Geothermal Development in Madagascar: An Alternative to the Energy Crisis

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Abstract – Energy consumption in Madagascar is low in per capita terms, and underdeveloped by structure. The electrical energy is currently predominantly on diesel generation and hydropower as consequence of an increasing demand for electricity. The high prices of oil are putting a strain on the national budget and constitute presently a serious hurdle to the economic growth for a developing country such as Madagascar. To minimize the dependency on energy imports and to save foreign currency, the use of alternate energy sources using renewable resources has become of great importance. Geothermal development seems to be the long term solution to this problem.

Madagascar is believed to have a geothermal potential which is estimated to be in excess of 350MW and it presents a huge number of medium and low enthalpy geothermal zones of interest. The exploration of geothermal energy in Madagascar is still at an early stage. In 2008, the country evaluated its low and medium enthalpy geothermal resources and the preliminary results from geology, geochemical data analyses and geophysical measurements indicate that medium temperature geothermal systems exist in the central and northern parts of the country and possibility of drilling into a medium temperature geothermal reservoir is high.

The overall objective of the study is to develop geothermal energy to complement hydro and other sources of power to meet the energy demand of rural areas in sound environment. This report gives an overview of Madagascar energy sector and presents the geothermal development update of the country**.**

Keywords: Madagascar, exploration, geothermal energy, electricity.

Résumé – La consommation d'énergie à Madagascar est faible par unité de personne, et sous-développée en structure. La majorité de l'énergie électrique est actuellement fournie par des centrales thermiques et hydroélectriques à cause d'une demande croissante en électricité. Les prix élevés en carburant posent des contraintes au budget national et constituent pour l'instant un obstacle sérieux à la croissance économique pour un pays en développement comme Madagascar. Pour minimiser la dépendance sur les importations en énergie et sauver les devises étrangères, l'usage de sources d'énergies alternatives qui utilisent des ressources renouvelables est devenu d'une grande importance. Le développement de l'énergie géothermique paraît être la solution à long terme à ce problème.

On pense que Madagascar a un potentiel géothermique qui est estimée à plus de 350MW et présente un certain nombre de zones géothermiques intéressantes de basse à moyenne enthalpie. L'exploration d'énergie géothermique à Madagascar est encore au stade de début. En 2008, le pays a évalué ses ressources géothermiques de basse à moyenne enthalpie et les résultats préliminaires provenant des analyses des données géologiques et géochimiques, ainsi que des mesures géophysiques indiquent que les systèmes géothermiques de moyenne

température existent dans les parties centrales et nord du pays ; et la possibilité de forer dans un réservoir géothermique de température moyenne est élevée.

L'objectif général de l'étude est de développer l'énergie géothermique en complément des centrales hydroélectriques ainsi que d'autres sources pour pouvoir faire face à la demande d'énergie des régions rurales dans un environnement sain. Ce rapport donne une vue d'ensemble du secteur énergie à Madagascar et présente la mise à jour du développement géothermique du pays.

Mots clés: Madagascar, exploration, géothermie, électricité.

1. INTRODUCTION

The Republic of Madagascar is an island in south-west Indian Ocean. The total area of the country is 587,040 km^2 with a population of 20 million of inhabitants. Eighty four percent of the population lives in rural areas with approximately two million people living in the capital city, Antananarivo. About 37% of the electricity production in Madagascar depends on imported diesel fuels and the electricity access to the population is only 15%. In 2007, the Government has set in its Madagascar Action Plan (MAP) and in its Millennium Development Goals the target to have total independency on energy by 2025. To reach these ambitious targets, the energy supply will be derived from all possible sources of energy available in Madagascar such as hydropower, geothermal, solar, wind, bio, etc.

Madagascar is believed to have a potential for geothermal resources and this is proven by the surfaces manifestations discovered mainly in the north and central regions of the country (Andrianaivo, 2008a).

In 1981 and in 2008, the Government of Madagascar was assessing possibilities of using geothermal energy as the available data indicates a significant potential in this resource that could end the energy crisis.

2. GEOLOGICAL BACKGROUND

Archean and Proterozoic rocks crop out in the eastern two-thirds of the island of Madagascar (Figure 1), most of which have been affected by Pan-African (650–490 Ma) orogenic events (De Wit, 2003).

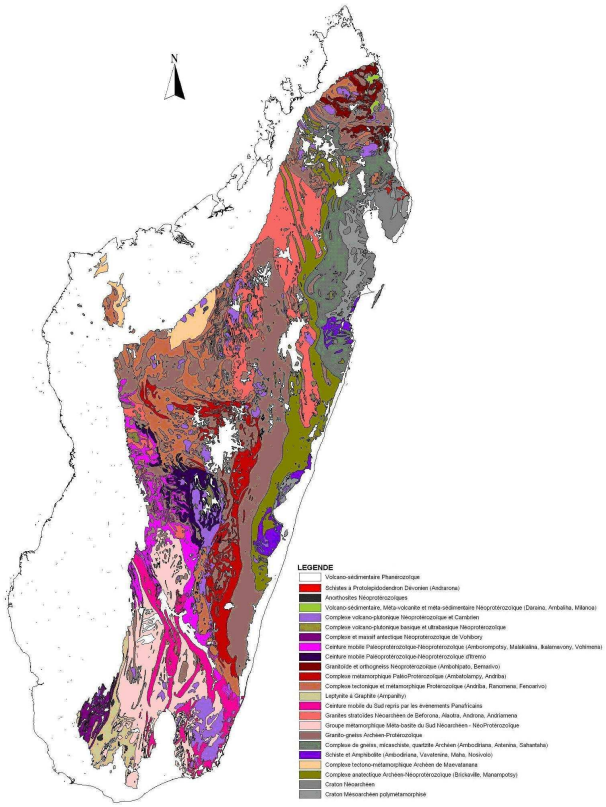

Figure 1: Geological map of Madagascar showing Archean and Proterozoic rocks (Randriamamonjy, 2006)

The volcanic history of Madagascar can be divided into a couple of periods (Brenon and Bussiere, 1959). During the Late Cretaceous, volcanism along the east and west coast of the island and in the southern Androy region was related to breakup of Gondwana and the separation of Madagascar from Africa and India. A second period of active volcanism occurred in the Late Tertiary (mostly Neogene), focused in the center of the island south of

Lake Alaotra, in the Alaotra graben and in the Andranomidioka Range. Recent volcanism is confined to the extreme north of the island (Figure 2). These periods of volcanic activity are probably associated with distinct fault orientations and geothermal manifestations (Andrianaivo and Ramasiarinoro, 2010; Manissale et al, 1999; Bertil and Regnoult, 1998; Besairie, 1959a; Brenon et Bussiere, 1959).

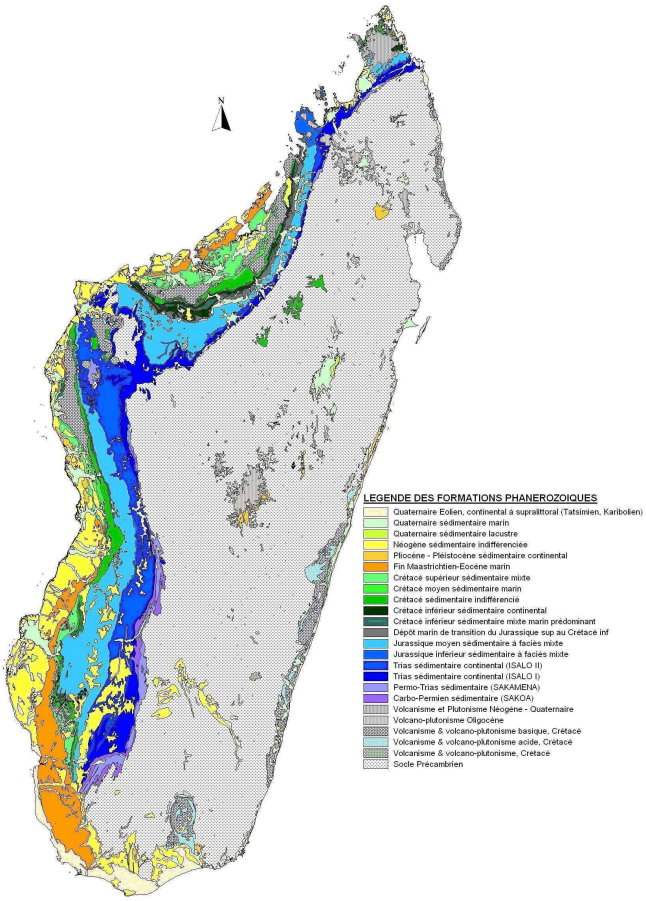

Figure 2: Geological map of Madagascar showing Phanerozoic rocks (Randriamamonjy, 2006)

Few low temperature thermal springs (geysers) are indicative for persisting geothermal resources.

Neogene to Quaternary volcanic rocks and active hot springs are found in several locations on the high central plateau of Madagascar.

3. ENERGY STATUS

Madagascar is currently confronted to an energy supply problem. Most of the population use wood as their basic energy need leading to an increasingly scares of fuel wood and thus creating deforestation (Andrianaivo, 2008f).

Imported petroleum fuels on the other hand dominate the local industries energy supply. Production of electricity in Madagascar was mainly from hydro resources.

Madagascar has an installed total electricity generating capacity of 810 MW (1MW = 10^6 watts) however only 753.3 MW (data of 1999) is consumed. The bulk of the capacity (electricity production by source) is derived from fossil fuel (37.04%, imported) and from hydro source (62.96%). The national cover rate is of about 15% only and the rate of access in the rural environment is less than 5%.

The average cost of electricity for domestic consumers is about 0.11 US$ (205 MGA) per Kilowatt hour. This high cost is principally due to use of expensive imported diesel fuel to feed the thermal plants.

In 2008, given the dependency on the oil imports and in the line of long term development of the country, the Government of Madagascar has set ambitious targets for extending electricity access under the Madagascar Action Plan (MAP). The MAP which covers the period 2007-2012 is the medium term programmatic framework for achieving the country's long term development aspirations as embodied in Madagascar Vision Naturally, as well as the long term targets in the Millennium Development Goals (MDGs) or "Objectifs du Millénaire pour le Développement" (OMD). In the targets, the Government of Madagascar has planned to increase the electricity access rate to 74% in urban environment and 10% in rural environment by the year 2011. The energy supply will be derived from all

possible sources of energy in Madagascar (solar, hydro, wind, bio).

To reach those targets, the Government of Madagascar has elaborated the national energy strategy and policy. The national energy policy contains policy statements on issues such as energy pricing and subsidies, energy sector governance and regulation, and the financing of energy sector investments. The policy also contains a separate policy statement on the electricity sub-sector, which confirms the policy commitment to enhancing access to electricity, particularly in rural areas.

The national energy strategy sets out how the energy transition in Madagascar will be achieved given the macroeconomic impacts of consuming more petroleum products and electricity. The strategy highlights that the Government's priorities to develop a knowledge-based economy and exploit indigenous energy resources will help to ensure that modern energy consumption is consistent with sustainable increases in national income levels.

Madagascar has a large range of renewable resources that can improve its energy situation, such as geothermal energy, solar energy, wind energy and micro hydro.

Three (mini)hydro projects are being developed by private company Hydelec SA: Sahanivotry 16.5 MW (1MW = 10^6 watts), Maroantsetra 1.2 MW and Mahitsy 12 MW ("chute de Farahantsana" - Manavoandro village).

Currently four mini and medium hydro projects are being developed by public company JIRAMA: Andekaleka 62 MW, Mandraka 24 MW, Telomita 8.2 MW, Manandona 1.5 MW.

For Antananarivo, the bulk of the capacity is derived from hydro (110.8 MW) and thermal plant (91.5 MW). This capacity satisfies slightly the local demand; the total available power is still low with a peak load of about 200 MW (Table 1).

Category	Name	Capacity (in MW)
Hydropower	Andekaleka	62
	Mandraka	24
	Antelomita	8.2
	Manandona (Antsirabe)	01.5
	Sahanivotry (Antsirabe)	16,5
Diesel generation or thermal plant	Mandroseza	40
	Ambohimanambola	20
	Antsirabe Ambalavato	7.5
	IPP Henri Fraise (private)	18 - 20
	EBM Antsirabe	04
Total		202.3

Table 1: Antananarivo electricity situation ("Réseau interconnecté d'Antananarivo")

Studies for micro hydro and geothermal projects are being carried out.

Therefore, in 2008, the priority of the Government of Madagascar was to develop other indigenous energy resources of the country in order to meet the increasing energy demand and reduce polluting thermal stations.

4. GEOTHERMAL POTENTIAL

The geothermal potential of Madagascar is estimated more than 350 MW (Andrianaivo, 2008a). Madagascar hosts more prospective areas for geothermal potential (Figure 3).

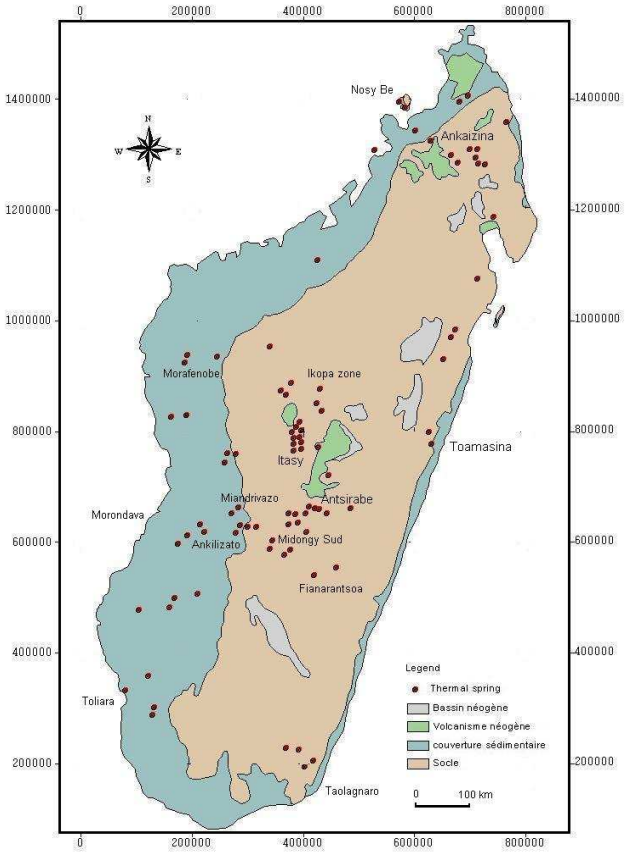

Figure 3: Simplified geological map of Madagascar showing the location of thermal springs (Besairie, 1959a)

The distribution of hot springs, geothermal wells and heat flow are controlled by geological structures. Based on the association of geological setting, resources and geothermal systems in Madagascar can be grouped into two main types: volcano-tectonic and non tectonic. Geothermal potential in the field volcano-tectonic generally may have a moderate to medium potential.

Following preliminary reconnaissance studies, three important zones presenting a geothermal potential interest for electricity production can be selected (Andrianaivo, 2008a):

- the northern parts geothermal zone (Ramena, Sambirano, Ankaizina),
- the Itasy geothermal zone and
- the Antsirabe geothermal zone in the central parts.

Low temperature reservoirs are widely spread in the vast area of the island.

5. GEOTHERMAL ASSESSMENT DEVELOPMENT

5.1 History

Madagascar does not have a long history of geothermal resources development. Reconnaissance missions and limited surface exploration works with a focus on hydro geological data collection were carried out in vast areas of the country from the period 1927 to 1959. About 175 hydrothermal springs of the country were identified and analyzed for the study (Besairie, 1959a).

Reconnaissance survey for geothermal resources started in 1980 with the VIRKIR Company (Gunnlaugsun et al, 1981).

In 2008, a serious initiative to begin developing geothermal project started in the country. Itasy and Antsirabe are the major areas which have been investigated in the country. Reconnaissance survey of these two selected geothermal prospects was carried out and it indicated that the reservoir temperature of the hot springs could be more than 150°C (Gunnlaugsun et al, 1981; Sarazin et al, 1986; Manissale et al, 1999; Andrianaivo, 2008a; Ramasiarinoro and Andrianaivo, 2010).

5.2 Present Exploration

Exploration for geothermal energy in Madagascar has been in progress in 2008. The studies have focused on three major geothermal areas namely Itasy, Antsirabe and the northern part of the island. The three areas are in advanced stages of surface exploration and must soon be subjected to geophysical survey and exploratory drilling that will pave the way for a resource assessment and prefeasibility study. The overall objective of the study is to develop geothermal energy to complement hydro and other sources of

power to meet the energy demand of rural areas in sound environment.

The current study has focused on geology, geochemistry, hydrology and geophysics with the aim of elucidating subsurface temperatures and the spatial extent of the geothermal systems. The results indicate that the geothermal activity in the three areas is related to volcanic and tectonic activities, which has a higher heat flow than the surrounding Precambrian crust. Subsurface temperatures between 60-155°C for the northern part of the island (Ramena, Sambirano, Ankaizina), 92-154°C for Itasy and 75-171°C for Ankaratra-Antsirabe in the central part have been predicted by geothermometry and mixing models (Gunnlaugsun et al, 1981; Sarazin et al, 1986; Manissale et al, 1999; Andrianaivo, 2008a; Ramasiarinoro and Andrianaivo, 2010).

Detailed geophysical measurements to delineate anomalous fields and to locate the deep reservoirs and drill sites in the three areas are recommended. The results will then be used to update the geothermal models that will be a basis for the drilling of deep geothermal wells.

The results of the preliminary geothermal investigations on other areas predict subsurface temperatures 56-131°C (Doany fault zone, Ikopa fault zone, Namorona Ifanadiana fault zone, Toamasina-Fenoarivo East costal band) suitable for small to medium scale electricity production and direct uses (Andrianaivo, 2008a). These areas have been ranked based on predicted subsurface temperatures and other geothermal features for further exploration and development.

6. FUTURE DEVELOPMENT

Detailed assessment of Madagascar geothermal resources is urgently needed in order to properly evaluate the country geothermal prospects. In 2008, it is in that view that the Government of Madagascar was working with the "GNS Science" Company and Marshfield Energy PTE Ltd. for the geothermal resource assessment and capacity building in the northern part and in the central part of the country. The exploration drilling is planned for 2011. Surface exploration of the central geothermal field of the country was planned to start end of year 2009 (Andrianaivo, 2008b).

The Government of Madagascar has in parallel started to develop the geothermal capability within the country. In 2008, successful contacts were made with these two Companies for their assistance in capacity building of Malagasy.

7. CONCLUSION

Given the frequent drought that affect the national hydropower, fluctuations in fossil fuel prices in the world and the rapid demand for more power, geothermal energy offers an indigenous environmental friendly alternative source of energy for Madagascar. The deficiency in Madagascar geothermal resource development has been due to the availability of cheap hydropower however due to the existing energy context, the development of this resource is now fundamental. The volcanoes area, the geological context and the hydrothermal manifestations of Madagascar indicate the existence of potential geothermal system.

In 1981 and in 2008, the Government of Madagascar in collaboration with its partners has started to carry out investigations of its geothermal resources. The Government of Madagascar has to build its human capacity within the sector. Private sector involvement for the development of the Madagascar Geothermal Resources is highly needed.

Government's Energy Policy of 2008 is an integral part of its overall development policy. It aims to facilitate the development of energy resources for economical supply

to consumers. It seeks to achieve the accelerated development of indigenous energy resources and the promotion of private investment in the production and supply of energy.

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