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# The Eastern Caribbean Geothermal Energy Interconnection Grid Feasibility Study

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**ABSTRACT**

The Eastern Caribbean region is an archipelago of islands that are closely knit, economically, politically, socially, culturally, spiritually and geographically. Some of these islands show great potential for geothermal development and have been using low temperature geothermal manifestations for bathing etc. since the 1600s. According to a study done by the United States Department of Energy (USDOE) in 1998, collectively, these islands have the potential to produce geothermal energy in excess of 16 GWe. Nonetheless, the region has only harnessed 0.1% of this energy for commercial used with the 15.7 MWe geothermal plant located in Guadeloupe.

The region however, has not abandoned the notion of replacing their fossil fuel electricity plant with renewable base type of energy and in recent times has make significant leaps and bounds in the development of geothermal across the region. It is understood that only the volcanic islands that lie on the inner arc from Saba in the North to Grenada in the South are being affected by the subduction zone of the Caribbean and North American plate and hence have geothermal potential. This comprises of 11 islands with a total of 21 volcanoes, but since the islands have little separation between each other, the probability that an inter-regional electrical grid can be built, linked by submarine cables becomes very practical.

The economies of these islands are heavily based on tourism and are often times affected greatly by natural disasters and changes in the international arena. With a small population of less than 200,000 people and on most of the smaller islands, 100,000 persons, economies of scale can seldom be attained and products to export found. With the exception of Trinidad & Tobago, who has natural gas, St. Vincent & The Grenadines and the Commonwealth of Dominica who have hydro electric plants, Guadeloupe with a geothermal plant, St. Kitts &Nevis and Jamaica with wind farms, the islands are dependent on fossil fuel for the generation of electricity. This dependency on fossil fuel has caused the cost of electricity to be staggering and has caused the populace to seek alternative means of electricity generation.

Intermittent sources of electricity generation will not suffice to make the region energy independent from fossil fuel since spinning reserves would be required to ensure grid stability. An Eastern Caribbean interconnection grid will make available this resource to all of the islands along the arc and realization of energy independence can be achieved for the region.

## 1. INTRODUCTION

The Eastern Caribbean region encompasses a small group of islands that are artistically arranged in an arc being washed on the western side by the Atlantic Ocean and on the eastern side by the Caribbean Sea. For the purpose of this paper these island will only include the islands from St. Kitts and Nevis in the North to Grenada in the South as shown in Figure 1.

The region is believed to be created from the subduction of the oceanic crust of the South American Plate under the Caribbean plate being the denser of the two plates (Maynard-Date, 2010). With the exception of Antigua & Barbuda and Barbados who are located on the extinct outer arc, these islands are situated on the inner arc and all have volcanic mountains of which some are dormant and others active. Amongst the islands there are a total of nineteen volcanoes as shown in Table 1. The most active volcano has notably been Soufrière Hill on Montserrat which has ongoing activity since its eruption in 1995 (UWI, 2014).

The Eastern Caribbean islands are geographically located on the Caribbean plate and their numerous volcanoes are by no means the only similarity that they share. These islands are poised socially, economically, historically and politically. They are fundamentally English speaking countries with the exception of Guadeloupe and Martinique being French territories.

The inherent small land masses of these island has limited their ability to have much home based industries and most utilize the fact that they have sun 365 days in a year to boost their tourism industry. This is a fragile industry since the location of the islands also is along the hurricane belt which can be a disruptive element to the industry.

Another major disadvantage of the region is that most of the fuel consumed is from fossil fuel and none of these islands are producers of oil. They are then forced to import all of this fuel creating an uncomfortable level of dependency on the oil producers. These high prices translate to an increased cost of living, of which the most significant factor is the high electricity price to consumers and businesses.

## 2. REVIEW MATERIAL

### 2.1 Geothermal Potential of Eastern Caribbean Islands

#### 2.1.1 St. Kitts

From studies done by Huttrer (1998) it was found that the island of St. Kitts has the potential to produce approximately 500MWe. This was found to be mainly concentrated under the National Park at Brimstone Hill. Other surfaces manifestations such as large

areas of steaming ground and hot springs can be founded by the crater of Mount Liamuiga. Given that the study suggested that the indicators are not well defined, exploration may not be quite successful.

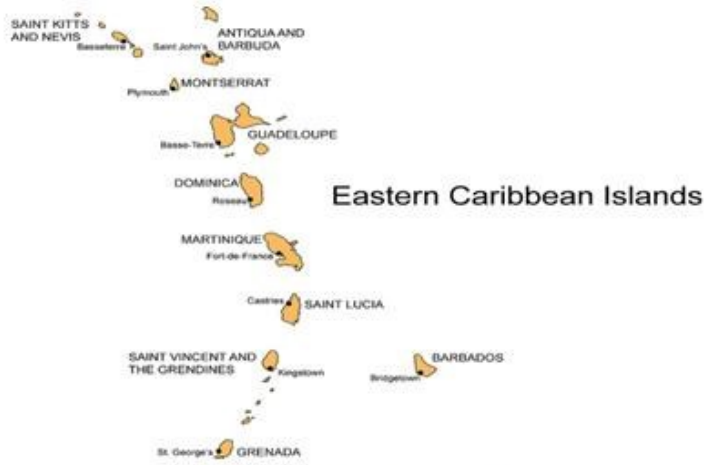


Figure 1: Map of the Eastern Caribbean (mapfordesign.com, 2008)

TABLE1:Caribbean countries with volcanoes (Stewart I, 2000)

| Country | Name of Volcano |
|---|---|
| St. Kitts | Mt. Liamuigua |
| Nevis | Nevis Peak |
| Montserrat | Soufriere Hills |
| Guadeloupe | La Soufriere |
| Dominica | Morne AuxDiables |
| | Morne Diablotins |
| | Morne Trois Piton |
| | Watten Waven/Micotrin |
| | Watt Mt. |
| | Valley of Desolation |
| | Morne Anglais |
| | Grand Soufriere Hills |
| | Plat Pays Volcanic Complex |
| Martinique | Montagne Pelee |
| St. Lucia | Soufriere Volcanic Centre |
| St. Vincent | The Soufriere |
| Grenada | Kick 'em Jenny (submarine) |
| | Ronde/Caille |
| | Mt. St. Catherine |

2.1.2 Nevis

Extensive geophysical analyses have been carried out in Nevis by various groups. However, in 2008, West Indies Power Holdings (WIPH) did a series of three slim hole wells and found that at depth of 0.7km and 1.1km, temperature ranged from 201$^0$C to 260$^0$C (see Table 2) respectively. Wells 1 and 3 was found to be self-flowing and Well 2 was left after the rig got stock at 0.74km and the temperature had already reached to 260$^0$C. The developers after reviewing all of their results became comfortable that site 1 dobbed Nevis 1 had the potential of supplying the country with a base load of at least 30MWe. A subsequent study done by Maynard-Date (2010) agreed with the conclusion of the developers that the resource was quite capable of supplying 30MWe and had a high

probability of sustaining this value over a prolonged period. Given that the entire western side of the island of Nevis showed surface manifestation of the existence of geothermal activity it is understood that the potential of the island may be able to exceed 30MWe. Initial studies done by the United State Department of Energy (USDOE), Huttrer (1998), estimates that Nevis has a geothermal potential of 800MWe.

TABLE 2: Slim hole wells information (WIPH 2008a and b)

| Well | Year | Depth (m) | Pressure (bars) | Temperature (˚C) |
|---|---|---|---|---|
| Nevis 1 | June 2008 | 1065 | 82 (bottom hole pressure) | 250 |
| Nevis 2 | July 2008 | 732 | - | 260 |
| Nevis 3 | October 2008 | 899 | 16 (well head pressure) | 201 |

2.1.3 Montserrat

The most recent volcano to erupt in the Eastern Caribbean and still quite active is that of Soufrière Hills, Montserrat. In the same studies done by Huttrer (1998), Montserrat was reported to have a potential of 940MWe. However, since the eruption, the greatest potential for geothermal exploration is now located in the restricted zone. Irrespective of this, this British territory has forged ahead and drilled two successful wells, and is in the process of selecting their power plant.

With its massive migration after the last eruption in July of 1995, the island only need to harness a mere 2MWe to supply the base load of the island leaving the vast remainder available for export to neighboring islands such as Antigua.

2.1.4 Guadeloupe

This is the only island in the Eastern Caribbean that has 15.7MWe of installed geothermal power. In 1969 to 1970, three wells were drilled and named Bouillante 1, 2 and 3 accordingly. Bouillante 1 reached a depth of 800m at 220ºC but was deemed a poor producer. Bouillante 2 with less than half the previous depth had higher temperatures and pressure of 242ºC and 14bars respectfully. In 1991 and 1994 Bouillante 2 was tested and retested, the first test being for a prolonged period of 6 months. Bouillante 3 was drilled to 445m and it crossed a sandy layer at 410-440m with temperature close to 240ºC, Battocletti, (1999). It was later deepened to 850m but with little change in the production rate. Bouillante 4 was drilled to 1200m but was a poor producer.

Geothermal usage for electricity generation started in 1984 with a 4.5 MWe double flash power plant at Bouillante to supply the leeward coast of Basse-Terre with electricity. In 2004 it was upgraded to a 15.7MWe plant, Joseph (2008). In the case of Guadeloupe, the USDOE estimated a total potential of 3,500MWe for the island.

2.1.5 Dominica

The Commonwealth of Dominica (Dominica) hosts the most volcanoes in the Eastern Caribbean islands and was estimated by USDOE study Hutterer, (1998) to have a power potential of 1,390 MWe. Having successfully completed the phase of drilling and testing of three exploratory wells and thus proving the existence of a viable geothermal resource, the Government of the Commonwealth of Dominica (GoCD) has progressed to the next stage of seeking to develop a 10 – 15MWe Small Geothermal Power Plant (SGPP) within the Roseau Valley Geothermal field. The GoCD has secured funding from the AFD by way of a €6.5M concessionary loan agreement for the implementation of the drilling and testing program that basically consists of the drilling and testing of 2 full size wells (a production well [WW-P1] and an injection well [WW-R1]). The sites for drilling are located in Laudat (Well Pad WW-3) and Trafalgar, approximately six (6) and four (4) miles respectively, from the capital Roseau, (Maynard-Date and George (2014)) all of which have successfully been completed and are now in the final stages of power plant selection and acquisition.

2.1.6 Martinique

The second French territory in the Eastern Caribbean has an estimated geothermal power potential of 3,500MWe. Given the success of Guadeloupe plus knowing that there are numerous surface manifestations such as solfararas, hot springs and well defined fracture systems, Huttrer, (1998) some geothermal exploratory work was done. Work done by EDF/CFG in geophysical studies and shallow drilling in 2004 were found to be inconclusive and will require deep drilling to further prove resource.

2.1.7 St. Lucia

This island is one of those located in the Eastern Caribbean whose geothermal exploration reached to the drilling of slim hole wells. The area of exploration was found to be quite acidic (pH of 2.8) and wells were later abandoned. The most significant geological information obtained from the drilling cores and cuttings is that the formations crossed by the wells SL-1 and SL-2 indicate an almost complete lack of juvenile pyroclastic products. This leads to the perception that the area under exploration may not be the center of a strong pyroclastic activity. Qualibou estimates that the geothermal potential near the small town of Sulphur Springs should provide 170MWe, Kaye, (2010).

2.1.8 St. Vincent

The Soufrière volcano which erupted in 1979 is located on the north western side of the island. Numerous surface manifestations such as fumaroles and hot springs in river valley are evident on the southeastern and western sides of the dome flank (Huttrer, 1996). USDOE also conducted geological and geochemical surveys and concluded that the island has 890MWe potential (Huttrer, 1996).

2.1.9 Grenada

Grenada was estimated to have geothermal potential of 1,110MWe. The prefeasibility study done documented a small solfatara on Mount Saint Catherine, several small thermal springs in ravines radial to the central volcano, and numerous relatively young phreatic explosion craters.

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 have geothermal potential (Joseph, 2008).

In summary it is clear that the Eastern Caribbean region has the potential to produce in excess of 16GWe from the studies done by USDOE. The region also show strong geothermal manifestations along the islands located in the inner arc on the Caribbean plate. This occurs as a result of the interaction of the American plates on that of the Caribbean plate causing activities at these borders as they create a subduction zone under it (Figure 2).

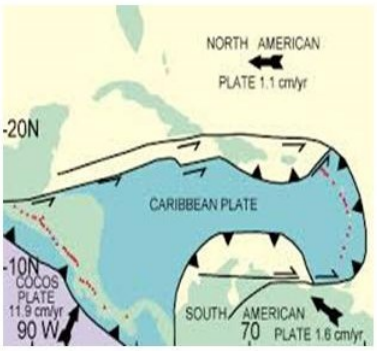


Figure 2: Caribbean Plate
(AstroGeoData, 2006)

**2.2 Electricity Consumption of the Eastern Caribbean Island**

Turning our attention to the electricity consumption of these islands it can be noted (see Table 3) that due to their size and population, the Eastern Caribbean islands use little electricity when compared to the larger countries in the region with the exception of the French territories. From Table 3, it would be observed that the countries use approximately 4,468GWh annually. With a growth rate of 2-3% according to statistics of the Eastern Caribbean Central Bank, ECCB, (2014), the region would not consume even 5% of the estimated geothermal potential in the region within 10 years. With a collective estimated geothermal power potential of 16GWe in the region, the annual production then becomes approximately 140,160GWh.

For discussion purposes let us assume that 10% of the total energy estimated can be harnessed, this would give 14,016GWh annually. Using a maximum of 3% growth rate over a 10 years period, the region would be using 43% of its total capacity. Now over 20 years, it would be using 58% and 30 years 77% respectively. The data suggest that even under the worst possible scenario, the region should be able to supply all the energy required for electricity generation at a minimum of 30 years in a sustainable manner.

The implications here are that the islands can have energy independence from fossil fuel for electricity generation; reduce carbon footprint in the world; increase the social and economical standing of the region, just to name a few advantages.

Outside the development of geothermal plants on the islands that has the potential to produce this resource, the Eastern Caribbean would now have to create an interconnection grid between the islands for the transmission of this energy from one place to another. What is currently happening is that this grid has started with studies being done by agencies within the French territories to transmit energy from the Commonwealth of Dominica to the French territories of Guadeloupe and Martinique, Maynard-Date and George (2013). Earlier work has also been done for the twin island state of St. Kitts and Nevis where based on the geographical closeness of the islands (approximately 4 km) the transmission of energy between the islands poses no problem. Additional submarine links would be needed to interlink the region, however, no new technology is necessary to do this since there are submarine cables already existing in the world that exceed the longest distance between any two islands.

**CONCLUSION**

The Eastern Caribbean Region now needs to take a closer look at this golden opportunity to become energy independent. This can be done by the initiation of feasibility studies in creating an interconnection grid and investing more in the development of geothermal on the islands. Bearing in mind that even if the region harnesses 10% of its potential, the islands can still become 100%

green and reap a vast number of benefits from the development and distribution of geothermal energy for electricity production within the region.

Secondly, due to the close proximity of these islands, it is clear that submarine cables can be used to create an interconnection grid to share this energy throughout the islands. Work has already started with this concept in Guadeloupe-Dominica-Martinique and Nevis-St. Kitts.

Table 3: Electricity Consumption in the Eastern Caribbean, Carilec (2012)

| Island | Electricity Consumption (GWh) |
|---|---|
| Nevis | 57 |
| St. Kitts | 122 |
| Montserrat | - |
| Antigua | 243 |
| Barbuda | 3 |
| Guadeloupe | 1,114 |
| Dominica | 91 |
| Martinique | 1,282 |
| St. Lucia | 333 |
| St. Vincent and the Grenadines | 129 |
| Barbados | 918 |
| Grenada | 176 |
| Total | 4,468 |

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