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2020 Country Update for Eastern Caribbean Nations

Gerald Huttrer

P.O. Box 2425, Frisco, Colorado 80443

ghuttrer@colorado.net

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ABSTRACT

Geothermal phenomena in the 11 volcanic Eastern Caribbean islands comprise active and dormant volcanoes, fumaroles, hot springs, mud pots, and altered ground areas. The reason for the existence of these thermal features is the westward subduction of the North Atlantic crustal plate beneath the Caribbean plate. Subsurface temperatures recorded in the region range from tepid to more than 290ºC as measured in a well drilled in 2013 on Montserrat. Since 2015, geothermal exploration and negotiations for the rights to explore have increased in the region.

On Montserrat, a contract was signed by the Government with Iceland Drilling Company to drill the third well intended to supply a 2.5-3.5 MW power plant. Funding was provided by the British Department for International Development (DFID).

Following the drilling of three successful slim holes in 2008, a highly permeable, 245ºC production-scale well was drilled in 2017 and 2018 by Nevis Renewable Energy International (NREI) with whom the Nevis Island Administration signed a contract and a power purchase agreement. Preliminary exploration on Saint Kitts has had encouraging results and the government has declared its intent to build a 18-35 MW power plant.

Also, since 2015, the government of Dominica and Icelandic Drilling, Inc. completed the drilling and testing of three exploratory slim holes in the Wotton Waven district, found temperatures up to about 240ºC, and made preparations to build a 7 MW power plant.

In St. Lucia, extensive geoscientific studies were conducted by Jacobs New Zealand Limited, the results of which identified drilling targets outside the areas previously explored. An EISA has been completed and slim-hole drilling is being planned. World Bank and other regional sources of funds have been and will continue to be utilized.

Finally, negotiations for the rights to explore and develop geothermal resources that began in 2013 continue in St. Vincent and in Grenada. Reykjavik Geothermal completed surface studies near the Soufriere Volcano on St. Vincent and, in 2018, a four-well contract with Iceland Drilling Company was signed. Actual drilling began in May 2019.

In 2016, on Grenada, Jacobs New Zealand Limited completed geologic, geochemical, and magneto-telluric studies centered about Mt. St. Catherine with promising results. Further geophysical studies and eventual exploratory drilling is being planned.

Direct use of thermal fluids has not increased significantly since 2015. It is limited to low temperature bathing facilities on Nevis, St. Lucia, and Grenada.

1. INTRODUCTION

There are nine English-speaking island-nations within the Eastern Caribbean archipelago that have potential for the discovery of geothermal resources capable of economically feasible power generation. (Figure 1). From north to south, they are: Saba, St. Eustatius, St. Kitts & Nevis, Montserrat, Dominica, St. Lucia, St. Vincent, and Grenada. Each of these governments is focused on conduct of activities that will improve the lives of the citizens. The provision of reliable and affordable electric power is one of the common, primary objectives. The rationale for this is, of course, that inexpensive power will help reduce the cost of manufactured items, allow for the widespread installation of air-conditioned facilities that are attractive to tourists, and finally, to attract overseas investment into energy-intensive ventures that can ultimately benefit the nation.

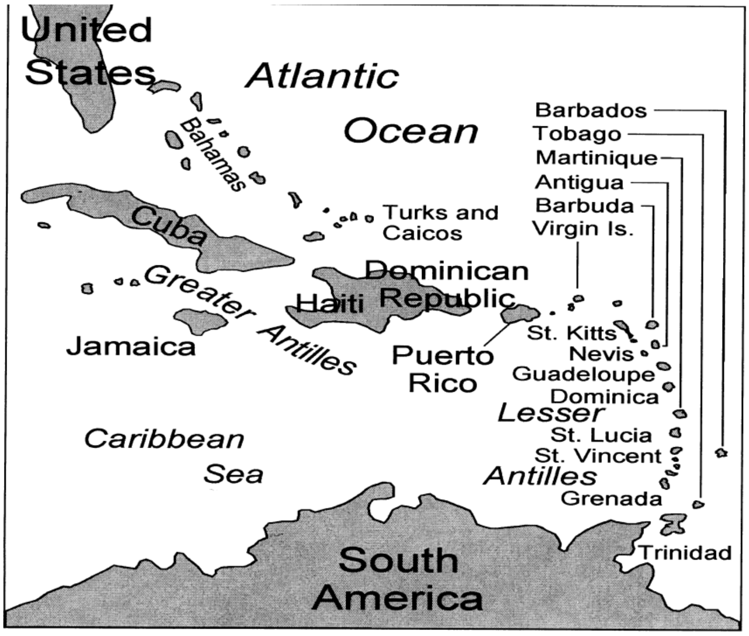

Figure 1 – Location Map

In the geothermally prospective Caribbean nations, the Ministries of Public Works, Infrastructure and/or Overseas Affairs are commonly the ones responsible for energy-related matters. Historically, there has been modest or sporadic geothermal exploration in these islands, so there is a correspondingly modest level of knowledge or understanding in these Ministries regarding the topic. Since 2015, this situation has been considerably ameliorated in Nevis, St. Kitts, Montserrat, Dominica, Saint Vincent, and Grenada by geo-scientific activities undertaken with funding from Multi-lateral Development Banks, the British and New Zealand governments, the local governments, some of the local utility companies, and several private developers.

2. GEOLOGIC BACKGROUND

The islands of the Caribbean region comprise two eastward convex arcs. South of Montserrat, these arcs merge to form a single curvilinear island chain. The western island arc is of relatively recent (~5 MYBP-<0.02 MYBP) 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 constitute a volcanic back-arc response to the subduction of the westward moving North American plate beneath the eastern margin of the Caribbean 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.

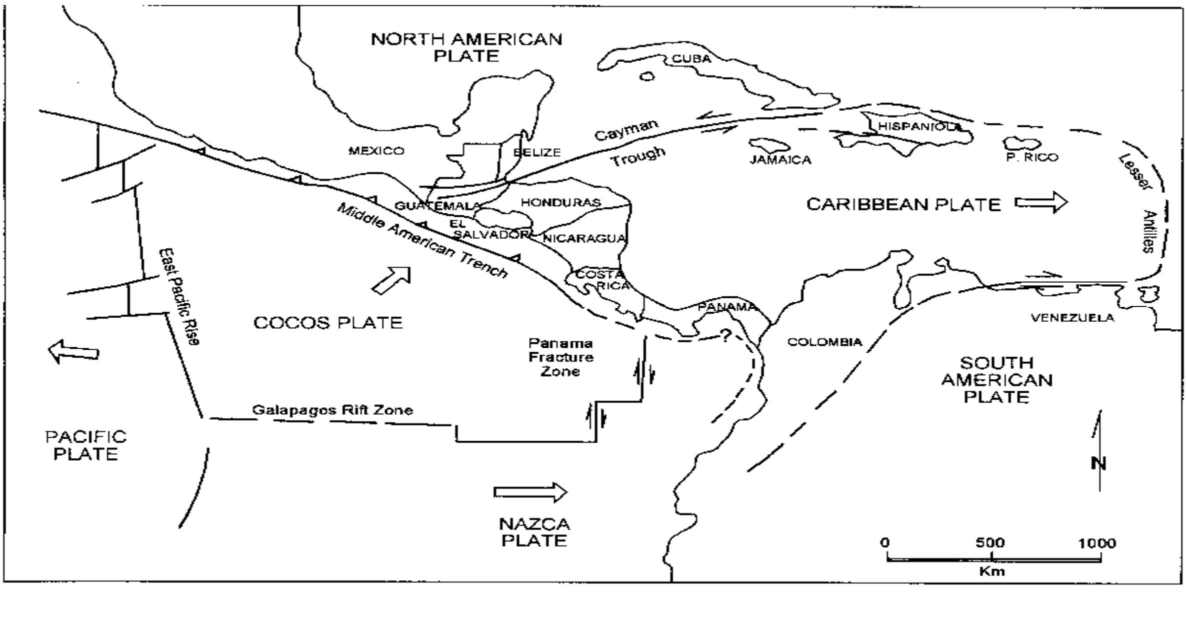

Figure 2 – Crustal Plates of the Caribean Region

This whole scenario is excellent for the development of geothermal reservoirs at economically drillable depths. There are active magmatic heat sources beneath most of the islands, there are intersecting fault systems that can comprise geothermal reservoirs of significant size, and there are fracture conduits, kept open and permeable by frequent earthquakes, that can conduct geothermal reservoir recharge waters of meteoric origin and/or seawater.

3. GEOTHERMAL RESOURCES AND POTENTIAL

Presented below are brief descriptions of the geothermal indicia and exploration/development activities on each of the nine prospective English-speaking islands:

3.1 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 years old) volcanic activity. There are at least 5 geothermal centers, of which two (Wotten Waven and Soufriere/Galion) appear to have the best prospects for early development.

In 2013, the Government of Dominica, with Multi-Lateral Development Bank assistance, sponsored the drilling of three slim exploration holes in the Wotton Waven area. Temperatures above 235ºC were recorded in these wells and between 2014 and 2015, the first of three planned production wells was drilled with similar temperatures encountered at a depth of just over 1,500 meters. This well was shut in for a three month heat build-up period after which the well was tested in accordance with international standards. Plans are reportedly to build a 7 MW (2 x 3.5 MW) power plant initially, which will contribute significantly to the current power demand of the island. The project is now under the control of a special purpose entity called Dominica Geothermal Development Company that is prepared to spend $US 50 million of national funds together with monies from IDA, CTF, DFID and SIDS Dock. Technical assistance has been provided by Jacobs New Zealand Limited and the Agence Francaise de Developpment. An ESIA has been completed, the gathering and injection line routes have been surveyed, and the power plant is anticipated to be on line in 2021.

3.2 Montserrat

Even before the 1995 eruptions, the southwestern flank of the Soufriere Hills volcano was the site of solfataric activity and of numerous thermal springs. There was also significant seismic activity along the several well developed fracture systems that transect the island. The geothermal potential was studied prior to and following the most eruptive phase and this led to the drilling of two exploratory wells in excess of 2,350 meters deep by the Icelandic Drilling Company under contract to the United Kingdom Department for International Development. Temperatures of 298ºC were recorded. In 2019, a third well was been begun so as to ultimately have the two production wells and one injection well required to service a 2.5 to 3.5 MW power plant. Unfortunately, this well encountered mechanical difficulties and had to be abandoned before reaching the target depth. Despite this, plans are still to build the power plant using steam obtained from the Mon-1 and Mon-2 wells drilled prior to 2015. It is anticipated that this new facility will provide electricity enough for present and future domestic needs. Costs have been estimated at $US 20 million.

3.3 Nevis

On Mt. Nevis' northwestern, western and southwestern flanks, there are two solfataras (Farms and Cades), numerous thermal wells (Charlestown and Browns), and a large area of hydrothermal alteration (Belmont). Also, strong earthquakes with hypocenters very near Nevis occurred in 1951 and 1961. The 1951 seismic event caused small fumarolic areas to develop in the Spring Hill Fault Zone in the northwest part of the island. There are encouraging geothermal indicia in at least 5 places on the island. (Huttrer, 1998).

Based on the data acquired to date, the hydrothermal system on Nevis is believed to have the potential to support power generation up to 45 MW, adequate to meet the demand of both Nevis and adjacent St. Kitts. The Commonwealth would then have the potential to become the first totally geothermally powered country in the world.

In 2008, West Indies Power Company drilled three small diameter exploratory wells about 3.7 km apart, to depths ranging from 782 to 1,134 meters in the Spring Hill, Jessups, and Hamilton Estates areas. All three wells encountered temperatures in excess of 225ºC and significant steam was produced. Geothermometric projections suggest reservoir temperatures of at least 260ºC. (LaFleur and Hoag, 2010).

In November 2013, Nevis Renewable Energy International (NREI) was selected by the Nevis Island Administration to replace West Indies Power as the resource developer. In 2018, NREI contracted with DOSECC of Salt Lake City, Utah, USA to drill a reduced diameter (slim-hole) well on the former Hamilton Estate site. The well, (N-4) was tested by GeothermEx, Inc and found to have high permeability, a temperature of 256ºC, and other characteristics adequate for use to fuel a power plant. NREI now (as of 2019) plans to identify funding sources and then build a 9 MW net power plant to generate electricity for domestic use and, if possible, export power to nearby St. Kitts. (Stacey, et.al., 2018).

3.4 St. Kitts

Though there are moderately large areas of steaming ground in the crater of Mt. Liamuiga, some small thermal springs along the western shore and in the Basseterre Plain, as well as reports of "scalding" water encountered while drilling for potable water near Brimstone Hill, the geothermal indicia on St. Kitts are less well defined than on some other islands. Accordingly, exploration will have to be extensive, time consuming, and expensive (Huttrer, 1988). In 2017 and 2018, surface exploration was conducted on St. Kitts by a French entity based in Guadeloupe. The work, funded by the Caribbean Development Bank and CARICOM, reportedly identified a potential for geothermal resources able to fuel 18-35 MW of power. As of early 2019, no firm plans for further geothermal work were announced though the dual-island state of St. Kitts and Nevis will receive EUR 5 million from the European Union to develop a sustainable energy sector and energy efficiencies technologies in public facilities.

3.5 St. Lucia

Geothermal indicia on St. Lucia comprise a very large solfatara near the village of Soufriere, thermal springs nearby, and very recent (<1000 years ago) volcanic activity including both phreatic and pyroclastic eruptions. Geothermal drilling conducted in the 1970's and 1980's disclosed the existence of a shallow (<700 meters deep) steam zone and of a hot (230°C) resource at moderate depths. Unfortunately, the fluids produced from the latter zone were acidic and are therefore very chemically aggressive. The 1980's drilling also showed that there are areas of hot dry rock down to ~2 km and that the geology of the prospective area is far more complex than previously believed.

In 2015 and 2016, with funding from World Bank and the government of New Zealand, Jacobs New Zealand Limited conducted a comprehensive geoscientific study within and around the Qualibou depression. The work included geologic mapping, geochemical sampling, a gravity survey, an aeromagnetic survey, magneto-telluric and audio-magneto-telluric surveys, as well as a LIDAR survey. The results of this work indicated the existence of two prospective areas in the depression and another to the south. Subsequently, Panorama Environmental Inc. of the USA completed an ESIA that met exacting World Bank standards and currently, plans are to drill three (possible four) slim holes in the three recommended target areas. The hope is to discover geothermal resources that are less chemically aggressive but still hot and abundant enough to fuel production about 30 MW in the early part of the 2020 decade.

The Government of Saint Lucia is currently evaluating their position with regard to an existing Memorandum of Understanding with UNEC Corporation and it is negotiating with an experienced international development company to undertake production drilling and power plant design/construction/operation. The World Bank and its consultants remain intimately involved in all project activities.

3.6 St. Vincent

La Soufriere volcano has erupted three times since 1902, there is a steaming resurgent dome in the crater, and there are numerous hot springs in the Wallibou River valley on the western side of the volcano. Exploration is difficult and expensive, however, the discovery of a geothermal reservoir could eventually bring financial rewards as there is a significant and growing demand for power on the island. (Huttrer, 1996). In 2013, negotiations with the government and with VINLEC (the national electric utility) were begun by Reykjavik Geothermal seeking acquisition of exploration and development rights. As of April 2014, geo-scientific fieldwork was reportedly underway, and plans were being made to initiate a drilling program following analyses of the surface study results.

In November 2018, Saint Vincent Geothermal Company, Ltd. (a quasi-governmental/utility entity), Reykjavik Geothermal and Iceland Drilling Company signed a four-well contract in the hopes of confirming the existence of resources indicated via the prior surface exploration studies. Development plans are for the generation of about 10 MW and for a power plant to be on line in 2021 or 2022. Current work is being funded by the Caribbean Development Bank and the Inter-American Development Bank. Jacobs New Zealand Limited and Mannivit of Iceland will be primary engineering consultants on the project. In May 2019, a full-size geothermal drill was moved onto a site at Bamboo Range, near Rabacca, in the north-central part of the island, just south of the Soufrierre Volcano. The first well drilled recorded temperatures in excess of 250°C at a depth of 2,700 meters. Unfortunately, permeability was not as good as hoped for. Accordingly, a second well was spudded in October 2019 so as to seek improved permeability and confirm the presence of high temperatures. The results of this well were not available as this report was submitted.

3.7 Grenada

Pre-feasibility studies have revealed one small solfatara on Mt. St Catherine, several small thermal springs in ravines radial to the central volcano, and numerous young phreatic explosion craters. Additionally, the sub-sea volcano Kick-em-Jenny lies only 5 miles off Grenada's north coast suggesting that the zone between it and central-northeastern Grenada may be geothermally prospective. (Huttrer and Michels, 1993). Reportedly, some interest has been shown by several private entities in obtaining exploration and development rights from the government. As of September 2014, no agreements had been signed.

In 2016, widespread geothermal surface exploration was conducted by Jacobs New Zealand Limited. The geologic, geochemical, and geophysical (MT) studies revealed an area of 4-8 km^2 north of Mt. St. Catherine having geothermometric temperatures of 220-240°C and an impermeable cap overlying prospective volcanic horizons all at drillable depths. The work, valued at about $US 2 million, was funded by the governments of Grenada, New Zealand, and the Japanese International Cooperation Agency (JICA). Further gravity surveys are planned in the region with goals of identifying accessible and environmentally acceptable drilling sites and eventually generating about 15MW of geothermally fueled power by 2022-2023.

3.8 Saba

Saba is a small island comprising a central volcano with at least 15 andesitic domes on its flanks and a prominent NE-SW trending fracture system that bisects the island. There is a record of volcanic eruption(s) less than 1000 years ago and there are numerous hot springs along the shoreline and just offshore. The islands volcanic carapace is highly fractured with some hot spring temperatures having risen within the last 45 years. (Huttrer 1998). West Indies Power signed agreements with the Government of Saba and conducted some surface geo-scientific studies. To date, the results have not been made public, but plans were announced to drill exploratory wells and to construct a power plant. Potential drill sites and a possible power plant site have reportedly been selected. No significant geothermal project progress has been reported by Saba since 2015.

3.9 St. Eustatius (Statia) 3.9 St. Eustatius (Statia)

While some heat probably remains beneath The Quill as evidenced by reported occurrences of thermal water in two wells drilled for drinking water, there are no known hot springs or paleo-thermal areas on the island. (Huttrer, 1998). Geothermal development interest on Statia has not been evidenced in the past 5 years (since 2015).

4. GEOTHERMAL UTILIZATION

There is not yet any utilization of geothermal resources for generation of electricity on any of the nine islands listed above nor are there any geothermal heat pump systems in use. Direct use is limited to "balneology" at The Baths on Nevis island, Ravine Claire and Malgretout on St. Lucia, at several small spas near Wotten Waven on Dominica, and just outside Peggy's Whim on Grenada. (Quotation marks are used because of the low-technology development style at each site).

4.1 At The Baths, a small (~3 x 3 meters x 1 meter deep) concrete sitting structure has been built adjacent to the Charlestown fault which leaks thermal waters at about 40°C. The waters flow through at rates that depend on the time of year and the abundance or lack of rainfall and there is ~1.5°C temperature change between the entering and leaving waters.

4.2 At Malgretout, water falls from a cliff into a small (3 x 3 x 1 meter deep) concrete sitting pond. The waters overflow into the creek with ~1.5°C inflow-outflow temperature change and at flow rates that depend on the time of year and the climatological conditions.

4.3 At Ravine Claire, the un-named ravine near Wotten Waven, and at the spring just outside of Peggy's Whim, bamboo pipes stuck into thermal water seeps focus water on shower-takers. Flow rates vary by time of year and drought/rainfall conditions. Inflow-outflow temperature changes are not measurable.

5. DISCUSSION

The figures in Table 1, "Present and Planned Production of Electricity (installed capacity)" differ because the capacity of the geothermal plant at La Bouillante, Guadeloupe has been left to the French to report and 2) growth of about 18 MW in fossil fuel power capacity has been estimated (no precise figures could be obtained). Please note that there are plans to install at least 35 MW of geothermal power in the region by developers, and these are reflected in Table 1 projected geothermal totals for 2015.

The entries in Table 3 have been augmented since the 2010 summary by the addition of statistics for the Malgretout springs in Dominica. The true capacity factor for these springs is unknown, but it has been assumed that they flow all year whether used or not.

Table 5 figures reflect those of Table 2 and are self-explanatory.

Table 6 reflects the fact that there was well drilling for geothermal purposes in Dominica and Montserrat in the last 5 years.

Table 7 shows that there was significant attention paid to geothermal matters by the governments in all nine countries of interest.

Table 8 shows that there was essentially significant money spent on Caribbean geothermal project by both the private and public sectors in the last 5 years.

6. BARRIERS TO THE INITIATION OF GEOTHERMAL PROJECTS IN THE REGION

There are several reasons why, in the past, there has been little geothermal project initiation in the region. The first is the relatively small power demand in these nations, the second is the high, marginally economical cost of undertaking projects small enough to sell all their power to the local utilities, and the third problem is that there are few laws, regulations, or rules in place in these nations that will facilitate the licensing, permitting or creation of geothermal power sales agreements in the islands. Finally, there is little technical or legislative capacity on these islands and commonly, responsible capacity that has been built is lost due to administrative change and replacement of personnel.

During the last 5 years, the variable (usually rising) costs of power caused by changing international oil prices have made even small sized geothermal developments more attractive. In Nevis, Dominica, and St. Lucia there has been on-going work to clarify geothermal laws, rules and regulations. Most importantly, the successful 2008 drilling on Nevis and the 2013-2014 drilling on Dominica and Montserrat has attracted the attention of Multilateral Investment Banks and other international governmental entities whose financial and technical assistance may serve to decrease the perceived risks of early stage exploration and thus entice more private developers into the region. Of note are the increasing, substantial involvements of the World Bank, the Caribbean Development Bank, and agencies of the British, New Zealand, and French governments.

7. FUTURE DEVELOPMENT AND INSTALLATIONS

Currently, there is power plant building being undertaken on Dominica with plans to build 7 MW within about two years. Drilling is finished on Montserrat and plans are to build a 2.5-3.5 MW power plant in the early 2020s. St. Lucia is planning to drill 3-4 slim-holes before 2020 and is negotiating with a reputable international geothermal development company to begin resource confirmation work hopefully leading to the construction of a moderately sized (~30 MW) power plant within a few years. Finally,

Full-size, production-scale drilling is in progress near Rabacca on St. Vincent with the objective of confirming the existence and character of a resource via a four-well project.

8. CONCLUSIONS

The generation of power on Nevis appears to be a reasonable possibility. If production and injection wells are drilled and all regulatory requirements are met, it should be possible to have power on line by 2021 or 2022. Subsea transmission between islands may also become a reality; the 5 km wide, shallow seafloor between Nevis and St. Kitts creates a very feasible possibility for submarine transmission between those two islands. The other projects likely to come on line may be a 7 MW plant located near Wotton Waven on Dominica, and a small (2.5-3.5 MW) plant on Montserrat. If the Dominica resource is found to be capable of generating 50-100 MW, it may be technically and economically feasible to export it via submarine cable to-Guadeloupe and/or

Martinique. If an economically exploitable resource can be confirmed on St. Lucia, a power plant could be built in the middle 2020s.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		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 2019	0	0	206	1250	14.4		0	0	0	0	220.4	1335.6
Under construction in December 2019	0	0	0	0	0	0	0	0	0	0	0	0
Funds committed, but not yet under construction in December 2019	0	0	0	0	0	0	0	0	0	0	0	0
Estimated total projected use by 2020	10	60 est.	277	1678.6	20	121	0	0	0	0	332	2011.8

TABLE 2. **UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2019**
(English-Speaking Caribbean Island Nations)

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash B = Binary (Rankine Cycle)
H = Hybrid
2F = Double Flash (explain)
3F = Triple Flash O = Other (please specify)
D = Dry Steam

3) Data for 2019

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe*	Total Running Capacity MWe*	Annual Energy Produced 2014[3)] GWh/yr	Total under Constr. or Planned MWe
All Islands	None					0	0	0	0
Total	None								0

* Installed capacity is maximum gross output of the plant; running capacity is the actual gross being produced.

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2019 (other than heat pumps)

1) I = Industrial process heat — H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling) — D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables) — B = Bathing and swimming (including balneology)
F = Fish farming — G = Greenhouse and soil heating
K = Animal farming — O = Other (please specify by footnote)
S = Snow melting

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.004184 (MW = 10^{6} W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1]	Maximum Utilization					Capacity[3]	Annual Utilization		
		Flow Rate	Temperature (^{o}C)		Enthalpy[2] (kJ/kg)			Ave. Flow	Energy[4]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5]
Nevis: The Baths	B	4.6	43.9	41.5			0.046	3.063	0.969	0.66
St. Lucia: Malgretout	b	6	36	34.5			0.067	9.13	1.806	1
TOTAL		10.6					0.103	12.143	2.775	0.854

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2019

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW =10^6 W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1)] (MWt)	Annual Energy Use[2)] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3)]
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)]	0.103	2.775	0.854
Other Uses (specify)			
Subtotal	0.103	2.775	0.854
Geothermal Heat Pumps	0	0	0
TOTAL	0.103	2.775	0.854

4) Other than heat pumps
5) Includes drying or dehydration of grains, fruits and vegetables
6) Excludes agricultural drying and dehydration
7) Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2015 TO DECEMBER 31, 2019 (excluding heat pump wells)

1) Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)	3				~6
Production	>150° C	5				~8
	150-100° C					
	<100° C					
Injection	(all)	1				~2
Total		9				~16

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

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

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	0	0	0	13	8	16
2016	2	1	0	10	3	5
2017	3	1	0	5	3	5

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2019) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	0.3	0			66	34
2000-2004	0	0			0	0
2005-2009	6	0			100	0
2010-2014	2	16	0	0	100	0