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Comparative Studies of EIA Review for Papua New Guinean and Icelandic Projects with a Focus on Geothermal Utilisation

Brendan Trawen

P.O Box 6093, BOROKO, NCD, Papua New Guinea

btrawen_28@yahoo.com

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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, legal environment has placed legal and regulatory challenges on the progress of geothermal utilisation in many countries. Permitting 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 planning stages of the geothermal developments are carried out for the benefit of a country and to motivate the promotion of geothermal projects. Iceland and Papua New Guinea are countries that distinguish legal and regulatory frameworks in relation to geothermal development. Both countries have regulations, similar yet different as regards permitting 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 indicates 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 policy and utilisation. These factors, in turn, provide practical experience and obstacles for Papua New Guinea that is emerging to become a promising country with a geothermal potential of about 3000 MW. Papua New Guinea will soon have regulatory framework for the exploration and development of geothermal energy. Hence a set-up of a regulatory framework including EIA and permitting processes should be reviewed.

1. INTRODUCTION

Geothermal energy is an emerging activity and is considered to be a sustainable and renewable resource. The geothermal energy resource is given a steady attention as an alternative source of energy to replace fossil fuels. Geothermal developments are slowly expanding and have brought considerable benefits to the people and the environment. There are now twenty-four countries generating electricity from geothermal resources with USA, the Philippines and Indonesia being the top three countries (Beltane, 2010). Papua New Guinea is one of the countries and 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 are promoting geothermal energy in the world (Figure 1).

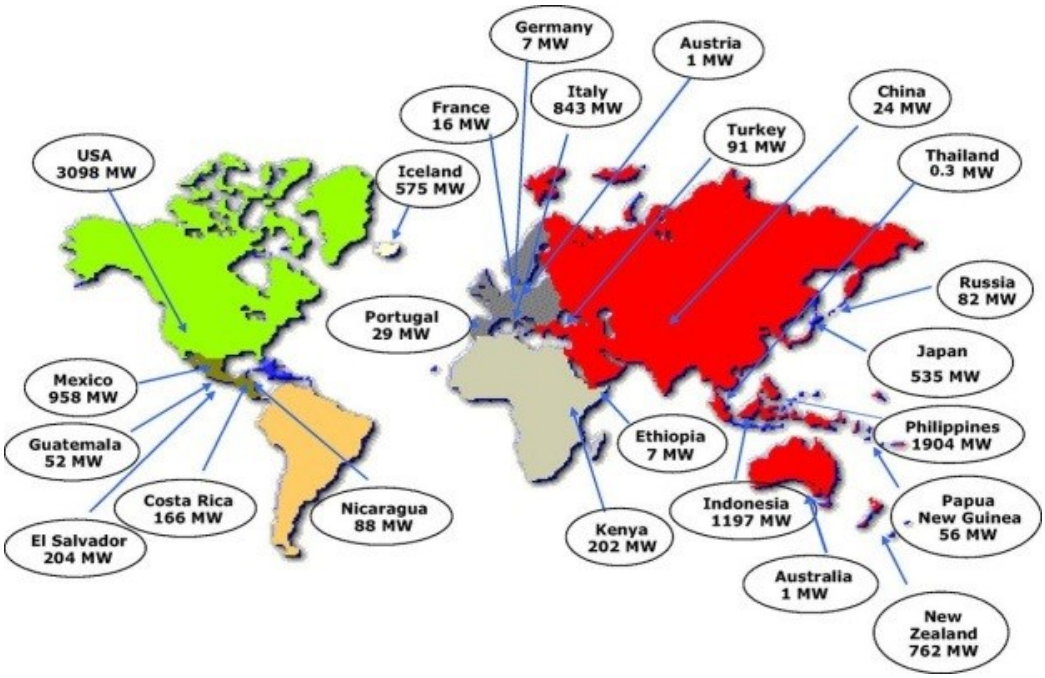

Figure 1: Geothermal-producing countries and installed capacity (Beltane, 2010).

However, the production capacity is the main concern that determines the level of resource supply which controls the geothermal system by reservoir pressure decline (Axelsson, 2008). Hence geothermal resource management plays an important role in planning and identifying risks and how to avoid problems. Geothermal resource management is needed to ensure long-term utilisation which involves close examination of a reservoir production scheme, avoidance of exploitation, application of step-wise development, minimizing environmental effects, minimizing costs and maximizing revenues and the avoidance of operational problems (Axelsson, 2008).

The issues focus on government management of regimes where resources are to be utilised, by whom and how both on private and public land. Regulatory framework must not be a barrier to geothermal development (Haraldsson, 2012). Legal and regulatory frameworks need to be attractive in such a way that they must address all aspects concerning utilisation of geothermal energy resources.

In the light of the above, this report will focus on geothermal development and regulatory process of Iceland and Papua New Guinea (PNG). This report describes the characteristics of geothermal and main regulatory framework governing geothermal in Iceland and Papua New Guinea respectively. This report also explains the comparison of main regulatory instruments between Iceland and PNG how it can best help PNG using Iceland´s practical experiences.

1.1 Iceland

Iceland, being 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 holds the biggest share of geothermal energy accounting for 26 per cent of the nation´s electricity use (Fridleifsson, 2002).

Iceland has several high temperature fields and numerous low temperature fields in most parts of Iceland. There are currently 7 major geothermal power plants in Iceland with only 3 plants being used to provide both heat and electricity (Table 1). The Hellisheidi geothermal power plant is the largest plant with an installed capacity of 303 MWe by 2012 and 133 MW heat (Orkuveita Reykjavikur, 2012.

Table 1: 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
Husavik	2000	2 MW	Only electricity

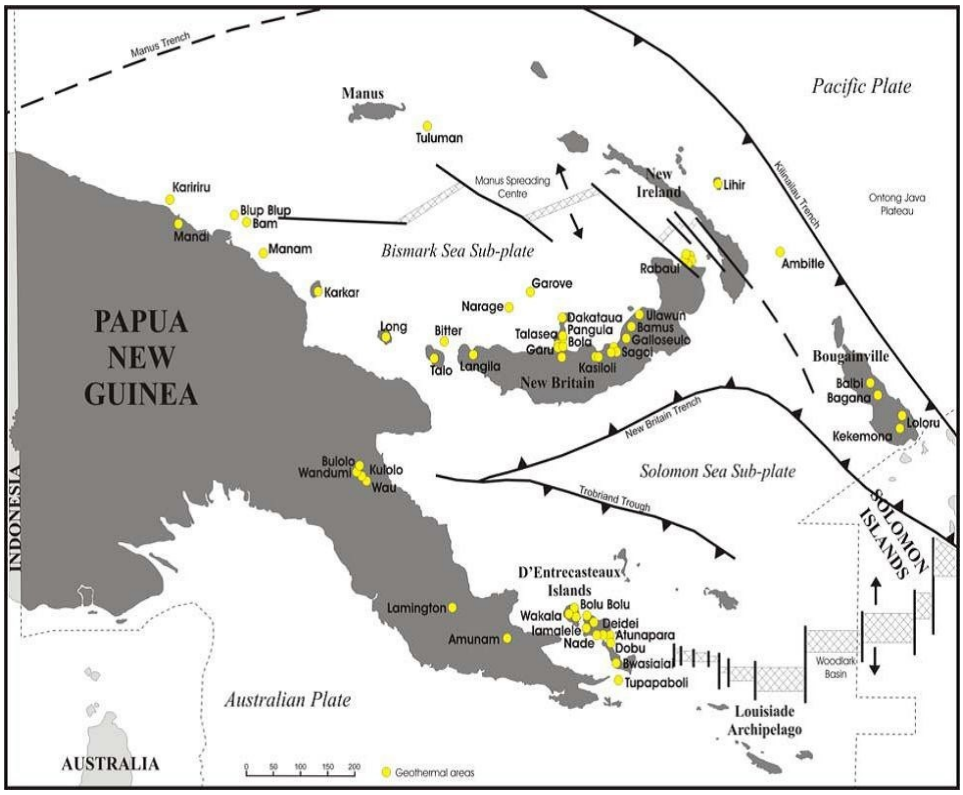

Figure 2: Map of Papua New Guinea showing known geothermal sites based from MRA report, 2011.

1.2 Papua New Guinea

PNG is located on the Pacific Ring of Fire and is a host to several volcanoes from the southeast to the northwest of the country with several known geothermal areas (Figure 2). Geothermal utilisation is insignificant in PNG but is becoming a new player in the field off 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 per cent, diesel 37 per cent, natural gas 14 per cent. Only 9 per cent is accounted for by geothermal energy. As a result, about 90 per cent of the population has no access to electricity. Most of the electricity 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 accessing proper power for the majority of the population and hence contributes to poverty in rural areas. The majority of the populations still use petroleum products for the energy needs of their everyday lives.

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 and owned by a private company and the electricity is only for its use. However, such as clean energy development project heralds the opportunity for further geothermal exploration and utilisation in PNG.

Table 2: Major active volcanoes in PNG (Volcanolive, 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

Table 3: Some volcanic activity with geothermal features in PNG (Volcanolive, 2012). NOTE: *Protected Areas under the Conservation legislation in PNG (FAO, 2012).

Name of Volcano	Province	Type	Summit Elevat.	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

Table 2 and Table 3 show numerous volcanoes and geothermal features that are found in PNG. Neither of these potential geothermal sites are utilised for power generation. There are numerous active volcanoes in PNG and majority of them are confined along the coastline and within both major and minor islands. Manam Island is a latest volcanic eruption this year (Volcanolive, 2012).

2. ENVIRONMENT MANAGEMENT AND IMPACT ASSESSMENT

Geothermal energy resources cannot be free of environment risks as there are possibilities of consequences of geothermal development (Ármannsson and Kristmannsdóttir, 1992). It is for this reason that geothermal resource management should put emphasis on the need for an effective legal environment regulatory framework. It is important to note that the legal and regulatory

frameworks reflect the significance of geothermal resource management and these are key management issues in balancing environmental and energy interests, sustainable utilisation and how to ensure that resources are utilised for the benefit of the nation (Haraldsdottir, 2010)

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

The changes in the environment brought about by geothermal development projects involves surface disturbances, physical effects due to fluid withdrawal, noise emission, thermal effects and emission of chemicals. Hence, geothermal exploration and developments projects should be subjected to proper legal environment regulatory but in the manner that is attractive and understood by geothermal developers and investors.

3. BACKGROUND OF LEGISLATIVE AND REGULATORY BACKGROUND

3.1 Regulatory framework and preparation of geothermal power developments in Iceland

All geothermal projects in Iceland are subject to important legal and regulatory frameworks before permits are issued for the commencement of the preparation of work. The fulfilment and finalization of the processes and requirements comprises granting the developer a permit to commence the work.

The main legislations 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.

The geothermal resource are classified as both mineral, energy and groundwater pursuant to the Act on Survey and Utilisation of Ground Resources (Research and use of underground resources) and are to be regulated under ground resources regulatory framework. It is a piece of legislation managed by National Energy Authority in Iceland and covers resources in the ground and underground in the sea and in lakes and other resources that have underground characteristics. 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, 1998).

The objective of the Act on Survey and Utilisation of Underground Resources 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 the geothermal development but it does not guarantee that the developer will be given utilisation permit as the Iceland government determines the ultimate decision (Althingi, 1998).

Simultaneously, the EIA is an important part of the preparation a geothermal development project and involves a holistic framework in Iceland. The EIA Act No. 106/2000 connects to other legislations regarding permits and environmental aspects and how this must be taken into account when planning and preparing geothermal projects. Figure 3 explains how each application process including the EIA for geothermal development in Iceland is regulated under different legal and regulatory frameworks.

3.1.1 Environment Regulatory Framework

The administration of Environment Impact Assessment is managed by the National Planning Agency (NPA) whilst the Environment Agency operates under the Ministry of Environment which is responsible for promoting the protection and sustainable use of Iceland's natural resources, as well as public welfare by helping to ensure a healthy environment.

The determination of the level of impact of the proposed geothermal project is regulated through Environment Impact Assessment Act No. 106/2000.

3.1.2 Environment Impact Assessment Act No. 106/2000 Amended by Act No. 74/2005

The Environment Impact Assessment Act includes the administration and implementations of EIA procedures for development projects including the geothermal projects. It is the key pathway for an eventual permit process before any actual project starts. NPA is empowered to administer and implement EIA. . Under the Act, the developer is required to present the Environment Impact Statement (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 satisfactorily 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 opinion on the environmental impact assessment (NPA, 2005).

The NPA is responsible for the administration and implementation of the EIA Act No. 106/2000 and is responsible for the facilitating of public participation and to promote co-operation of stakeholders and concerned parties with regard to projects subject to the provisions of this Act.

3.1.3 Geothermal Projects Subject to EIA

All geothermal projects are screened with respect to the significance of their environmental impacts as shown on Figure 4.

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: Geothermal energy works and other thermal power

installations with a heat output of 50 megawatts thermal or more, and geothermal power stations and other thermal power installations with an electricity output of 10 megawatts electric or more

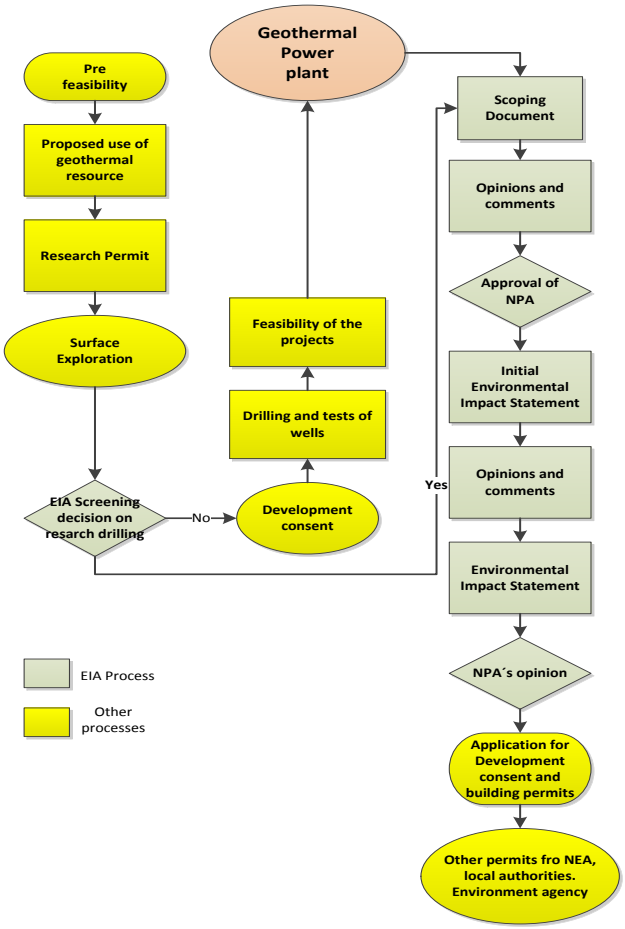

Figure 3: Simple geothermal development regulatory framework (Modified from Gunnlaugsson 2008).

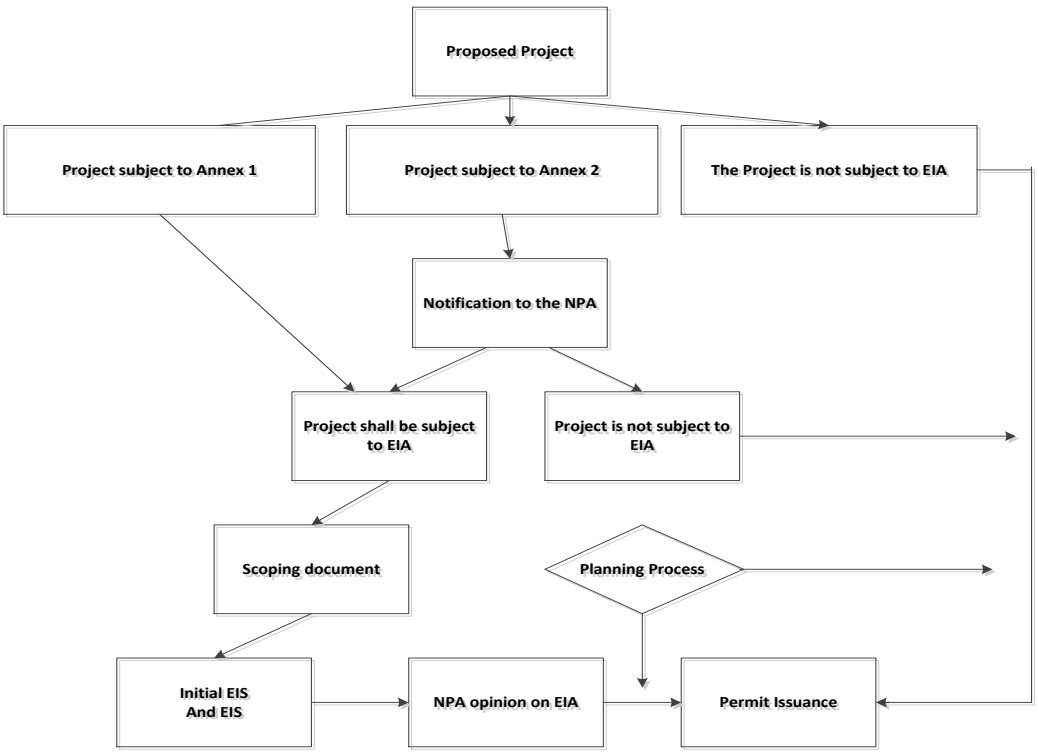

Figure 4: EIA project assessment for geothermal projects (Thóroddsson, 2012a).

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 on the surface or in the 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; and Installations of pipes for carrying steam and hot water, underground electric cable 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 given 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 utilization as well as pollution, disturbance and the cumulative effects of the projects (NPA, 2005).

3.2 Regulatory framework and preparation of geothermal exploration and development in PNG

PNG will soon have regulatory framework put in place to cater for geothermal development by the end of 2014. Under the proposed geothermal regulatory framework, the geothermal energy resource is classified as a mineral resource and is legislated under existing PNG´s Mining Act 1992. Under Mining Act 1992, the existing mineral tenement licensing process, application, administration and regulation will be applied for use and development of the geothermal resource by mining regulator, Mineral Resources Authority. The geothermal projects are also subject to Environment Act 2000 and the Electricity Supply (Government Power Stations) Act 1970 and its Regulation.

Therefore the main legislations that may affect geothermal project development in PNG are Mining Act 1992 and Regulation, Environment Act 2000, Land Act 1996, Mining Safety Act 1977, Electricity Supply (Government Power Stations) Act 1970, Mineral Resources Authority Act 2005 and Land Disputes Settlement Act 1975.

Under proposed geothermal policy, geothermal resource is classified as a mineral pursuant to the PNG's Mining Act 1992 and to be regulated under the existing mining regulatory framework by Mineral Resource Authority (MRA) The application process for the exploration and production of geothermal resources is administered by the MRA and the tenements available for purposes of geothermal resource exploration and development are exploration licence, mining lease, lease of mining purpose and mining easement.

The Department of Environment & Conservation (DEC) is responsible for ensuring compliance with the Environment Act 2000 and the Environmental Prescribed Activities for permitting and compliance purposes. It is an obligation for developer to have an environment permit where the developer carries out a prescribed activity.

3.2.1 Environment Regulatory Framework

The environment regulatory framework in PNG is regulated under the Environment Act 2000 (Department of Environment and Conservation, 2000). The Environment 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 environment approval and permitting system.Specifically, the environment impact assessment is also regulated under the Environment Act 2000 managed by DEC and it is applicable for Level 3 prescribed activities under the Environment (Prescribed Activities) Regulation 2002.

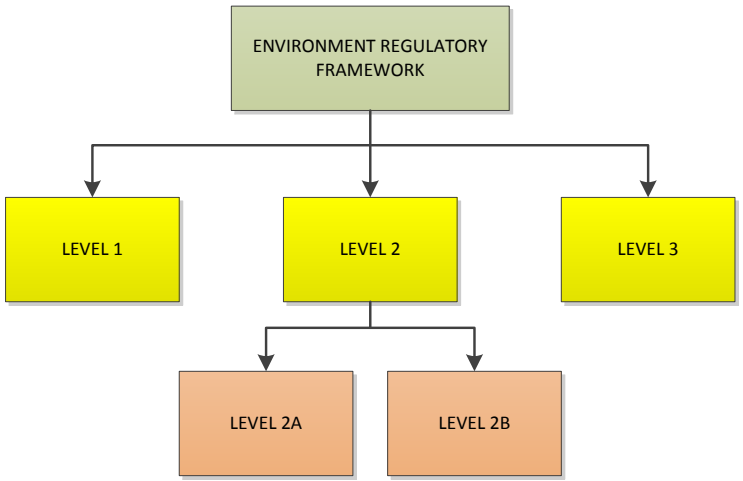

Figure 5: Simple level of activities in PNG under environment regulatory framework (Modified from Environment Act 2000).

Like all prescribed activities under Environment (Prescribed Activities) Regulation 2002, Geothermal activity may be classified into Level 1, Level 2 or Level 3 activity. Level 1 activities are those activities that are not prescribed in the Environment (Prescribed Activities) Regulation 2002 of the Environment Act.

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 compare to Level 2 (Category B). Level 2B activities are based on the scale and nature of the project 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 applications for Level 2B activity should be processed within 60 days from the receipt of the application before the permits are issued. Applications within Level 2A activities are processed within a 30 day assessment before permits are issued.

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 Environment Permit can be obtained.

However, neither geothermal projects nor any other activities concerning geothermal energy are defined in the Environment (Prescribed Activities) Regulation 2002 under the Environment Act 2000 for the purpose of undertaking exploration to quantify geothermal resources and to evaluate the feasibility of large scale geothermal production.

3.2.2 Environment Impact Assessment 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 Environment Permit can be obtained.

The EIA procedures are as follows:

Screening

The developer should notify the DEC of his intention to carry out a Level 3 activity and the notification should be consistent with the guidelines set out in the Environment 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 environment inception report.

Environment 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 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 s Proponent is notified about the decision for preparation of an environment impact statement.

Environment 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 on 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 l 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 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 on two options:

The Minister may grant "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).

4. COMPARATIVE REVIEW OF LEGISLATIVE AND REGULATORY AND THE EIA FRAMEWORK FOR PNG AND ICELAND

4.1 Geothermal Development compatible with National development goals and planning strategies

Iceland has carried out a Master Plan for geothermal and hydropower development and identified several potential geothermal areas and has focused on promoting the sustainable development. The Icelandic government has considered the energy projects that are economically feasible, social prosperity for the wellbeing of the Iceland people and to ensure environmental sustainability.

PNG, on the other hand, does not have an energy plan at all but has developed a general long-term National Vision 2050 to guide our future direction to become a smart, wise, fair and happy society by 2050. Under National Vision 2050, one of the specific strategy focuses on the need for large renewable energy projects to be developed to 100 per cent to promote sustainable development in the country. This paves the way for the formulation of a geothermal policy to increase the production of electricity for the majority of the population who has no or little 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 availability of rural electrification and communication access, ensuring environmental sustainability and reducing greenhouse emissions.

Interestingly, PNG government has formed relationship with New Zealand government in early June 2014 to set up the geothermal power plant in PNG and is ready to help the Department of Mineral Policy and Geohazard Management to fast-tracked the geothermal resource policy.

4.2 Legislative and Regulatory Framework

There are major differences in terms of procedures between Iceland and Papua New Guinea and they are mainly due to different legal and regulatory frameworks. Legal and regulatory framework in Iceland motivates developers of geothermal energy and the Icelandic government has been supporting the growth of geothermal development since the 1924 with the development of Bjarnarflag geothermal power plant being the first geothermal power generation plant in Iceland (Orkuveita Reykjavikur, 2012). This power plant set the impetus for more geothermal power plants to come in Iceland. Iceland has utilised geothermal energy to produce electricity to support local industries, especially local aluminum industries, fish farming, tourism and salt production. Other uses of electricity are widespread in Iceland.

In contrast, PNG will soon become a new player in geothermal industry given that the geothermal regulatory framework is currently undergoing policy deliberation which should be regulated under the existing Mining Act 1992. The Mining Act 1992 remains effective which administers the discovering, appraisal, development and exploitation of minerals and the regulation of exploration for minerals and mining in PNG. PNG has the biggest commercial mines in the world including the Ok Tedi Copper mine, Lihir Gold mine and Porgera Gold mine, Ramu Nickel Mine and Hidden Valley mine, and there are several prospecting mines soon to be developed together with high number of exploration activities being undertaken.

The comparative matrix for legal and regulatory frameworks for geothermal developments between Iceland and Papua New Guinea is shown in Table 4 below. 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 emergence of additional research and exploration program 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 regulatory framework to cater for geothermal development. There are reported numbers of proposed exploration applications being made to carry out geothermal exploration in PNG areas. There are several applications pending the setup of a proposed regulatory framework. One case example is Kuth Energy PNG Ltd which has been pursuing the geothermal exploration at three geothermal potential sites which in 2008 were put on hold due to lack of a regulatory framework mechanism but still maintain their strategy to further explore the selected areas (Kuth Energy, 2012).

Table 4: 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 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 by National Energy Authority	To be regulated under Mining Act 1992 by Mineral Resource Authority
Other legislation governing geothermal resources.	Nature Conservation Act No 44/1999 by Environment Agency	Environment Act 2000 by Department of Environment & Conservation
	Environmental Impact Assessment Act No 106/2000 by National Planning Agency	Environment Act 2000 by Department of Environment & Conservation
	Electricity Act 65/2003 by National Energy Authority	Electricity Industry Act 2000, Independent Consumer and Competition Act, by Independent Consumer and Competition Commission
Legislations being amended	YES	NO -Soon to be developed

4.3 Permitting and Administrative process

Application process for geothermal projects in Iceland is more vigorous and effective than in PNG. In Iceland, the permit needed for geothermal development involves a multi-disciplinary approach and cooperation from relevant bodies as shown in Table 5 below and 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 the NEA under the Act on Survey and Utilisation of Underground Resources to carry out a geothermal exploration program. Once the exploration drilling is planned, the NPA is notified of the project, 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, utilisation permit is required from the NEA under the Energy Act No.65/2003 to exploit the resources for power generation.

Table 5: Administration and permits.

Actions - responsibility	Iceland	Papua New Guinea
Who is responsible for geothermal exploration and production	National Energy Authority	Mineral Resources Authority
Who is responsible for electricity generation, transmission and distribution	National Energy Authority	Independent Consumer and Competition/PNG Power Ltd
Official monitoring for resource	National Energy Authority	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	National Energy Authority	Mineral Resources Authority
Issuance of utilization permit (construction)	National Energy Authority	Mineral Resources Authority
Environmental impact assessment	National Planning Agency	Department of Environment and Conservation
Permit for power utilization or generate power	National Energy Authority	Independent Consumer and Competition
Master plan	Ministry of Energy, Tourism and Industry	National Planning Department and Department of Energy/Petroleum
Permit for protected area	The Environment Agency	Department of Environment and Conservation

Under the Mining Act 1992, exploration licence in PNG is required from the MRA for any drilling program which geothermal may fall under. The environment permit is required under the Environment Act 2000 and is required for any drilling program with 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 the electricity generation, transmission and distribution licences under the Electricity Industry Act. PNG Power Ltd (the Company) is the national electricity utility that has been issued with respective licences under the Electricity Act 2002 by the Independent Consumer and Competition Commission to generate, transmit, distribute and sell electricity in PNG (REEP, 2012).

In Iceland, the permit for power utilization to generate power is regulated by NEA under Energy Act No. 65/2003 while the ICCC in PNG regulates the energy sector that issues licences for electric power. It also establishes electricity tariffs and controls prices in PNG.

Table 6: Comparative matrix for EIA.

EIA	**Iceland**	**Papua New Guinea**
Single EIA Legislation	Yes	No
Name of Legislation	Environment Impact Assessment Act No. 106/2000	Environment Act 2000
EIA Regulator	National Planning Agency	Department of Environment and Conservation
When EIA policy became effective	1994	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)

4.4 Environment Impact Assessment

The EIA process is different for PNG and Iceland where Iceland has a single legislation on EIA while PNG does not have it. Table 6 below shows the matrix comparing 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 development projects are properly screened and assessed to protect the environment from possible serious environment 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 development projects.

5. SUMMARY AND CONCLUSIONS

The success of EIA during the preparation and development of geothermal projects depends on the proper implementation of regulatory framework requiring team work and holistic approach and understanding the protocols involved in the EIA procedures. It also requires gathering of 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 in 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 EIA is carried out in the early stage of the preparatory work, before it is decided whether a project shall be permitted. In that process not only environmental issues are introduced but also social well-being and the economic significance of the project according to the interest of parties. The responsibility of protecting the environment at the same time as contributing to increased prosperity during and after a 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 that it is necessary 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 is a potential to increase the well-being of the people of PNG in the future but must be well prepared in good cooperation with all stakeholders.

REFERENCES

Althingi: Act on the survey and utilisation of ground resources (with amendments). Act no. 57/1998, (1998), 10 pp. Website: eng.idnadarraduneyti.is/media/Rafraen_afgreidsla/Log_57_1998_ENS_020107.pdf

Ármannsson, H., Kristmannsdóttir, H.,: Geothermal environmental impact. *Geothermics,* 21, **5/6**, (1992), 869-880.

Axelsson, G.: Management of geothermal resources. *Proceedings of the "Workshop for Decision Makers on Direct Heating Use of Geothermal Resources in Asia",* organized by UNU-GTP, TBLRREM and TBGMED, Tianjin, China, (2008), 14 pp.

Beltane, R.: Geothermal power generation in the world: 2005-2010 update report. *Proceedings of the World Geothermal Congress 2010, Bali,* (2010), Indonesia, 41 pp.

Department of Environment and Conservation: Environment act no. 64 of 2000, (2010), Lexadin website: www.lexadin.nl/wlg/legis/nofr/oeur/lxwepng.htm

Enex: Geothermal power plant and geothermal heating district, (2012). Enex website: www.enex.is/?PageID=280

Fridleifsson, I.B.: Geothermal energy - present status, future prospects and place among the renewables. *Proceedings of the 9th International Energy Conference* ENERGEX, Krakow, Poland, (2002), 21-35.

Gunnlaugsson, E.: Permit process for geothermal development in Iceland. *Proceedings of the "Workshop for Decision Makers on Direct Heating Use of Geothermal Resources in Asia",* organized by UNU-GTP, TBLRREM and TBGMED, Tianjin, China, (2008), 10 pp.

Haraldsdottir, K.: Introduction to the legal environment in Iceland for utilisation of geothermal. *J. Energy & Natural Resources Law,* 28,**1**, (2010), 1-49.

Haraldsson, I. G.: Legal and regulatory framework –Barrier or motivation for geothermal development?. *Proceedings of the "Short Course on Geothermal Development and Geothermal Wells"*, organized by UNU-GTP and LaGeo, Santa Tecla, El Salvador, (2012), 23 pp.

Kuth Energy: Papua New Guinea next steps. Kuth Energy PNG, Ltd. , (2012). Website: www.kuthenergy.com/index.php?item=fileandtarget=png_11jan2012

Melaku, M.: Geothermal Development at Lihir – An overview. *Proceedings of the World Geothermal Congress 2005*, Antalya, Turkey, (2005), 4 pp.

MRA: Geothermal development in Papua New Guinea: Consultancy for a desktop study of potential sites. Mineral Resources Authority, Papua New Guinea, unpubl. report, (2011).

NPA: Guidelines for an Environmental Impact Assessment for projects. National Planning Agency, Iceland, report, (2005), 61 pp.

Orkuveita Reykjavikur: Hellisheidi geothermal plant. Orkuveita Reykjavíkur, (2012), Website: www.or.is/English/Projects/HellisheidiGeothermalPlant/

REEP: Policy DB Details: Independent State of Papua New Guinea. *The Renewable Energy and Energy Efficiency*, (2012), Website: www.reeep.org/index.php?id=9353andtext=andspecial=viewitemandcid=71

Volcanolive: Volcanoes of Papua New Guinea. Volcano Live, (2012), Website: www.volcanolive.com/png.html