GEOTHERMAL SMALL POWER GENERATION OPPORTUNITIES IN THE LEEWARD ISLANDS OF THE CARIBBEAN SEA

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INTRODUCTION

The northern islands of the Lesser Antilles are all potential sites of geothermal resources because virtually all of the islands are underlain by active or dormant (but not extinct) volcanoes. The 11 islands falling into this category are: (Figure 1 - from north to south) Saba, St. Eustatius (Statia), St. Christopher (St. Kitts), Nevis, Montserrat, Guadeloupe, Dominica, Martinique, St. Lucia, St. Vincent and Grenada.

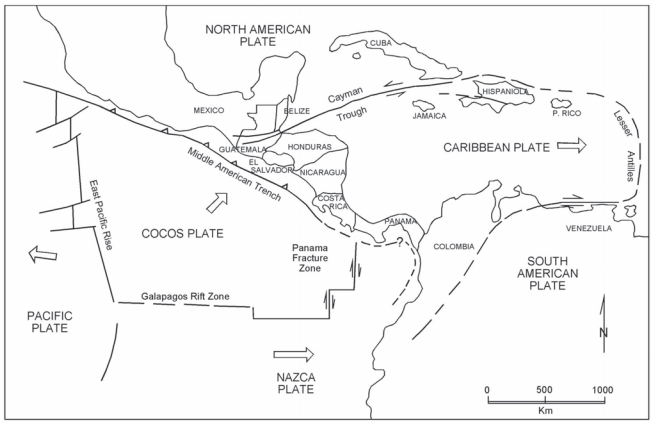

Figure 1.

The islands, comprise two eastward convex arcs. South of Montserrat, these arcs merge to form a single curvilinear island chain that intersects the South American continent at the Peninsula de Paria of Venezuela. The western island arc and its southern extension are of relatively recent volcanic origin. The northern and eastern islands, though once loci of volcanism, are now mantled by thick sedimentary deposits.

The reason for the active volcanism is that the Caribbean islands occupy a crustal plate that is moving eastward along the North and South American Plates, and subducting eastward beneath the Atlantic Plate (Figure 2). Accordingly, volcanic arcs typical of plate boundaries have formed over time and, in the Caribbean, each volcano or group of volcanoes forms the foundation of a discrete island.

SMALL GEOTHERMAL POWER GENERATION OPPORTUNITIES

The potential for construction of small geothermal power generation facilities, though not off-grid or "villiage power," is excellent in many Caribbean islands. The countries are still developing, their transmission and distribution grids are ubiquitous and their power requirements are growing. Excluding the French islands, which have power demands in the tens of

Figure 2.

megawatts, the largest loads are on St. Vincent, St. Lucia and Dominica, where 10-20 MW is or will soon be needed. Next in size is Grenada where 8-12 MW could be used, and finally come all the rest of the islands whose current needs range from 2 to 5 MW.

In virtually all of the islands, generation, transmission and distribution costs (including all soft costs) range between $0.12 and $0.15 per kWh. It is important to note that while none of the utility companies have an accurate accounting of their real costs, it seems very likely that geothermally-generated power could be provided for a lower cost than the utilities now pay in-house. In many countries, O&M-caused brownouts or power outages are all too common and are reportedly on the increase.

Careful, realistic calculations of planned geothermal project economics and of current true power costs must be made. Assuming that they confirm the economic viability of a planned project, they will be critically important in convincing governments and utility officials that geothermal power will be less expensive and more reliable than their traditional generating systems.

CARIBBEAN GEOTHERMAL POWER PROJECT PROS AND CONS

The conditions favoring small geothermal power developments in the Lesser Antilles include:

- Good to excellent chances for discovery of economically-viable geothermal resources,
- A generally positive attitude by all of the national governments toward the exploitation of their indigenous resources,
- A growing realization that power generation by entities other than the government can be simultaneously beneficial to the host nation and to independent power producers,
- Increasing impatience on the part of citizens and government officials, on all the islands, towards long standing, excessive O&M problems with diesel generator sets,
- Power demand growth of 7-10% per year in most countries. This may actually accelerate because all of the nations are seeking to increase their revenues by attracting tourists. More tourists will require more hotels and more air-conditioned hotels will require more power,
- The high cost of power generation on most islands that almost certainly could be decreased with the addition of geothermally-generated electricity, and
- The pressing needs for freshwater on all the islands except Dominica and St. Lucia. If more economical electricity were to become available on the dry islands, large reverse osmosis installations could be built and operated to alleviate periodic water shortages, rationing and the need to depend on rainfall collection in cisterns.

Some negative aspects or obstacles regarding initiation of Caribbean small geothermal power projects are:

- The difficulty in financing small (<$50 million) projects,
- The relatively low rate of return likely on small Caribbean geothermal power projects, and the associated need to minimize exploration expenditures which unavoidably will increase the risk level perceived by potential investors,
- The speckled history of fiscal responsibility on the part of governments of several of these islands and their consequent low-international credit rating,
- The marginal solvency of many of the national utility companies, and the inability or unwillingness of the national governments to guarantee payments by their utilities for power purchased, and
- The common occurrence of destructive hurricanes in the region, and the recent experiences with damage due to the volcanic eruptions on Monstserrat.

GEOTHERMAL RESOURCE INDICIA SUMMARIES

Presented below, in descending order of development potential, are brief descriptions of geothermal indicia on each of the 11 volcanic islands:

Guadeloupe - The volcano La Soufrière on Basseterre has large fumerolic areas and there are thermal springs on the mountain flanks.

St. Lucia - Geothermal indicia on St. Lucia comprise a very large solfatara near the village of Sulfrière, thermal springs nearby and very recent volcanic activity including both phreatic and pyroclastic eruptions.

Dominica - The likely presence of geothermal resources beneath Dominica is suggested by a boiling lake, numerous boiling hot springs, several large solfataras and very recent (<500 YBP) volcanic activity. There are at least three geothermal centers.

St. Vincent- La Soufrière volcano has erupted three times since 1902, there is a steaming resurgent dome in the crater, and there are numerous hot springs in river valleys on the western side of the volcano.

Nevis - On Nevis' western and southern sides, there are two solfataras, numerous thermal wells and a large area of hydrothermal alteration. Also, strong earthquakes with hypocenters very near Nevis occurred in 1951 and 1961. There are encouraging geothermal indicia at five places on the island.

Saba - Saba is a small island comprising a central volcano with at least 15 andesitic domes on its flanks. There is a record of volcanic eruption(s) less than 1,000 years ago, and there are numerous hot springs along the shoreline and just off shore. The island is highly fractured, and some hot springs' temperatures have risen in the last 40 years.

St. Kitts - Though there are moderately large areas of steaming ground in the crater of Mt. Liamuiga and some small thermal springs along the western shoreline, the geothermal indicia are less well defined than on the previously described islands.

Grenada - Prefeasibility studies have revealed one small solfatara on Mt. St. Katherine, several small thermal springs in ravines radial to the central volcano and numerous relatively young phreatic explosion creaters. Additionally, the sub-sea volcano Kick-em-Jenny lies only five miles off Grenada's north coast suggesting that the zone between it and central northeastern Grenada may be geothermally prospective.

Martinique - The very active Mt. Pele comprises an obvious locus for geothermal resources. There are solfataras, hot springs, earthquake epicenters nearby and well developed fracture systems.

Montserrat - Even before the 1995 eruptions, the southwestern flank of the Soufrière Hills volcano was the site of solfataric activity and of numerous thermal springs. There was also significant seismic activity and several well developed fracture systems transecting the volcano.

Statia - While some heat probably remains beneath The Quill as evidenced by reported occurrences of thermal waters in two wells drilled for drinking water, there are no known hot springs or paleo-thermal areas on the island.

EXPLORATION/DEVELOPMENT STATUS SUMMARIES

Prefeasibility and reconnaissance exploration, exploratory drilling and the construction of one power plant have been accomplished in the Caribbean islands under discussion. The scope of these activities is summarized below.

Prefeasibility Studies - The author, with assistance from Republic Geothermal Inc. staff, U.S. Geothermal Industries Corporation representatives, Dr. D. E. Michels and J. Renner, has conducted prefeasibility studies on St. Lucia, Dominica, Grenada, St. Vincent, Saba, Statia, St. Kitts and Nevis since 1982. In all cases, the work included reviews of geothermally-relevant literature, acquisition and stereoscopic analysis of airphotos, reconnaissance (confirmatory) geologic mapping, petrographic studies of fresh and altered rock samples, geochemistry of thermal and non-thermal waters, and collection of large amounts of non-resource related information. The latter included data regarding electric power, environmental topics, permitting, government philosophies about use of indigenous resources, locally available labor, facilities, supplies and costs, and logistical/construction matters.

Reconnaissance - This second stage work is herein defined to include some or all of: detailed geologic mapping, comprehensive water and/or gas geochemistry, electrical surveys (resistivity, S-P, CSAMT, MT, etc.), gravity or magnetic surveys, soil mercury, radioactivity or CO_2 and shallow (thermal gradient or slim-hole) drilling. It has been done on Dominica, Guadeloupe and Martinique by the French; on St. Lucia by the English, Los Alamos National Laboratories and an Italian group; on St. Vincent by a U.S. company; and on Montserrat by British, Italian and U.S. entities. These studies have resulted in advanced characterization of the chemistry, temperature and depth of resources.

Deep Exploratory Drilling - Following reconnaissance studies, this expensive work has been undertaken to date only on Guadeloupe by CFG and BRGM, and on St. Lucia where two wells were drilled by a multilaterally-funded team led by Italian geothermists. The first St. Lucia well found heat but low permeability; however, the second well discovered what appeared to be an economically exploitable resource. Unfortunately, this well suffered mechanical failures and the produced steam was never harnessed to generate power.

Development - The drilling of successful deep wells on Guadeloupe in the early-1980s led to the building of a 4.2-MW double flash power plant in 1984. This plant has had intermittent problems caused by relatively high amounts of non-condensable gasses and associated H_2SO_4; but, there seem to have been mitigated by CFG and the plant is now in operation. There is excellent potential for expansion of this development; but, for some reason, neither CFG nor Electricite de France (EDF), the Guadeloupe utility, seem anxious to move forward.

WORK NEEDED TO SITE DEEP WELLS

On the islands where strong geothermal indicia have been mapped, reconnaissance work as defined above should be conducted. The extent and precise type of the geophysical work will be dictated by logistical considerations and the nature of

the preliminary geothermal system model. Thermal gradient drilling should comprise no less than five 300-meter holes sited in accordance with the results of preceding surveys.

Once thermal gradient drilling results are available, decisions will have to be made whether to drill one or more slim holes or to drill a full-scale exploratory well. A discussion of the factors to be considered when making these decisions is beyond the scope of this paper; but, it is estimated that preproduction well drilling costs will approximate $1.5 million.

SUMMARY

There are 11 volcanic islands in the Lesser Antilles of the Caribbean Sea having modest-to-very significant geothermal resource potential. Prefeasibility and reconnaissance phase exploration and power generation have been accomplished to varying degrees on these islands with generally encouraging results.

Power demands range from 2 to 20 MW, and the average annual power demand growth rate of 7-10% is anticipated to increase. Access to grids is not a problem on any island. Geothermal power could almost surely be sold to the utilities for less than the $0.12 to $0.15 per kWh cost of generation now estimated by the various utility companies, and the prospect of initiating significant savings is appealing to government officials as well as the citizens-on-the-streets.

Though financing of small projects may be difficult to obtain and greater returns on investment may be possible via other types of projects, these obstacles should be surmountable. The environmental and social benefits of geothermal resource use are very impressive, and they virtually mandate that the developed nations make strong efforts towards its development in the Caribbean island nations.