Geothermal Status and its Potential in Madagascar

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Abstract

Madagascar is willing to develop his geothermal resource to complement hydro and other sources of power to meet the energy demand of rural areas in sound environment.
Three important zones presenting a geothermal potential interest for electricity production are recognised. In the field volcanotectonic, geothermal resources of medium temperature exist in the recent volcanic areas, mainly in the north and the central part of the country. The subsurface temperatures range from 130°C to 200 °C and have been predicted by geothermometry and mixing models. For geothermal power plant project, volumetric method is used to estimate the heat storage and the electrical potential. The estimated generation potential for the country is about 350 MW.
Challenge and recommendations to accelerate the development and electrical utilization of geothermal energy are given in this paper.

Keywords: *Geothermal energy, resource assessment, potential estimation, development update, Madagascar*

1. INTRODUCTION - GENERAL BACKGROUND

Madagascar is currently confronted to an energy supply problem. Energy consumption in Madagascar is low in per capita terms and underdeveloped by structure. Most of the population use firewood and charcoal and thus creating deforestation. Imported petroleum fuels on the other hand dominate the local industries energy. The solution to this problem is the use of alternative energy.
Madagascar has considerable potential for developing a broad range of renewable energy resources (RES), principally geothermal, biomass, mini-hydro, solar, and wind. Madagascar has a large number of discharging thermal springs. There are many sites throughout the country that may have potential for utilization of geothermal resources.
The long term solution is the geothermal development of the country.
Some major questions need to be resolved:

- What’s the potential of geothermal energy of the country?
- How can it best be sustainably developed?
- What issues will need to be managed?

So, the compilation of this report is:
- to provide a description and explanation on geothermal resources in Madagascar as one of the priority of energy development.
- to develop geothermal energy (electricity) to complement hydro and other sources of power to meet the energy demand of rural areas in sound environment.
- to mitigate rural poverty through sustainable geothermal energy development.
- to present the geothermal development update of the country.

2. GEOTHERMAL SYSTEM AND DISTRIBUTION OF THE RESOURCE IN MADAGASCAR

Madagascar hosts several signs indicating the presence of geothermal resource such as the presence of Eocene-pleistocene volcanoes (Figure 1), hot springs (Figure 2), seeps, geyser and travertine mound (Figure 3).

Figure 1: Quaternary cone volcano in Itasy area

Figure 2: Mud and haut spring in a river

Figure 3: Geyser and travertine mound

2.1. Geothermal System in Madagascar

Based on the association of geological setting, the geothermal areas can be divided in three sections: volcanic terrain, fault zone, and sedimentary basin [1],[2]. Based on the association of geological setting, resources and geothermal systems in Madagascar can be grouped into two main types: volcanotectonic and tectonic (Table 1). Geothermal potential in the field volcanotectonic generally may have a moderate to medium potential.

2.1.1. Graben System - Volcanic Cone (Volcano - Tectonic)

- Tectonic system can be formed at the continental rifting (continental crustal strain) and along active fault zones (e.g. Itasy, Ankaratra)
- Environmental tectonic extension (strain) has a tendency to occur in the continental crust thinning so hot material (magma) will come out and formed at more shallow areas
- Potential resources vary from 30MW to100MW, with moderate to high temperatures (150-200°C) [1],[2].

2.1.2. Non-Volcanic

- Tectonic origin
- Generally dominated by the occurrence of intrusive rocks which have undergone cooling, but still save the heat (e.g. Anosyan chain)
- Potential less than 50 MW, low to moderate reservoir temperature (about 150°C).

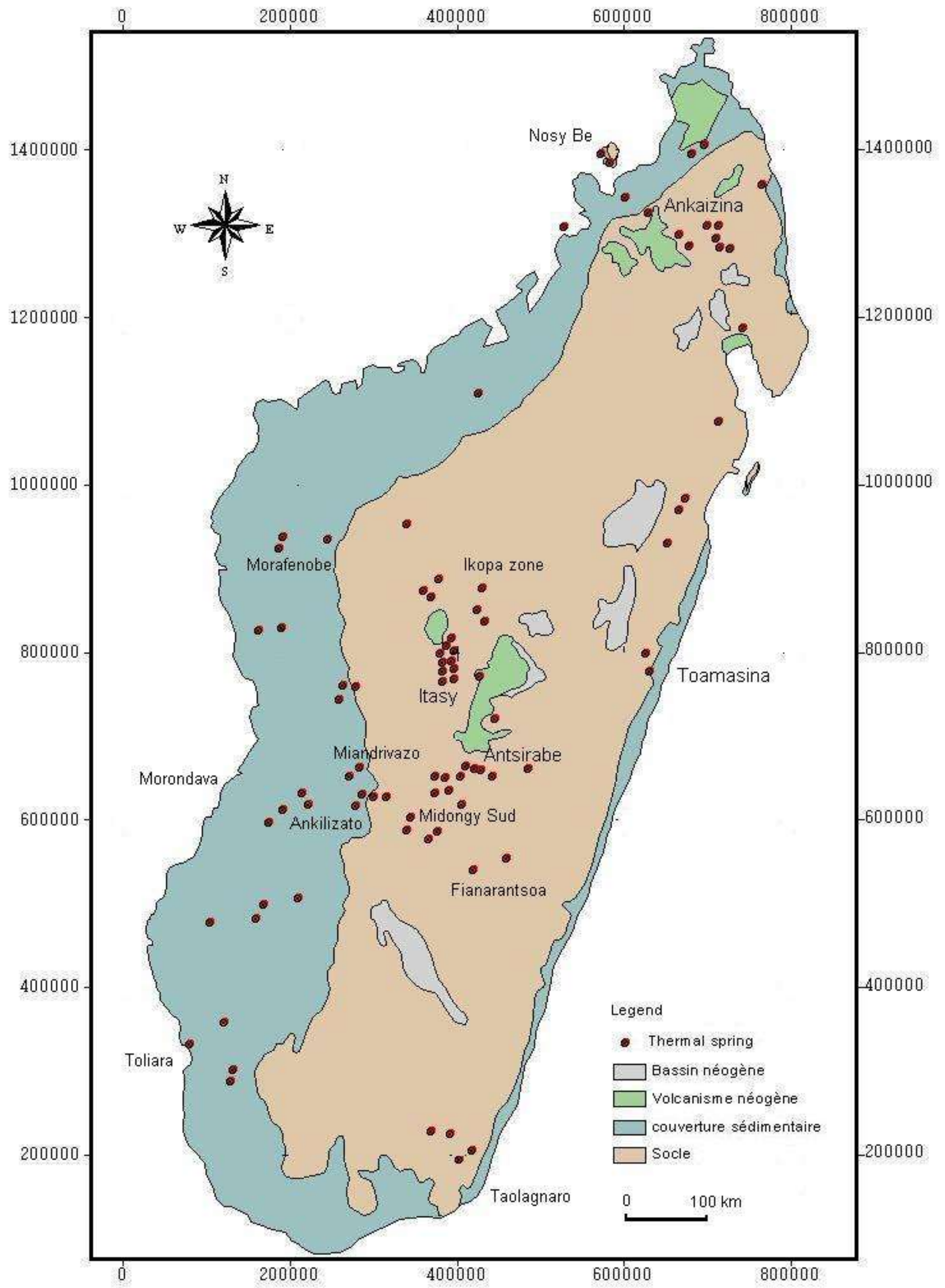
Table 1: Main types of geothermal system and their potential in Madagascar

Type		Temperature/ Enthalpy	Potency	Example
Volcanic	Single Stratovolcanic	High - Medium > 200 °C	Medium > 100 MW	?
Volcanotectonic	(graben and volcano)	High - Medium 200 - 150°C	High - Medium 50 – >100 MW	Itasy, Ankaratra Nosy-Be, Mt. Ambre
Non - Volcanic	Intrusion	Low - Medium ~ 150°C	Low - Medium ~ 50 MW	Fault zone: Andavakoera, Antongil-Doany, Anosyan chain, Sambirano, Sedimentary basin

Groupings of this type can be used as a guide in estimating the amount of potential energy in the beginning of a geothermal system.

2.2. Distribution of Geothermal Resource in Madagascar

Based on the results of geological, geochemical, and geophysical surveys, there are about 117 thermal springs in Madagascar [3],[4] that can be devised into12 geothermal locations (Figure 4) that are [1],[2]:
- Quaternary volcanic of north Madagascar
- Andavakoera fault zone
- Sambirano fault zone
- Antongil-Doany/Ankaizina lineament
- Ikopa fault zone (North Antananarivo)
-Itasy volcano-tectonic system
- Ankaratra volcano-tectonic system
- Ambatofinandrahana non volcanic system
- Fianarantsoa: Namorona-Ifanadiana
- East coast : Fenoarivo Est - Brickaville - Vatomandry
- Anosyan Cain (SE coast)
- Morondava Sedimentary basin



Following preliminary reconnaissance studies, three important zones presenting a geothermal potential interest for electricity production are recognized [1],[2]: the northern part geothermal zone (Ramena, Sambirano, Ankaizina), the Itasy geothermal zone and the Antsirabe geothermal zone in the central parts.

Subsurface temperatures around 155°C for the northern part of the island (Ramena, Sambirano, Ankaizina), 92-176°C for Itasy zone and 88-265°C for Ankaratra-Antsirabe in the central part have been predicted by geothermometry and mixing models [4],[5],[1],[2].

3. GEOTHERMAL ASSESSMENT DEVELOPMENT

3.1. Summary of the exploration and investigation

Exploration of geothermal energy is still at early stage.
From 1927 to 1959 (Besairie et al): the study composed mainly the reconnaissance mission and limited surface exploration (thermal springs data collection)
In1981 (Virkir Co) the study included reconnaissance survey for geothermal resource, five sites of interest are founded with reservoir temperature of more than 150°C (Gunnlaugsson et al, 1981)
Between 2007 and 2008: beginning of geothermal project by Marshfield Energy PTE Ltd. , and by "GNS Science" - Dr. Colin Harvey
In 2008: The University team under the Ecole Supérieure Polytechnique d'Antananarivo started the investigation of Itasy & Antsirabe areas.The result indicate reservoir temperature of about 150°C.
Present exploration and current study focused on geology, hydrology, geochemistry and geophysics to delineate anomalous fields, and to locate the deep reservoirs and drill sites in the 3 areas (Itasy, Antsirabe & North zones).

3.2. Electrical Geothermal Energy Potential Estimation in Madagascar

The method used in estimating the amount of potential geothermal energy could be done by using the comparison method and the volumetric method.
- Comparison method is used to estimating the speculative potential resource
- Volumetric method is used to estimate the potential of geothermal energy resources of hypothetical, possible, probable and proven reserves.

For example, the obtained prospect area of Ranomafana in the Miarinarivo district is approximately 9 km^2, which was predicted based on geochemical anomaly and soil anomaly. Considering the geological environment which is still associated with Quaternary volcanism, estimated reservoir temperature is about 150°C. Calculation of geothermal energy potential is made using the following assumptions:

- The average rate of saturated density = 2,5 * 10E3 (kg/m^3)
- The average rate of specific heat = 1 * 10E3 (kJ/kg °C)

The average thickness of reservoir =1 * 10E3 (m)

For Ranomafana geothermal prospect, the heat storage (J) obtained is:

= T(°C) * A(km^2) * 10E6 * 1 * 10E3(m) *2,5 * 10E3(kg/m^3) * 1 * 10E3(J/kg m^3)

= 1,875 * 10E18 J

To calculate the electric potential, the following assumptions are used:

- basic temperature of heat source for minimum generation of 120°C
- 30 years of exploitation period (=1 * 10E9 s)
- Rates of resource extraction efficiency and generation efficiency = 0,035

Electric potential (MW) can be calculated as follow :

= 2,5 * 10E15 * A(km^2) * (T-120°C) * 1 * 10E-6 * 0,035 * 1 * 10E-9 (/s)

= 31.5 MW

Electrical geothermal potential in Madagascar is estimated to be about 350MW.

4. BARRIERS, CHALLENGE AND RECOMMENDATIONS

Sustainable development is one of the challenge. But some problems such as barries need to be managed. One of the them concern financing geothermal development.
Barriers to the financing of geothermal energy may be:
- high front-end capital cost per kW installed and negligible variable costs (operation and maintenance),
- many renewable energy technologies remain expensive compared to conventional energy supplies
- limited human capital investment and development , etc.

Non-technical barrier is always:
- lack of government policy support
- lack of consumer awareness on benefits and opportunities of renewable energy
- lack of stakeholder/community participation in energy choices and renewable energy projects, etc.

To accelerate the development and utilization of geothermal energy, we propose at least the following recommendations:
- Policy and legislative framework: to be harmonized to avoid creating uncertainties to the would be private developers
- Financing and funding : must be readily available
- Tax incitatives: should be enacted to provide tax savings, giving concessions and waiving duties for geothermal resource development work this reduces the budget and will make geothermal much more economically attractive and thus much easier to finance hence attracting investors.
- Establishment of risk fund

5. CONCLUSION AND PERSPECTIVES

For the geothermal power plant of the Itasy prospect, the investigation and mining planning is composed of five phases:

(1) Project structuring and preliminary resource assessment (one year):
- mobilization of local and international skills;
- exploitation (examination and synthesis) of the information and data acquired (geology, geochemistry, geophysics, etc.)

(2) Exploration of the resource and determination of potential (one year):
- refined geophysical studies;
- overall summary of measurements, analysis and interpretation;
- reservoir modeling;
- location of the area recommended for reconnaissance by drilling

(3) Reconnaissance drilling at least 1000 m deep and real assessment of the potential (one year):
- monitoring and interpretation of drilling results;
- (pre)feasibility study (development of thematic maps, risk assessment, planning, design and estimation of the overall drilling cost, definition of the operating site, development of the project timing, etc.);
- environmental impact study;
- decision on the viability of commercial exploitation

(4) Development of the geothermal field (one year):
- carrying out production or exploitation drilling if an economic analysis justifies it;
- choice and design of the power plant
(binary system, back pressure, single flash, double flash, dry steam, etc.)

(5) Construction of infrastructure and power plant; reservoir management and further development (one year)

Note that phases (4) and (5) are conditioned by phase (3).

The following success conditions must be applied:
- joint implementation of administration, organization and a progressive and rational scientific approach
- participation of research laboratories (public and private) and expert organizations in geothermal energy (university and private)
- complementarity of scientific and technical skills coming from various backgrounds (national, foreign)

That is to say:
- combination of maximum skills and knowledge
- optimal progress of the project

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