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Energy Development in Dominica

Jónas Ketilsson

Prepared for the EDIN Steering Committee

OS-2009/007

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National Energy Authority

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Abstract:

Small islands like Dominica face unique energy challenges. The Iceland and Dominica Collaboration will support the capacity-building efforts of the Commonwealth of Dominica. Dominica has significant geothermal resources, and Iceland will lend its longstanding technical and legal expertise in developing this sustainable energy source to help Dominica address the economic, social, and environmental benefits geothermal energy can contribute to. The methodology applied in this report is based on EDIN's clean energy initiative and Iceland's proven model and know-how of transition from a fossil fuel dependent economy to a clean energy economy. Dominica has the volcanic setting and range of surface thermal activity that are typical of many large commercially developed geothermal fields around the world. In this report the current energy development in Dominica is analysed by characterising the current generation mix, establishing energy baseline and load profile, grid reliability constraints and stability requirements and the possibility of exporting clean energy to nearby French islands is discussed. A renewable resource assessment revealed abundant hydropower and geothermal resources. Stakeholder partnership for geothermal development has been established with authorities on nearby French islands and West Indies Power.

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1 INTRODUCTION

Small islands like Dominica face unique energy challenges. Islands are often highly dependent on fossil fuels for electricity and transportation and often have very high retail electricity rates. Islands often have abundant renewable resources and small populations as is the case for Dominica. The International Partnership for Energy Development in Island Nations (EDIN), which Iceland founded with the United States and New Zealand in year 2008, aims at helping island nations to move away from its dependence on fossil fuels for electricity and ground transport but rather focus on harnessing domestic renewable resources. The methodology applied in this report is based on EDIN's clean energy initiative and Iceland's proven model and know-how of transition from a fossil fuel dependent economy to a clean energy economy.

The Iceland and Dominica Collaboration will support the capacity-building efforts of the Commonwealth of Dominica. Dominica has significant geothermal resources, and Iceland will lend its longstanding technical and legal expertise in developing this sustainable energy source to help Dominica address the economic, social, and environmental benefits geothermal energy can contribute to.

When the oil crisis struck Iceland in 1973 and 1979, it revamped its energy policy, deemphasizing oil and turning to domestic energy resources using hydropower and geothermal. Today Iceland is a world leader in the use of renewable energy, meeting 81% of its primary energy needs and generating 99.9% of its electricity through renewable sources. A highlight of this pilot project will be geothermal training provided to the relevant energy institutions

This report is based on a previous technical assessment on energy development in the Commonwealth of Dominica conducted on behalf of the Icelandic International Development Agency (ICEIDA). Iceland's *Island Growth Initiative* (IGI), introduced in 2007, initiated Icelandic-Caribbean cooperation and was the cornerstone to collaboration between the two countries in the field of energy.

Figure 1: *The Permenant Representatives of Iceland, Ambassador Gunnar Pálsson, and the Commonwealth of Dominica, Ambassador Crispin S. Gregoire, to the United Nations in New York after signing the Memorandum of Understanding for Energy Cooperation between Iceland and Dominica the 6th of April 2009.*

2 THE COMMONWEALT OF DOMINICA

The Commonwealth of Dominica is the third largest island in the eastern Caribbean, 751 km^2 in size with 72.660 inhabitants (2009 est.). About 23.000 live in or around the capital Roseau.

Dominica was the last of the Caribbean islands to be colonized by Europeans due chiefly to the fierce resistance of the native Caribs. Some 3,000 Carib Indians still living on Dominica are the only pre-Columbian population remaining in the eastern Caribbean

Dominica has been nicknamed the “Nature Isle of the Carribean” for its seemingly unspoiled natural beauty. It is the youngest island in the Lesser Antilles, still being formed by volcanic activity as evidenced by the world’s second largest boiling lake.

The topography is characterized by very rugged mountains of volcanic origin. A series of high peaks with connecting ridges runs north to south with several peaks rising above 1,220 meters. The highest point, Morne Diablotins at 1,447 m, is located in the north-central portion of the island. Morne Trois Pitons, Morne Micotrin, Morne Anglais, and Morne Plat Pays are mountain peaks extending to the south of the island.

France ceded possession to Great Britain in 1763, which made the island a colony in 1805. In 1978, Dominica became an independent nation from Britain. Dominica is a parliamentary democracy within the Commonwealth of Nations. Unlike other former British colonies in the region, Dominica was never a Commonwealth realm, instead becoming a republic on independence. Dominica is a full and participating member of the Caribbean Community (CARICOM) and the Organisation of Eastern Caribbean States (OECS).

Figure 2: *The Commonwealth of Dominica (CIA World Fact Book, 2009).*

3 ENERGY DEVELOPMENT IN DOMINICA

Electricity production and supply in the Commonwealth of Dominica is currently a monopoly of a privately owned Electric Utility body known as the Dominica Electric Power Company (DOMLEC). DOMLEC is a vertically integrated company, i.e. is responsible for the generation, transmission, distribution and sale to customers. However, major players within the hotel sector continue to self generate electricity (IRC, 2009). The NEA was unable to receive statistical information from this sector.

3.1 Historical Overview

Electricity service first became available in Dominica as long ago as 1905 with a small generating plant that served Roseau. In the mid-50s, the first hydroelectric plant was built and operated by CDC, the Commonwealth Development Corporation. The Dominica Electricity Services Limited, known here as DOMLEC, was incorporated as a public limited liability company in 1975. At the time of its incorporation, the majority shareholder was CDC. The Government and many members of the public also owned shares. An Electricity Act was passed in 1976 (IRC, 2009).

Following the devastating hurricane that hit Dominica in 1979, CDC was slow in repairing the electric lines downed by the storm and expanding service to the rural areas. Consequently, the Freedom Party Government purchased CDC's interest in the company for $1. Over the next fifteen years, DOMLEC repaired the downed lines and expanded coverage throughout the country. Then in 1996, a newly elected Government sold its interest in DOMLEC back to CDC. The sale was controversial and was hotly debated for several years. As part of the sales agreement, the Government enacted "The Electricity Supply Act of 1996." The Act gave DOMLEC a twenty-five year exclusive license to generate, transmit, distribute and sell electricity and gave the company the right to prevent anyone else from generating electricity in Dominica, even for their own domestic consumption. It also guaranteed the company a 15% annual profit without regard to the reasonableness of the company's operating expenses. These two provisions, along with frequent power outages, kept the debate about the sale of CDC alive (IRC, 2009).

After several years of highly publicized disagreements between CDC/DOMLEC and the Government, CDC finally decided in 2004 to sell its shares in DOMLEC. Fifty-two percent of the issued share capital is now owned by an American company, WRB Enterprises, using a Turks and Caicos subsidiary named Dominica Private Power Limited, and twenty-one percent is owned by the Dominica Social Security. Twenty-seven percent of the company remains in the hands of the public. As noted earlier, following the sale of DOMLEC, the Government passed a new Electricity Supply Act in 2006, an act developed in collaboration with the World Bank that is intended to liberalise the sector. It provides for an independent regulatory body for the sector and makes it possible for competing providers to enter the sector. It also changed DOMLEC's licence to end in 2015 rather than 2025. It was in this heated atmosphere that the Independent Regulatory Commission (IRC) was appointed in mid-2007 (IRC, 2009).

3.2 Characterization of Current Generation Mix

The characterization of current generation mix is based on information received from the Dominica Electricity Services Ltd. (DOMLEC), the main service provider with 34,361 customers in year 2008 (Cover, 2009). However, major players within the hotel sector continue to self generate electricity. The NEA was unable to receive statistical information from this sector. The Independent Regulatory Commission (IRC) could accumulate and maintain such databases on the total energy generation and consumption in Dominica as to facilitate in administration of energy affairs.

Total installed capacity in year 2009 amounts to 27.6 MW after instalment of three 1.5 MW medium speed diesel generators as shown in Table 1 (Cover, 2009). The installed capacity of diesel generating plants thus increased to 20.5 MW in year 2008. Installed capacity of hydro-power plants amount to 6.4 MW, including Padu power plant that has not generated power due to damage caused by the passage of Hurricane Dean in year 2007. Repairs are in progress (DOMLEC, 2008).

Electricity generation in the fiscal year 2008 was equivalent to 87 GWh of which hydro plants produced 20.6 GWh (23%) and diesel generating plants 66.9 GWh (77%). As shown in Figure 3 generation from hydro has decreased from 35 to 21 GWh between 2002 and 2008 whereas generation from diesel has increased from 43 to 67 GWh respectively (Bruney, 2009). In the early 1950's and 1960's, hydropower met approximately 90% of electricity generation. In 1994, Dominica generated 78% of its electricity from hydropower. However, in year 2008 the relative share has dropped down to 23%. This has been changing over time, due to weather trends, increased demand and outages due to damage caused by e.g. hurricanes.

Electricity sales totalled 71.4 GWh for 2007, 2.7% higher than sales in 2006. Growth in the commercial sector was above average at 8.8% while unit sales in the industrial sector grew by 4.6%. The performance of the hotel sector was dismal, falling by 18% as major players within this sector continue to self generate. Demand within the domestic sector fell by 1.3% between 2006 and 2007 as domestic users have continued to conserve energy in a period of rising fuel prices.

Electricity generation per capita is quite low in Dominica or only 1.2 MWh in comparison to OECD countries like e.g. Britain with 6.4 MWh per capita (CIA World Fact Book, 2009). As shown in table 2, electricity rates are high in Dominica. For a typical OECD user the consumer is paying 33 US cents.

Table 1: *Electricity Plant Capacity 2009 (Ministry of Energy of Industry, 2008) and (Cover, 2009).*

	Capacity [MW]	Units	High Speed [MW]	Medium Speed [MW]
Diesel Generating Plants				
Fond Cole Plant, Roseau	10.25	9	4.5	5.75
Sugar Loaf Plant, Portsmouth	5.78	5	5.78	
Fond Cole Plant (2008)	4.5	3		4.5
Total	***20.53***		***10.28***	***10.25***
Hydro Plants (in operation)				
Laudat	1.3	1		
New Trafalgar	3.52	2		
Total	***4.82***			
Hydro Plants (not operating)				
Old Trafalgar	*0.64*	-		
Padu (repairs in progress)	1.6	2		
Total	***2.24***			
Total Capacity	***27.6***			

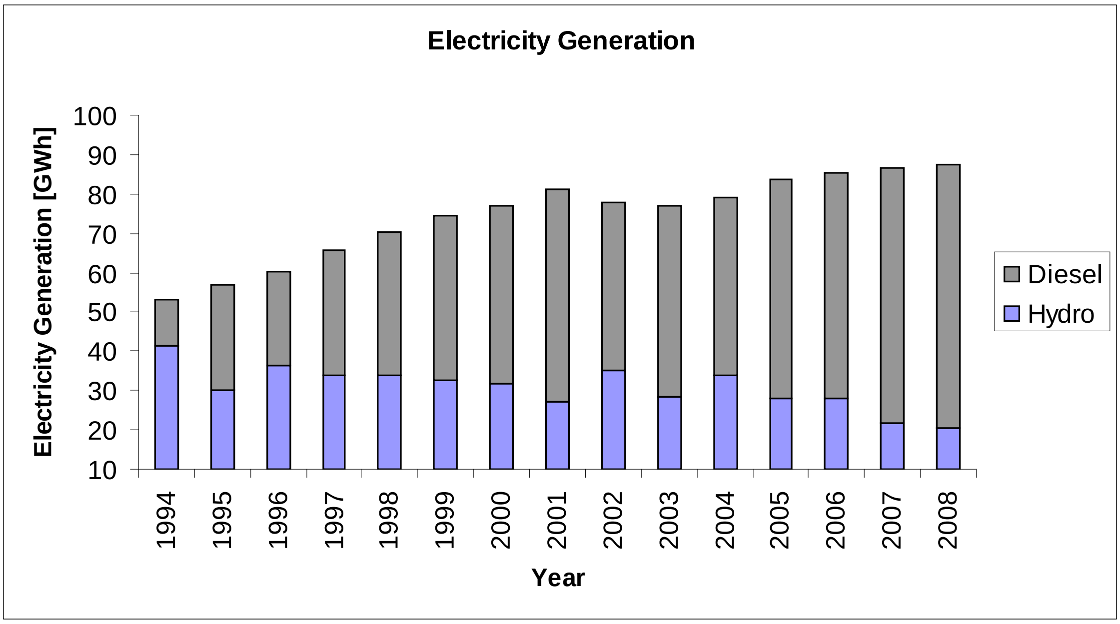

Figure 3: *Electricity Generation from 1995 to 2007 by hydro and diesel (DOMLEC, 2008).*

Table 2: *Electricity rates, still effective from September 2007 (fuel surcharge varies) (DOMLEC, 2009).*

Domestic use	USD/kWh	kWh	USD	Avg. USD/kWh
First 50 kWh/month	0.21	50	11	
Above 50 kWh/month*	0.25	283	70	
Fuel Surcharge Jul-08	0.26	333	86	
Fuel Surcharge May-09	0.08	333	28	
TOTAL Jul-08**			167	**0.50**
TOTAL May-09**			109	**0.33**

*Annual consumption = 4000 kWh (333 kWh/month)

**VAT 15% excluded

3.3 Energy Baseline and Load Profile

In year 2008 peak demand was 14.6 MW compared to 14.5 MW (daytime) in June 2007 with a base load of 7.2 MW (Cover, 2009). Typical daily load profiles are illustrated in Figure 4 for year 2007.

The installed capacity in year 2009 is 27.6 MW. However, if shut-downs for maintenance, hydro dry-season and plant retirement plans are taken into consideration the available power from diesel and hydro can be estimated to be around 20 MW.

Expected growth of the home market is modest or roughly 2% on average per year. In 2013 the peak demand is expected to be 16.4 MW (DOMLEC forecast), up by 1.8 MW compared with 2008.

Energy consumption could though increase dramatically if a supply of cheaper power will become available which could as well change industry preferences, e.g. heating and cooling from gas/oil to electrical. Electricity consumption per capita is e.g. quite low relative to neighbouring countries. It is recommended that a thorough analysis will be conducted prior to estimating future energy baseline and load profile to prevent underestimating the need for electricity in the near future taking into consideration major players within the hotel sector that self generate electricity.

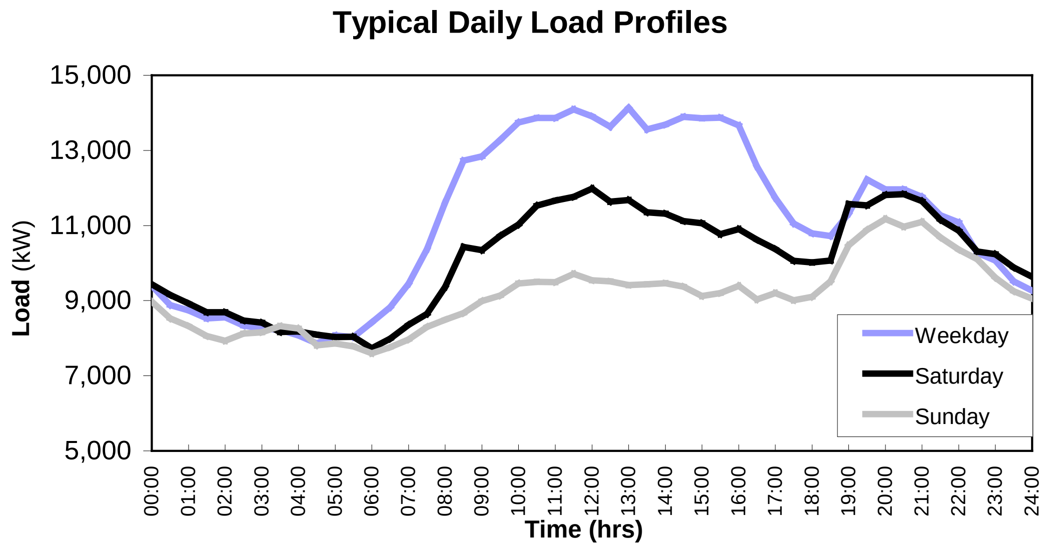

Figure 4: *Typical Daily Load Profiles from year 2007 (DOMLEC)*

From the above mentioned energy baseline and load profile it is estimated that with a 15 MW geothermal power plant the goal of outfacing the diesel generators altogether can be achieved (retained for stand-by service) with 50% load factor. The geothermal power plant and the current hydro plants could thus generate around 20 MW during normal season and 18 MW during dry season.

3.4 Grid Reliability Constraints and Stability Requirements

At present, the highest voltage level in Dominica is 11 kV. In Dominica it is common to have 11 kV transmission poles used for 400 V distributions by insulated OH cables.

System losses have been quite high in Dominica over the past few years. In e.g. year 2005 system losses amounted to 17.3% of generation. As part of the efficiency goals of DOMLEC, the system losses have gradually decreased since then to 12.5% in year 2008 (Cover, 2009), below the legislated level of 14.5% (DOMLEC, 2008). This was e.g. due to installation of capacitor banks, the upgrade of 10 primary circuits from single to three phase, modification of 16 secondary circuits to include downsizing of transformers and load balancing (DOMLEC, 2008). DOMLEC has as well been installing new meters which probably deceased losses related to inefficient metering. In Iceland system losses amount to 6% of generation.

System Average Interruption Duration Index (SAIDI) hours is an indicator of interruptions. The index is commonly referred to as customer minutes of interruption and is designed to provide information about the average time the customers are interrupted. In Dominica this is measured in hours. On average SAIDI hours amounted to 76.1 hours plus 4.2 hours caused by the Hurricane Omar in year 2008 (Bruney, 2009). SAIDI hours in Iceland on average is below one hour.

According to IRC it was the lack of adequate government oversight and ineffective managerial strategies that resulted in the continuing poor performance of the utility at the beginning of this century. IRC has pointed out that a national electric power policy is urgently needed, which will define the framework for the electricity sector reform in Dominica. However, as statistics show, DOMLEC has been improving grid reliability. Stability requirements are today below the legislated level.

High speed diesel generators (typically 1000-1500 rpm) amount to half of installed diesel capacity as shown in Table 1. They are typically used to power cars and small generators. Medium speed engines are used in e.g. large electrical generators. Medium speed engines can burn lower grade (slower burning) fuel than high speed engines. Thus, the high-speed generators require more energy and thus are not as efficient. With installment of three 1.5 MW medium speed diesel generators in year 2008, DOMLEC has taken the right step in outfacing the less efficient, high speed diesel generators.

3.5 Exporting Clean Energy to Nearby Islands

The energy market in Dominica is limited in comparison to the estimated production capacity of renewable resources. However, on the nearby islands (50 km distance), Martinique and Guadeloupe, electricity production is in total 2.8 TWh as shown in Table 3. About 200 MW of installed capacity on both of the islands are not compliant with EU NO_x Directive and thus will have to be outfaced. It is estimated that both of the islands could easily import 50 MW of base load power from Dominica.

Table 3: *Electricity Generation in 2004 on Martinique and Guadeloupe (AETS, 2006).*

	Martinique	Guadeloupe
Installed Capacity [MW]	420	440
Electricity generation [GWh]	1380	1430
Peak Load [MW]	218	221
Electricity generation [GWh]	1380	1430
Share of Diesel Generation	100%	~75%

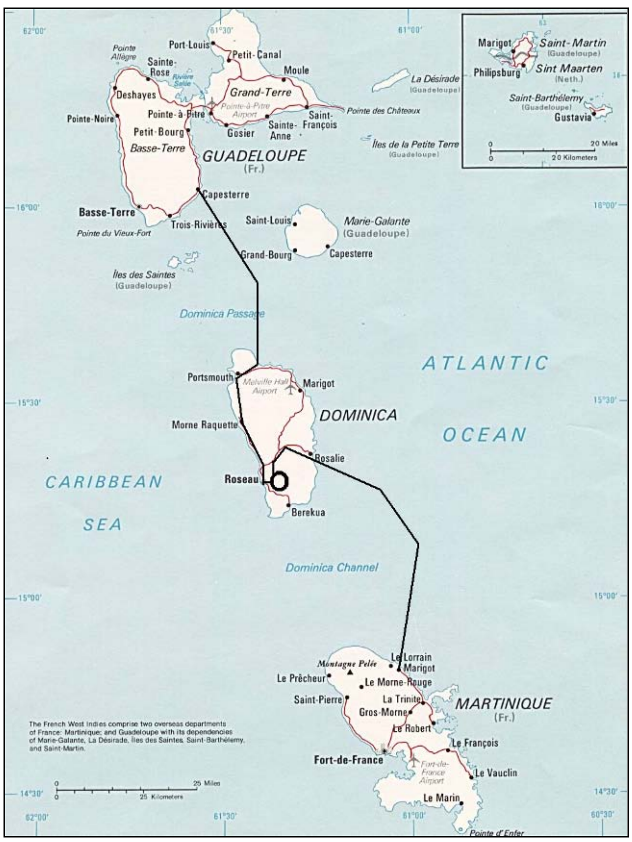

Figure 5: *Geothermal based cross boarder electrical interconnection in the Caribbean.*

4 RENEWABLE RESOURCE ASSESSMENT

The Government has supported various research assessments on domestic renewable resources e.g. geothermal, hydropower and wind. Due to the abundant resources of both geothermal and hydro the NEA, from experience, sees no reason to discuss further the potential of wind energy from an economical stand point. However, a wind energy assessment was carried out in 2003 by the German Technical Assistance, GTZ for the Government. The reports stated that the northeast coast of Dominica present the best opportunities for large scale development of wind power on wind farms. The report also stated however that the weakness of the electricity distribution system does not currently allow for large injections of power along the east and northeast coasts (Ministry of Energy, 2009).

4.1 Hydropower Potential

Rivers are the main source of water supply for potable use, irrigation, and hydropower in Dominica. The country has a total of 365 rivers and streams. In addition to high rainfall (762 centimetres per year), Dominica has significant forest cover. These physical conditions assure an abundant freshwater supply for domestic consumption, export markets, hydropower, irrigation, and other uses. The abundance of surface water has minimized the need to explore ground water resources, and hydrological studies have indicated limited aquifers with low yields (US Army Corps, 2004). The NEA was unable to find a total potential of hydropower resources on the island.

Prior to 1990, Dominica met 40 percent of its energy requirements through two hydroelectric stations, Old Trafalgar and Padu, both located along the Roseau River. A new facility was expected to raise their usage to 60 percent in the mid 1990s. The expansion project comprised of the Roseau river valley from Fresh Water Lake to the capital city of Roseau. The expansion involved two schemes to increase hydro electrical generating capacity above the capacity of the existing Old Trafalgar and Padu power stations. Final design was completed in April 1987 and construction commenced in January 1989. The Laudat power station was put in service in December 1990 and the New Trafalgar power station was commissioned in September 1991 (US Army Corps, 2004).

The Laudat scheme develops 211 m of head between Fresh Water lake and the village of Laudat. The New Trafalgar scheme develops 283 m of head between the tailrace of the Laudat power station and the village of Trafalgar at the foot of Trafalgar Falls. Ti Tou Gorge is a narrow and deep channel in the headwaters of the Roseau River near Laudat. Water flowing through the gorge was first harnessed for power in the 1950s. Damming the gorge allowed the diversion of its water into canals and pipes leading to a power station. Raising the water level created a recreational swimming area and encouraged tourism to the site (US Army Corps, 2004).

Feasibility studies on hydro power for Dominica were carried out by GTZ in 2004. Part of the objectives of the studies was to assess the rehabilitation and upgrading of the Trafalgar and Padu hydro power plants according to DOMLEC's priority. The reports concluded that "all of the investigated rehabilitation and upgrading options are technically feasible and economically and financially viable" (Ministry of Energy, 2009).

The experience of combined utilisation of hydropower and geothermal in Iceland is quite positive. The NEA thus recommends combined utilisation of those two renewable resources. Even though precipitation and topographic relief is very high in Dominica, only 23 percent electricity is generated with hydro as further outlined in chapter *3.2 Characterization of Current Generation Mix*. Further development of hydropower in Dominica, while technically feasible, is hampered by environmental considerations and natural hazards caused by hurricanes (US Army Corps, 2004).

4.2 Geothermal Energy Potential

Dominica has the volcanic setting and range of surface thermal activity that are typical of many large commercially developed geothermal fields around the world. There is likely an exploitable geothermal resource beneath the Wotten Waven area and other geothermal systems can probably be found. Production capacity of geothermal systems in Dominica has been estimated to be 1,400 MW of electric power (Battocletti and Lawrance, 1999).

Dominica has nine active volcanic systems whereas all the other volcanic islands of the Lesser Antilles have only one active volcano. However, there has yet not been a major magmatic eruption since Columbus visited the island and as a result it has today the best and most extensively preserved tropical rainforests (Roobol and Smith, unpublished).

4.2.1 Plate Tectonic Movements of the Caribbean Plate

The Carribean plate is thought to have been an 8-20 km thick igneous province 90 million years ago where the Galapagos Islands are today. As the Atlantic ocean widened, North America and South America were pushed westward, separated for a time by oceanic crust. The Pacific Ocean floor subducted under this oceanic crust between the continents. The Caribbean Plate drifted into the same area, but as it was less dense (although thicker) than the surrounding oceanic crust, it did not subduct, but rather overrode the ocean floor, continuing to move eastward relative to North America and South America. With the formation of the Isthmus of Panama 3 million years ago, it ultimately lost its connection to the Pacific (Kerr and Tarney, 2005).

The Atlantic oceanic plate now subducts under the Carribean plate forming the Lesser Antilles as shown on a West-East cross section of Dominica on Figure 6.

4.2.2 Regional Setting in the Volcanically Active Lesser Antilles

Dominica lies at the center of the Lesser Antilles Island arc as shown on Figure 7, where the islands of the active arc (shown in red) are large and complex comprising many coalesced stratovolcanoes.

The structure of the island is interesting as north of Dominica the Lesser Antilles arc divides into two, with the active arc lying to the west in Basse Terre of Guadeloupe and the extinct Limestone Caribbee arc (brown) lying to the east in Marie Galante and Grande Terre of Guadeloupe.

The Lesser Antilles includes 21 live volcanoes spread across 11 volcanically active islands, and volcanic eruptions are one of the main hazards that threaten the eastern Carribean region (Lindsay et al., 2005). Best estimates indicate that there have been at least 34 historical eruptions of volcanoes in the Lesser Antilles. 21 of these occurred

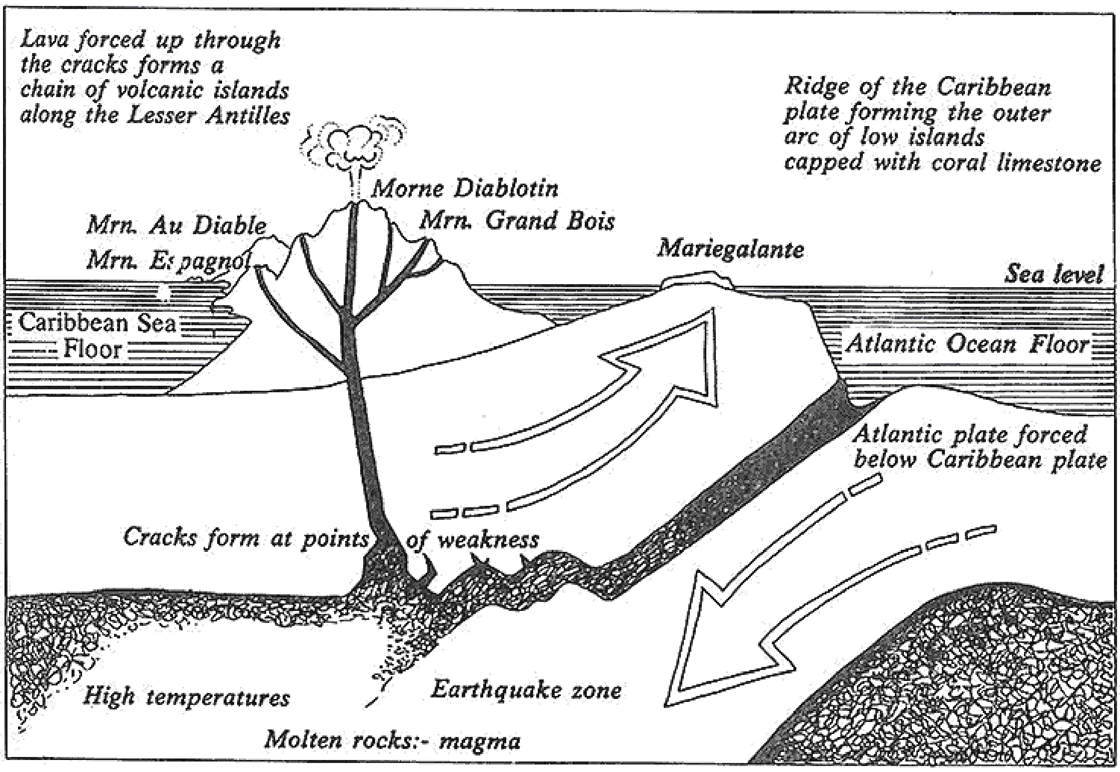

Figure 6: *Subduction of the Atlantic Plate under the Carribean Plate in Dominica (Honychurch, 1995).*

since 1900; 9 on land from volcanoes on Guadeloupe, Martinique, St. Vincent, Montserrat and Dominica, and 12 from the submarine volcano Kick'em Jenny, 9 km north of Grenada (Lindsay et al., 2005).

One of the most devastating in terms of destruction of lives and property is the eruption on Martinique from Montagne Pelée. The eruption led to the total destruction of the town of St. Pierre and the deaths of approx. 30,000 people (Lindsay et al., 2005).

4.2.3 Geology of Dominica

For a detailed description of the seismic and geothermal activity and a discussion of the types of volcanic hazard presented by the different active volcanoes on Dominica the reader is referred to Lindsay et. al, (2005). A geologic map of Dominica is given in Figure 8. The following paragraphs entail a geological description of the island summarised by two geologists Roobol and Smith.

The youngest dated volcanic deposits on the island are associated with the Morne Patates dome on the flanks of the large active Plat Pays Volcano that comprises the south-western end of the island. This was a Pelean eruption (similar to the eruptions of Mt. Pelee on Martinique in 1902 and 1929) and radiocarbon ages from the block and ash deposits suggest it occurred about 500 year ago. In addition there have been two steam explosions (phreatic activity) in the Valley of Desolation in 1880 and 1997. Frequent seismic swarms and vigorous and widespread geothermal activity today characterize the island. In fact it is the most worrying of all the Caribbean volcanic areas and there is a general feeling that it (like Montserrat pre-1995) is long overdue for an eruption (Roobol and Smith, unpublished).

What is of particular concern is that the capital Roseau and most of the islands infrastructure lie on a pyroclastic flow fan derived from the Wotten Waven caldera situated on the eastern outskirts of the capital. The pyroclastic deposits of the Roseau area abound with ignimbrites (pumiceous pyroclastic flows), surge and airfall deposits with radiocaron ages ranging from 38,000 to 1000 years B.P. The Icelandic volcanologist, Haraldur Sigurðsson, as long ago as 1972 described one of the units which he called the Roseau ash and together with other workers traced its submarine extension. As a result of this work they concluded that about 38,000 years ago the island erupted around 56 cubic kilometers of pumiceous materials in what was described as the largest eruption in past 200,000 years in the Caribbean. Pyroclastic flows deposited about 30 cubic km on the Caribbean floor and the remainder was deposited on the Atlantic floor from AntiTrade Wind dispersal. More recent work suggests that there are several ignimbrite sheets separated by ancient soils and the deposits may have resulted from several eruptions. However all conclusions indicate that the capital Roseau is situated in one of the most hazardous areas of the island (Roobol and Smith, unpublished).

On Dominica, Miocene rocks (7-5.3 million years) of the Extinct Limestone Caribbees occupy the east or windward coast where deeply dissected volcanoes form rugged mountains. The main bulk of the island was built up by coalesced volcanoes during the Pliocene (4.0-2.0 million years). During the Pleistocene (<2 million years) a number of young volcanic centers have been building over the Pliocene rocks and are separated from them by an extensive saprolite-laterite soil horizon caused by a long period of tropical weathering that formed about 2 million years ago. The distinctive center of Morne aux Diables in the north and Plat Pays in the south have extended the area of the Miocene-Pliocene volcanic island. In the south central part of the island, in what was a large basaltic shield volcano, a central graben developed in the Pleistocene that measures 6km east-west by 12 km north-south and is bounded by conspicuous cliffs to the west and north (Roobol and Smith, unpublished).

Within the Central Graben two calderas have formed and occupy most of the floor of the graben. The Trois Piton caldera is to the north and the Wotten Waven caldera to the south. Following the eruption of pumiceous material from these calderas, the Trois Pitons and Micotrin centers formed. Both of these are Pelean dome complexes with surrounding aprons of block and ash flow deposits (from nuées ardente type pyroclastic flows named by Alfred LaCroix when describing the 1902 eruption of Mt. Pelée) (Roobol and Smith, unpublished).

Arcuate cliffs truncate the south-western flanks of the Plat Pays stratovolcano and form the eastern margin of a depression now occupied by the Morne Patates and Crabier Pelean dome complexes and their pyroclastic aprons. The villages of Soufriere and Scotts Head also lie within this structure. Although there has been much debate as to whether the structure is a caldera or a sector collapse scar, the problem was resolved by Anne Le Fraint and others in 2002 when detailed bathymetric studies revealed that not only does the collapse scar continue down to depths greater than 2000m, but three collapses have resulted in the most extensive debris avalanche fan found associated with the Lesser Antilles arc with an area of 3,500 sq.km. On the proximal part of the fan numerous megablocks up to 2.8km long and 240m high exist and it seems that Scotts Head is such a block (Roobol and Smith, unpublished).

There are a number of high temperature surface manifestations in Dominica. As shown in Lindsay et al. there are a number of vigorous fumaroles, bubbling pools and small steam fumaroles with 75-100°C found in Valley of Desolation, Plat Pays Complex and Wotten Waven. Further information can be found in Lindsay et al. (2005) with a table of temperature and acidity of the main geothermal features in Dominica.

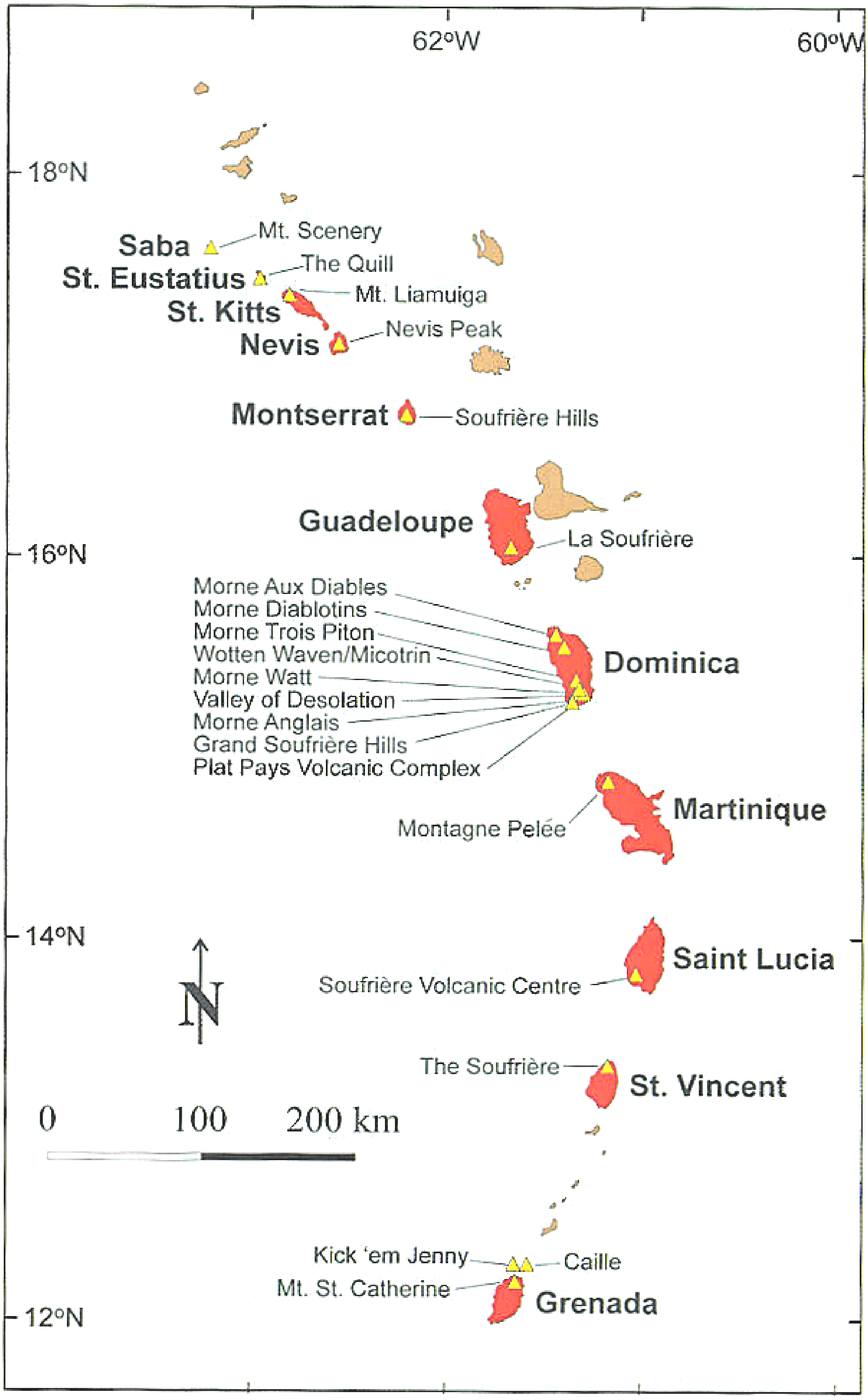

Figure 7: *Map of the Lesser Antilles showing the islands of the Volcanic Caribbees in red and those of the Limestone Caribees in brown. Live volcanoes are represented by yellow triangles (Lindsay et. al, 2005)*

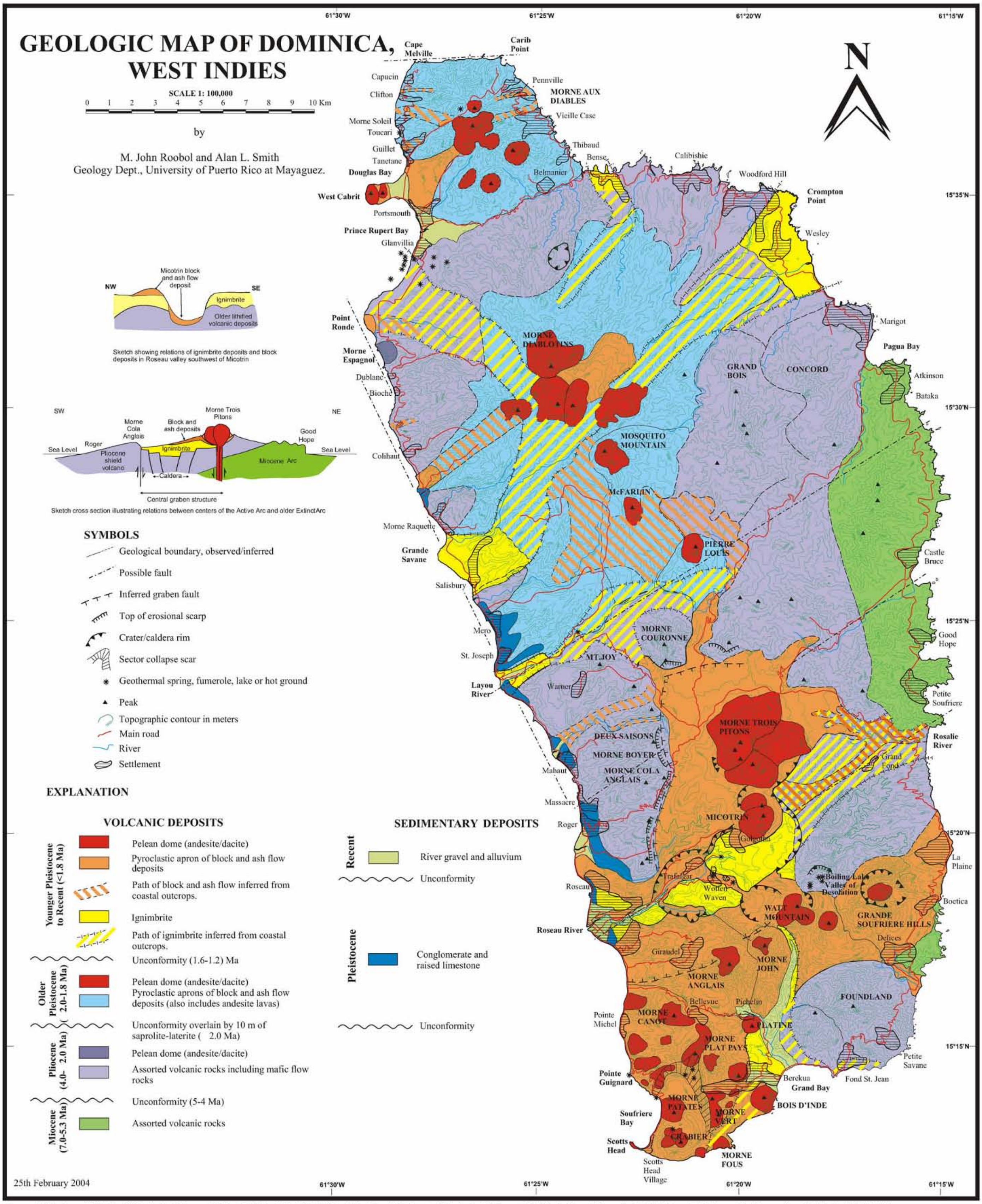

Figure 8: *Geologic map of Dominica (Lindsay et al, 2005).*

4.3 Stakeholder Partnerships and Pre-feasibility Studies

The French institute of Geological investigations and mines, Bureau de Recherches Géologiques et Minières (BRGM), began the first integrated exploration of Dominica's geothermal resources in 1977, identifying three areas of interest: Wotten Waven, Boiling Lake, and Soufrière. Morne Diablotin and Morne au Diable, two active volcanic complexes, are located in the northern part of the island but are considered of lower priority. BRGM began an expanded exploration program in 1982 with a focus on Boiling Lake and Wotten Waven, considering the sites the area of highest priority due to its proximity to the capital, Roseau. Exploration indicated the probable existence of a geothermal system with temperatures on the order of 230ºC at an estimated depth of 800-1500 m. BRGM identified as well the location of exploratory wells. In years 1991 to 1992 BRGM, in conjunction with the UN Department of Technical Cooperation for Development (UN/DTCD), confirmed the site's priority; proposed a feasibility study to the Government which was unfortunately not pursued. INEEL, GMC, and USGIC prepared a preliminary assessment of the potential for the development of geothermal resources of Dominica under a DOE-sponsored program.

Negotiations between Caribbean Power Enterprise, Ltd. and the Government of Dominica began in 1994. Concession was assigned year later to a private joint venture company, Dominica Geothermal Power Co. (DGPC), composed of 51% ownership by Caribbean Power Ltd. and 49% Dominican ownership. DGPC obtained the complete concession for geothermal resources and all their possible applications. In the following year from 1998 to 2004 developments where planned for instalments of four modules of 2.5 MW each. The project was abandoned apparently due to political and financial obstacles.

4.3.1 Wotten Waven Field

In April, 2008, the Dominica Government signed a Transnational Partnership Agreement (TPA) with the Regional Councils of Guadeloupe and Martinique and other development agency partners to continue research into the feasibility of geothermal development in the Wotten Waven area and of interconnectivity between Dominica and Guadeloupe and Martinique for geothermal power transmission. The Geothermie Caraibe project as it is called, funded under the INTERREG III B programme of the EU, is the preliminary phase of the more comprehensive geothermal development initiative. The INTERREG III B project is focussed on key points which will ensure the success of the project from a technical, administrative and legal point of view. The TPA is the prelude to the project "Preparation of a Geothermal-based Cross-Border Electrical Interconnection in the Caribbean" financed by the European Union , AFD and FFEM to the tune of 5.5 million euros over three years. Within the next two years the investment will provide the Government with technical, financial, institutional and legal information for the establishment of geothermal plants with the capacity to supplement local needs at much reduced cost and to sell 100 MW of electricity to Guadeloupe and Martinique via submarine cable as part of the EU's 20/20/20 commitment (Ministry of Energy, 2009).

CFG Services carried out a geological and geochemical studies in Wotten Waven in January 2005 which corresponded to the second phase of the Work Programme in the frame of the OAS Eastern Caribbean Geothermal Development Project (Geo-Caraïbes) The geological work included mainly lithologic and stratigraphic mapping at 1/10.000 scale, structural mapping, thermal features mapping, analysis of recent UWI-SRU documents. Geochemistry included Re-sampling of the "deep reservoir" sodium-chloride rich fluids evidenced by BRGM in the 1980's, sampling of new springs pointed out during the survey for lab analysis, field measurements of "non conservative" parameters. About one hundred stations where visited during fieldwork for geology and/or geochemistry observations and sampling. They are scattered on the surveyed area with higher density observations in River Blanc and its vicinity due to the abundant thermal features (Traineau and Lasne, 2005).

CFG recommended additional exploration activities in order to reduce uncertainties regarding the extension and characteristics of deep geothermal resources. CFG believed that more data is required from exploration surveys and exploratory drilling to refine models and better assess the Wotten Waven geothermal potential. A geophysical survey (MT) was also recommended to highlight relationships between Wotten Waven, Du Mas Estate and Boiling Lake/Valley of Desolation areas (Traineau and Lasne, 2005).

After surface exploration survey, the next phase should be sub-surface exploration with thermal gradient and/or slim hole drilling. The objectives will be to check high temperature conditions at depth, permeability, deep fluid chemistry and reservoir lithology. This information will be useful to refine the geothermal reservoir model and to locate sites for drilling production and re-injection wells with confidence. According to the results obtained during field survey and proposed models of deep reservoirs location, five sites suitable for exploratory drilling have been identified (Traineau and Lasne, 2005).

CFG conducted further research last year with an Icelandic engineering consultant, Jónas Mattíasson at Verkís. CFG plans to finalise a pre-feasibility study this year. The study will entail a description of the Wotten Waven geothermal resource, power plant development strategies and plant location and a conceptual design.

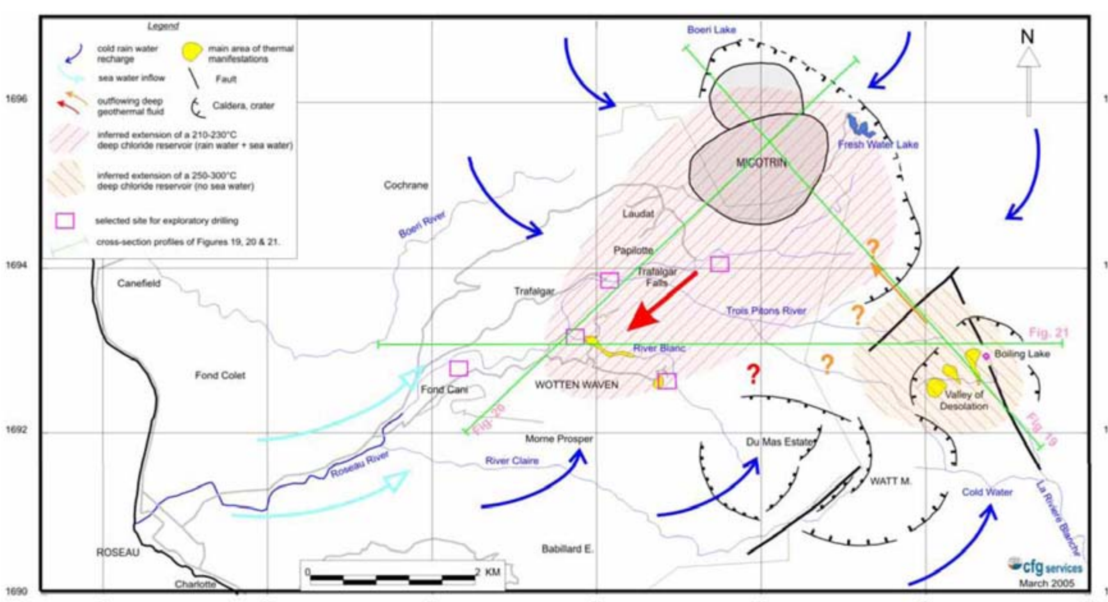

Figure 9: *Sketch of the proposed geothermal model of Wotten Waven with inferred location of deep chloride reservoirs and fluid circulation pattern. Proposed exploratory drilling sites are marked with a question mark (Traineau and Lasne, 2005).*

4.3.2 Galion Soufriere Field

In July, 2008, the Government issued a license to West Indies Power (Dominica) Ltd for the exploration and exploitation of the geothermal resources in the Galion Soufriere area at the southern tip of the island. Since then WIP with support from the Ministry of Energy and the Ministry of Energy of Housing, Lands and Telecommunications has identified the geothermal reservoir based on some surface measurements i.e. the geological, geochemical and geophysical characteristics of the Soufriere Resource area. Results so far are sufficiently favourable to encourage the company to pursue the development of its proposed geothermal energy investment programme (Ministry of Energy, 2009). WIP plans to build a 15 MW geothermal power plant in the Soufrière area for the home market.

Figure 10: *Geothermal baths in Soufrere Bay.Photo: Ketilsson.*

5 LEGAL FRAMEWORK AND ENERGY POLICY

5.1 Sustainable Energy Plan

In order to drive a clean energy initiative, authorities in Dominica should establish an energy policy clearly stating the target e.g. for 2020 in terms of share of renewable electricity generation, system losses, grid reliability etc. For this, Organisation of American States (OAS) and the German Technical Assistance (GTZ) have consented to provide technical assistance for the formulation of a National Energy Policy and Sustainable Energy Plan for Dominica.

In year 2002 the Ministry of Energy had drafted a Sustainable Energy Plan for Dominica although it was never made official. In the drafted plan the goals are outlined:

- Ensure the existence of adequate energy supplies at affordable rates to sustain economic development, while meeting current and projected power demand.
- Provide for stable, reliable, and affordable electricity supplies for all customers.
- Lower the price of electricity for consumers.
- Enhance the security of energy supply and use for all sectors of the economy.
- Allow reasonable incomes for businesses engaged in the local energy sector, while attracting international investment where appropriate.
- Promote energy efficiency and conservation at all levels of the economy in order to achieve optimum economic use of renewable and non-renewable sources of energy.
- Protect the local and global environment by maximizing the use of renewable-energy and energy-efficiency alternatives where viable. This is especially relevant in Dominica as much of the renewable energy generation may take place in nature preserves. It is essential that this be done in a manner that does not threaten biodiversity, forestation levels, and other environmental aspects.
- Promote the generation of income through energy exports produced from indigenous energy sources (esp. geothermal resources).

The goals could be more detailed as to clearly state the vision of the Government. A good example is the regulated legislative level of 14.5% system losses in the Electricity Supply Act 2006/10 which DOMLEC achieved to fulfil in year 2007. The Government could as well look into regulating the system average interruption duration index (SAIDI) which is relatively high in Dominica compared to OECD countries.

In the drafted proposal there are a number of suggested actions that already have been implemented, e.g. various assessments of renewable resources and the appointment of the Independent Regulatory Commission (IRC) in June 2007 to assume the responsibilities conferred on them under the Electricity Supply Act 2006/10. With IRC new relationships of the parties operating in the sector have begun to take shape. The Act makes the IRC principally responsible for electricity sector investment planning, a role which traditionally fell to DOMLEC as exclusive service provider.

The IRC will eventually provide guidance on the power generation and transmission options that it expects licensees to implement to meet the anticipated expansion of economic activity in Dominica especially those projects planned for relatively undeveloped areas in the north and east of the island. However, since DOMLEC is the only licensee at the moment it falls to DOMLEC to make those investments that are needed now to prevent deterioration of the service in the short term.

5.2 Electricity Sector Targets

DOMLEC's strategic renewable energy targets aims at generating 30% from renewable resources by 2013 and 40% by 2017. This could probably be achieved by upgrading and rehabilitating existing hydropower stations. As an example, the Ministry of Energy has supported the restoration, and possibly expansion of the Padu hydro electricity generation station that will have the capacity to increase the generation from 1.6 MW to 3 MW.

DOMLEC installed three 1.5 MW medium speed diesel generators in year 2008. Development of a 12 MW diesel plant on a suitable new site is currently being assessed by DOMLEC to be in operation within three years.

As a vision the Government could state that it indents to generate 90-100% of electricity with renewable resources prior to 2020 which could easily be achieved with the abundant geothermal and hydropower potential in the country. This could set precedence to service providers to look further into harnessing domestic renewable resources instead of installing new large diesel generators. See as an example below:

- Decrease System Losses:
  - 2015: Reduce system losses by X%; X GWh generated; X GWh sold
  - 2020: Reduce system losses by X%; X GWh generated; X GWh sold
- Renewable Energy Installations
  - 2015: X MW (X% of projected demand)
  - 2020: X MW (X% of projected demand)
- GHG Emissions Reductions: X% reduction in diesel consumption/X% reduction in GHG (TOC)

5.3 Legal Framework

Following the sale of CDC shares in DOMLEC in year 2004, the Government passed a new Electricity Supply Act in 2006, an act developed in collaboration with the World Bank that is intended to liberalise the sector. It provides for an independent regulatory body for the sector and makes it possible for competing providers to enter the sector. It also changed DOMLEC's licence to end in 2015 rather than 2025 (IRC, 2009).

The Independent Regulatory Commission (IRC) was established in 2006. In broad terms, the functions of the IRC are to encourage the expansion of electricity supply to Dominica where this is economic and cost effective and in the public interest, and to generally encourage the operation and development of a safe, efficient and economical electricity sector in Dominica. The IRC is to ensure the security and efficiency of the supply of electricity, and facilitate the promotion of sustainable and fair competition in the sector, while protecting the interest of all classes of consumers of electricity in Dominica (IRC, 2009). Under the Electricity Supply Act, the IRC is empowered to license all industry participants involved in the following activities:

- Electricity Generation in excess of 20 kW
- Electricity Distribution and Supply

- Electricity Transmission
- System Operation
- Trading
- Electrical Installation/Wiring

IRC has proposed to amend the Act to place minimum capacity levels on the electricity generation for domestic purposes (section 31 - 4) and electricity distribution and supply. The drafting of regulations in respect of the Act will, for example, provide guidance for creation of power purchase agreements between a dominant distributor of electricity and independent power producers.

The law requires the IRC to be independent in the performance of its functions and duties, and it shall not be subject to the direction and control of the Government or of any person, corporation or authority, except that the Commission shall have due regard to the public interest and overall Government policy as embodied in the legislation (IRC, 2009).

This reform should lead to the unbundling of the privately owned monopoly, and further lead to the establishment of successor companies; electricity generation companies, one transmission company and a number of distribution companies. The action will also lead to private sector participation in the forementioned generation and distribution sectors and the operation of a number of independent power plants (IRC, 2009).

Developing an appropriate licensing framework for the Dominica's electricity sector will not be without a number of challenges. Helping islands establish a regulatory framework that enables utilities to increase the use of renewable energy and energy efficiency technologies is quite important and can drive energy development for the nation. The Government of Dominica has requested technical assistance from the World Bank under the Growth and Social Protection Technical Assistance project to produce draft legislation and regulations that will provide the legal and regulatory framework for the development of alternative energy. According to the Minister, such draft legislation and regulations will focus on the development of geothermal energy resources as the primary source of energy and electricity generation in Dominica.

5.4 Public Monitoring in Iceland

The public monitoring of utilisation of geothermal resources in Iceland is rather extensive and is the responsibility of different public authorities, as is addressed in the article. The monitoring of geothermal utilisation can be divided into three main sectors as shown in Figure 11. The objective of the monitoring for each sector is different, respectively: to protect the environment, to prevent overexploitation of the resource, and to secure occupational safety and safety of delivery at the power plants.

In an appendix with utilization licenses and power plant licenses it is stipulated what detailed information the developer is supposed to present once a year to the NEA. The information required is as follows:

- The amount of fluid extracted from or reinjected into each well in the geothermal field, each month.
- The temperature of the water reinjected into the geothermal reservoir each month.
- Results of water level measurements in wells in which the water level can be measured and are within the geothermal field.

- The pressure changes or drawdown determined in the geothermal reservoir.
- The results of measurements of the enthalpy of the fluid from every production well in the geothermal field.
- Chemical analysis of the geothermal water (and steam, if appropriate).
- Results from simulations of the geothermal reservoir.
- Results of measurements made to monitor changes in the geothermal reservoir.
- Information on drilling in the industrial area.
- A resume of improved understanding of the physical characteristics of the geothermal reservoir based on the results of the latest drilling.

The above mentioned items should provide all the necessary information for the monitoring authority to monitor the utilization of the resource. See Appendix A for further information.

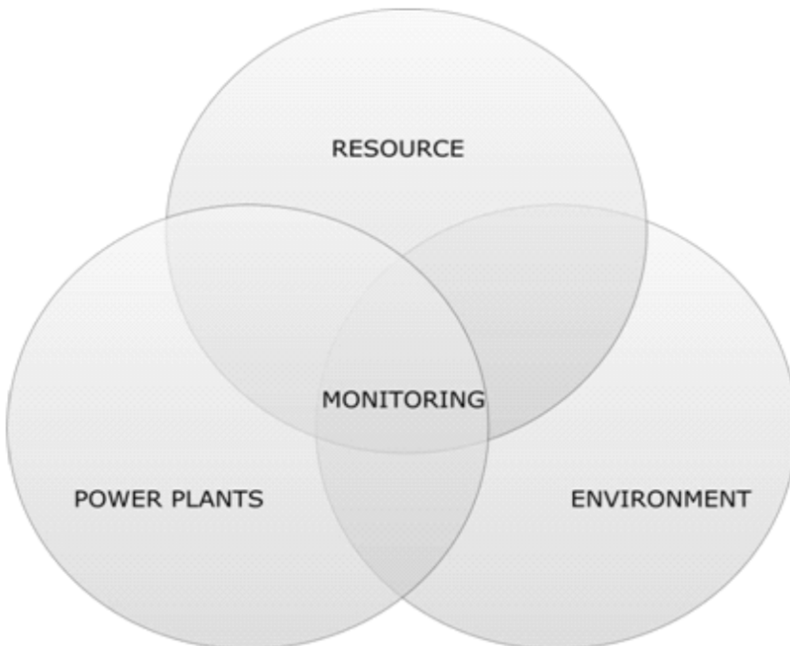

Figure 11: *The monitoring of geothermal utilisation can be divided into three main sectors (Ketilsson et al., 2009)*

CONCLUSION AND RECOMENDATIONS

Dominica has the volcanic setting and range of surface thermal activity that are typical of many large commercially developed geothermal fields around the world with estimated potential of 1.4 GW.

In this report the current energy development in Dominica is analysed by characterising the current generation mix, establishing energy baseline and load profile, grid reliability constraints and stability requirements and the possibility of exporting clean energy to nearby French islands is discussed. In the early 1960's, hydropower met approximately 90% of electricity generation but today only 23% are generated with hydro. The installed capacity in year 2008 is 27.6 MW with peak demand at 14.6 MW and base load of 7.2 MW. Electricity generation was equivalent to 87 GWh. It is estimated that a 15 MW geothermal power plant could generate enough electricity for the home market, with 50% load factor and combined generation with the existing hydropower plants. With consumer price currently at around 0.33 US$ / kWh it is likely that a geothermal power plant is highly feasible. Although domestic market for electricity is low, the nearby French islands, Martinique and Guadeloupe, consume in total 2.8 TWh mostly produced with diesel generators. It is estimated that the islands could easily import 50 MW each of baseload.

Stakeholder partnership has been established with (1) Regional Councils of Guadeloupe and Martinique and other development agency partners to continue research into the feasibility of geothermal development in the Wotten Waven area and of interconnectivity between Dominica and Guadeloupe and Martinique for geothermal power transmission and (2) with a private developer, West Indies Power, at the Galion Soufriere area for a development of a 15 MW geothermal power plant for the home market.

The Independent Regulatory Commission was established by the Electricity Supply Act No. 10 of 2006. This reform should lead to the unbundling of the privately owned monopoly, and further lead to the establishment of successor companies; electricity generation companies, one transmission company and a number of distribution companies.

The following are recommendations of NEA to the Ministry of Energy in Dominica:

Energy Market in Dominica and Nearby Islands

1. The NEA has analysed the current generation mix, the energy baseline and load profile. The conclusion is that a 15 MW geothermal power plant could generate enough electricity in combination with current hydropower plants for the home market.

2. The NEA has analysed grid reliability constraints, efficiency and stability requirements. The conclusion is that SAIDI hours and system losses are very high. It is recommended that the distributor of electricity should provide an analysis of the problem and suggest amendments to the grid and metering.

3. Half of the diesel generators are high speed, consuming more fossil fuel then medium speed diesel generators. This reduces the efficiency and increases the cost. Further instalments of diesel generators should only be high efficiency diesel generators. The Ministry could enforce this in the legal framework.

4. The NEA has analysed briefly the possibility of exporting clean energy to nearby islands. It is obvious that a large energy market is close by and likely that building e.g. a 100 MW geothermal power plant is a feasible choice for all stakeholders. It is estimated that both Martinique and Guadeloupe could easily import 50 MW of base load each.

Resource Assessment and Pre-Feasibility Studies

5. The NEA has analysed briefly the hydropower potential in Dominica. The NEA agrees with GTZ that it is likely that rehabilitation of the current hydropower plants is a feasible choice. The experience of combined utilisation of hydropower and geothermal in Iceland is quite positive. The NEA thus recommends combined utilization of those two renewable resources.

6. The NEA has analysed the geothermal energy potential on Dominica. Dominica has the volcanic setting and range of surface thermal activity that are typical of many large commercially developed geothermal fields around the world. There is likely an exploitable geothermal resource beneath the Wotten Waven area and probably other geothermal systems can be found.

Energy Policy and Legal Framework

7. An important aspect of geothermal development is effective policy making for sustaining a renewable energy society. In order to drive a clean energy initiative, authorities in Dominica should establish an energy policy clearly stating the target for 2020 in terms of share of renewable electricity generation, system losses and grid reliability and how the authorities intend to achieve that goal.

8. The Ministry of Energy should as well establish evaluation criteria as part of an environmental impact assessment as to inform the developer of what the authorities request for prior to assessing the environmental impact and granting licenses for utilisation of geothermal resources.

9. As a vision the Government could state that it aims at generating 90-100% of electricity with geothermal and hydropower which easily could have already been achieved with the abundant geothermal and hydropower potential in the country. This could set precedence to service providers and developers to look further into harnessing domestic renewable resources.

   Decrease System Losses:

   a. 2015: Reduce system losses by X%; X GWh generated; X GWh sold
   b. 2020: Reduce system losses by X%; X GWh generated; X GWh sold

   Renewable Energy Installations

   c. 2015: X MW (X% of projected demand)
   d. 2020: X MW (X% of projected demand)

   GHG Emissions Reductions:

   a. X% reduction in diesel consumption/X% reduction in GHG (TOC)

10. The NEA has suggested what data the developer should turn in to the Compliance Officer which could be enforced in a power plant license like in Iceland or in a regulation. Since the resource is owned by the state this data should be made public each year in e.g. the annual report of WIP on Nevis:

    a. The amount of fluid extracted from or reinjected into each well in the geothermal field, each month.

b. The temperature of the water reinjected into the geothermal reservoir each month.
c. Results of water level measurements in wells in which the water level can be measured and are within the geothermal field.
d. The pressure changes or drawdown determined in the geothermal reservoir.
e. The results of measurements of the enthalpy of the fluid from every production well in the geothermal field.
f. Chemical analysis of the geothermal water (and steam, if appropriate).
g. Results from simulations of the geothermal reservoir.
h. Results of measurements made to monitor changes in the geothermal reservoir.
i. Information on drilling in the industrial area.
j. A resume of improved understanding of the physical characteristics of the geothermal reservoir based on the results of the latest drilling.

Looking Ahead

11. The Ministry of Energy has already a stakeholder partnership with West Indies Power on Soufriere site and with the Regional Councils of Guadeloupe and Martinique and other development agency partners to continue research into the feasibility of geothermal development in the Wotten Waven area (INTERREG III B). As part of the INTERREG III B programme, a legal framework for geothermal development will be created.

12. Due to the lack of technical know-how on geothermal energy within the Ministry of Energy, NEA recommends that the Ministry of Energy should seek independent peer review. The peer review panel would assist the authorities to take the proper measures as to secure proper geothermal development for the next decades. The cost of this review can be made part of the license fee.

13. The Ministry of Energy and IRC could seek training, e.g. through the programmes offered by the UNU-GTP. The six months training in Iceland is open for all Caribbean SIDS that have geothermal resources and an energy policy that aims at utilization of these, and have qualified candidates. The Ministry of Energy can greatly benefit from the programmes offered by the UNU-GTP in Iceland and short courses around the world. The NEA therefore recommends that Dominica will be offered to participate in UNU-GTP.

The Icelandic Proven Model of Transition

14. The Icelandic nation has prevailed in a country with eruptions every five years and we have learned to harness this resource in harmony with nature, and in ways we thought never to be possible a century ago. Today, annual savings of heating houses with geothermal instead of oil amount to 400 million USD per year, 3% of the state budget and 12% of imported goods. The average electricity price to consumers is 7 cents per kWh excluding VAT. This is truly a result of an effective energy policy and level of education as the public in Iceland understands the greatness of this resource and its potential and are aware of both the positive and negative sides of its utilization.

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