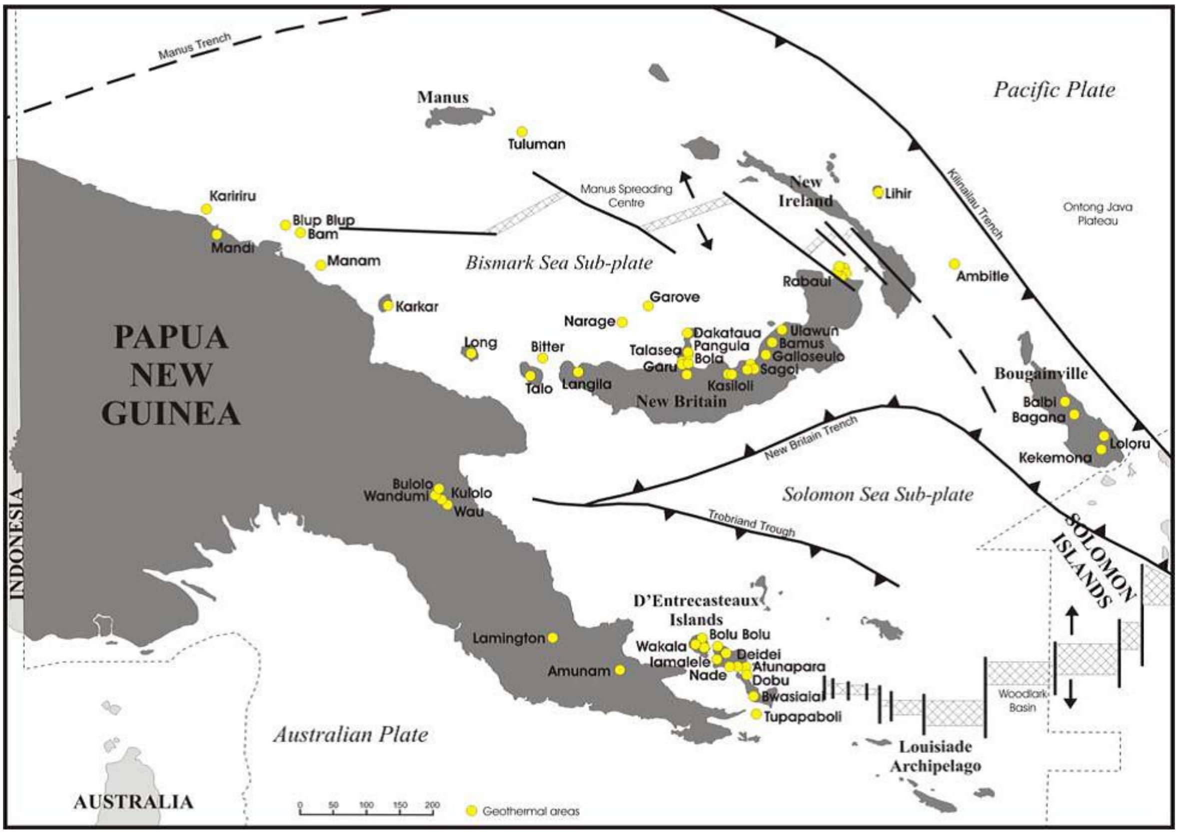

FIGURE 7: Map of Papua New Guinea showing known geothermal sites based on MRA report, 2011

is available centrally in the capital city, Port Moresby and other urban areas. PNG has had capacity problems in providing power to urban developments and the major economic activities and numerous power interruptions have taken place. Electricity in PNG is often unreliable, and relatively expensive. This has led to difficulty in providing the majority of the population with power and hence contributed to poverty in rural areas. The majority of the population still uses petroleum products for the energy needs of their everyday lives. Such regular usage of petroleum products for energy leads to environmental problems.

Lihir geothermal power plant was the first geothermal development in PNG and has been used to power the mining processing and development on Lihir Island, New Ireland Province (Maleku, 2005). The development of the geothermal power plant in Lihir was commissioned in 2003. It is owned by a private company and the electricity is only for its use. However, such a clean energy development project heralds the opportunity for further geothermal exploration and utilisation in PNG. The Lihir power plant accounts for the only geothermal utilisation on PNG; more geothermal research and exploration are required for further geothermal utilisation. PNG has a huge geothermal potential that could provide 21.9 TWh (REEP, 2012).

TABLE 4: Some volcanic activity with geothermal features in PNG (Volcano live, 2012)

Name of volcano	Province	Type	Summit elevation	Geothermal features
Umboi	Morobe	Complex Volcano	1584 m	Hot springs, bubbling mud pools, solfatara
Lihir	New Ireland	Complex Volcano	700 m	Hot springs, mud pools, solfatara
Goodenough	Milne Bay	Volcanic field	2566 m	Hot springs
Dobu*	Milne Bay	Strato Volcano	300 m	Fumoralic activity
Kairiru	East Sepik	Crater	800 m	Hot springs (geothermal activity)
Musa	Oro	Hydrothermal Field	808 m	Hot springs
Oiau	Milne Bay	Strato Volcano	400 m	Fumarole activity
Garua*	West New Britain	Volcanic Field	656 m	Hot springs, boiling pools, fumaroles, geysers
Dakataua	West New Britain	Caldera	400 m	Solfatara, warm springs
Walo	West New Britain	Hydrothermal Field	15 m	Solfatara and mud springs
Karai	West New Britain	Strato Volcano	565 m	Hot springs
Narage	West New Britain	Strato Volcano	307 m	Hot springs and geysers
Garove	West New Britain	Strato Volcano	368 m	Solfatara field and thermal areas
Bamus*	East New Britain	Strato Volcano	2248 m	Fumaroles
Ambitle	New Ireland	Strato Volcano	450 m	Hot Springs, mud pools, fumaroles
Balbi*	Bougainville	Strato Volcano	2715 m	Boiling mud, active fumaroles, solfataras
Loloru	Bougainville	Pyroclastic shield	1887 m	Thermal activity
Karkar	Madang	Strato Volcano	1839 m	Fumoralic activity
Kadovar	East Sepik	Strato Volcano	365 m	Fumoralic/thermal activity
Bam	East Sepik	Strato Volcano	685 m	Hot springs
Doma Peaks	Southern Highland	Strato Volcano	3568 m	Geothermal activity

Note: *Protected areas under the conservation legislation in PNG (FAO, 2012)

Tables 3 and 4 show numerous volcanoes and geothermal features that are found in PNG. None of these potential geothermal sites are utilised for power generation. There are numerous active volcanoes on PNG and the majority of them are confined to the coastline, within both major and minor islands. Manam Island hosted the latest volcanic eruption this year (Volcano live, 2012).

PNG does not have a regulatory framework that caters for geothermal development. Numbers of proposed exploration applications being made to carry out geothermal exploration in PNG areas have been reported. There are several applications pending the setup of a proposed regulatory framework. One example is Kuth Energy PNG Ltd., which has been pursuing geothermal exploration at three geothermal potential sites which, in 2008, were put on hold due to the lack of a regulatory framework mechanism but the company still maintains its strategy to further explore the selected areas (Kuth Energy, 2012).

In a country-wide plan, PNG embraced a National Vision 2050, putting forth a long-term strategy that should map out the future direction for PNG. This long term strategy is designed to make it possible for PNG to become a smart, wise, fair and happy society by 2050 (PNG Treasury, 2010). The Vision 2050 is supported by seven pillars and these are:

- Human capital development, gender, youth and people empowerment;
- Wealth creation;
- Institutional development and service delivery;
- Security and international relations;
- Environmental sustainability and climate change;
- Spiritual, cultural and community development;
- Strategic planning, integration and control.

One of the seven pillars concerning renewable energy is the environmental sustainability and climate change. This is the pillar that sets out the need for development of large renewable energy projects to promote sustainable development in all sectors, and heralds the provision of 100% power generation from renewable energy sources by 2050. Hence, geothermal energy is covered in the context of renewable energy and this will enable the formulation of short-term and long-term developmental plans for increased utilisation of renewable energy resources in line with Vision 2050 and the development of sustainable developmental policies to provide for the increase in electricity needs. According to the Treasury (2010), Vision 2050 also foresees the establishment of a sustainable developmental policy in all sectors, especially forestry, agriculture, mining, energy and oceans by 2015. This spells out the chance for PNG to come up with the proposed regulatory framework to meet demands for geothermal exploration and utilisation. The establishment of sustainable developmental policies, especially the provision of 100% power generation from renewable energy sources, allows for the possibility of future geothermal utilisation in PNG in line with Vision 2050. Such a policy drive will improve the wellbeing of the people and the economy of the country.

A regulatory framework is required to motivate further geothermal research and exploration as PNG is potentially expected to benefit a lot from geothermal utilisation and its possibilities to improve the living standards of the people.

4. PHASES OF GEOTHERMAL EXPLORATION AND DEVELOPMENT

According to Steingrímsson (2009), the phases of geothermal development for the systematic exploration and development based on the Icelandic Generic plan of 1982 (Figure 8) are:

- *Preliminary study* – First phase involves undertaking of a reconnaissance survey, prospect investigations and exploratory drilling.
- *Appraisal study* – Geothermal appraisal drilling and reservoir evaluation are carried out to prove the production capacity of the geothermal reservoir, and the economic feasibility to find out the capital and operating costs for the overall aspects of power plants.
- *Project design* – Following an appraisal study, a project design is carried out to confirm the production drilling and re-injection, reservoir evaluation, and the meeting of environmental and other licences as well as the preparation of tender documents and the feasibility evaluation.
- *Construction and field development* – Implementation of a project design.
- *Operation* – Production and resource management are involved with careful management and monitoring.
- *Shut-down and abandonment* – The final phase of geothermal development to ensure that the closure of a geothermal is done with environmental management.

Furthermore, Steingrímsson (2009) added that a stepwise strategy (Figure 8) is preferred, given past experience, to achieve successful geothermal exploration and development. A stepwise strategy minimises the investment and operating costs, avoids possible repercussions from the geothermal operations, and secures the geothermal reservoir production capacity and sustains economic benefits. Axelsson (2008b) pointed out that successful utilisation depends upon the proper management of a

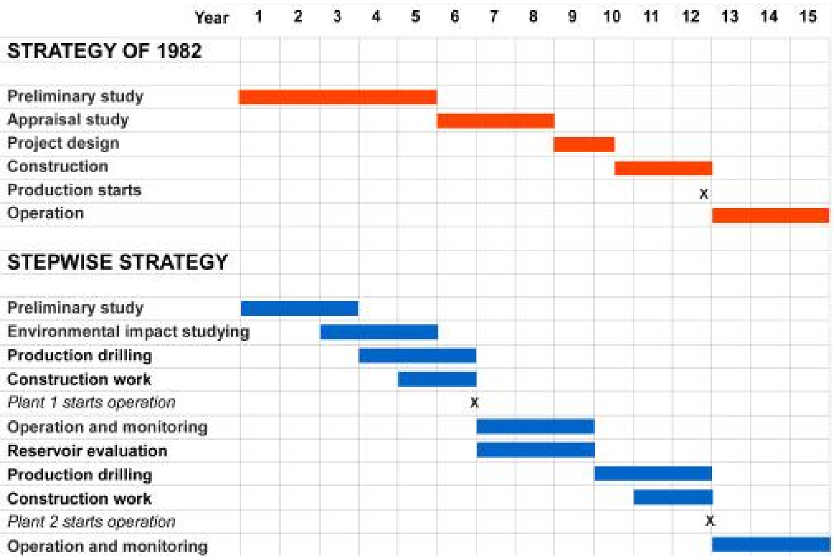

FIGURE 8: General plan and stepwise strategy for geothermal power plants (Steingrímsson, 2009)

geothermal system but also on the size of the geothermal reservoir, the permeability of the reservoir rocks, the reservoir storage capacity, the water recharge and the geological structure.

Financing a geothermal project varies in different developing countries and proper financial evaluation studies are required to ensure the success of geothermal exploration and development. Financial cost is the major hurdle to the accomplishment of geothermal projects. According to Steingrímsson (2009), the appraisal study has been regarded as the most expensive and complicated phase, requiring huge financial resources to maintain the geothermal projects in most developing countries. The World Bank and the United Nations Development Program provide financial assistance to developing countries to exploit geothermal resources for electricity and there are some instances involving issuance of leases to international companies for the development of geothermal fields and a contractual basis between the developing countries and the independent power producers (Steingrímsson, 2009).

5. BACKGROUND OF EIA IN ICELAND AND PNG

5.1 Icelandic EIA act and the EIA process

5.1.1 Regulatory framework and preparation for geothermal power development in Iceland

All geothermal projects in Iceland are subject to legal and regulatory frameworks (Figure 9). Geothermal projects are subject to the legal treatment before permits are issued for the commencement of the preparation of work. The fulfilment and finalization of the processes and requirements comprise granting the developer a permit to commence work (Andrésdóttir et al., 2003).

The main legislation concerning geothermal project development are The Act on Research and Use of Underground Resources No. 57/1998, The Energy Act No. 65/2003, The Environment Impact Assessment Act No. 106/2000, The Planning Act No. 123/2010 and The Nature Conservation Act No. 44/1999.

1. The Act on Research and Use of Underground Resources No. 57/1998

The Act on Survey and Utilisation of Ground Resources (Research and use of underground resources) is a piece of legislation managed by Orkustofnun – the National Energy Authority. This Act covers resources in the ground and underground in the sea and in lakes and other resources that have underground characteristics. It can be interpreted as a law which applies to a geothermal project. Geothermal energy is a vital resource that is fully exploited underground and, hence, subject to the jurisdiction of the Act on Survey and Utilisation of Underground Resources (Althingi, 1998a).

The objective of the Act is twofold, i.e. Research and Exploration permits, and Utilisation permits. An Exploration permit is required for a developer to carry out research and exploration and the Utilisation permit for construction and development during the project. The exploration permit is a prerequisite for the utilisation permit if the developer intends to carry out geothermal development, but it does not guarantee that the developer will be given the utilisation permit as the Icelandic government makes the ultimate decision (Althingi, 1998a).

2. The Planning Act No. 123/2010

The Planning Act is a key piece of legislation that deals with controlled planning. The National Planning Agency (NPA) manages and implements the Planning Act. The Act stipulates the submission of a development plan and sets out the plan at a regional level, a municipal level and a local level which enables the NPA to scrutinise the development projects in line with the general developmental plans. The Act also stipulates the need for applications for development and building permits (Althingi, 1998b). The Development permit is a key licence issued by the municipality and shows that the geothermal project is in accordance with the development plan and must also be consistent with the approved EIA. When NPA gives its opinion, built on the final Environment Impact Statement (EIS), the developer will be given a written notification of the NPA's opinion. The licensor shall examine the developer's environmental impact statement on the project, and adopt a reasoned view on the National Planning Agency's opinion on the assessment of its environmental impact. The licensor shall publish its decision concerning a permit as well as the National Planning Agency's opinion on the environmental impact assessment within two weeks of the permit being issued (Althingi, 2010).

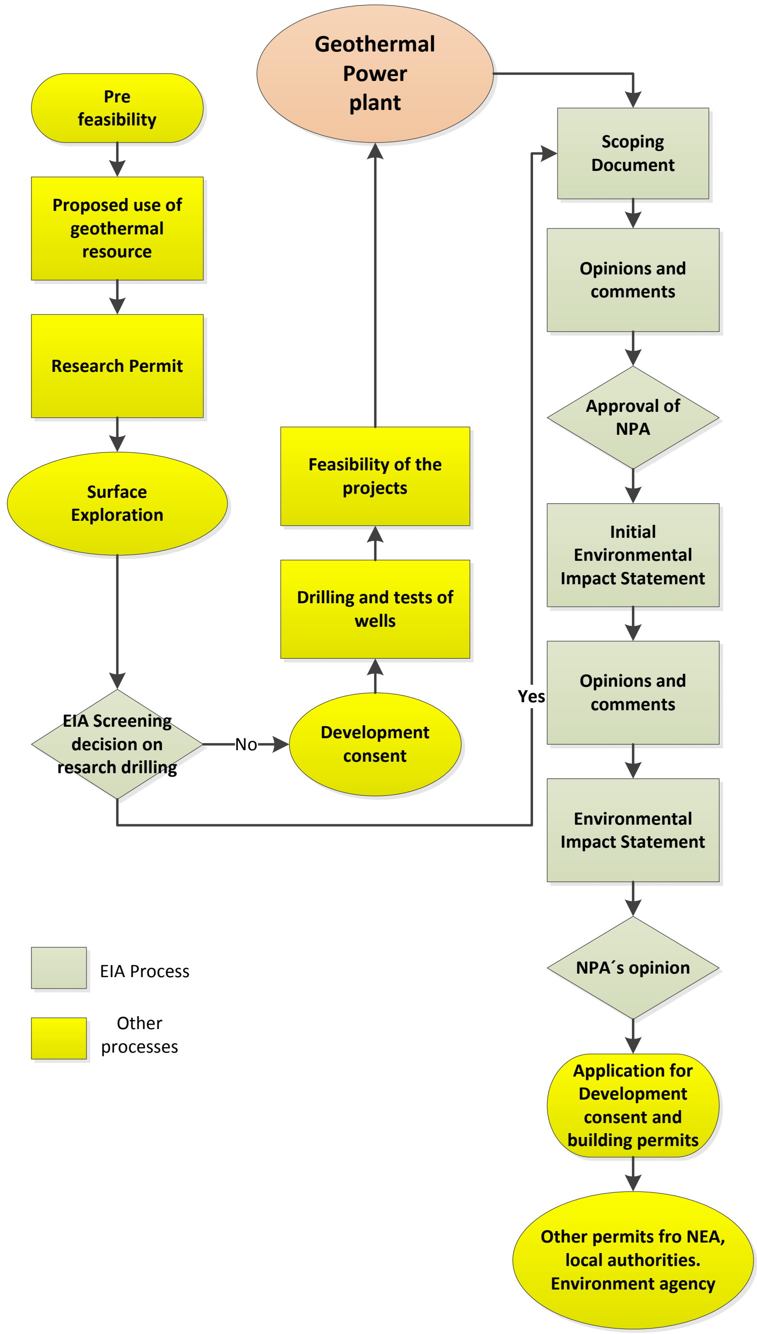

FIGURE 9: Simple geothermal developmental regulatory framework (modified from Gunnlaugsson, 2008)

A Building permit is a permit that is given to a developer and gives him the right to build, demolish and alter features in the land. The permit also governs the approval of general drawings and developmental proposals and commencement of work (Althingi, 1998b). There are conditions set out in the Building permit with which the developer must comply.

3. The Energy (Electricity) Act No. 65/2003

The Energy (Electricity) Act No. 65/2003 is a key law that governs the administration and implementation of generation, transmission and distribution of electricity in Iceland. It is specifically focused on matters relating to electricity utilisation and other energy mechanisms involved in the construction and consumption, and the economic modules. Orkustofnun is the body responsible for the implementation and administration of the act (Althingi, 2003).

This Act also covers the provision for granting a power development licence which enables the developer of the geothermal project to construct and operate an electric power plant. The construction and operation of the power plant applies only to power plants producing more than 1 MW of electricity; those geothermal projects that are likely to produce less than 1 MW do not require permits for power utilisation unless the electricity is sold through the grid-distribution system (Andrésdóttir et al., 2003).

4. The Nature Conservation Act No. 44/1999

The Nature Conservation Act concerns the preservation and protection of unique nature. This Act is administered by the Environmental Agency of Iceland.

Geothermal resources commonly comprise hot springs, fumaroles, and boiling mud, as well as steam vents; these areas are of natural interest to Iceland and, hence, require protection and preservation. The natural sites needing protection in accordance with the Act can be classified into national parks, nature reserves, protected species, habitats and ecosystems, and natural monuments (Althingi, 1999). There is a provision for the risk of disturbing sites of natural interest which allows the Environment Agency to consider the review of a geothermal project in the EIA procedure.

5.1.2 Environmental Impact Assessment Act No. 106/2000 *amended by* Act No. 74/2005

The Environmental Impact Assessment Act includes the administration and implementation of EIA procedures concerning geothermal projects. It is the key pathway to an eventual permit process before any actual project starts. NPA is empowered to administer and implement an EIA. This is different from Kenya and El Salvador where EIA legislation is implemented by the respective environmental bodies. The EIA has been effective since 1994 in Iceland and it is an important decision making tool for environmental risk assessment of geothermal projects before they are given the necessary licences. Under the Act, the developer is required to present the EIS to the NPA after which the NPA makes a decision on whether the EIS meets the requirements, as stipulated under the act, and whether the project and its environmental impacts are described in a satisfactory manner (NPA, 2005). After NPA has published its opinion of the EIA of a project, the licensor shall publish its decision on the issue of a permit and the findings of the National Planning Agency on the environmental impact assessment (NPA, 2005).

EIA was legalised in Iceland in 1993 in line with European Union Directive number 85/337/EBE with the Environmental Impact Assessment Act No. 63/1993 (EIA) (Albertsson et al., 2010). According to Albertsson et al. (2010), EIA was further strengthened under EU Directive number 97/11/EB in 2000 but with the initiative of the Icelandic government. The NPA is responsible for the administration and implementation of EIA Act No. 106/2000 and is responsible for facilitating public participation and promoting the co-operation of stakeholders and concerned parties with regard to projects subject to the provisions of this Act. According to a High court ruling in Iceland, negative impacts on nature cannot be justified because of positive impacts on the people. An example is a case where increased traffic safety at a proposed new road could not be justified because of significant negative impacts on nature, e.g. flora and fauna (Haraldsdóttir, 2010).

Geothermal projects subject to EIA

All geothermal projects are screened with respect to the significance of their environmental impacts, as shown in Figure 10.

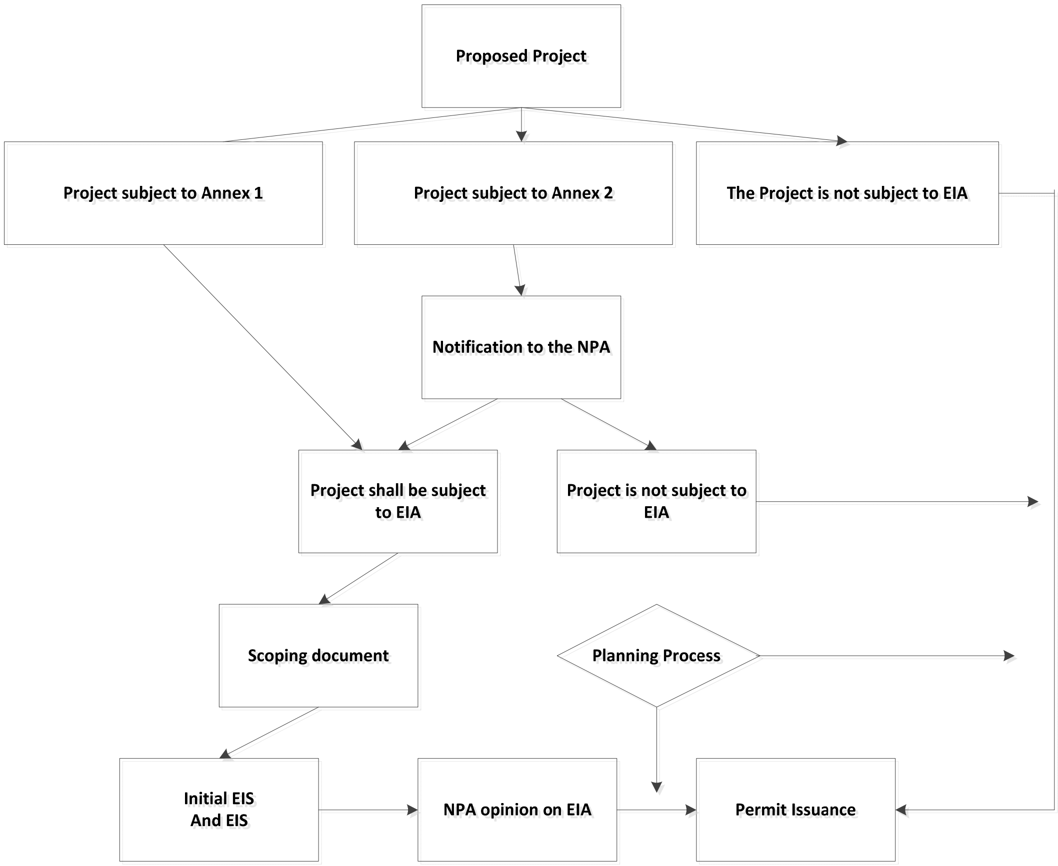

FIGURE 10: EIA project assessment for geothermal projects (Thóroddsson, 2012a)

Geothermal projects unequivocally subjected to EIA are listed in Annex 1. These projects are major projects that are likely to produce adverse environmental effects. Annex 1 geothermal projects include (NPA, 2005):

- Geothermal energy works and other thermal power installations with a heat output of 50 megawatts thermal or more
- Geothermal power stations and other thermal power installations with an electricity output of 10 megawatts electric or more

Projects that are subject to the notification requirement, and may be subject to EIA are listed in Annex 2. Annex 2 geothermal projects include:

- Drilling of production holes and research holes in high-temperature geothermal regions
- Geothermal drilling in low-temperature areas where mineral sources or hot springs are present on the surface or in near proximity
- Industrial installations for production of electricity, steam and hot water with an output of more than 200 kW
- Geothermal heating production amounting to 2,500 kW gross power or more
- Installation of pipes for carrying steam and hot water, underground electric cables of more than 10 km length, overhead transmission lines in protected areas, and submarine cables

Projects in Annex 2 may be subject to EIA after consideration based on the nature of the project, the location of the project and the characteristics of the potential impact of the project. Such a consideration will carefully delve into the size and extent of the project and the significance of natural resource utilisation as well as pollution, disturbances and the cumulative effects of the projects (NPA, 2005). In this regard, considerations specify the environment sensitivity of geographical areas that are likely to be affected with respect to existing or planned land use. Also, sustainable resource utilisation is encouraged to ensure that the abundance, quality and capacity of natural resources are managed; that means protected areas need to be considered, especially the absorption capacity of the natural environment (NPA, 2005). This EIA Act enables scoping of the important issues to be considered and validates whether research drilling in high temperature areas or low temperature areas, where geothermal manifestations are found, should be subjected to a full Environmental Impact Assessment.

Scoping document

Projects in Annex 1 are subject to a full EIA. The developer must submit a scoping document to the NPA to identify all issues to be considered for an EIA. Under the Act on Article 8 and Regulation No. 1123/2005, the developer submits the document to the NPA in the initial preparatory stage of the project. The document should be brief, should describe the nature and location of the project, and provide information on the planning of the project site and how the project will comply with the development plans. The developer is required to list the issues that are likely to arise from the proposed project and to find alternative options to address the issues. The developer also needs to have a plan for making information available and for public participation. The objectives of the proposed project should be consistent with the regional, municipal and local plans (Althingi, 2000).

The NPA makes a decision on the developer´s proposal within 4 weeks of its receipt as per Article 8 of the Act (Figure 11). The NPA must inform the licensors and relevant bodies about the scoping documents and get opinions before making a decision. It is important that those respective bodies be informed earlier so as to be able to form an opinion on the proposed project according to the legislation affected by the particular project. The NPA makes a decision on whether to approve the scoping document proposal with or without comments. NPA may provide comment(s) and the comments are then a part of the scoping document. If the NPA does not approve the scoping document, it should provide grounds for its decisions, indicate what is deficient and instruct the developer to improve the scoping document and how it can be further elaborated.

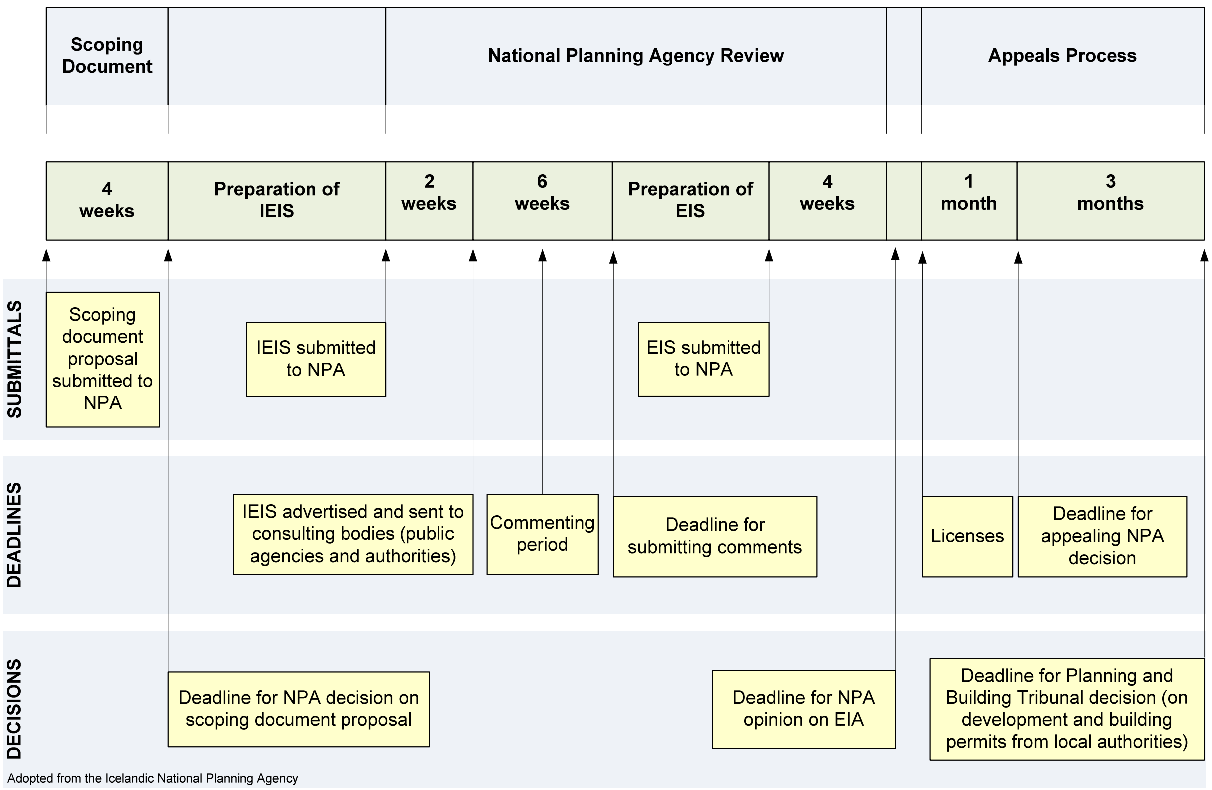

FIGURE 11: Assessment and licensing process in Iceland (modified from Ministry for the Environment and Natural Resources, 2005)

The Act stipulates that the NPA informs the licensors and consultation bodies if the scoping document proposal is approved before proceeding on to the Initial Environment Impact Assessment.

Initial Environment Impact Statement
The developer is required to prepare the Initial Environmental Impact Statement (IEIS) which must be consistent with the scoping document and the NPA decision on the document, according to Article 9 in the EIA law (Althingi, 2000). The IEIS must describe the assessment of the environmental impacts of the developmental project and accompanying activities.

Review by the National Planning Agency
Under EIA law in Article 10, the NPA has 2 weeks to review the IEIS after its submission by the developer. The submitted statement will be compared to the scoping document. If the NPA is not satisfied with the IEIS, it will notify the developer that a further amendment is required prior to acceptance.

After accepting the IEIS, NPA must advertise the IEIS, which must be easily accessible, in order to give the public the opportunity to submit comments. The time limit for submitting written comments is 6 weeks. The agency shall elicit comments from licensors and other consultation bodies where appropriate; the time limit for submitting them is 3 weeks. The NPA receives the comments and submits them to the developer who includes them in the final EIS (Althingi, 2000).

National Planning Agency´s opinion on EIA
Within four weeks of receiving the Environmental Impact Statement, the National Planning Agency shall deliver a reasoned opinion on whether the report meets the criteria of this Act and regulations issued on the basis of the Act, and whether the environmental impact is satisfactorily described. The National Planning Agency's opinion shall explain the main premises of the assessment, including the quality of the data on which the assessment is based, and its conclusions. The opinion shall also discuss the developer's response to the comments and opinions received when the Initial Environmental Impact Statement was made public. Should the National Planning Agency be of the view that further conditions should be laid down for the project, or that other and more extensive mitigating measures are required than those for which provision is made in the Environmental Impact Statement, the Agency shall specify such conditions and mitigating measures, and the reasons for them.

Should the National Planning Agency be of the view that the developer's Environmental Impact Statement is inconsistent with the preliminary assessment report in important aspects, it shall be presented again to the public as provided in art. 10. When the National Planning Agency has given its opinion, this shall be made known to the Minister for the Environment, the developer, the licensors, the consultation bodies, and also those who made comments on the initial environmental impact statement during the period of public presentation. The public shall have ready access to the National Planning Agency's opinion and the Environmental Impact Statement, and the Agency shall advertise in a national newspaper that the opinion and Environmental Impact Statement are complete (Althingi, 2000).

Developmental consent
Under Article 13 of the EIA law, the developmental consent will be issued to the developer once the opinion of the NPA on the EIA has been given. Other permits include a construction permit and operating permits (Althingi, 2000). The developmental permit must be in accordance with a new regulation, No. 772/2012, and construction may not start until the necessary permits are issued. Operating permits for geothermal projects are issued to the developers by the Environmental Agency or the local Public Health Committee (Althingi, 2000).

Other provisions of the EIA Act
There are other provisions stipulated in the EIA Act that deal with revisions of an EIA, or an appeal to the claims committee for the purpose of solving disputes in the environmental area on whether projects

in Annex 2 should be subject to EIA and to municipalities granting developmental consent (Althingi, 2000).

Application process for geothermal projects in Iceland
The EIA is an important part of the preparation for a geothermal developmental project and involves a holistic framework in Iceland. Table 5 explains the application process for geothermal development in Iceland. The EIA Act No. 106/2000 connects to other legislation regarding permits and environmental aspects and how this must be taken into account when planning and preparing geothermal projects.

TABLE 5: Permits and processes for geothermal projects in Iceland (Albertsson et al., 2010)

	Permit Process	**Institutions**	**When to apply**
Resource	Research permit	Orkustofnun (NEA)	Optional
	Utilisation permit	Ministry of Industry, Energy and Tourism and Orkustofnun	Optional
	Harnessing permit	The Ministry of Industry, Energy and Tourism	When the size of the project and the extent of building has been decided
Land use	Change in land use plan	Local authority	In the preliminary phase of the project
	Detailed land-use plan	Local authority	When execution of the project is announced
EIA	Project subject to assessment	The NPA	When the decision on the project is ready
	Scoping document	The NPA	
	Environment impact statement	The NPA	
Development	Development consent	Local authority	Granted when planning is ready and EIA is completed
	Building permit	Local authority	Before building – blueprints have been approved
	Operating licence	Local health committee	Apply months before operations begin
	Project in areas protect-ted as natural phenomena	The Environment Agency	If project disrupts protected natural phenomena

5.2 PNG Environment Act and EIA process

5.2.1 Legal regulatory framework

The definition of geothermal energy and geothermal resources in PNG is vague when it comes to a policy framework of governing the geothermal utilisation and resource management. The geothermal energy resource is classified as a mineral resource and is legislated for in PNG´s Mining Act 1992 (Department of Mining, 1992). Under this Act, the developer must apply for an exploration licence before starting additional research and drilling exploration wells.

The main legislations that may affect geothermal project development directly and indirectly in PNG are:

1. *Mining Act 1992 and Regulation*
2. *Land Act 1996*
3. *Physical Planning Act 1989*
4. *Electricity Industry Act 2002*
5. *Independent Consumer and Competition Act*

6. *Environment Act 2000*
7. *Conservation Areas Act 1978*

Table 6 displays a possible overview of the application process concerning a geothermal project in PNG, which permits are applied for and which legal body issues these permits. The developer is responsible for applying for these permits. The application process for possible geothermal projects accords with the PNG Mining Act 1992 and its regulated provisions for exploration applications for the purpose of locating and evaluating mineral deposits, including feasibility studies and reconnaissance surveys (Department of Mining, 1992). The Mineral Resource Authority is the main body responsible for mineral exploration in PNG and also issues exploration licenses in accordance with Section 20 of the Act. Under the current legal and regulatory framework, geothermal exploration and utilisation may fall under the same category of mineral exploration as any drilling program at a defined prospect where the aggregate depth of holes drilled is greater than 2,500 m.

TABLE 6: Policy framework and permitting process concerning possible geothermal projects in PNG (from Department of Mining 1992, Department of Environment and Conservation, 2000 and ICCC 2002)

Legislation	Regulatory institutions	Permit	When to apply
Mining Act 1992	Mineral Resources Authority	Exploration licence Mining lease Special mining lease	Before carrying out a research and exploration program
Land Act 1996	Department of Lands and Physical Planning	Land title/state lease	During mining development
Physical Planning Act 1989	Department of Lands and Physical Planning	Authority approvals	Before carrying out substantial development projects
Electricity Industry Act 2002	Independent Consumer and Competition Commission	Licence to generate, transmit, distribute and sell electricity	Before utilising resources for electricity production
Environment Act 2000	Department of Environment and Conservation	Environment permit Approval in principal	Before undertaking an exploration and research program
Conservation Act 2000	Department of Environment and Conservation	Approval for protected area and wildlife management area	During the Environment Permit Application/ Assessment

The Department of Petroleum and Energy is responsible for the development of energy policies and plans, including those for geothermal energy, which may involve data collection and analysis, and advice to the government on sector issues (REEP, 2012). PNG does not have a policy or legislation that requires increased production of energy from renewable energy sources. A policy on geothermal energy resources tends to be lacking.

PNG Power Ltd (the Company) is the national electricity utility that has been issued with licences under the Electricity Act 2002 by the Independent Consumer and Competition Commission to generate, transmit, distribute and sell electricity in PNG (REEP, 2012). PNG Power has three main licences under the Electricity Act 2002 (ICCC, 2002) and these are:

- Electricity Generation Licence
- Electricity Transmission Line
- Electricity Distribution Licence

Furthermore, PNG Power plays a leading role in power sector planning in PNG since the Department of Petroleum and Energy has extremely limited resources and suffers a lack of technical capacity to play a technical regulatory role in the energy sector.

5.2.2 Environment Regulatory Framework

The environment regulatory framework in PNG is regulated under the Environmental Act 2000 (Department of Environment and Conservation, 2000). It is this act that provides the mechanisms for dealing with activities with the potential for causing environmental harm. The Environmental Act 2000 is PNG´s only legislation that provides the administrative mechanism for environmental impact assessment and evaluation of activities regulating impacts on the environment through an environmental approval and permit system (Appendix I). However, neither geothermal projects nor any other activities concerning geothermal energy are defined in the Environment (prescribed activities) Regulation 2002 under the Environmental Act 2000 for the purpose of undertaking exploration to quantify geothermal resources and to evaluate the feasibility of large scale geothermal production. Environment (prescribed activities) Regulation 2002 is one of the regulations under the Environmental Act 2000 that categorises the activity to be a Level 1, Level 2 (Category A or Category B) or Level 3 activity (Figure 12).

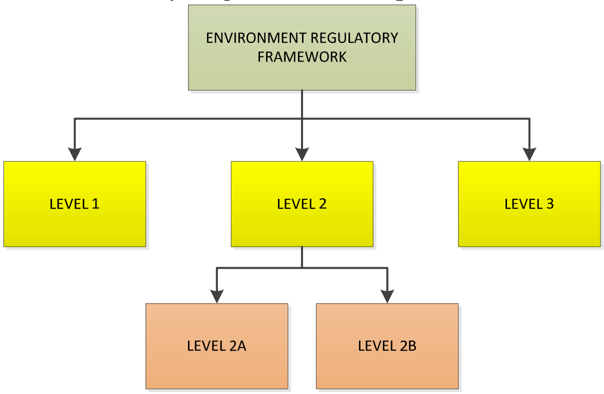

FIGURE 12: Simple level of activities in PNG under environment regulatory framework (modified from Environmental Act 2000)

Geothermal activity may be classified into Level 1, Level 2 or Level 3 activity. Generally, the environment regulatory framework determines criteria for a geothermal project in the three-tier process that is potentially able to cause environmental harm. Geothermal activities may fall into the following prescribed categories but their categorisation may be imprecise:

- *Level 2 Category A activities*
  - Sub-category 2.1 of mineral exploration – Any drilling program at a defined prospect where the aggregate depth of all holes is greater than 2,500 m
  - Sub-category 13.2 of other activities – Discharge of waste into water or onto land in such a way that it results in the waste entering the water
- *Level 2 Category B activities*
  - Sub-category 12.6 of infrastructure – Construction of electricity transmission lines or pipelines greater than 10 km in length
- *Level 3 activities*
  - Sub-category 14 of general – activities involving investment of a capital cost of more than K50 million, except where such investment is made in pursuing an activity otherwise dealt with in this Regulation in which case that category of activity will apply to the investment.
  - Sub-category 14 of general – activities that may result in a significant risk of serious or material environmental harm within Wildlife Management Areas, Conservation Areas, National Parks and Protected Areas or any area declared to be protected under the provisions of an International Treaty to which Papua New Guinea is a party and which has been ratified by the Parliament of the Independent State of Papua New Guinea

Any activity with the risk of causing environmental harm and serious environmental harm is defined in the *Environmental Act 2000* as a prescribed activity and requires a permit (Department of Environment and Conservation, 2000). Non-prescribed activities do not require permits to operate but they must operate in accordance with the requirements of the Act.

The environmental regulatory framework for an environmental impact assessment and evaluation of activity regulated impacts through an established environmental approval and permit system is shown as a flowchart in Appendix I. Those activities with a very low risk of causing environmental harm are classified as Level 1 activities and are exempt from the permit requirement. Level 2 activities have a low to high potential for causing environmental harm and are subject to the permit process. Activities that present a high risk of causing serious environmental harm are classified as Level 3 activities; they are put through an EIA before an environmental permit can be issued (Department of Environment and Conservation, 2000).

Level 1 activity
Level 1 activities are those activities that are not prescribed in the Environment (prescribed activities) Regulation 2002 of the Environment Act as Level 2 or Level 3 activities. Level 1 activities are exempt from the obligation to obtain an environmental permit. Level 1 activities are, however, obliged to comply with the Act and the regulations or statutory policies developed under the Act.

Level 2 activity
Those activities that are classified as Level 2 under the *Environment (prescribed activities) Regulation 2002* within the *Environment Act 2000* are required to have an environment permit prior to the commencement of work. Level 2 category is further categorised into Level 2 (Category A) and Level 2 (Category B).

Level 2 (Category A) are those activities with a low potential for causing environmental harm and are exempted from the notification and public consultation requirement under the permit assessment process. Applications within Level 2A activities are processed within a 30 day assessment before permits are issued.

On the other hand, Level 2 (Category B) activities have a high potential for causing environmental harm and hence are put through the full environment permit assessment process. Level 2B activities are different from Level 2A ones, based on the scale and nature of the projects which are likely to produce high environmental risks. These project activities will be subject to the notification and referral requirements under the permit assessment process. An application for Level 2B activity should be processed within 60 days from receipt of the application before the permit is issued.

Level 3 activity and EIA procedures
The Level 3 category is where EIA comes in. The consultation between the applicant (developer) and the DEC plus relevant bodies is essential and should take place before an application is formally lodged. Permit applications from Level 3 activities for which an *Approval in Principle* has been issued by the Minister are exempted from the notification and referral requirements under the permit assessment process (Department of Environment and Conservation, 2000).

The Minister for Environment and Conservation is mainly responsible for the issuance of an Approval in Principle to a Level 3 geothermal activity before an environmental permit can be obtained.

Procedures for projects subject to EIA
Screening
The developer should notify the Department of Environment and Conservation (DEC) of his intention to carry out a Level 3 activity and the notification should be consistent with the guidelines set out in the Environmental Act 2000 and accompanied by a cover letter. The result of the DEC‘s examination will determine whether the activity should be classified as Level 3 activity or not before the full EIA process is commenced. If the project is subject to EIA, the developer shall submit an environmental inception report.

Environmental Inception Report (EIR)
Following the confirmation of a Level 3 activity, the developer submits ten copies of the Environmental Inception Report to the DEC. The DEC assesses the EIR using requirements in the Information Guidelines as a benchmark. If the DEC is not satisfied with the EIR, it is rejected and the DEC notifies the developer that a further amendment is required before the EIR can be accepted. If the DEC is

satisfied with the EIR, it is accepted and a Proponent is notified about the decision for preparation of an Environment Impact Statement.

Environmental Impact Statement (EIS)
Following the acceptance of the EIR, the developer submits ten copies of the EIS along with a fee as per the Environment (Fees) Regulation 2002. The statement should comply with the Information Guidelines for Conduct of Environmental Impact Assessments and Preparation of Environmental Impact Statements. The DEC *assesses* the EIS using the requirements of the Information Guidelines as a benchmark. If the DEC is not satisfied with the EIS and the fee, it is rejected and the DEC notifies the developer that a further amendment is required before the EIS can be accepted. If the DEC is satisfied with the EIS and the fee, it is accepted and the DEC notifies the developer of the decision and advises an assessment period. A copy of the Assessment Schedule and a receipt are attached with the notice.

Assessment of the Environmental Impact Statement
Following the assessment schedule, the DEC advises the developer to conduct a public presentation and requests a proposed program for public review from the developer. The developer provides a proposed program for public review to the DEC for approval. The developer conducts a public review (including the advertisement and referral of application and public presentation) in accordance with the approved public review program. The DEC refers the EIS to the developer for amendment or to clarify issues raised during the Public Review. The developer amends the EIS or provides additional information to the Director to clarify concerns raised during the public review.

Acceptance of the Environmental Impact Statement
Following the assessment of the EIS, the DEC accepts the EIS and notifies the Proponent of his Decision through a written letter. The DEC then refers the accepted EIS to the Environment Council to notify the Council of their decision to accept the EIS.

Referral of the EIS to the Environment Council
The Environment Council will deliberate the EIS and the decision made by the DEC to accept the EIS after completion of the assessment of the EIS. The Environment Council then makes recommendations and gives advice to the Minister with the decision to accept the EIS. The Environment Council accepts the EIS and notifies the Minister of its decision with two options:

- The Minister may refuse to grant an “Approval in Principle”. The Minister refuses to approve the application and directs the Council to appoint a working committee under Section 24 of the Act (Department of Environment and Conservation, 2000)
- The Minister accepts the recommendation of the Council and issues an Approval in Principle. After the Minister has issued an Approval in Principle, the developer is then expected to apply to the Director for an Environment permit. It is also at this stage that the Level 3 process converges with the Level 2 Environment Regulatory Process (Department of Environment and Conservation, 2000)

5.2.3 Comparative review of regulations and the EIA framework for PNG and Iceland

There are major differences between the procedures in Iceland and Papua New Guinea and they are mainly due to different legal and regulatory frameworks. These tend to influence the management of geothermal development as shown in case studies from Iceland and Papua New Guinea. The legal and regulatory framework in Iceland motivates developers of geothermal energy, and the Icelandic government has continued to support the growth of geothermal development since 1924, with the development of Bjarnarflag geothermal power plant being the first geothermal power generation plant in Iceland (Orkuveita Reykjavíkur, 2012). This power plant set the impetus for more geothermal power plants in Iceland. Iceland has utilised geothermal energy to produce electricity to support local industries, especially local aluminium industries, fish farming, tourism and salt production. Other uses of electricity are widespread in Iceland.

Lack of a policy framework has been a barrier to geothermal development in Papua New Guinea even though PNG shares the same characteristics of geothermal resource potential with Iceland in terms of temperature classification, heat source classifications and possible resource utilisation. Lack of a regulatory framework in PNG suppresses geothermal development; it will not progress unless the government intervenes and realises the great potential of the geothermal resources. Papua New Guinea has the potential to harness more than 1000 MW, not only to provide electricity but to support the growth of economically important projects and to improve the living standards of the people.

Table 7 shows the main characteristics of geothermal resources in Iceland and PNG and their utilisation. Geothermal features with active volcanism are useful for major economic projects in PNG including cocoa, copra oil palm, mineral exploitation, and tourism and fisheries.

TABLE 7: Geothermal utilisation

Characteristics of geothermal resource	Iceland	Papua New Guinea
Availability of geothermal	High	High
Temperature geothermal classification	High temperature and low temperature	High temperature and potentially low temperature
Heat sources	Volcanic heat and deep circulation of groundwater	Volcanic heat, potentially deep groundwater
Resource – utilisation	Electric-power generation/Direct use	Potential electric power generation/direct use
Number of geothermal electricity power plants	7	1
Current installed electric generation and hot water production	Electricity output = 575 MW; Heat Output = 753 MWth	Electricity output = 56 MW Heat output = Nil
Economic benefit of geothermal	Highly felt	Less benefits, but Lihir Geothermal Project opened new ways for PNG
Utilisation of geothermal energy	Major significant - Electricity generation, space heating, swimming pools, fish farming, greenhouses, industrial uses, tourism and recreation	Not yet
Business opportunities	Very high	PNG has yet to experience geothermal development

The comparative matrix for legal and regulatory frameworks for geothermal development between Iceland and Papua New Guinea is shown in Table 8. Iceland has a policy covering geothermal energy resources and has been developing a policy framework since the 1940s when it realised the great potential of exploiting geothermal energy resources for space heating and for electricity generation. This resulted in a vast improvement in further development of geothermal energy in stages, resulting in the development of geothermal power plants and the emergence of additional research and exploration programs in Iceland. The Icelandic government has been active in the promotion of geothermal development and has been reviewing the policy framework to motivate further geothermal development in Iceland.

PNG does not have a geothermal policy and even lacks an energy policy for the promotion of renewable resources. However, the hydropower sector has been exploited with significant progress in providing clean energy. The electricity from hydropower does not benefit the majority of the rural population; only about 10% live in urban areas and have access to electricity and, up to now, electricity has been expensive and unreliable. The PNG government has been relatively inactive in the promotion of

TABLE 8: Comparative matrix showing legal and regulatory frameworks for geothermal development

Legal and regulatory frameworks	**Iceland**	**Papua New Guinea**
Definition of geothermal resources	Ground resources	Mineral
Ownership of geothermal resource	Private land by landowners, public land by state	All minerals are property of the State
Any single geothermal policy	Yes	No
Government involvement and interest	Strong and active	Less active
When geothermal policy started	1963	Not yet
Policy attractive to developers?	Yes	Little, lack of policy
Names of the specific legislation geothermal resource and utilisation	Act on Ground Resources No. 57/1998	No legislation or policy exists in PNG that requires production of energy from renewable energy sources; but under Mining Act
	Electricity Act No. 65/2003	Electricity Industry Act 2000, Independent Consumer and Competition Act
Other legislation governing geothermal resources‘ relation to the environment in general	Planning Act No. 123/2010	Physical Planning Act
	Nature Conservation Act No. 44/1999	Land Act 1996
	Environmental Impact Assessment Act No. 106/2000	Physical Planning Act 1989
	Strategic Environmental Impact Assessment No. 105/2006	Environment Act 2000
	Hygiene and Pollution Control Act No. 7/1998	Conservation Areas Act 1978
	National Heritage Act No. 107/2001	
Legislation being amended	Yes	No

renewable energy. However, PNG has recently witnessed the major development and commercialisation of liquefied natural gas, the PNG LNG Project, which is set to start production in 2014. This is likely to increase access to clean energy for the population. PNG still does not have an energy policy or legislation that requires an increased production of energy from renewable energy sources. The lack of a regulatory framework for geothermal resources still remains a barrier to increased production of energy from renewable energy sources. The Lihir geothermal power plant was the first geothermal project in PNG to use geothermal energy to generate electricity, and was commissioned in 2003. The Lihir geothermal power project brought new opportunities for PNG as a whole as it brought new technologies to PNG for the future and paved the way for the promotion of geothermal energy resources for the generation of electricity. As a result, many interested proponents have been pursuing geothermal exploration for energy resources in PNG, pending the proposed setup of a regulatory framework. Iceland has been reviewing and amending the legislation framework governing the management of geothermal resources designed to encourage and facilitate the safe production of geothermal energy.

Iceland has carried out a Master Plan for geothermal and hydropower development and identified several geothermal potential areas. Iceland has focused the energy plan: on the promotion of sustainable development; and to consider energy projects that are economically feasible and which grant social prosperity for the wellbeing of the Icelandic people; and to ensure environmental sustainability.

PNG, on the other hand, does not have an energy plan at all but still has a great potential to harness renewable energy resources and geothermal energy is one of them. However, PNG has developed a long-term strategy in order to become a smart, wise, fair and happy society by 2050; the strategy focuses on the need for large renewable energy projects to be developed up to 100% to promote sustainable development in the country (Table 9). This will, in turn, open the door to the formulation of a geothermal policy in order to increase the production of electricity for the majority of the population who now have little or no access to electricity. This is also to support and facilitate the economic impetus and social prosperity in other sectors (other strategy focus areas) in line with Vision 2050 by supporting wealth creation (agriculture, fisheries, tourism), increasing the manufacturing sector, facilitating robust economic growth, increasing the availability of rural electrification and communication access, ensuring environmental sustainability and reducing greenhouse emissions.

TABLE 9: National plan and geothermal plan concerning geothermal resource

Geothermal plan and development plan	Iceland	Papua New Guinea
Geothermal plan	Yes	No
Name of geothermal plan	Master plan of geothermal and hydropower development	Not applicable
Country-wide	Master plan	National Vision 2050
Expectations of master plan	Very good. Maximise most sustainable developmental projects. Parliament to approve master plan.	Not a master plan but a good plan put forward to provide energy up to 100% from renewable resources

The permit and administrative process in Iceland is more vigorous and effective than in PNG. The permit needed for geothermal development involves a multi-disciplinary approach and cooperation from relevant bodies, as shown in Table 10. Iceland has an interrelated geothermal regulatory framework that encompasses planning and building, exploration and utilisation, health, environment, nature conservation, electricity and economic costs. Following the geothermal field assessment and research in Iceland, an exploration licence is required from Orkustofnun under the Act on Survey and Utilisation of Underground Resources No. 57/1998 in order to carry out a geothermal exploration program. Once exploration drilling is planned, the NPA is notified of the project and the EIA process is used to judge whether a full EIA is required or not. If the exploration drilling is promising, the developer can plan to build a power plant and subject it to the full EIA process. Following the EIA process, a utilisation permit is required from Orkustofnun under the Energy Act No.65/2003 in order to exploit the resources for power generation.

Under the Mining Act 1992, an exploration licence is required in PNG from the MRA for any drilling program (under which geothermal exploration might fall). The environmental permit is required under the Environmental Act 2000 and is required for any drilling program to a depth of more than 2500 metres. Neither geothermal projects nor any other activities concerning geothermal resource energy are defined in the Environment Act 2000, e.g. exploration to quantify geothermal resources or evaluation of the feasibility of large scale geothermal production. The Independent Consumer and Competition Commission in PNG is mainly responsible for electricity generation, transmission and distribution licences under the Electricity Industry Act. PNG Power is the exclusive licence holder to supply electricity throughout PNG to generate, transmit, distribute and sell electricity. The PNG Power exploits both hydro-energy resources for the operation of a hydro-electric plant, and the operation of fuel burning power stations to supply electricity.

TABLE 10: Administration and permits

Actions - responsibility	Iceland	Papua New Guinea
Responsible for geothermal exploration	Orkustofnun	Mineral Resources Authority
Responsible for electricity production from geothermal	Orkustofnun	Independent Consumer and Competition / PNG Power Ltd
Ministry responsible	Ministry of Energy, Industry and Tourism	Ministry of Petroleum and Energy/Ministry of Mining
Official monitoring for resource	Orkustofnun	Mineral Resources Authority
Official monitoring for environment	Local health authority, The Environment Agency	Mineral Resources Authority/Department of Environment and Conservation
Issuance of geothermal exploration permit	Orkustofnun	Mineral Resources Authority
Issuance of utilisation permit (construction)	Orkustofnun	Not applicable
Environmental impact assessment	NPA	Department of Environment and Conservation
Permit for power utilisation or to generate power	Orkustofnun	Independent Consumer and Competition
Master plan	Ministry of Energy, Tourism and Industry	National Planning Department and Department of Energy/Petroleum
Local plan (development plan)	Local municipality	Not applicable
Building permit	Local municipality	Department of Physical Planning and Land
Operating licence	Local health authority	Not applicable
Permit for protected area	The Environmental Agency	Department of Environment and Conservation

Note: There are 75 local municipalities in Iceland (Wikipedia, 2012)

The EIA process is different for PNG and Iceland where Iceland has a single legislation on EIA while PNG does not. Table 11 compares the EIA features and issues in PNG and Iceland.

Iceland's EIA law is administered by the NPA and under the law there are relevant provisions and stipulations that ensure that geothermal developmental projects are properly screened and assessed to protect the environment from possibly serious environmental harm while promoting economic growth and social prosperity. In PNG, the EIA is confined within the Environment Act 2000 whereby projects that are likely to produce high environmental harm are subjected to EIA. On the same note, PNG does not have a prescribed activity(s) associated with geothermal drilling and developmental projects.

5.3 EIA review of the Hellisheidi high-temperature project

The Hellisheidi power plant is located within the Hengill geothermal area and is one of the seven major geothermal power plants in Iceland (Figure 13). It is the largest geothermal power plant in Iceland and is owned by Reykjavík Energy. The power plant has a combined heat and power capacity to meet an increasing demand for electricity and hot water for space heating. According to Gunnlaugsson (2007), the Hellisheidi power plant produces 303 MW of electrical power and 133 MW of thermal power. The geothermal power plant was commissioned in 2006. The development of the power plant evolved with several changes between 2006 and 2011.

TABLE 11: Comparative matrix for EIA

EIA	Iceland	Papua New Guinea
Single EIA legislation	Yes	No
Name of legislation	Environmental Impact Assessment Act No. 106/2000	Environmental Act 2000
EIA regulator	NPA	Department of environment and conservation
EIA policy became effective	1994	In 2000 under the Environment Act
Prescribed geothermal activity	Yes	Not applicable
Project subject to assessment	Project annex1 and Project annex 2	Not applicable
Time frame of assessment	Annex 1 – 32 weeks Annex 2 – 4 weeks	90 days for EIA (Level 3 activity)
Notification	Yes	Yes
Fees/Charges	Yes, based on the NPA manpower cost	Yes, based on the cost of the project within the Environment (Fees and Charges) Regulation 2002
Scoping document	Scoping document	Environmental Inception Report
Environmental Impact Statement	Yes	Yes
Review	Yes	Yes
Public participation	Yes	Yes
Type of EIA approval	NPA opinion	Minister approval-in-principle
Management plan	No (EIA covered)	Yes
Number of high-temperature geothermal areas	30 (NEA, 2012 and Figure 6)	>21
EIA an important tool	Yes	No
SEA legislation	Yes	No

The Hengill geothermal area hosts several high-temperature geothermal fields and is considered to be the second or third largest geothermal area in Iceland. The Hengill geothermal area covers about 110 km^2 and is located in the middle of the volcanic zone, i.e. the plate boundary between the North American and European crustal plates (Gunnlaugsson, 2007). Furthermore, the Nesjavellir power plant is another power plant in the Hengill area and has an installed capacity of 120 MWe of electricity output and 300 MTh of heat output.

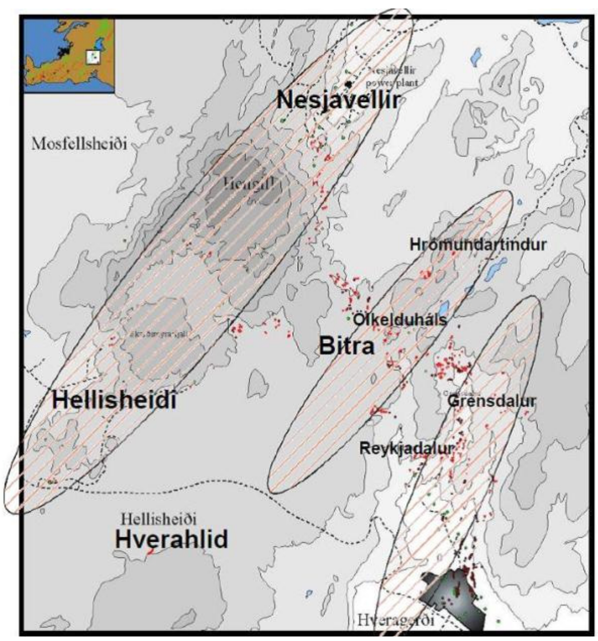

FIGURE 13: The Hengill geothermal area where Hellisheidi field is located (Gunnlaugsson, 2007)

An EIA was first carried out in 2003 for the preparation and development of the Hellisheidi power plant and there were several drilling programmes before and after the first EIA studies. According to Gunnlaugsson (2007), the initial drilling took place back in 1947 and progressed within several geothermal fields in the Hengill geothermal area. Research drilling became significant in 1985 and exploration drilling in 2001.

The latest developmental plans that have passed the EIA process are for Hverahlíd and Bitra, expected to produce 90 MWe and 120 MWe, respectively, but no decision has been made on their construction. (Thóroddsson, 2012b).

5.3.1 History of EIA development

Two EIAs have been issued for the Hellisheidi power plant. An EIA was first carried out in 2003-2004 for the proposed 120 MWe Hellisheidi power plant. The second EIA was carried out in 2005-2006 for the expansion of the power plant by 120 MWe. The low pressure turbine, 30 MWe, was not subject to an EIA nor the increased production of 30 MWe which resulted from increased performance of the turbines. The drilling of several research wells was assessed in the screening process but did not lead to a full EIA. Table 12 shows how the sequence of events for Hellisheidi power plant progressed through the EIA process under the EIA law in Iceland. The NPA made 4 decisions, respectively, for the development of the Hellisheidi geothermal project, including Bitra and Hverahlíd power plants, to boost the production capacity of Hellisheidi power plant (Table 12).

TABLE 12: EIA decisions and events regarding the Hellisheidi geothermal project (Thóroddsson, 2012b)

Time	Activities	EIA Status
January 2001	1st Phase - Drilling of 2 exploration wells at Hellisheidi	Screening decision
Sept. 2001	2nd Phase - Drilling of 3 exploration wells at Hellisheidi	Screening decision
April 2002	Scoping decision on Hellisheidi PP 120 MWe and 400 MWth	Scoping decision
Feb. 2003	3rd Phase - Drilling of 3 exploration wells at Hellisheidi	Screening decision
Feb. 2004	Decision in Hellisheidi PP 120 MWe and 400 MWth	NPA opinion
Jan. 2005	Drilling of a total of 7 exploration wells in 4 areas in Hellisheidi region	Screening decision
June 2005	Scoping decision on 120 MWe enlargement of Hellisheidi PP	Scoping decision
Dec. 2005	Changes in location of reinjection area for Hellisheidi PP	Screen decision
March 2006	Decision on the 120 MWe enlargement of Hellisheidi PP	NPA opinion
April 2006	Drilling of 2 exploration wells at Ölkelduhals in the eastern part of the Hellisheidi region	Screening decision
April 2006	Drilling of 2 exploration wells at Hverahlíd in the southern part of the Hellisheidi region	Screening decision
Dec. 2006	Scoping Decision on Bitruvirkjun PP 135 MWe in the east Hellisheidi region	Scoping decision
Dec. 2006	Scoping decision on the Hverahlíd PP, 90 MWe in the south Hellisheidi region	Scoping decision
April 2007	Changes in the location of reinjection area for Hellisheidi PP	Screening decision
Nov. 2007	Drilling of 2 exploration wells at Litli-Meitill to the south of the Hellisheidi region	Screening decision
Nov. 2007	Drilling of 1 exploration well at Gráuhnúkar in the southern Hellisheidi region	Screening decision
May 2008	NPA opinion on the Hverahlíd PP 90 MWe in the southern Hellisheidi region	NPA opinion
May 2008	NPA opinion on the region	NPA opinion
July 2008	Additional power plant building for the Hellisheidi PP	Screening decision
August 2008	Changes in the location of reinjection area for Hellisheidi PP	Screening decision
May 2009	Scoping decision on geothermal exploitation at Gráuhnúkar in the southern Hellisheidi region	Scoping decision

Reykjavík Energy developed a 90 MW Hellisheidi power plant in 2006 and has been planning to build two more power plants in the Hengill area; these two plants have been subjected to the Environmental Impact Assessment process. These include the plant at Bitra, 120 MWe in the eastern part of the field and Hverahlíd, 90 MWe in the southern part of the field. Both these plants were planned to be online in late 2010 (Table 12). The Environmental Impact Assessment was carried out in two steps, first for the initial plant and later for the enlargement. The Hellisheidi geothermal power plant now produces 303 MWe and 133 MWth (Orkuveita Reykjavíkur, 2012).

The Assessment Act No. 106/2000 in Iceland is relevant for a geothermal power plant with an electricity output of more than 10 MW. The second EIA was carried out in 2005 for the expansion of the power plant by 120 MWe. The first EIA for the proposed Hellisheidi power plant was carried out in 2003.

5.3.2 Environmental issues

According to Gunnlaugsson (2007), the main environmental factors that have to be dealt with in the EIS are:

- *Geological factors* - Including the geothermal field, its size and impact on the reservoir
- *Water resources and disposal* - This includes extensive knowledge of the groundwater systems, their size and flow patterns
- *Landscape and visual effects* - This is one of the main factors where the public is concerned
- *Tourism and recreation* - Often there may be conflicts between the developer and other uses of the land such as for tourism
- *Biology* - Vegetation, hot spring microbiology and fauna have to be studied
- *Other parameters* - Such as noise, pollution, air quality and cultural relics

The Hengill area is known for hiking and recreational activity and these have been considered in the EIA. Tourism has been consistent in the Hengill area where the Nesjavellir power plant attracts some 20,000 guests per year; therefore tourist attractions have been planned for at the Hellisheidi PP (Gunnlaugsson et al., 2010). Land use was considered in the EIA in connection with recreation and tourism in the Hengill area.

Some volcanic fissures are located on the southern side of the Mt. Hengill where craters are also found. The material from craters has been used for road construction since the 1970s (Gunnlaugsson et al., 2010). In the EIA the volcanic craters in the Hengill area are considered to have been damaged due to use for road construction in the past; therefore, geothermal development was planned to be located within the damaged area. Gunnlaugsson et al. (2010) said that the developer had identified the areas of supply of geothermal fluid to the power plant, shown in Figure 14. The purpose was to minimize the environmental risks and to develop directional drilling within the field in an attempt to reduce environmental

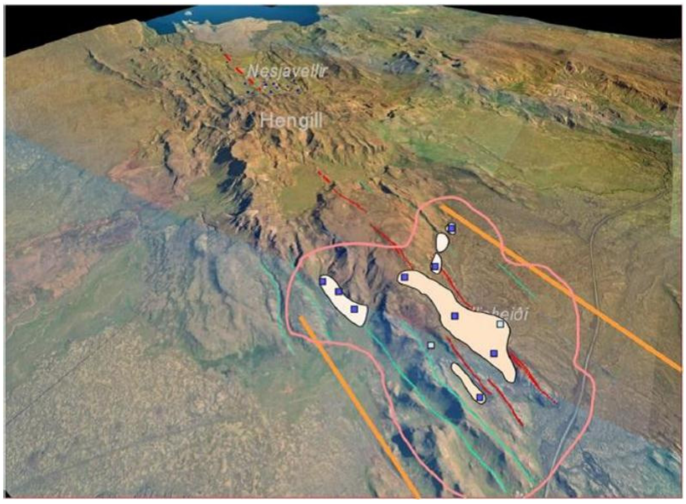

FIGURE 14: Map of the Hengill area showing Hellisheidi geothermal field; volcanic fissures are red, green lines indicate main faults; between yellow lines are several production fields; pink area shows where drill holes can be located with minimum impact on the environment; blue squares show the location of well platforms (Gunnlaugsson et al., 2010)

damage. Development of the Hellisheidi power project followed a stepwise strategy (Steingrímsson, 2009).

Revegetation was carried out in Hellisheidi to reconstruct and reshape the damaged volcanic craters (Gunnlaugsson et al., 2010). In the EIA, ecological restoration was emphasized for the selected areas within the Hellisheidi that had been damaged in the 1970s as the result of road construction. The reason for considering revegetation in the EIA is to reconstitute the land to a relatively undisturbed state.

Groundwater was also considered in the EIA for the Hellisheidi power plant as it was planned as both a heating plant and a power plant (Gunnlaugsson, 2007). Groundwater pollution is a possible environmental impact that needs to be avoided in connection with other geothermal fields such as Bitra and Hverahlíd. The project was also intended to map the groundwater or geothermal water systems to find suitable channels for reinjection of the geothermal fluid. There is very high precipitation and limited surface runoff (Gunnlaugsson, 2007) with most of the runoff taking place underground. Thus, Gunnlaugsson et al. (2010) concluded that all separated water had to be re-injected to the geothermal reservoir to protect the groundwater system from pollution and to reduce possible pressure draw-down in the Hengill geothermal systems.

The change in the location of a reinjection area for the Hellisheidi power plant was screened in December 2005, prior to the 120 MWe enlargement of the Hellisheidi power plant. Formerly, this area had been utilised for the purpose of wastewater disposal from the power plant, to minimise decline due to mass extraction within the Hellisheidi geothermal system, and to maintain the production capacity at Hengill (Thóroddsson, 2012b).

Other environmental impacts have been assessed in the EIA for the Hellisheidi power plant including visual and social impacts as well as those due to air quality problems and noise. Landscape alters as a result of installations such as drill holes, pipelines and power plants (Gunnlaugsson, 2010). The Hellisheidi power plant is a major power plant and this constitutes a major concern in terms of landscape classification and visual effects. Careful planning and design of power plants, pipes and drilling platforms have been addressed in the EIA to reduce visual impacts.

In the operation of the plant in recent years, two factors have caused inconvenience to the public and are widely discussed, i.e. the amount of H_2S discharged to the air and earthquakes associated with rejection.

5.4 EIA review of Lihir geothermal project

The Lihir geothermal power plant is the only geothermal power plant in Papua New Guinea generating from the resource on Lihir Island. The plant was commissioned in 2003. The geothermal site is located in the Lihir Group in New Ireland Province of Papua New Guinea and sits within the Luise Caldera (Figure 15).

Map courtesy of Lihir Gold Limited

FIGURE 15: PNG map and Lihir Island map showing Lihir geothermal project site (Booth and Bixley, 2005)

The geothermal development is part of the Lihir gold mine, one of the largest in the world which constitutes an open pit mine and processing plants that are developed to extract and process gold minerals (Melaku, 2005). The commercial mining operation has been operating since 1997 and has been a major economic contributor to PNG, providing various benefits to the people of Lihir and the country as a whole.

The development of the geothermal project was carried out as a result of the company's vision and commitment to help reducing greenhouse effects in line with the Kyoto Protocol i.e. the Clean Development Mechanism (CDM). It was a CDM project carried out by the developer and carried out separately from the PNG government, using its own company strategy to supplement clean energy for this mining development (Det Norske Veritas, 2006).

5.4.1 Geothermal utilisation

Geothermal power generation is specifically intended to increase output during commercial production. The Lihir mining activity once depended on petroleum products for energy to generate power but is now utilising geothermal resources for this purpose. Commercial production at the Lihir processing plant involves major operational costs and needs intense power generation.

Geothermal power production helped boost the mine and processing production but, at the same time, reduced carbon dioxide (CO_2) emissions. According to Newcrest (2012), the current production capacity of the geothermal power plant is 56 MW, utilised to generate power solely for the mining company, processing plant and associated infrastructure such as camps, offices, houses and local villages. Figure 16 shows how the geothermal resource at Lihir in the Luise Caldera beside the open pit mine has been utilised and for what. The temperature is high near the Lihir geothermal power plant which uses dry-steam from a vapour-dominated resource. This makes it possible to generate electricity, as the steam can be piped directly to the turbine generators (Figure 16). In Lihir, the surface expressions of steam resources are in the form of steam vents.

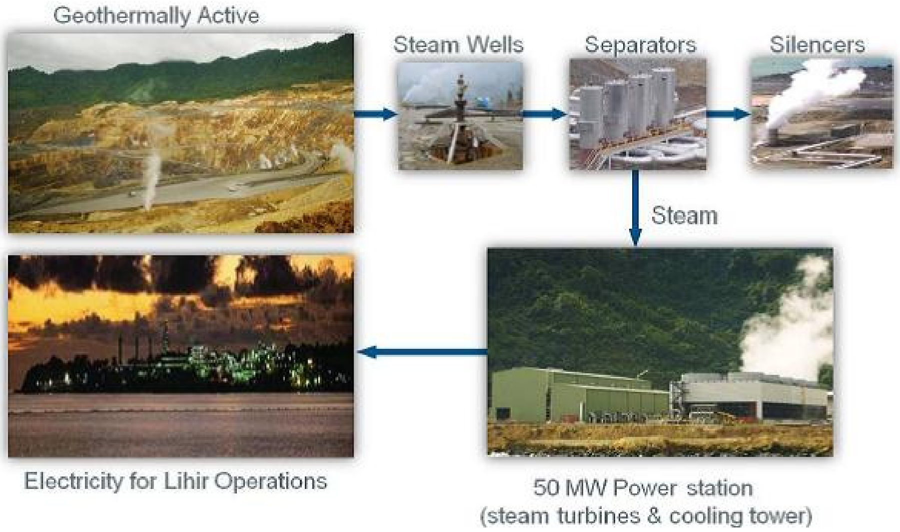

FIGURE 16: Lihir geothermal generation – how geothermal energy has been utilised in Lihir (Newcrest, 2012)

The development of the geothermal power plant used carbon credit trading under CDM which generated USD 4.5 million in revenue in 2008 by selling Certified Emission Reductions (CERs) on the global market (Lihir Gold Mine Ltd, 2009). The company made use of this opportunity to utilise this energy in order to capitalise on the stock market to generate profits. There exist several potential renew-able energy projects for power generation which could generate revenue based on CER under CDM.

Furthermore, geothermal utilisation at Lihir helps to combat CO_2 emissions and, thus, contributes to the world´s efforts to reduce greenhouse effects caused by high consumption of fossil fuels. According to Lihir Gold Mine Ltd. (2009), the utilisation of the geothermal power plant has resulted in the reduction of 280,000 tonnes of greenhouse gas emissions per annum. Geothermal utilisation provides impetus for a huge reduction in greenhouse gas emissions from major industries.

5.4.2 History of EIA developments

The Environmental Act 2000 does not deal with the operation and development of geothermal power plants. The Environment (Prescribed Activities) Regulation 2002 does not deal with associated activities in relation to geothermal projects except for drilling programs under Level 2 category A within sub-category 2.1 for mineral explorations and mining. However, Level 2A does not constitute the need for an EIA as it only requires an environmental permit.

As a result, the Lihir geothermal power plant was built in accordance with the clean development process in terms of a validation protocol associated with the criteria of the United Nations Framework on Climate Change Convention (UNFCCC). Such criteria were also used to evaluate the project operations, monitoring and reporting aspects of the geothermal power plant. This project, according to Det Norske Veritas (2006), did not require an environmental impact assessment under the PNG Environment Act 2000. Furthermore, the Lihir gold mine had been approved with licensing requirements under the Mining Act 1992, including the undertaking of drilling programmes and the eventual construction of a power plant.

Because the mining operation was started in 1997 before the enactment of the Environment Act 2000, the Lihir gold mine and associated activities were reissued a permit under a transitional arrangement under the Environmental Act 2000 and its Environment (Permits and Transitional) Regulation 2002. This transitional arrangement prescribed that the Lihir gold mine had an approval licences under the repealed act and under Section 28(b) of the Environment (Permits and Transitional) Regulation 2002. The Lihir Gold Mine was eligible to continue carrying out operations without any requirement to apply for a separate permit or undergo an environmental impact assessment. Hence, additional environmental impact analyses were not required for the geothermal power plant project (Det Norske Veritas, 2006).

Furthermore, under Section 28(c) of Environment (Permits and Transitional) Regulation 2002, the company submitted the Environmental Inception Report (EIR for Lihir geothermal power plant in December 2004) on a voluntary basis and received approval in February 2005. Det Norske Veritas (2006) said that the environmental impacts of the project, specifically a geothermal power plant, were identified and evaluated in the EIR and the impact issues were relative to the discharge of steam to the atmosphere and some geothermal liquids within the host caldera. The environmental permit was issued with conditions being set for dispensing a permit for a geothermal power plant.

5.4.3 Environment permits

The Environment permit issued for the Lihir geothermal power plant is not admissible as the power plant is a part of the overall project that had been issued with licences under the repealed act and still continues to carry out its operations with reference to the Environmental Act 2000 under the transitional arrangement. The existence of the geothermal developmental project was made known to the Department of Environment and Conservation (DEC) through submission of an Environmental Inception Report (EIR) in 2004 and got approval of the EIR in 2005. The approval of the EIR allowed the Lihir geothermal power plant to operate in line with the current overall environment permit.

5.5 Discussion – EIA case studies

The Hellisheidi geothermal power plant has been producing both heat and electricity since 2006. Two EIAs have been issued for the Hellisheidi power plant. The first EIA was carried out in 2003 for the proposed Hellisheidi power plant. The proposed activity was subjected to the Environmental Impact Assessment Act No. 106/2000 in Iceland as it planned an electricity output of more than 10 MW. The second EIA was carried out in 2005 regarding the expansion of the power plant by 120 MWe. The Lihir geothermal power plant is the only geothermal power plant in Papua New Guinea generating from the resource on Lihir Island. The plant was commissioned in 2003. The geothermal site is located in the Lihir Group in New Ireland Province of Papua New Guinea and sits within the Luise Caldera.

Lihir Geothermal power generation is specifically intended to increase output during commercial production. The Lihir mining activity previously depended on petroleum products to generate power but is now using geothermal resources for this purpose. Commercial production at the Lihir processing plant involves major operational costs that need intense power generation. Hellisheidi geothermal power plant provides electricity which is supplied mainly to local aluminium production and to meet the general increasing demand for power.

Scoping documents for EIAs were prepared for the Hellisheidi geothermal power plant concerning: the geothermal system, landscape and visual impacts, geology, hot springs and its fauna, tourism, recreation, flora – geothermal flora, archaeology and watershed – drinking water, sound/noise, smell of H_2S, and accumulative impacts on the landscape, tourism and social impacts.

6. SUMMARY AND CONCLUSIONS

The success of EIAs during the preparation and development of geothermal projects depends on the proper implementation of a regulatory framework, requiring team work, a holistic approach and understanding the protocols involved in the EIA procedures. It also requires gathering correct baseline data and background information to understand the environmental conditions crucial for sustainable geothermal resource management.

The regulatory institutions play an important role in regulating and coordinating the preparation and development of geothermal projects and ensuring that legal requirements are met satisfactorily. EIA is an important tool, enabling relevant authorities to critically assess the impacts of geothermal development projects at the preparation stage, both for exploration and later utilisation of a geothermal resource. A very important factor in the EIA process is public participation and consultation with relevant authorities who are asked to give reasoned comments on the project and the EIA.

It is necessary that the EIA be carried out in the early stage of the preparatory work, before it is decided whether a project shall be given a permit. In that process, not only environmental issues are introduced but also issues regarding social well-being and the economic significance of the project, according to the interests of the parties involved. Protecting the environment at the same time as contributing to increased prosperity, both during and after geothermal development rests, is the responsibility of the developer, regulatory authorities and the government.

The case studies highlight the differences in legislation in PNG and Iceland and the necessity to focus on different environmental factors in these countries and also in different geothermal areas in each country.

It is a general conclusion of this study that PNG can, and should, improve its legislation and regulatory framework to be better prepared to utilise the geothermal resources in the country in a sustainable manner. The utilisation of geothermal resources in PNG can potentially increase the well-being of the people of PNG in the future, but must be well prepared for in advance with good cooperation between all stakeholders.

7. RECOMMENDATIONS

- Road map - Geothermal Regulatory Framework – A road map needs to be developed to start the exploration of geothermal systems in order to identify potential geothermal sites. A clear policy is needed to define the road for geothermal development and utilisation in PNG.
- Geothermal activity should be upgraded to a prescribed activity. It is necessary to incorporate geothermal activity into the existing legislation so as to allow geothermal exploration and development, in line with relevant legislation. Although a geothermal resource is a renewable resource, it must undergo an EIA as all development projects concerning exploration and utilisation must undergo EIA in order to ensure sustainable resource management.
- Required support of UNU-GTP, ISOR and the Icelandic Government: PNG may require support to push for geothermal exploration and development. A team is required to carry out geological, geochemical and geophysical studies to evaluate possible geothermal sites in PNG.
- High-temperature areas are a valuable resource in their natural state. During development in PNG, consideration must be given to the protection of important natural sites like hot springs, volcanoes and geysers. Tourism must be balanced with the development of geothermal resources and should be economically beneficial to the communities.

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to the Government of Iceland and the United Nations University Geothermal Training Programme for giving me the opportunity to participate in this training. My heartfelt gratitude goes to Dr Ingvar B. Fridleifsson and Mr Lúdvík S. Georgsson for their support in completing this training. I am grateful to the very kind staff of the UNU-GTP, ISOR and all the UNU fellows for their support over the six months.

Sincere thanks to my two supervisors, Dr Halldór Ármannsson and Mr Thóroddur Thóroddsson for their wonderful and interesting guidance and assistance in the preparation of this report. I am very thankful for the opportunity to work with two different institutions, i.e. the National Planning Agency and ISOR.

I extend my appreciation to my employer, the Department of Environment and Conservation of Papua New Guinea, for allowing me to participate in this golden training. Special thanks to my former boss former department secretary of the department Dr Wari Iamo, for his support and confidence, and for selecting me to go to Iceland.

I also want to thank my family and my wife for their invaluable support during my studies these months and for my whole life. And above all, I would like to thank GOD for giving me the wisdom and necessary knowledge to complete this project and for giving me the strength and guidance.

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APPENDIX I: OVERVIEW OF ENVIRONMENT REGULATORY FRAMEWORK IN PNG FROM DEPARTMENT OF ENVIRONMENT AND CONSERVATION, 2000