Geothermal Resources Direct-Use in the volcanic areas of Itasy-Antsirabe, central Madagascar

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Abstract - The primary forms of utilization of geothermal energy in Madagascar currently are mainly direct uses that are gaining momentum in various parts of the country. For example, a tourist hotel at Antsirabe is utilizing spring water at 45°C to heat a spa pool. Despite the availability and enormous potential in direct use applications, little use has been made of low to medium enthalpy fluids in Madagascar. This paper therefore discusses direct use applications and available opportunities in swimming, bathing, balneology, agricultural, aquaculture and in residential and industrial sectors. Barriers to direct use development, recommendations to accelerate direct use growth and benefits to the Malagasy economy are also reviewed.

Keywords: Geothermal, direct use, swimming pool, bathing, balneology, space heating, greenhouses, agriculture, aquaculture, industrial processes, Madagascar.

Résumé – Les principales formes d'utilisation actuelle de l'énergie géothermique à Madagascar sont principalement des usages directs qui gagnent de vitesse dans plusieurs parties du pays. Par exemple, un hôtel touristique à Antsirabe utilise une source chaude de 45°C pour chauffer une piscine de station thermale. En dépit de la disponibilité et de l'énorme possibilité dans les applications directes, on n'utilise qu'une faible partie pour les fluides de faible à moyenne enthalpie à Madagascar. Ce papier discute par conséquent des utilisations directes de la géothermie et des occasions disponibles telles que piscine, bain, balnéothérapie, agriculture, aquaculture ainsi que dans les secteurs résidentiels et industriels. Les barrières dans le développement de l'utilisation directe, les recommandations pour accélérer l'augmentation de l'usage directe et les avantages pour l'économie de Madagascar sont aussi examinées.

Mots clés: Géothermie, usage direct, piscine, bain thermal, balnéothérapie, chauffage d'espace, serres, agriculture, aquaculture, processus industriels, Madagascar.

1. INTRODUCTION

Itasy-Antsirabe region is part of a continental divergent zone in central Madagascar, a zone where spreading occurs resulting to the thinning of the crust hence eruption of lavas and associated volcanic activities including geothermal (Andrianaivo and Ramasiarinoro, 2010; Rufer et al, 2006; Manissale et al, 1999; Bertil and Regnoult, 1998; Besairie, 1959a; Brenon et Bussiere, 1959).

Geothermal activity is widespread in the entire region as indicated by presence of strong thermal surface manifestations (Figure 1). They occur in form of geyser, hot springs, altered grounds and silica sinter deposits (Besairie, 1959a). These manifestations indicate presence of an enormous geothermal energy resource potential for both electric and non-electric or direct utilization in the country.

2. DIRECT USE UTILIZATION

Direct or non-electric utilization of geothermal energy refers to the immediate use of the heat energy rather than to its conversion to some other form such as electrical energy.

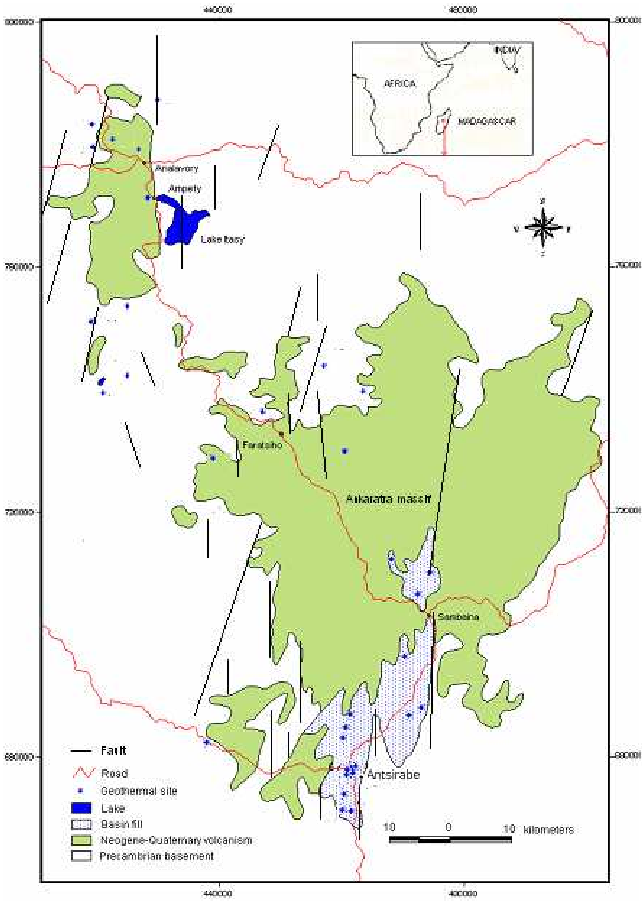

Figure 1: Simplified geological map of the study area showing the tectonic and geothermal sites

The primary forms of direct use that can be harnessed in Madagascar include swimming, bathing and balneology (therapeutic use), space heating and cooling, agriculture (mainly greenhouse heating and some animal husbandry), aquaculture (mainly fish pond), industrial processes, and heat pumps (for cooling). In general, the geothermal fluid temperatures required for direct heat use are lower than those for economic electric power generation.

Most of the accounted under bathing and swimming are the hot springs in central Madagascar such as Antsirabe area. There are, however, operational hot springs in other regions of the country which have not yet been assessed and hence were not included in the study.

The direct utilization of geothermal energy is difficult to determine since there are many diverse uses of the energy and these are sometimes small and located in remote areas in Madagascar. There is difficulty in finding knowledgeable persons except for indigenous knowledge among the people. This is especially true of geothermal waters used for swimming pools, bathing and balneology. In addition, even if the use can be determined, the low rates and temperatures are usually not known or reported.

Otherwise, most direct use applications use geothermal fluids in the low-to-moderate temperature range between 50°C and 150°C, and in general, the reservoir can be exploited by conventional water well drilling equipment. Low temperature systems are also more widespread than high temperature systems (above 150°C) so, they are more likely to be located near potential users. Some authors (e.g. Gudmundsson et al., 1985) assessed the potential use of geothermal water and steam in relation to their temperature (Figure 2) and from this figure it is clear that thermal waters with temperatures as low as 20-30°C constitutes a useful energy resource. Discussed below are some direct use options that can be applicable in Madagascar.

2.1 Swimming, bathing and balneology

Romans, Chinese, Japanese and central Europeans have bathed in geothermal waters for centuries. The Itasy-Antsirabe region's weather conditions and its attraction as a tourist spot, suggest the possible development of hot spring areas (Figures 3, 4 and 5) for medicinal, recreational and tourism purposes (spas, swimming pools and saunas).

These uses are particularly developed in the Asia and in European countries, while they are not frequently exploited in Africa. These developments if realized will enhance local and foreign tourism hence boosting the economies of the local population and the country at large.

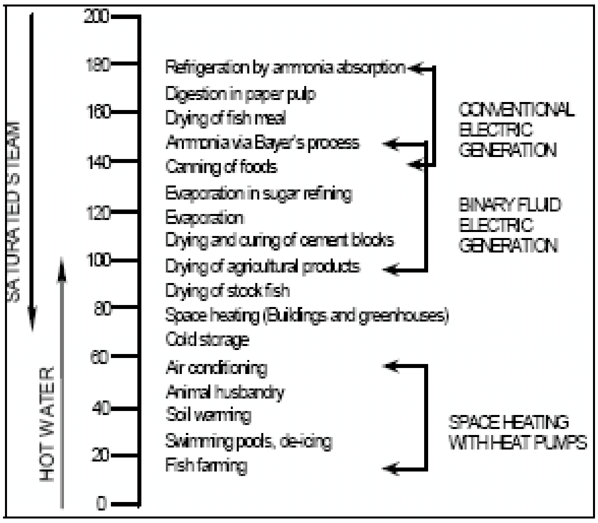

Figure 2: The Lindal diagram (after Gudmundsson et al, 1985)

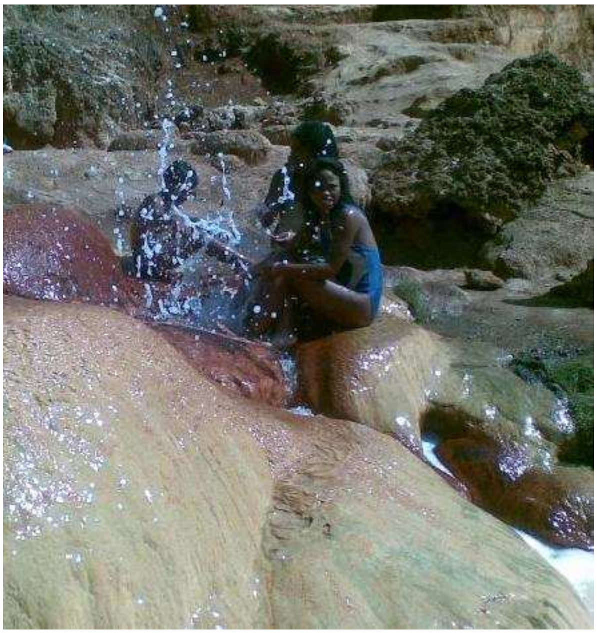

Figure 3: Hot spring sprouting (geyser) at Andranomandevy in the northwestern part of Analavory Itasy

Figure 4: Swimming pool at Andranovisy Antsirabe

Figure 5: Balneology at Andranomaimbo Antsirabe

2.2 Agriculture

Geothermal resources are used worldwide to boost agricultural production. Water from geothermal reservoirs is used to warm greenhouses to help grow flowers, vegetables and other crops. For hundreds of years, Tuscany in Central Italy has produced vegetables in the winter from fields heated by natural steam.

Numerous commercially marketable crops have been raised in geothermally heated greenhouses in Hungary, Russia, New Zealand, Japan, Iceland, China and the U.S (Freestone, 1996). These include vegetables, such as cucumbers and tomatoes, flowers, houseplants and tree seedlings. Unlike those countries mentioned above which have extreme climatic conditions part of the year, the central Madagascar climate is more or less stable. The Itasy-Antsirabe region is particularly suitable for the creation of a climatized environment, all year round, with optional temperature (heating and cooling), desired humidity conditions, and eventual addition of CO_2 of geothermal origin, which stimulates the production of biomass.

The advantage of using geothermal energy for heating is that it results in drastic reduction in operating costs. The localities, which should be targeted for greenhouse heating, using geothermal, include the areas around Lake Itasy and Lake Andraikiba.

2.3 Aquaculture

Geothermal aquaculture, the "farming" of water-dwelling creatures, uses natural warm water to speed the growth of fish, shellfish, reptiles and amphibians. This kind of direct use is increasing in popularity (Fridleifsson, 1998).

The use of geothermal energy for raising shrimp, tilapia, eels, and tropical fish has produced crops faster than by conventional heating. Using geothermal heat allows better control of pond temperature, thus optimizing growth (Figure 6). Fish breeding has been successful in Japan, China and the United States (Freestone, 1995). The most important factors to consider are the quality of the water and disease. If geothermal water is used directly, concentrations of dissolved heavy metals (fluorides, chlorides, arsenic, and boron) must be considered.

Fishing products and particularly, high protein content algae, make up an alimentary resource of significant nutritive value, which is still nowadays, neglected in the diets of a good part of the Malagasy population. The rapid growing cycle and its production abundancy per unit area, make this resource critical in the battle against hunger.

These high protein algae grow naturally in many of the Malagasy lakes and offer ideal feed for herbivorous fish, as well as directly providing for human consumption. Use of geothermal to raise fish drastically reduces operations costs from energy saving due to fast growths and also fish will be available where there are no lakes or rivers in the vicinity.

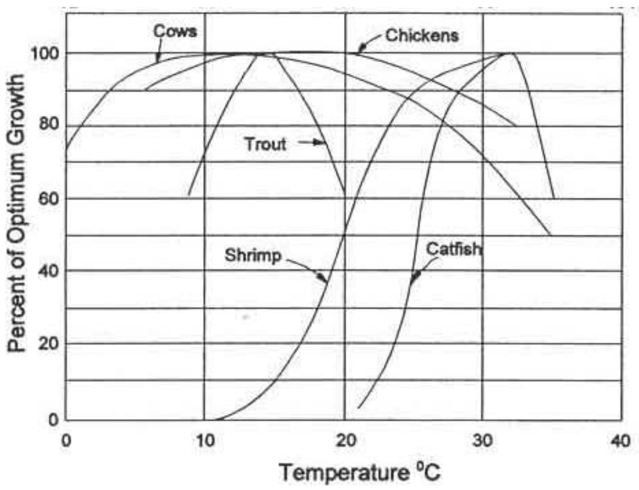

Figure 6: Effect of temperature on animal and fish growth (after Lund, 2000).

2.4 Residential heating or cooling and hot water supply

The largest potential use of geothermal energy is for geothermal heat pumps (GHP). GHP's circulate water or other liquids through pipes buried in a continuous loop (either horizontally or vertically) next to a building. Depending on the weather, the system is used for heating or cooling. The GHP is the highest efficiency heating and cooling system available, and would provide much lower energy costs for the consumer and also greatly reduce Electric Peak demand for the utility. In central Madagascar, the annual temperature ranges are not extreme and therefore GHP's would be mainly used to cool and to a small extent heat residential house in the cooler months of the year to provide for stable temperatures. Hot water supplies can either be gotten from anomalous boreholes with temperatures over 50ºC common in the volcanic area and as a byproduct of used geothermal fluids. Urban centers, especially in the high altitude and the colder regions like Antsirabe, Betafo, which are close to proven geothermal systems, can utilize this resource and energy savings from use of geothermal waters should be realized.

2.5 Industrial applications

The heat from geothermal water is used worldwide for industrial purposes. Some of these uses include drying fruits, vegetables and tea leaves, washing wool, manufacturing paper and production of alcohol.

2.5.1 Diatomite

Although the Lindal diagram (Figure 2) shows many potential industrial and process applications of geothermal energy, the world's uses are relatively few. The diatomaceous earth drying plant in northern Iceland uses geothermal steam (Ragnarsson, 1995).

The geothermal waters in the Antsirabe area could possibly be used for special "wet" processes and subsequent drying. The abundant geothermal resource within the Betafo and Antsirabe basins could be utilized to dry the diatomite, hence saving electricity for more demanding uses.

2.5.2 Drying of agricultural products

Drying and dehydration are important moderate temperature uses of geothermal energy. Various vegetable and fruit products are feasible with continuous belt conveyors or batch (truck) dryers with air temperatures from 40°C to 100°C. Geothermally drying onions, pears, apples and seaweed are examples of this type of direct use. Using geothermal energy increases the efficiency of the process and extends the production into the wet months.

2.5.3 Sugar cane industry

The sugar cane industry is one of the most significant users of supplementary energy, derived from either firewood or fuel oil. Taking into account that most of Madagascar's sugar production is concentrated in the east or the west coastal, where the presence of geothermal fluids of low-medium temperatures is highly probable, it would be worthwhile to consider the possibility of substituting part of those combustible fuels such as bagasse, which could be more fruitfully used for the generation of electricity, with geothermal fluids.

2.5.4 Production of alcohol

Alcoholic beverages like beer, whisky, etc. can be produced with cereals, using geothermal heat processes. Production of alcohol is feasible for countries such as Madagascar, which have an energy deficit coupled with an overproduction of biomass alcohol, which can meet many of the needs of the transportation sector, as well as those of other energy consumers. Plants, in which alcohol is produced using geothermal energy, have been operating for some time now, mainly in the United States (Freestone, 1996). Methanol and ethanol can be obtained from wood and biomass such as bagasse respectively. Ethanol can, also be obtained from cereals and from the sugar industry. The production of alcohol requires large amounts of heat. Temperatures required for alcohol production are 35°C for fermentation and 110ºC for the distillation and concentration processes respectively. These reservoir temperature ranges are readily available in most of the low to intermediate temperature geothermal resources in Madagascar. Production plants with above the temperature range can utilize geothermal energy effectively.

2.5.5 Wood industry (paper, wood pulp or straw pulp)

Paper and wood industries require significant amounts of energy and availability of hot water. About 2.5 tons of wood or 2 tons of straw are necessary to produce 1 ton of dry paste at 60% humidity employing 18-21 m^3h^{-1} of hot water and 7.5-8.5 t/h of steam. Such amounts of hot water and steam are feasible in geothermal power plants as a by-product of generation of electricity. New Zealand possesses the world's largest plant, which produces wood pulp by means of geothermal energy (Freestone, 1996) and Madagascar should borrow a leave from them.

2.5.6 Tea curing and drying

Temperatures of 25-45°C are required for curing and 70°C for drying tea leaves. It should be noted that 100 kg of green leaves are necessary to obtain 23 kg of dry tea. Drying is usually accomplished by means of forced air electric ventilation, and has a duration of aproximate1y 18 hours. More than ten percent of the tea produced in Madagascar is dried in wood burning dryers and therefore use of geothermal resources will drastically reduce the use of firewood and conserve forests.

2.5.7 Liquid CO_2 mining

A plant for the commercial production of liquid carbon dioxide (CO_2) has been in operation at Haedarendi in south west Iceland since 1986, (Ragnarsson, 1995). The geothermal fluid used is of medium enthalpy, but with a high gas concentration (1.4% by weight) of a nearly pure carbon dioxide. The deep-seated faults at the rift flanks tap magmatic CO_2.

Several thermal springs of Antsirabe geothermal field have a high CO_2 gas contents. Future wells could used to tap CO_2 for industrial and enriching greenhouses.

2.5.8 Raw wool washing and drying

The grease and dirt in raw wool has to be washed with hot water at 50ºC. Geothermal water at 50ºC can be utilized to wash the wool and steam to dry it. By utilizing geothermal energy instead of using boilers, and a lot of heat energy will saved, hence reduction of forest cover and also reduction of use of heavy diesel.

3. BARRIERS TO DIRECT USE DEVELOPMENT

This chapter has been discussed in previous study (Andrianaivo, 2008b).

3.1 Resource Identification

The Malagasy Government has to make an effort to identify its indigenous geothermal potential by conducting some investigations and inventory studies of potential geothermal reserves. In many cases, however, there is limited development beyond this exploration stage. This has been mainly as a result of lower prices of competing energy sources and lack of exploration funds.

3.2 Technological Constraints

For his largely untapped source of energy in Madagascar to be realized, specialists in the fields of exploration, exploitation and utilization are required.

Madagascar has to managed to train a number of professionals in most fields, though others are still not covered and the country still require the services of external consultants.

3.3 Exploration Risk

Geothermal projects typically progress through stages of reconnaissance, exploration and development with various decision points along the way. In the early exploration stage when there are uncertainties of finding a useable heat resource no private developer is willing to risk funding reconnaissance, surface exploration and/or drilling exploration wells.

3.4 Commercial Financing

Commercial financing barriers result from the higher upfront costs of geothermal energy projects. The capital costs of geothermal projects include the well field development and plant equipments. As a result the front-end capital cost for a geothermal project is much greater and commercial institutions view this as increasing the project's financial risk profile.

Multilateral agencies with expensive and time-consuming structured procedural requirements are often the only source available for financing geothermal power projects in developing countries. Most of these developing countries in which Madagascar is among then may not meet this stringent conditions and therefore availability of funds from multilateral agencies are not always forthcoming.

3.5 Credit Risk Barriers and Political Risks

Credit risk barriers are particularly prevalent in geothermal and renewable energy projects since these projects are mostly located in developing countries. As a result countries, which can benefit the most from renewable energy projects, are often the least attractive to the financing institutions.

Risk may be encountered in developing countries through changes in economic fortunes, as experienced in Asia in the late 1990's, and from changes in government policy, such as rescinding incentives for the development of rural and renewable energy sources.

3.6 Markets

Unlike fossil fuels where they can be transported to long distances, geothermal plants usually sits on top of the resource or a few tens of kilometers away and therefore utilization is on or close to the geothermal resource. In Madagascar however, most of the geothermal areas are located in the rural and remote sites where the markets are not readily available. This has drastically slowed the rate of development of this resource.

3.7 Legislative Framework

Geothermal energy is unique because it must be used on sight, whether for electric generation or for direct utilization, and often involves substantial outlays requiring amortization periods of up to 20-30 years. In the world, legislative frameworks have been creating uncertainties and this has been unattractive to private developers.

4. RECOMMENDATIONS TO ACCELERATE DIRECT USE GROWTH

4.1 Funding

The first step in geothermal development is to conduct surveys of moderate cost that will provide the operators with a rapid assessment of large areas and permit to select, within this large area, the most promising parts. Specifically, more expensive investigations can then be carried out in these areas to identify one or more favorable sites for deep exploratory drilling. Exploratory drilling and well testing represent the next stage of the project; the cost of this stage is higher than that of the preceding surveys since drilling is cost-intensive. The project will end with field development and exploitation, which, in addition to further drilling, entail reservoir engineering studies and the construction of surface plants and equipment. These activities are also cost-intensive. Funds to carry out all these stages are not usually readily available in Madagascar and therefore the Government should set aside funds to carry out these activities and also to train professional in all fields of geothermal development.

4.2 Policy and Legislative Framework

Many developing countries have adopted energy policies that focus on: improving access to electricity for rural households, creating an environmentally sound energy sector, making optimal use of local resources by diversifying the primary energy sources for electricity production and stimulating private sector involvement. Geothermal energy development is compatible with these policy priorities. In Madagascar however, these policies have not been harmonized and it has been discouraging investors. The Legislative frameworks should also be harmonized to avoid creating uncertainties among the would be private developers.

4.3 Tax Incentives

Tax incentives such as tax holidays 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. Major policy changes and attractable incentives should therefore be reviewed to encourage private sector participation in the industry.

4.4 Risk Fund

Establishment of a risk fund that could be used to accelerate geothermal development in Madagascar should be considered. New project such as Global Environmental Fund (GEF) must be asked to coordinate the establishment of the same within the South African Development Corp (SADC region). This will oversee the initial risky phases of exploration leaving the public and the private sector compete for resource utilization.

5. ADVANTAGES OF USING GEOTHERMAL ENERGY TO THE MALAGASY ECONOMY

5.1 Renewability and sustainability

Earth's heat is continuously radiated from within, and each year rainfall and snowmelt supply new water to geothermal reservoirs. Production from individual geothermal fields can be sustained for decades and perhaps centuries. The International Geothermal Association (IGA) classifies geothermal energy as renewable.

5.2 Conservation of resources

When we use renewable geothermal energy for direct use or for producing electricity, we conserve exhaustible and more polluting resources like fossil fuels and uranium (nuclear energy). Worldwide direct uses of geothermal water avoid the combustion of fossil fuels equivalent to burning of 830 million gallons of oil or 4.4 million tons of coal per year.

5.3 Clean

Geothermal plants, like wind and solar power plants, do not have to burn fuels to manufacture steam to turn the turbines. Use of geothermal energy helps to conserve nonrenewable fossil fuels, and by decreasing the use of these fuels, we reduce emissions that harm our atmosphere (Andrianaivo, 2008f). There is no smoky air around geothermal plants in fact some are built in the middle of farm crops and forests, and share land with cattle and local wildlife.

5.4 Easy on the land

The land area required for geothermal plants is smaller per megawatt than for almost every other type of plant. Geothermal installations don't require damming of rivers or harvesting of forests and there are no mineshafts, tunnels, open pits, waste heaps or oil spills. After construction is complete, rehabilitation of land is usually done and it would be difficult to note that there were major construction works going on there (Andrianaivo, 2008f).

5.5 Reliable

Geothermal plants are designed to run 24 hours a day, all year. A geothermal plant sits right on top of its fuel source. It is resistant to interruptions of energy supply due to weather, natural disasters or political rifts that can interrupt transportation of fuels. When installed the operation costs are so minimal compared to other forms of energy.

5.6 Flexible

Geothermal plants can have modular designs, with additional units installed in increments when needed to fit growing demand for energy. So revenues gotten from the existing plants, can be used to develop the next phases.

5.7 Keeps dollars at home

Money does not have to be exported to import fuel for geothermal plants. Geothermal "fuel"' like the sun and the wind is always where the plant is; economic benefits remain in the region and there are no fuel price shocks.

5.8 Helps the country grow

Geothermal projects can offer all of the above benefits to help developing countries grow without pollution. And installations in remote locations can raise the standard of living and quality of life by bringing energy to people far from "serviced" population centers.

6. DISCUSSIONS

In Madagascar like elsewhere in the world, low to intermediate temperature resources are far much more abundant than the high temperature resources, and therefore this presents a huge potential of untapped vital resource. These low enthalpy resources are currently under-exploited due to financial constraints and the low price of competing energy sources. Given the right environment, and as gas and oil supplies dwindle, the use of geothermal energy will provide a competitive, viable and economic alternative source of renewable energy. Using geothermal energy, obviously replaces the use of other forms of energy, especially fossil fuels.

The benefits thus accrued for the country is less dependence on imported fuels, and for all, elimination of pollutants and greenhouses gas emissions into the atmosphere. The direct positive impact of developing these resources will be creation of employment opportunities in the hotel industry, agro-business and the industries created utilizing the low enthalpy fluids. This will lead to increased productivity and hence increased revenues from both local and export sales. The energy saved from utilizing the low enthalpy geothermal fluids will thus be used for more demanding uses and saves on additional power plant construction.

7. CONCLUSIONS

- Geothermal energy will remain one of the primary renewable clean energy sources of direct uses in Madagascar.
- A huge potential of untapped low to medium enthalpy energy resource is available in Madagascar.
- The initial high-risk investment stages of geothermal development should be borne by the Government, but the later stages to be shared between the public and the private sector.
- Incentives like the e.g. tax holidays and enabling proper Legislative framework should be set to attract more private investors in the industry.

- Installations of greenhouses, spas and industries utilizing geothermal in remote locations will raise the standard of living and quality of life for the local population by creating employment.

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