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Geothermal Energy Resources of Madagascar - Country Update

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ABSTRACT

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 exploration of geothermal energy in Madagascar is still at an early stage. In last recent years, the researchers from our university evaluated their geothermal resources using geology, geochemical data analyses and geophysical measurements. The preliminary results of this exploration indicate that about 130 natural geothermal outcrops are recognized in the country. The distribution of thermal springs, heat flow and the nature of the geothermal reservoirs are controlled by the geological structures. The geothermal areas can be divided in three sections: volcanic terrain, fault zone, and sedimentary basin. Resources and geothermal systems are of two types: volcano-tectonic and tectonic. Concerning the possibility of electrical geothermal energy production, Madagascar presents a huge number of medium and low enthalpy geothermal zones of interest. Geothermal systems of medium temperature exist in the recent volcanic area and the possibility of drilling into a medium temperature geothermal reservoir is high, especially in the north and the central part of the country. Subsurface temperatures of approximately 60-155°C for the northern zone of the island, 92-154°C for Itasy and 87-171°C for Antsirabe-Betafo have been predicted by geothermometry and mixing models. Geophysical measurements 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. Despite the availability and enormous potential in direct use applications, little use has been made of low to medium enthalpy fluids in Madagascar. These thermal phenomena are still not developed and their exploitation is limited. Currently, geothermal water is used for bathing, swimming, balneology, tourism and washing with little economic return. An overview of the energy sector, known geothermal resources and their potential and present geothermal utilization are given in the paper.

1. INTRODUCTION

Energy consumption in Madagascar is low in per capita terms and underdeveloped by structure. Madagascar is also currently confronted to some energy supply problem. The solution to this problem is the use of alternative energy. Knowing that Madagascar has considerable potential for developing a broad range of renewable energy resources (RES) and there are many sites throughout the country that may have potential for utilization of geothermal resources; we speculate that the long term solution is the geothermal development.

In this country the new technologies of direct use of geothermal energy are either partly developed or remain still untouched. Integrated and cascade use of geothermal energy of low enthalpy will represent an important direction for profitable investment.

This paper represents a summary of the important results of the geothermal development update of Madagascar, including the energy status and a description of geothermal resources.

2. ENERGY STATUS

Madagascar has an installed total electricity generating capacity of 810 megawatts (1MW = 10^6 watts). 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 about 15% only and the rate of access in the rural environment is less than 5% (INSTAT, 2011). The average cost of electricity for domestic consumers is about US$ 0.14 per kilowatt hour. This cost is principally due to the use of expensive imported diesel fuel to feed the thermal plants.

Given the dependency on the oil imports and in the line of long term development of the country, Madagascar has set ambitious targets for extending electricity access. In the targets, Madagascar plans to increase the electricity access rate to 74% in urban environment and 10% in rural environment by the year 2019. The energy supply will be derived from all possible sources of energy in Madagascar (solar, hydro, wind, bio).

To reach those targets, 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 micro hydro projects are being developed by private company Hydelec SA: Sahanivotry 16.5 MWe, Maroantsetra 1.2 MWe and Mahitsy 12 MWe (INSTAT, 2011).

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

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

Table 1: Antananarivo electricity situation

Category	Name	Capacity (in MWe)
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

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

Therefore, the priority is to develop other indigenous energy resources of the country, such as geothermal energy, in order to meet the increasing energy demand and reduce polluting thermal stations.

3. GEOTHERMAL POTENTIAL

Madagascar hosts several signs indicating the presence of geothermal resource such as volcanoes (young/dormant), hot springs, geyser, travertine mound and seeps.

The distribution of hot springs, heat flow and the nature of the geothermal reservoirs are controlled by the geological structures. Based on the association of the geological setting, the geothermal areas can be divided in three sections: volcanic terrain, fault zone, and sedimentary basin. Resources and geothermal systems in Madagascar can be grouped into two main types: volcano tectonic and 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, 2008): the northern part geothermal zone (Ramena, Sambirano, Ankaizina), the Itasy geothermal zone and the Antsirabe geothermal zone in the central parts (Figure 1).

Exploration of geothermal energy is still at an early stage. 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 following three potential 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 the Itasy zone 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, 2008; Ramasiarinoro and Andrianaivo, 2010).

4. GEOTHERMAL RESOURCES UTILIZATION

The two main utilization categories, power generation and direct use, are already introduced in many countries around the globe; further, expanding distribution is possible and should be increasingly enforced.

Direct heat use is one of the oldest, most versatile and also the most common form of utilization of geothermal energy. The commonest uses of geothermal energy in Madagascar are the traditional ones: balneology and recreation. Bathing, swimming and balneology (therapeutic use) are the best known forms of utilization in Madagascar.

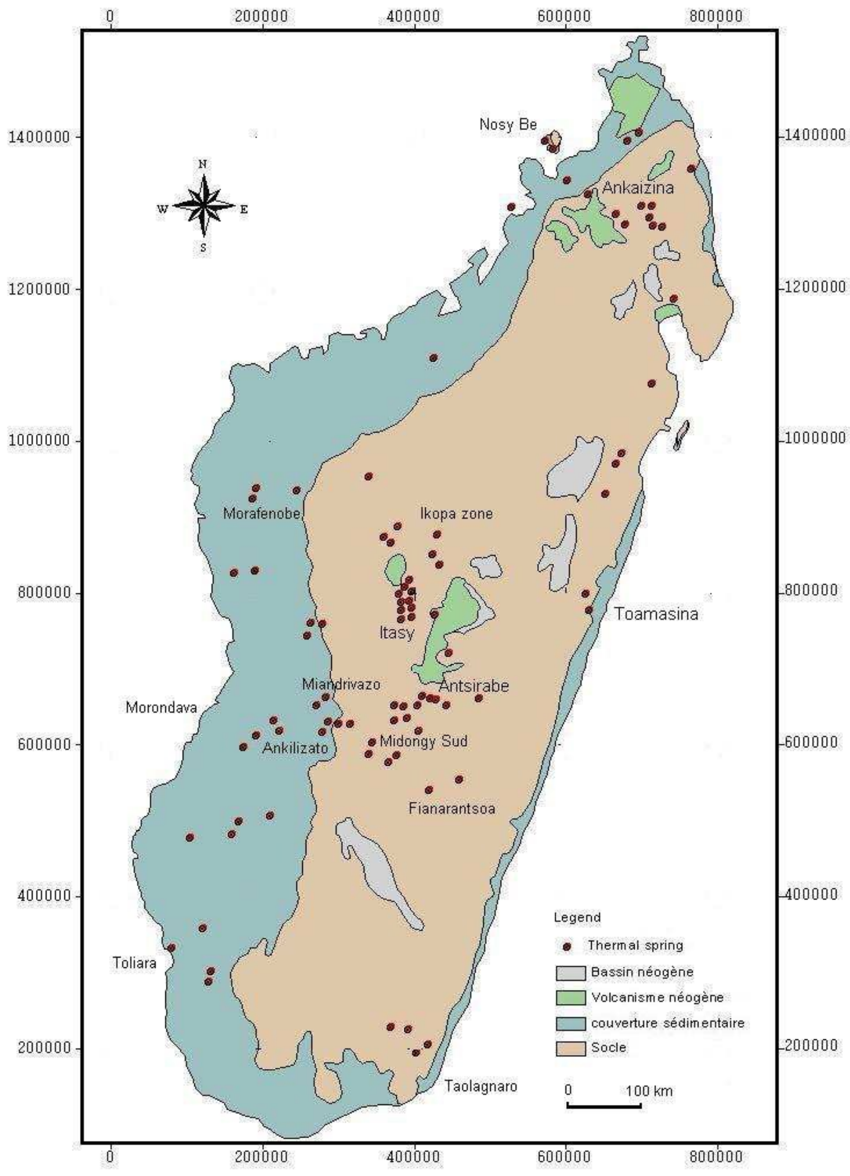

Figure 2: Map of Madagascar showing the localization of thermal springs

There are today in Madagascar five thermal water spas used for balneology, sports and recreation and as tourist centers. Thermal waters are also bottled by three mineral water bottling companies. Bottling of mineral water is regulated by the Law on Concessions.

A large hotel and rehabilitation center with a swimming pool is heated in Antsirabe Spa. A similar use is practiced in Ranomafana Namorona Spa near the Ranomafana National Park. Thermal springs in Bezaha Spa and in Betafo Spa are used for a rehabilitation center and recreation center.

Drinking water out of taps allows massive use for disease prevention. Utilized water for relaxation, sanitary needs and prevention has the highest share in balneology.

5. DISCUSSION AND CONCLUSION

The primary energy production from domestic sources hasn't changed considerably during last five years. The highest shares get hydropower (63%) and thermal plant (37%). The contribution of renewable sources is jointly presented with hydropower.

According to the published report by the Ministry of Energy a target of 10% share of RES in 2019 could be achieved mainly by increasing the contribution of hydro power plants.

A National Program promoting development of renewable energy sources for the period 2014-2019 has been approved. It is focused on the reduction of electricity and liquid fuels as sources for heating and their replacement with renewable.

A State Commission for Energy issues licenses and sets compulsory preferential purchasing prices for electricity generation from renewables. The prices are formed based on the analysis of investment expenditures by technology, expenses for energy generation by technology and the rate of capital repayment. No purchasing prices are available for electricity generation from thermal waters because such activity is still missing in the country.

A substantial problem in RES development in the country is the lack of coordination of this process. Still, no official register for renewable application is available.

Among the different types of geothermal application only balneology (sanitary needs, prevention, treatment and rehabilitation), swimming pools, drinking water and relaxation have shown a growth. Some quantities of thermal water have been used to meet the demand of potable and domestic water. The total installed capacity for direct heat use runs up to 2.814 MWt (Table 2).

Major current barriers stated for the previous 5 years period for the geothermal development in the country remain the same:

- Lack of preferential status to the use of geothermal energy for heat production.
- Lack of expertise in preparation of exploration and business plan.
- Insufficient commercial financing.
- Local taxes and fees are important but very insufficient source of funds for the Municipalities budgets.
- Lack of investments and organizational problems are still the major obstacles for the geothermal development in the country

Existing Spa centers located in central Madagascar would increase the share of thermal water in their activity and the type of applications as well.

A process of assessment of the existing geothermal resource regarding possibilities for electricity generation by using modern technologies is in progress.

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STANDARD TABLES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (wind)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2014			~199.8	~799.2	340.2	~1360.8			~13	~52	~540	~2035.8
Under construction in December 2014												
Funds committed, but not yet under construction in December 2014												
Estimated total projected use by 2020			~267	~1068	~476	~1904			~13	~52	~756	~3024

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2014 (other than heat pumps)

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Antsirabe Ranomafana I	B	2.3	51	30			0.202	2.2	6.094	0.956
Antsirabe Ranomafana II	B	1.5	51	30			0.132	1.25	3.462	0.833
Antsirabe Lac	B/O	0.25	35	25			0.01	0.22	0.29	0.88
Antsirabe Lac	B	0.7	38.5	26			0.037	0.5	0.824	0.714
Antsirabe Hôpital	B/O	0.58	42	27			0.036	0.5	0.989	0.862
Antsirabe Hôpital	B	1.5	45	30			0.094	1.2	2.374	0.8
Antsirabe Ranovisy	B/O	2.3	42	27			0.144	2	3.957	0.869
Antsirabe Ranovisy	B	2	46	35			0.092	1.7	2.467	0.85
Betafo Ranomafana	B	0.4	57.5	35			0.038	0.35	1.039	0.875
Ranomafana Betafo 1	B	0.5	58	30			0.059	0.4	1.477	0.8
Ranomafana Betafo 2	B	0.3	48	30			0.023	0.25	0.594	0.833
Ranomafana Betafo 3	B	0.3	46	25			0.026	0.2	0.554	0.666
Faratsiho Ramainandro	B	0.1	42	25			0.007	0.07	0.157	0.7
Soavinandriana Ranomafana	B	3.2	45	35			0.134	3	3.957	0.937
Itasy Masahona	B	3	57	35			0.276	3	8.705	1
Itasy Andranomangotraka	B	10	28	25			0.126	8	3.166	0.8
Itasy Marais d'Ifanja	B	3	46	30			0.201	3	6.331	1
Mahatsinjo Ambohipano	B	3	40	25			0.188	2.8	5.54	0.933
Ifanja Anosibe Ranomafana	B	5	49	35			0.293	4	7.386	0.8
Ranomafana Namorona 1	B	0.7	41	30			0.032	0.6	0.871	0.857
Ranomafana Namorona 2	B	0.9	44	30			0.053	0.8	1.477	0.889
Ranomafana Namorona 3	B	11.2	46.5	35			0.539	10	15.169	0.893
Ranomafana Namorona 4A	B	0.7	47.5	35			0.037	0.55	0.907	0.785
Ranomafana Namorona 4B	B	0.36	46.5	35			0.017	0.3	0.455	0.833
Ranomafana Namorona 4D	B	0.69	31.5	25			0.019	0.4	0.343	0.58
TOTAL							2.814		78.585	20.942

B = Bathing and swimming (including balneology), O = Other

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2014

Use	Installed Capacity[1)]	Annual Energy Use[2)]	Capacity Factor[3)]
	(MWt)	(TJ/yr = 10^{12} J/yr)	
Individual Space Heating[4)]			
District Heating [4)]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5)]			
Industrial Process Heat[6)]			
Snow Melting			
Bathing and Swimming[7)]	2.814	75.585	0.852
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps			
TOTAL	2.814	75.585	0.852

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2010 TO DECEMBER 31, 2014 (excluding heat pump wells)

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)	none	2			0.3
Production	>150^o C	none				
	150-100^o C	none				
	<100^o C	none				
Injection	(all)	none				
Total		0	2			0.3

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

Year	Professional Person-Years of Effort					
	-1	-2	-3	-4	-5	-6
2010			2			
2011			2			
2012			3			
2013			5			
2014		1	7			
Total		1	19			

(1) Government, (2) Public Utilities, (3) Universities, (4) Paid Foreign Consultants, (5) Contributed Through Foreign Aid Programs, (6) Private Industry

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2014) US$

	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
Period	Million US$	Million US$	Million US$	Million US$	%	%
1995-199	none	none	none	none	none	none
2000-200	none	none	none	none	none	none
2005-200	none	none	none	none	none	none
2010-201	unknown	unknown	unknown	unknown	unknown	unknown