2010 Country Update for Eastern Caribbean Island Nations

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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 features is the westward subduction of the Atlantic crustal plate beneath the Caribbean plate. Subsurface geothermal temperatures in the region range from tepid to 214C as measured in wells drilled near Soufriere, St. Lucia in the 1980s. On Guadeloupe, resource temperatures are adequate for the use of a double flash power cycle at the 15 MW La Bouillante project.

Since 2004, geothermal exploration has accelerated in the region. In 2004 and 2005, the Organization of American States (OAS) funded a program that included geologic, geochemical, and geophysical studies on Nevis, reinterpretation of geophysical data on St. Lucia, and detailed geologic and geochemical work in the Wotton Waven, Dominica area. Additionally, OAS provided geothermally-relevant legal and institutional assistance to these three nations.

In 2008, West Indies Power initiated exploration on the western flanks of Mt. Nevis. Three small diameter wells were drilled, about 3.7 km apart, to depths of more than 1 km at which levels recorded temperatures were in excess of 225C. There was also some attendant steam production. Plans are to drill production scale wells in 2009, to build a 35 MW power plant, and to export power to nearby St. Kitts.

In late 2008, the Government of Dominica signed agreements for exploration, development, and export of power with the French for their Wotton Waven project and with West Indies Power for a project in the Galion-Soufriere area. Currently several private entities are negotiating for the acquisition of similar agreements with the governments of Saba, Montserrat, St. Lucia, St. Vincent, and Grenada.

Utilization of thermal fluids has not increased significantly in the islands since 2005. It is thus limited to low temperature balneological facilities built 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 economically developable geothermal resources (Figure 1). From north to south, they are: Saba, St. Eustatius, St. Kitts & Nevis, Montserrat, Dominica, St. Lucia, St. Vincent, and Grenada. The governments of these nations all function in similar ways. They are modeled on the British system, being headed by a Prime Minister and governed by a Cabinet of Ministers whose numbers vary from country to country and from administration to administration.

The policies of each of these governments are 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 keep the cost of manufactured items low, 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.

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 little or no geothermal exploration or development in these islands, so there is a correspondingly low level of knowledge or understanding in these Ministries regarding these topics. The same can be said for the local educators, the members of the print and electronic media, and the general public. In the latter instance, there is often significant religiously or superstitiously based fear of “disturbing the local volcano” and stimulating an eruption if geothermal drilling is undertaken. This situation has been considerably ameliorated in Nevis, St. Lucia and Dominica by OAS funded geoscientific, legal and institutional activities undertaken in 2004 and 2005.

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 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 (~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 occupy a crustal plate that is moving eastward along the North and South American Plates while it is being subducted by the westward moving 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.

The stresses related to the subduction and the strike-slip horizontal motions to which the region is being subjected result in constant tectonic readjustment. This is evidenced by frequent earthquakes, the generation of major NE-SW trending fracture systems and signs of magma movement at depths as shallow as 2-5 km.

This whole scenario is excellent for the development of geothermal reservoirs at economically drillable depths.

There are heat sources beneath many of the islands, there are fault systems that, where they intersect, can comprise geothermal reservoirs of significant size, and there are fracture conduits, kept open and permeable by frequent seismicity, that can conduct meteoric recharge waters from the surface, to depths at which they can be heated to the thermal reservoir temperatures.

3. GEOTHERMAL RESOURCES AND POTENTIAL

Presented below, in (arguable) descending order of development potential, are brief descriptions of the geothermal indicia 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. French explorationists have signed agreements with the government to explore and develop Wotton Waven while West Indies Power has a similar agreement for the Galion/Soufriere region.

3.2 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^{o}C) resource at moderate depths. Unfortunately, the fluids produced from the latter zone are 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. Work by OAS-funded geoscientists reinterpreted some of the geophysical data collected in the 1980s while geothermally-relevant legal and institutional assistance was rendered to the Government by experienced attorneys also sponsored by OAS.

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. There are encouraging geothermal indicia in at least 5 places on the island so that exploration should be focused and relatively inexpensive. (Huttrer, 1998). In 2008, West Indies Power drilled three small diameter exploratory wells about 3.7 km apart, to depths in excess of 1 km, in the Spring Hill, Jessups, and Hamilton Estates areas. All three wells encountered temperatures in excess of 225^{o}C and significant steam was produced. Plans are to drill production scale wells in 2009, to have about 35 MW on line in 2010, and to export power to St. Kitts via sub-sea cable crossing the narrow strait that separates the two islands.

3.4 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 will be 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 2008, negotiations were begun by several private entities for acquisition of exploration and development rights from the government. As of early 2009, no agreements had been signed.

3.5 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 1000 years ago and there are numerous hot springs along the shoreline and just offshore. The island is highly fractured with some hot spring temperatures having risen within the last 45 years. (Huttrer 1998). In early 2009, West Indies Power signed agreements with the Government of Saba giving the firm the rights to explore for and develop geothermal resources. Announced plans are to drill one or more exploratory wells in 2009-2010.

3.6 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, and reports of "scalding" water encountered while drilling for potable water near Brimstone Hill, the geothermal indicia are less well defined than on other islands. Accordingly, exploration will have to be extensive, time consuming, and expensive.(Huttrer, 1998)

3.7 Grenada

Pre-feasibility studies have revealed one small solfatara on Mt. St Katherine, 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 early 2009, no agreements has been signed.

3.8 Montserrat

Even before the 1995 eruptions, the southwestern flank of the Sufriere 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 is obviously very high, but the risk, as would probably be perceived by potential entrepreneurs and lenders, is likely too high to allow geothermal development any time soon. Reportedly, West Indies Power is seeking to develop the resources underlying the island, but as of mid 2009, no agreement signings had been announced.

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.

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 "balneolgy" at The Baths on

Nevis island, Ravine Claire and Malgretout on St. Lucia, an un-named ravine 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

At The bath, 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

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 climatelogical conditions.

4.3 At Ravine Claire

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 from those presented in the year 2000 because in this summary 1) the geothermal 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 as yet to be identified, and these are reflected in Table 1 projected geothermal totals for 2010.

The entries in Table 3 have been augmented since the 2000 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 no well drilling for geothermal purposes in the English-speaking Caribbean islands in the last 5 years.

Table 7 shows that there was very minimal attention paid to geothermal matters by the governments in all nine countries of interest. The 0.1 person years listed annually is meant to show that it is possible that a few contacts on the subject might have been fielded by officials and some time spent on initial responses.

Finally, Table 8 shows that there was essentially no money spent on Caribbean geothermal project by either the private or public sectors in the last 5 years. It is possible that a few thousand dollars might have been expended by individuals traveling to the region to investigate the geothermal potential, but no projects were initiated from such forays.

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 very small power demand in these nations, the second is the very 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 whenever some capacity is obtained by one or more responsible government officials, it is soon lost as administrations change and personnel are replaced. During the last 5 years, the rising costs of power necessitated by increased international oil prices have made even small sized geothermal developments more attractive. Also, the OAS-funded work referenced above has helped clarify laws, rules and regulations in the region. Most importantly, the successful drilling on Nevis has attracted regional attention that may soon rationalize and break down most barriers to further geothermal development.

7. FUTURE DEVELOPMENT AND INSTALLATIONS

The barriers described above were noticed by officials within the Organization of American States (OAS) and they therefore initiated the Geo-Caraïbes Project designed to help the Caribbean region nations overcome these obstacles to geothermal development. The first countries that were assisted were St. Lucia, Dominica and St. Kitts & Nevis. The project also involved the French Department-islands of Guadeloupe and Martinique.

8. CONCLUSIONS

As of early 2009, near future generation of power on Nevis appears to be a real possibility. If production and injection wells are drilled and all regulatory requirements are met, it should be possible to have power on line in 2010. Despite the difficult international credit conditions existing in 2009, funding of this project should be facilitated by the positive results of early drilling that should have significantly reduced the levels of perceived risk. After Nevis, the next projects likely to come on line may be a relatively large one near Wotton Waven, a modestly sized one near Soufriere, both in Dominica, and a small installation on Saba. Subsea transmission between islands may also soon become a reality.

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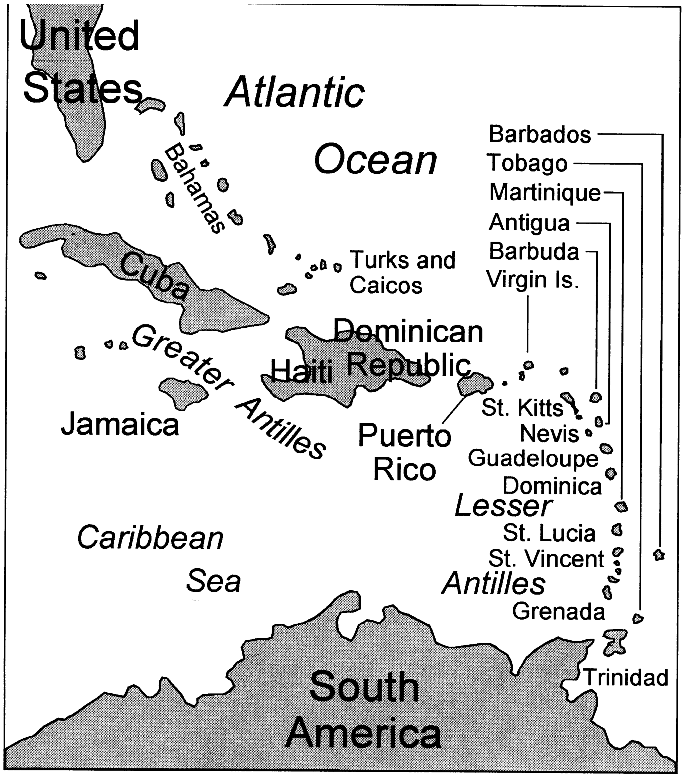

Figure 1 – Location Map

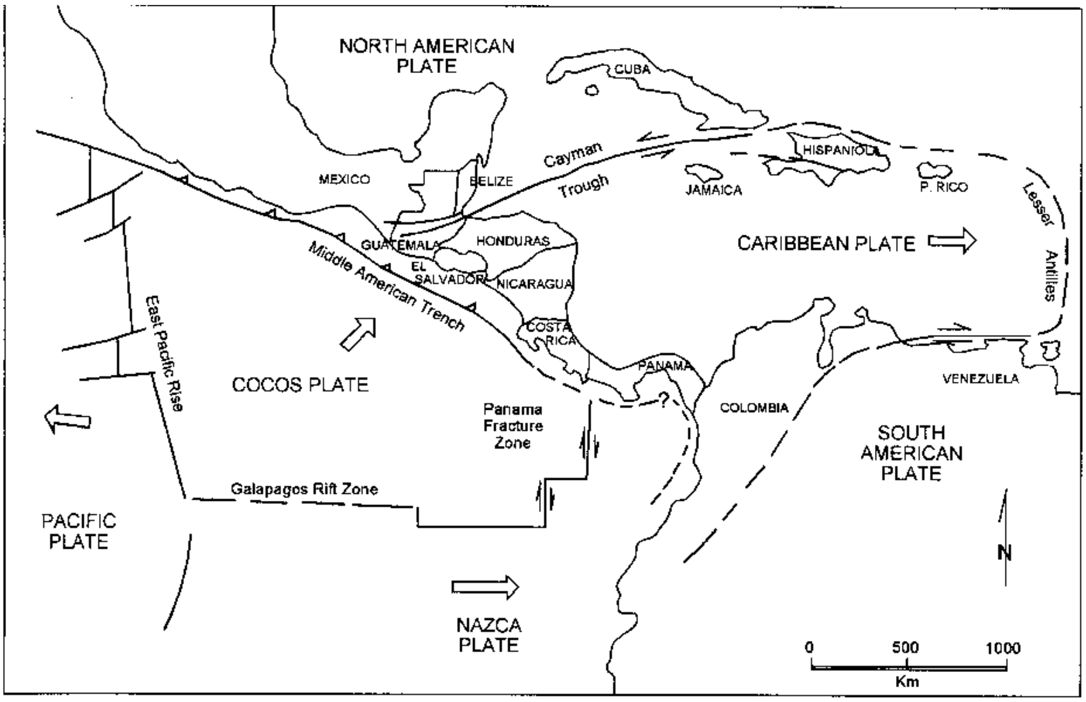

Figure 2 – Crustal Plates of the Caribean Region

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY (Installed capacity)

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in December 2009	0		~ 212	~800	14.4	57.6					~226	~857.6
Under construction in December 2009	0											
Funds committed, but not yet under construction in December 2009	0											
Total projected use by 2015	35	~140	~250	~1000	20	~80					~305	~1220

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2008

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

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

3) Data for 2008

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe	Annual Energy Produced 2004[3)] GWh/yr	Total under Constr. or Planned MWe
Guadeloupe	La Bouillante	2006	3		2F	15	~60	
Total								

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2008 (other than heat pumps)

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

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

[3] Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (°C) - outlet temp. (°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. (°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

[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 (°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
Dom. Malgretout	B	6	36	34.5			0.057	9.13	1.806	1
TOTAL		10.6					0.103	12.193	2.775	0.854

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2008

[1)]Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] 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. (^oC) - outlet temp. (^oC)] 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 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)
2005	1.0			3.0	3.0	
2006	1.0			3.0	2.0	
2007	2.0			2.0	1.0	2.0
2008	3.0			2.0	1.0	6.0
2009	3.0			3.0	1.0	8.0
Total	10.0	0	0	13	8	16

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2004) 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				66	34
2000-2004	0				0	0
2005-2009	6.0				100	0