

An Assessment of the Socio-economic and Marine Environmental Impacts Associated  
with the St. Kitts and Nevis Geothermal Energy Interconnectivity Project

By

*Randel Thompson*

Submitted in partial fulfillment of the requirements for the degree  
of  
Master of Marine Management

at

Dalhousie University  
Halifax, Nova Scotia

November 2014

© *Randel Thompson, 2014*

## Table of Contents

<b>List of Illustration.....</b>	<b>vi</b>
<b>List of Tables.....</b>	<b>vii</b>
<b>Abstract.....</b>	<b>viii</b>
<b>List of Abbreviations.....</b>	<b>ix</b>
<b>Acknowledgements .....</b>	<b>x</b>
<b>CHAPTER 1: GENERAL INTRODUCTION.....</b>	<b>1</b>
<b>1.1 Introduction.....</b>	<b>1</b>
<b>1.2 Assumptions and Limitations.....</b>	<b>2</b>
<b>1.3 Background of Study.....</b>	<b>3</b>
1.3.1 Historical Context.....	3
1.3.2 Location and Population.....	6
1.3.3 Economy.....	6
1.3.4 Governance.....	7
<b>1.4 Research Question.....</b>	<b>8</b>
<b>1.5 Methodology.....</b>	<b>9</b>
<b>CHAPTER 2: ST. KITTS AND NEVIS ELECTRIC SYSTEMS.....</b>	<b>10</b>
<b>2.1 St. Kitts Electric System.....</b>	<b>10</b>
<b>2.2. Nevis Electric System.....</b>	<b>10</b>
<b>2.3 St. Kitts and Nevis Energy Dilemma.....</b>	<b>11</b>
<b>CHAPTER 3: RENEWABLE ENERGY ALTERNATIVES.....</b>	<b>14</b>
<b>3.1- Bio-energy Project.....</b>	<b>14</b>
<b>3.2- Wind Energy Project.....</b>	<b>14</b>

<b>3.3 Solar Energy Project.....</b>	<b>15</b>
<b>3.4 Geothermal Energy Project.....</b>	<b>16</b>
<b>3.5 Wastes to Energy Project.....</b>	<b>16</b>
<b>3.6 Comparative Analysis of Wind Energy versus Geothermal Energy.....</b>	<b>17</b>
<b>CHAPTER 4: ST. KITTS AND NEVIS GEOTHERMAL ENERGY INTERCONNECTIVITY PROJECT .....</b>	<b>23</b>
<b>4.1 Description of Proposed St. Kitts and Nevis Geothermal Interconnectivity Project.....</b>	<b>23</b>
<b>4.2 Geographic Characteristics of “The Narrows” .....</b>	<b>25</b>
<b>4.3 Analysis for the Justification of St. Kitts and Nevis Electrical Interconnectivity Project.....</b>	<b>26</b>
<b>CHAPTER 5: OVERVIEW OF SUBMARINE ELECTRICAL CABLES.....</b>	<b>30</b>
<b>5.1 Submarine Electrical Cables.....</b>	<b>30</b>
<b>5.2 Submarine Electrical Cables (AC vs. DC).....</b>	<b>30</b>
<b>5.3 St. Kitts- Nevis and Nevis-Puerto Rico Interconnections.....</b>	<b>31</b>
<b>5.4 Impacts of Submarine Electrical on the Marine Environment.....</b>	<b>32</b>
<b>CHAPTER 6: ANALYSIS OF THE GEOTHERMAL ENERGY INTERCONNECTIVITY PROJECT.....</b>	<b>34</b>
<b>6.1 SWOT Analysis of Geothermal Energy Interconnectivity Project.....</b>	<b>34</b>
<b>6.1.1 Evaluation of SWOT Analysis.....</b>	<b>35</b>
<b>6.1.2 Critical Issues.....</b>	<b>36</b>
<b>6.2 PESTLE Analysis of Geothermal Energy Interconnectivity Project.....</b>	<b>39</b>
<b>6.2.1 Political.....</b>	<b>41</b>
<b>6.2.2 Social.....</b>	<b>42</b>
<b>6.2.3 Economical.....</b>	<b>44</b>

6.2.4 Technology.....	44
6.2.5 Legal.....	45
6.2.6 Environmental.....	46
<b>6.3 Discussion.....</b>	<b>49</b>
6.3.1 Impacts of Submarine Electrical Cable on the Marine Environment.....	49
6.3.2 Impacts of Coastal Development on the Marine Environment.....	50
<b>CHAPTER 7: CONCLUSION AND RECOMMENDATIONS.....</b>	<b>56</b>
<b>7.1 Conclusion.....</b>	<b>56</b>
<b>7.2 Recommendations.....</b>	<b>59</b>
<b>REFERENCES.....</b>	<b>63</b>
<b>APPENDIX.....</b>	<b>69</b>

## List of Illustrations

<b>Fig 1. Showing the location of St. Kitts and Nevis and the delineation of its EEZ.....</b>	<b>5</b>
<b>Figure 2. Showing the location of the proposed Geothermal Plant and the Prospect Power Station.....</b>	<b>23</b>
<b>Figure 3. Showing the proposed submarine cable route of the St. Kitts and Nevis Interconnectivity Project.....</b>	<b>24</b>
<b>Figure 4. Marine Habitat Map of The Narrows.....</b>	<b>25</b>
<b>Figure 5. Peak Demand and Operational Capacity for St. Kitts for the period 2005-2020.....</b>	<b>27</b>
<b>Figure 6. Peak Demand and Operational Capacity for Nevis for the period 2005-2020.....</b>	<b>27</b>
<b>Figure 7. All the external environmental factors (PESTLE factors).....</b>	<b>39</b>
<b>Figure 8. Showing paths of the submarine electrical cables though archipelagic waters of a section of the Eastern Caribbean ...</b>	<b>46</b>

## List of Tables

<b>Table 1. Showing Key Facts of St. Kitts and Nevis.....</b>	<b>5</b>
<b>Table 2. Comparison between wind and geothermal energy.....</b>	<b>17</b>
<b>Table 3. St. Kitts and Nevis Geothermal Interconnectivity Project SWOT Analysis.....</b>	<b>34</b>
<b>Table 4. Ranking of strengths.....</b>	<b>35</b>
<b>Table 5. Ranking of weaknesses.....</b>	<b>35</b>
<b>Table 6. Ranking of opportunities.....</b>	<b>36</b>
<b>Table 7. Ranking of threats.....</b>	<b>36</b>
<b>Table 8. PESTLE Analysis for the Geothermal Interconnectivity Project.....</b>	<b>40</b>
<b>Table 9. Summary of Benefits and Negative Effects of the St. Kitts and Nevis.....</b>	<b>58</b>
<b>Table 10. Energy consumption forecast for St. Kitts and Nevis.....</b>	<b>69</b>

## Abstract

Thompson. R., 2014. An Assessment of the Socio-economic and Marine Environmental Impacts Associated with the St. Kitts and Nevis Geothermal Energy Project [Graduate Project]. Halifax, NS: Dalhousie University.

Caribbean islands, St. Kitts and Nevis inclusive, are suffering from high fuel cost to produce electricity. The cost of electricity has been stifling economic development and standard of living. Fortunately St. Kitts and Nevis possesses large geothermal energy resources, which can be the key to economic development and improving standard of living. There is a proposed geothermal energy electrical interconnection project for both islands that seeks to transfer surplus electrical energy from Nevis to St. Kitts. It is important to assess the potential socio-economic and marine environmental impacts to determine if this project is sustainable. A SWOT and PESTLE analysis was done to get a general understanding of the project. This analysis facilitated further identification and examination of potential socio-economic and marine environmental impacts associated with the project. From the assessment, the potential marine environmental impacts caused by the submarine cable were deemed localized and temporary. The social and marine environmental impacts caused by economic growth and development can be mitigated by the use of proper planning and management. As a result, the St. Kitts and Nevis geothermal energy interconnectivity project is deemed socially and environmentally sustainable.

*Keywords:* economic growth; socio-economic; SWOT Analysis; PESTLE Analysis; localized; interconnectivity; assessment; sustainable; socially; environmentally

**\*\*Disclaimer:** The research was carried out during the period of January 2014 to October 2014; hence data used in this graduate project may not reflect the current state of affairs.

## **List of Abbreviations**

MW: Megawatt

KWh: kilowatts per hour

NSRL: National Renewable Energy Laboratory

IPCC: Intergovernmental Panel on Climate Change

OAS: Organization of American States

EEZ: Exclusive Economic Zone

ECPA: Energy and Climate Partnership of the Americas

EMF: Electromagnetic Field

WIP: West Indies Power Company

CREDP: Caribbean Renewable Energy Development Programme

OSPAR: Oslo and Paris Convention

PSA: Partial Scope Agreement

IMF: International Monetary Fund

SKELEC: St. Kitts Electrical Company Ltd

NEVLEC: Nevis Electrical Company Ltd

REPs: Renewable Energy Projects

GoSKN: Government of St. Kitts and Nevis

GSII: Global Sustainable Energy Islands Initiative

NREI: Nevis Renewable Energy International Ltd

HVDC: High Voltage Direct Current

HVAC: High Voltage Alternating Current

CBI: Citizen by Investment



## **Acknowledgements**

The journey to completing the graduate project wouldn't have been successful without certain key individuals. Throughout my project they have continuously offered support and guidance. No good deed should go unnoticed and therefore, I want to express my gratitude to everyone who played a role in this project.

Firstly I would like to thank my academic supervisor Mr. Hugh Williamson, who guided me and provided lots of encouragement, criticisms and suggestions to my project. Thanks to my second reader, Timothy Little for agreeing to read and evaluate this graduate project. Barbara Pike and team at the Maritime Energy Association were instrumental in helping me to get a greater understanding of environmental assessment by hosting me as an intern.

I would like to thank Mr. Frank Farrell of the Department of Marine Resources who provided a body of information that assisted me greatly. Thanks to Mr. Graeme Browne for providing the beautiful maps and special thanks to Philippa Ovonji-Odida for assisting with editing the graduate project.

Last but not least, I would like to thank the Marine Affairs Program; the staff for their wealth of knowledge, my classmates and my family for supporting me through the last 16 months.

## **CHAPTER 1: GENERAL INTRODUCTION**

### **1.1 Introduction**

The use of geothermal energy for the production of electricity is becoming increasingly popular. As of 2010 the reported installed capacity of geothermal energy was 50,583 megawatts thermal energy (MWt) worldwide, a 78.9 percent (%) increase from 2005 (Lund, Freeston, Boyd, 2010). The Intergovernmental Panel on Climate Change (IPCC) scoping meeting on renewable energy resources identified 90 countries with geothermal energy potential, including the Caribbean region. Geothermal energy exploration in the Caribbean region has accelerated since 2004 (Lund et al., 2010). Majority of the Eastern Caribbean countries are completely dependent on oil. Oil prices increased during 2004 to 2008 and greatly affected the economies of these small islands placing increased pressure on the standard of living of their inhabitants (NSRL/OAS, 2012). St. Kitts and Nevis has taken the initiative to find alternative renewable energy resources to reduce the burden of high fuel cost by proposing the development of a geothermal energy plant on Nevis. This geothermal energy plant would provide power to Nevis and is expected to expand to supply power to its sister island of St. Kitts with the use of a submarine electrical transmission cable. The installation of submarine cables has the potential to cause a wide range of potential socio-economic and marine environmental impacts due to their placement and operation (OSPAR, 2009). This research project will identify and assess these potential impacts of the proposed geothermal energy interconnectivity project in St. Kitts and Nevis.

## **1.2 Assumptions and Limitations**

This project is based on the key assumption that the geothermal energy interconnectivity project for St. Kitts and Nevis is still considered to be politically viable under the right circumstances. The project was supposed to be started in the first half of 2011 but never materialized for unknown reasons. It was initially supposed to be developed by the West Indies Power Company (WIP), but the company has been replaced with a new developer called the Nevis Renewable Energy International Ltd (NREI) by the Nevis Island Administration (Huie, 2014).

Another key assumption is that the proposed 10MW geothermal plant in Nevis can be upgraded to facilitate electrical energy demands in St. Kitts. The excess energy produced from the upgraded geothermal plant will be transferred to St. Kitts through an electrical submarine cable. This project has gained lots of political interest on both islands as it is viewed as a means to reduce the burdensome national debt and a way to generate revenue. A World Bank study found that the islands of St. Kitts and Nevis could benefit tremendously by potential savings from the geothermal interconnection project (World Bank/ Nexant, 2010).

This project also takes into consideration the prospects of a larger interconnectivity project involving other neighboring islands including Puerto Rico. The larger interconnectivity project was incorporated because the World Bank Report identified eight sub-regional electric markets that could be formed by interconnecting islands, with three of them involving Nevis. A pre-feasibility study done by KEMA for the Organization of American States (OAS) under the Energy and Climate Partnership of the America (ECPA) Caribbean Initiative, studied the prospect of a Nevis-Puerto Rico

(400MW), and Nevis-United States (U.S) Virgin Islands, 80 megavolts amperes (MVA) interconnection projects if the Nevis 500 MW geothermal energy potential is utilized (ECPA/OAS, 2013).

### **1.3 Background**

#### **1.3.1 Historical Context**

The Caribs who migrated from South America first inhabited the Federation of St. Kitts and Nevis for many years. They named the island Liamuiga, which stands for rich fertile lands. Christopher Columbus happened upon the island in 1493 on his second voyage and named it St. Christopher after himself (Griffiths and Nerenberg, 2005). In 1623 the island became a British colony after English settlers lead by Sir Thomas Warner took up residence on the island. The French took up residence on the island in 1627 shortly after (Griffiths and Nerenberg, 2005). The English and French in their quest to control the island and acquire more lands for tobacco and sugar cultivation, joined forces and wiped out the Carib's population. The island was shared peacefully between the Europeans until the Anglo-French rift developed that resulted in the British successfully controlling the whole island after a number of wars in 1782 (Griffiths and Nerenberg, 2005). Tobacco was the main cash crop cultivated on the island before it was replaced by sugar cane cultivation. The introduction of the sugar industry on the island also saw the introduction of African slaves to work on the sugar plantations. In 1967, St. Kitts, Nevis and Anguilla became an associated state of the United Kingdom with full internal autonomy (Griffiths and Nerenberg, 2005). Anguilla seceded from the tri-nations in 1980 to become an overseas British Territory. St. Kitts and Nevis gained its independence in 1983, and was able to acquire all the sugar lands from the former ruling plantocracy. In

1998, Nevis had a referendum in the quest to secede from St. Kitts but fell short of acquiring the two-thirds majority required by registering 62% majority who voted for secession (Byron, 2010). Since the 1980's, the economy of St. Kitts and Nevis has diversified to adapt to the fall in sugar prices (Griffiths and Nerenberg, 2005). This sugar industry that was deeply rooted into the society of the country operated for three hundred and fifty years before closing in 2005.

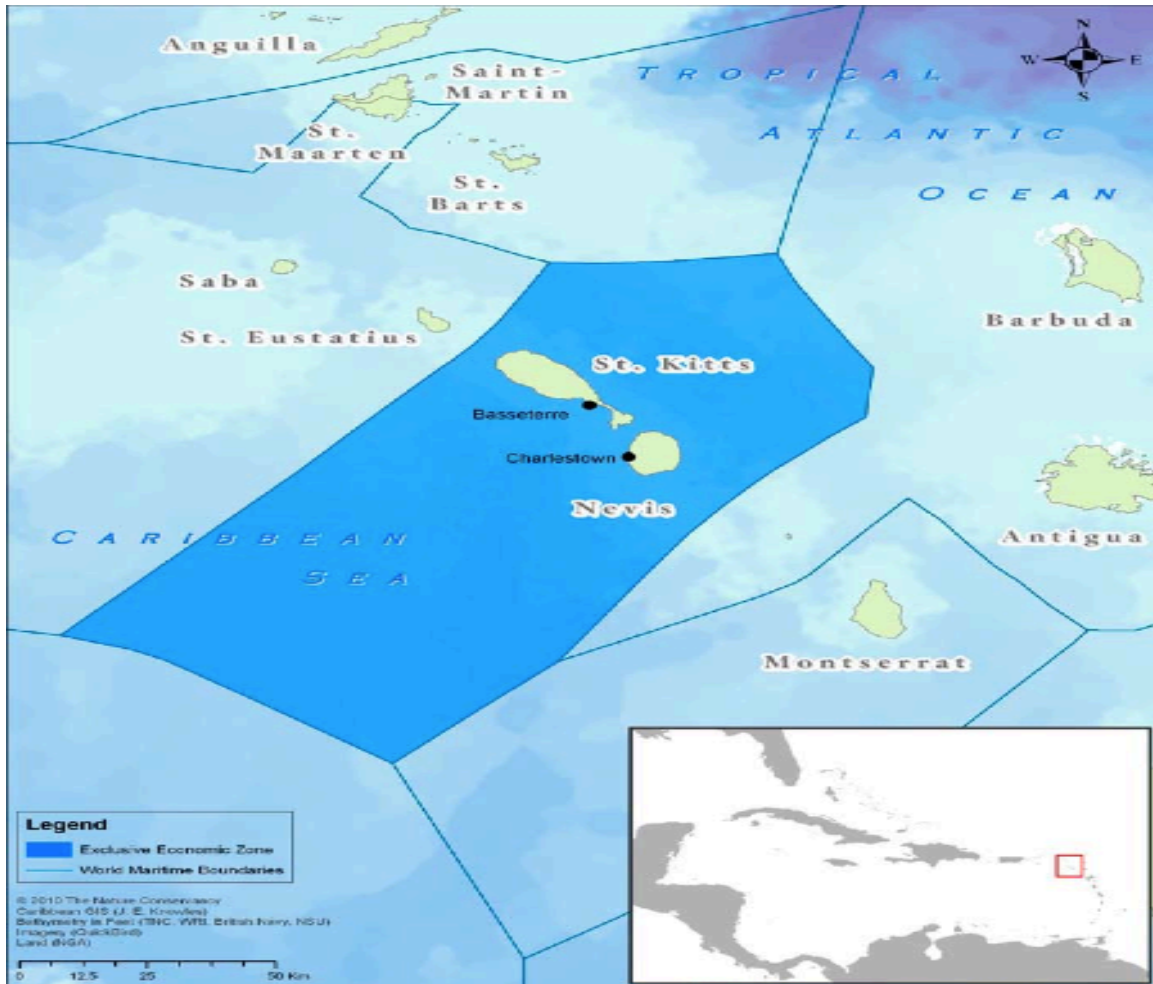
### **1.3.2 Location and Population**

St. Kitts and Nevis is the smallest country in the Americas and is located in the Eastern Caribbean centered on 17° 20' N, 62° 45' W (Buckner and Williams, 2011) (See Fig.1). Both islands are volcanic and experience a tropical maritime climate with heavy influence from the northeasterly trade winds. The annual average temperature is 27° C with little diurnal and seasonal variations (Agostini, Margles, Schill, Knowles and Blyther, 2010). Nevis is located 2 miles southeast of St. Kitts separated by a shallow channel called "The Narrows". St. Kitts is the bigger of the two islands with an area of 168 square kilometers (sq. km), coastline of 167 km and a population of approximately 38000 inhabitants (227 people/sq. km) (Buckner and Williams, 2011). Nevis on the other hand has an area of 94 sq. km, coastline of 94 km and a population of approximately 12000 inhabitants (128 people/sq. km) (Buckner and Williams, 2011). The Federation has a natural continental shelf of 845 sq. km, but is zone locked by territorial seas of St. Eustatius, St. Barts, Antigua and Barbuda, and an Exclusive Economic Zone (EEZ) that extends 20,400 sq. km (Agostini et al., 2010). The annual population growth rate is expected to continue increasing at 1.3 % until 2015 (Government St. Kitts and Nevis

(GoSKN), 2006). The low population growth is largely influenced by the high rate of migration.

**Table 1. Showing Key Facts of St. Kitts and Nevis**

Capital: St. Kitts Nevis	Basseterre Charlestown
Official Language	English
Government	Parliamentary democracy
Independence	19 September , 1983
Highest Point	1156 meters
Population	54000
GDP (Gross Domestic Product), 2014	13822.3
Literacy Rate	98%
Human Development Index	World ranking 72



**Fig 1. Showing the location of St. Kitts and Nevis and the delineation of its EEZ (From: Agostini et al., 2010)**

### **1.3.3 Economy**

Tourism, offshore export manufacturing and offshore banking dominate the economy of St. Kitts and Nevis. Since the closure of the 350 years sugar industry in 2005, St. Kitts economy has transitioned into a service-based economy that has seen remarkable development in its tourism industry (GSEII/OAS, 2007). Tourism is the country's main foreign exchange earner accounting for 60% of the foreign exchange. In 2009 tourism contributed 31.7% to the GDP and employed approximately 32.2% of the labor force (GSEII/OAS, 2007). Since the closure of the sugar industry, GoSKN has increased efforts to diversify the agricultural sector to enhance food security (GSEII/OAS, 2007). The country was very indebted. As of 2011, the public debt was estimated at US\$1.05 billion, approximately 200% of GDP (International Monetary Fund (IMF), 2011). The high public debt placed enormous constraints on the governance of the country, and in recent years led to the introduction of a 36 months Stand-By Arrangement (SBA) with the International Monetary Fund for the execution of a comprehensive debt restructuring program (IMF, 2014). St. Kitts and Nevis has rebounded strongly and has exhibited significant fiscal and debt sustainability and economic growth after a four years recession. Currently the country's economy benefits from a robust Citizen by Investment (CBI) Program that has been the main contributor for improving economic performance (IMF, 2014).

### **1.3.4 Governance**

A federal government, with a 1983 constitution establishes a parliamentary democracy. Despite being an independent nation, the head of state remains the queen of the United Kingdom, represented by the Governor General. A unicameral national assembly

comprised of 14 members makes federal laws and laws specifically for St. Kitts. Nevis has some autonomy where the Nevis Island Administration and Nevis Island Legislature carry out executive and legislative functions for Nevis (GoSKN, 2006). The Nevis Island Administration is responsible for a number of local ministries on Nevis such as the ministry of energy. The legal system in St. Kitts was derived from the English common law.

### **1.3.5 Energy**

In relations to energy generation, both islands have separate electrical companies, St. Kitts Electrical Company Ltd (SKELEC), Nevis Electrical Company Ltd (NEVLEC) in Nevis. The utility companies on both islands are governed by government appointed board of directors and are protected by law under monopoly status (CREDP/GIZ, 2013). Approximately 88% of the energy on both islands comes from imported oil products (Inter-American Development Bank (IDB), 2013). St. Kitts and Nevis is the only country in the Eastern Caribbean that provides subsidized tariffs that are below the cost of service. The development and implementation of the energy policy remains the obligation of the Ministry of Public Works, Housing, Energy and Utilities, and the Ministry of Finance. The importation, storage and sale of petroleum products is governed by the Petroleum Ordinance of 1954. The Geothermal Resources Ordinance, that was enacted in 2008 facilitates the exploration, drilling and use of geothermal resources (CREDP/GIZ, 2013).



## 1.4 Research Question

St. Kitts and Nevis has suffered dreadfully from the synergistic impact of the increase price of imported oil products and the recent recession. The country has been considering renewable energy projects (REPS) in order to mitigate the negative economic impacts of high cost of imported fuel, to improve social conditions and to reduce greenhouse gas emissions. St. Kitts and Nevis has taken into consideration the use of solar energy, biofuel from sugar cane, wind energy and geothermal energy. There is currently an on going 1.1 MW wind park in Nevis, in addition to a proposed geothermal energy project (NSRL/OAS, 2012).

A pre-feasibility study on the St. Kitts and Nevis geothermal energy project by OAS and the ECPA Institute concluded that the estimated cost, which includes the cost of the interconnection and the geothermal energy generation, will deliver power at a cost of Eastern Caribbean dollars (EC) 10.5 cents (¢) to EC 13.3¢ per kilowatts per hour (kWh) (ECPA/OAS, 2013). This estimated amount is less than the current 27¢ per kWh cost for the use of conventional diesel generators. This geothermal energy interconnection project has been given enormous support and is soon expected to accelerate in its development. This research project will identify and assess the potential socio-economic and marine environmental impacts of the proposed geothermal energy interconnectivity project. The following research question has been identified:

*“Is the St. Kitts and Nevis geothermal energy interconnectivity project environmentally and socially sustainable?”*

## **1.5 Methodology**

An extensive desktop study was done to gather general information on St. Kitts and Nevis, the electrical system of both islands and the description of the proposed St. Kitts and Nevis geothermal energy interconnection project. A SWOT analysis followed to identify the critical strengths, weaknesses, opportunities and threats associated with the project. The SWOT analysis facilitated and enabled a further understanding of the project. The strengths, weaknesses, opportunities and threats that were identified are important in assisting decision makers. A PESTLE analysis was also done to identify and analyzed potential issues that can be caused by the project. The issues noted set the basis for further assessment and discussion.

## **CHAPTER 2: ST.KITTS AND NEVIS ELECTRIC SYSTEMS**

St. Kitts and Nevis is heavily dependent on imported fossil fuel, mainly diesel, for electricity generation. The electric systems of both islands are typical of small islands where a main power station distributes electricity throughout the island.

### **2.1 St. Kitts Electric System**

The energy system of St. Kitts comprises of several diesel generators that produce 40 MW of electrical energy. The power generated accommodates the peak energy demand on the island of 24MW (ECPA/OAS, 2013). The electrical power from the Basseterre Need Must power plant is distributed through 11-kilovolts (kv), 60-hertz (Hz) radial feeders (ECPA/OAS, 2013). There are eight feeders currently in operation, which are each capable of serving 6-8 MW to their particular regions. There are also two important loads that are not connected to the SKELEC system. The Marriot Beach Resort and Royal Beach Casino at Frigate Bay, and Christophe Harbour development, which is located on the Southeast Peninsula. The Marriott Beach Resort and Royal Beach Casino operates on its own diesel generator that services a peak load of 2 MW (ECPA/OAS, 2013). Christophe Harbour development, which will comprise of a mega yacht marina, a golf course, two five-star hotels, restaurants and a private yacht club currently, operates on a load less than 1MW. However, there are future plans of using a diesel generator to facilitate its 10 MW load on completion of the project (ECPA/OAS, 2013).

### **2.2 Nevis Electric System**

Several installed diesel generators also power the energy system of Nevis. These diesel generators produce 13MW of electricity to service peak demands of 8 MW on the island (ECPA/OAS, 2013). The power generated from the Prospect power station is also

distributed through 11 kV, 60 Hz radial feeders throughout the island. There are five feeders, four of which form two circles. One of the circles distributes electricity around the island and the other circle distributes electricity within Charlestown (ECPA/OAS, 2013). The fifth feeder is devoted to the Four Seasons Resort, which is the most significant hotel on the island.

### **2.3 St. Kitts and Nevis Energy Dilemma**

Like most Caribbean islands, St. Kitts and Nevis is faced with increasing energy cost caused by increasing oil prices. World oil prices have been increasing over the last decade due to increasing international demand for oil. This creates a problem for small islands like St. Kitts and Nevis to secure energy supply. Global projections show that energy demands will increase by 50% in the next 25 years (GoSKN, 2010). The Economy of St. Kitts and Nevis is susceptible to increase in oil prices. In 2010, \$877 million Eastern Caribbean dollars (EC) was spent on imports, with \$61 million EC of the import amount spent on petroleum imports (GoSKN, 2010). The importation of petroleum constitutes a large proportion of the national budget and is one of the main contributors to the country's high national debt. This situation negatively affects the standard of living of the country and reduces the amount of funds that could be available for development and social programs. Despite the high petroleum import cost, St. Kitts load growth is forecasted to increase at a rate of 2.9% and 5.2% in Nevis (ECPA/OAS, 2013). The increase in electrical demands elevates the reliance on imported oil products, and will continue to diminish livelihood and economic advancement on the island.

In 2005 St. Kitts and Nevis along with other Caribbean islands established the Petro Caribe energy cooperation agreement with Venezuela (GoSKN, 2010). This

agreement was made to secure an energy supply as it became more competitive to secure due to increase global demands. The agreement also allows members to purchase oil on preferential financial terms. Under the agreement St. Kitts and Nevis purchases petroleum derivatives at market price but the federal government receives a credit of 60% of the value per barrel with an interest rate of 1% over 25 years (GoSKN, 2010). Despite this favorable arrangement, oil prices continue to increase making reducing energy cost a very important issue for the present federal government of St. Kitts and Nevis.

The GoSKN has made a concerted effort to diversify its energy sector. In his 2013 Budget Address, the Prime Minister expressed that a small island state such as St. Kitts and Nevis has no control over escalating oil prices, and it remains vulnerable to the effects of geopolitical forces and internal shift in the Middle East (GoSKN, 2013). In 2006, the country partnered with the Global Sustainable Energy Islands Initiative (GSEII) through the OAS's Caribbean Sustainable Energy project (CSEP) and the Eastern Caribbean Geothermal Energy Project (Geo-Caraïbes) ("St. Kitts and Nevis Profile", nd). The goal of this partnership is to overcome the barriers for the development of geothermal energy in the Caribbean, and develop a long-term national energy policy in conjunction with a short-term sustainable energy plan ("St. Kitts and Nevis Profile", nd).

The National Energy Policy seeks to transform St. Kitts and Nevis into a country that utilizes sustainable, clean, reliable, and more affordable energy alternatives (GoSKN, 2010). The island has been very proactive by facilitating the development of renewable energy projects before the development of a National Energy Policy. The government has also instituted waivers on imported and customs services charges on alternative energy and generating equipment such as solar photovoltaic panels, hydrogen fuel cells, wind

turbines and solar water heaters. In doing so, the government aims to integrate renewable energy into daily operations for both the public and private sector (GoSKN, 2010). With hope of becoming a green country that is completely free of fossil fuels for the generation of electricity, St. Kitts and Nevis is considering a number of renewable alternative energy sources.

## **CHAPTER 3: RENEWABLE ENERGY ALTERNATIVES**

Renewable energy projects (REPs) that are taken into consideration are biomass energy, wind energy, solar energy, geothermal energy and in more recent times waste to energy.

### **3.1 Bio-energy Project**

The sugar industry of St. Kitts and Nevis experienced serious financial losses and as a result ended its 350 years operation in 2005 (NRSL/OAS, 2012). The resulting 6000 hectares (ha) of abandoned lands were initially considered for the production of ethanol for the generation of electricity in 2007 (GSEII/ESG/OAS, 2007). An investigation done by GSEII reported that the production of electricity from biomass is economically feasible, with a production cost ranging from United States dollars (US) \$ 0.05 to US \$0.17 per kw/hr. (GSEII/ESG/OAS, 2007). There was also a proposition to replace the sugar cane with a fast growing bamboo-grass, which can be harvested year round. It was estimated that 120,000 tons of dry biomass could be produced from 4000 acres of land (Brederode and De Cuba, 2012). This biomass produce could have been used for the production of bio-oil to facilitate a 5MW bioenergy plant. However, in 2008 due to competition for land by the service sector and general public, the biomass to energy project never materialized.

### **3.2 Wind Energy Projects**

St. Kitts and Nevis has the potential to rely almost exclusively on renewable wind energy. Wind energy has blossomed into a mature global business and has made its way into the Caribbean. Over the last twenty years, the generation cost for wind energy has decreased by 50%, with massive improvements in power rating, efficiency, and

reliability. Wind energy has been considered by the GoSKN with Nevis currently benefitting from a 2.2 MW wind turbine park. There are prospects of this park expanding to 10MW in its second phase (Brederode and De Cuba, 2012; NRSL/OAS, 2012)

On the other hand, St. Kitts has considered a number of wind energy projects but none have been implemented yet. One of the early proposals was for the development of a 0.9-1.2 MW wind turbine park next to the Robert Llewellyn Bradshaw (RLB) International Airport (Brederode and De Cuba, 2012). This project proposal never materialized, but a recent proposal has been made for the development of a 5.4 MW wind turbine farm to be developed by the North Star Company in Bellvue (“Wind Farm Initiative”, 2014).

### **3.3 Solar Energy Projects**

St. Kitts and Nevis is exposed to constant sunlight all year round hence there is an opportunity to exploit solar energy. The solar intensity is very high compared to other regions as Europe or North America, thus the theoretical potential is expected to be large (De Cuba, 2006, p.63). In 2013, the government collaborated with the Republic of China (Taiwan) to open a 1.3MW solar energy farm (“Taiwanese Solar Panel”, 2013). This farm consists of 3500 solar panels, and produces electricity for the RLB International Airport. Speedtech, a local based Taiwanese Company, constructed the farm and opened a \$1.5 million solar panel factory at the C. A. Paul Southwell Industrial Site (“Taiwanese Solar Panel”, 2013). The Republic of China (Taiwan) has further partnered with the government to install solar streetlights along the main road between Sandy Point and St. Paul’s, along the Kim Collins Highway and Frigate Bay Road. The government recently



announced that the next set of affordable residential houses that will be built would have solar panels installed (“Taiwanese Solar Panel”, 2013).

### **3.4 Geothermal Energy Projects**

The Nevis Island Administration (NIA) established the geothermal energy bill in 2008. This bill was passed to facilitate the delineation and regulatory framework for the implementation of geothermal energy on Nevis. According to the United States Department of Energy (USDOE), Nevis is reported to have a geothermal energy potential of 500 MW (Koon Koon, 2012; Maynard-Date and Farrell, 2011). West Indies Power, the company initially responsible for the development of the geothermal energy project signed a power purchasing agreement with NEVLEC in 2009. The construction of a 10 MW plant in Nevis was supposed to come on stream in the first half of 2011, but never materialized. The newly formed NIA recently replaced WIP as project developer and has awarded the NREI with the job to develop geothermal energy on the island.

### **3.5 Wastes to Energy Project**

The federation has recently added waste to energy projects to its list of potential renewable energy alternatives. The NIA is currently partnered with Omni-Alpha LLC, a company based in Baltimore, Maryland, United States, for the development of a waste to energy project. The company is expected to invest US \$20 million on renewable energy projects on the island (Bacchus, 2014). St. Kitts is experiencing an increase in the amount of waste produced from households and commercial entities as a result of the country’s development. Thus the Federal government is considering waste to energy as a viable substitute to fossil fuel energy. The government is pursuing a joint venture between Nano Energy Incorporated and NICOL International Services for the development of a 14MW

waste to energy plant (Dixon, 2013). This plant is expected to be built over a two-year period, will utilize 180 tons of waste daily and the electricity energy generated will be sold to SKELEC (Dixon, 2013).

### 3.6 Comparison of Wind Energy vs. Geothermal Energy

Worldwide, wind energy is considered as the only realistic competitor to geothermal energy (Hohmeyer and Tritton, 2008). Therefore, these are the two main alternatives being considered by St. Kitts and Nevis to assist with decreasing reliance on fossil fuels for electricity generation. This section compares both options based on cost, technology, advantages, disadvantages and environmental issues.

**Table 2. Comparison between wind and geothermal energy**

Categories	Wind Energy	Geothermal Energy
Electricity Produced by	Wind	Geothermal steam
Electrical Energy Cost	5-15¢US/ kWh	2-10¢ US/kWh
Technology	*Mature Technology  * Modern Wind Turbines	* Mature Technology  *EGS (Enhance geothermal systems) *Binary Plant
Advantages	*Wind energy is widely distributed  * Less than 10% thermal lost  * Reduction in carbon emissions  * No mechanical noise  * Wind turbine manufacturing provide income in the rural areas	* There is ample geothermal energy resources  *Continuous source of power  * Significance experience in geothermal energy  * Geothermal energy is independent on weather conditions  *Can be used for baseload and peak power plants  * Can make a serious contribution towards reducing emission of greenhouse gases
Disadvantages	*Wind velocity may vary	* Site specific

	*High upfront capital cost * Increase competition for land	* High upfront capital cost
Environmental Issues	* Visual Impacts  * Noise produce by generators, yaw drive, gear box and blades  * Negatively affect birds and bats (habitats, foraging, breeding and impact collision)	*Geothermal fluids contain variable chemical quantity of nitrogen (N), carbon dioxide (CO <sub>2</sub> ), hydrogen sulfide (H <sub>2</sub> S), ammonia (NH <sub>3</sub> ), mercury (Hg), radon (Rn) and boron (B).  *Release of CO <sub>2</sub> and H <sub>2</sub> S into the atmosphere

Wind turbines are used to generate electricity from the kinetic power of the wind (World Bank/Nexant, 2010, p.103). Approximately 0.5% of global electricity generation is provided by wind energy, with most produced in Europe. The electrical energy cost ranges from 5-15¢ US/kwh (Fridleifsson, 2001). The cost of production of wind energy has reduced as a result of the massive improvements made over the last 25 years in the wind energy sector. Wind energy technology is now categorized as mature technology, with the main technological improvement being the design of the wind turbines. These have led to increased efficiency and lower construction costs. Modern Turbines are able to generate high quality network frequency electricity, and to operate continuously for over 20 years. The blades of the turbines are now made of glass polyester and glass epoxy (Hohmeyer and Tritton, 2008). The size of turbines and their associated energy output has constantly increased over the years. In the 1980's, a wind turbine produced 20-60kw, while one produces 6000 kW per unit today (Hohmeyer and Tritton, 2008). There are two main types of wind turbines used for electrical generation. There are those with a horizon axis, which is comprised of 2-3 blades that are operated facing the wind, and

those with a vertical axis (World Bank/Nexant, 2010).

The use of wind energy has many advantages. It is widely distributed around the world, which allows many countries to tap into the renewable source. Wind speed that averages 11 miles per hour is required for grid-connection application. Any wind speed lower is adequate for connecting mechanical applications and charging batteries (World Bank/Nexant, 2010). The Caribbean islands are fortunate because average wind speed in the region exceeds 11 miles per hour on most islands. Wind energy operations also benefit from the fact that only 10% thermal heat is lost from the system, which means most of it is being transformed into electrical energy (Hohmeyer and Tritton, 2008). The advancement of the wind turbine has included the rectification of mechanical noise, which was a former disadvantage associated with wind energy operations. Another important advantage of switching to wind energy is that it brings revenue to rural areas where few jobs are available. Wind turbine manufacturing and wind farm operations will create new jobs where they occur. There is no carbon emissions directly related to wind turbine operations. Therefore the use of wind energy can mitigate climate change.

Disadvantages of wind energy include the large upfront capital cost for the development of wind farm projects, the variation of wind energy, and the increase in competition for lands that could be otherwise used for development. The strength of wind varies constantly. As a result, wind turbines will not produce a constant amount of electricity. Occasionally, they will not produce any electricity. Due to these factors wind energy has a capacity factor of approximately 21%. Environmental issues of wind energy are visual impacts, noise pollution, and negative impacts on birds and bats. The visual impact of wind energy stems from the perception of wind turbine farms by nearby

communities. Construction of a large number of wind turbines can be an eye sore to many. However, wind turbines are also welcomed as a means of improving environmental conditions, hence are sometimes viewed in good light. Despite rectifying mechanical noise associated with wind turbines. Their generators, blades, yaw drives, and gearboxes still generate noise (aerodynamics). This noise affects people living nearby as well as animals. Due to their height and position within wind streams, turbines are able to negatively affect birds and bats that collide with turbines. Destruction of habitats can also result, which negatively affects these animals' foraging and feeding (Hohmeyer and Tritton, 2008). Despite the progress made by wind energy over the last 25 years, there is still a lot of room for improvements in relation to large-scale electricity production.

On the other hand, geothermal energy is derived from the natural heat of the earth primarily due to the naturally radioactive isotopes of uranium, thorium and potassium (World Energy Council, 2010, p.453). Geothermal energy produces about 0.3% of the world global electricity generation, with a stable long-term growth of 5% (Hohmeyer and Tritton, 2008). The use of geothermal energy has increased drastically over the last decade. The current electrical energy cost is less than that of wind, at a price of 2-10 US ¢/kWh (Fridleifsson, 2001).

Geothermal energy was first used to produce electricity commercially in 1913. Since then, the technology has improved tremendously to advance efficiency and reduce the cost for the generation of electricity. Today, geothermal energy is categorized as a mature renewable energy alternative. The major technological advancements are Binary Cycling, which came on in the 1980's, and Enhance Geothermal Systems (EGS). Binary Cycling enables the use of geothermal resources at low temperatures of about 90°C

(Hohmeyer and Tritton, 2008). This process utilizes heat exchangers that are more volatile than water, to drive turbines. EGS entails constructing an extended fracture network in the deep subsurface at 150-200°C to act as new pathways (Hohmeyer and Tritton, 2008). Cold water that comes from the surface and water from deep wells are facilitated through this deep reservoir through injection and production wells before returning to the surface (World Energy Council, 2010, p.456). The surface installation system for the generation of power completes the circulation system.

Geothermal energy has many advantages. Its resources are ample and found in large quantities. Unlike wind energy, it is independent of weather conditions and the production of electricity stays fairly constant with time. As a result, geothermal energy has a capacity factor above 75%, compared to wind energy's 21% (Hohmeyer and Tritton, 2008). Another advantage is that geothermal energy can be utilized for base load and peak load demands. However, it is normally used to facilitate base load demands. In terms of large-scale electrical energy production geothermal energy is more suited than wind energy, as it has been used at the scale of hundreds of MW for installed electric capacity. Due to its low CO<sub>2</sub> emission, geothermal energy can contribute towards mitigating climate change. There is a large amount of experience in the field of geothermal energy, which plays to its advantage. The disadvantages of geothermal energy are related to its high upfront capital start-up cost. This necessary cost can be very discouraging to the investors. Geothermal energy operations are very site specific, which can cause conflict with other land use objectives, and increase expense based on where the geothermal energy resources are located.

There are environmental issues associated with geothermal energy operations.

Varying quantities of gases mentioned in table 1, are inside geothermal fluid, hence there is a fear of these gasses getting into the atmosphere (Fridleifsson, 2001). However, most of the disposable fluid is re-injected in drill holes and not released into the environment. In the case of hydrogen sulfide, it is removed from the geothermal steam at the geothermal plant preventing it from entering into the environment. The amount of CO<sub>2</sub> emission from high temperature geothermal fields used for electricity ranges from 13-380 grams (g)/ kWh (Fridleifsson, 2001). In comparison to other energy resources such as natural gas, oil and coal, this is a substantially low value figure.

The Caribbean region is fortunate to have both geothermal energy resources and sufficient wind resources at their disposal. In St. Kitts and Nevis, wind energy has been deemed a top option. One factor that must be taken into consideration is the availability of land to foster its development on these small islands or looking at prospects of offshore operations, especially if there is consideration for expansion of projects in the future. The prospect of geothermal energy in St. Kitts and Nevis is of great importance, especially sine there is a proposal to develop a plant with the capacity to transfer 400MW of energy to Puerto Rico. Wind energy and geothermal energy should not be viewed as competitors for St. Kitts and Nevis, but rather complimentary solutions to the present energy problem caused by the high fuel cost.

## CHAPTER 4: ST. KITTS AND NEVIS GEOTHERMAL ENERGY

### INTERCONNECTIVITY PROJECT

#### 4.1 Description of Proposed St. Kitts and Nevis Geothermal Interconnectivity Project

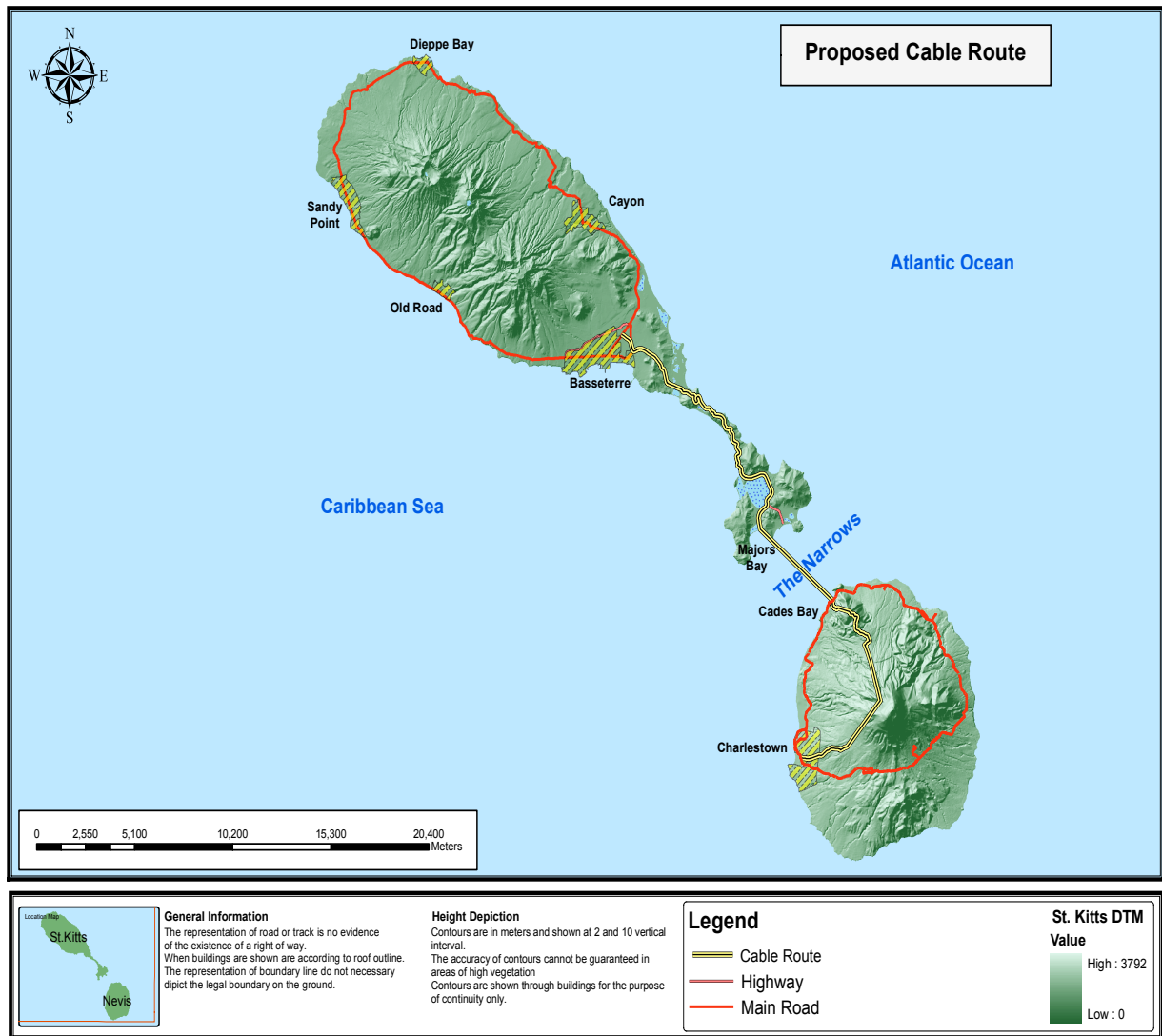
The geothermal power facility will be built in Spring Hill, Nevis, (see figure 2). Three considerations have been made for the size of the geothermal power plant. In the initial stages, a 14MW or a 20MW geothermal power plant is being considered, with potential of an expansion to a 35MW power plant (ECPA/OAS, 2013). The geothermal power plant will operate at base load to facilitate the 8MW demand on Nevis. A 33kv cable has been proposed that will be deployed underground to connect the geothermal power plant to the local Prospect Power Station which feeds into the grid (ECPA/OAS, 2013).



**Figure 2. Showing the location of the proposed Geothermal Plant and the Prospect Power Station (From: ECPA/OAS, 2013)**



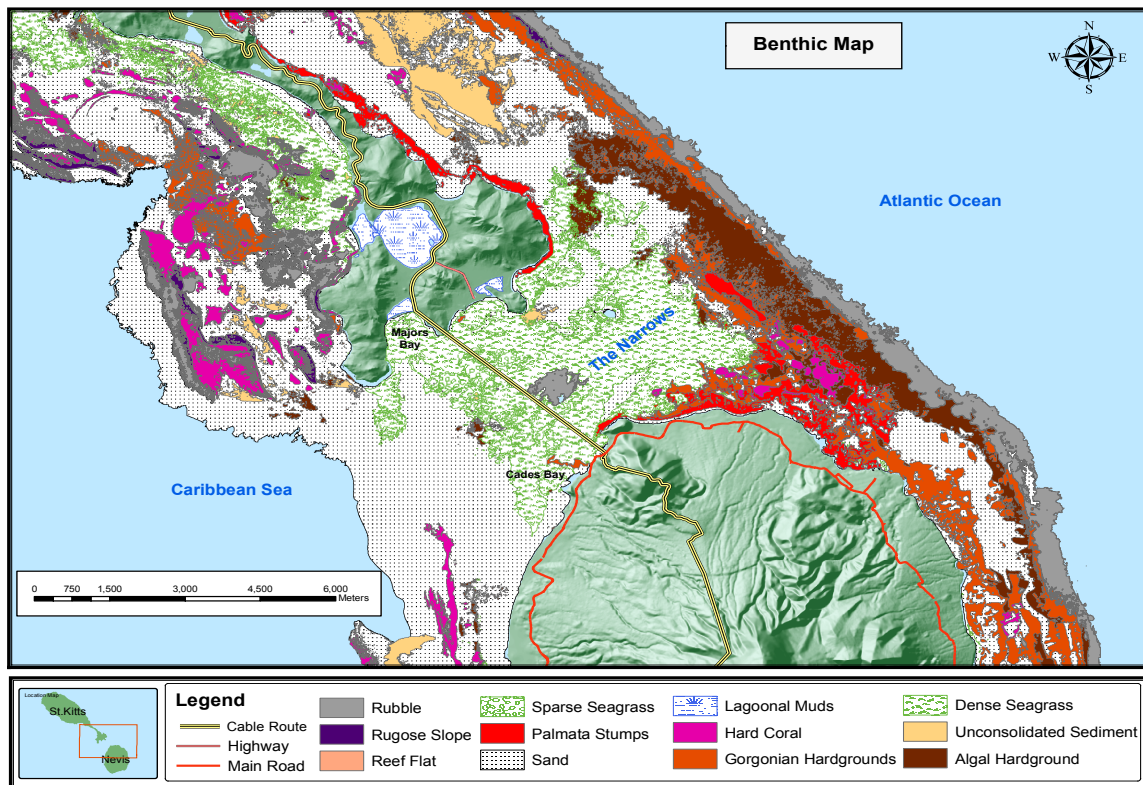
The remaining power from the proposed generation sizes will be sent to St. Kitts through a 3-miles buried HVAC submarine electrical cable (ECPA/OAS, 2013). The submarine electrical cable will be connected to substations on each end of Cades Bay, Nevis and Major’s Bay, St. Kitts, see figure 3.



**Figure 3. Showing the proposed submarine cable route of the St. Kitts-Nevis Interconnection (From: Department of Physical Planning, St. Kitts)**

## 4.2 Geographic Characteristics of “The Narrows”

The Narrows, which is the channel of water located between St. Kitts, South East Peninsula and Nevis, is 3.2km long with a maximum depth of 11 meters (m) (Brederode and De Cuba, 2012). Majority of the sea bottom is covered with sea grasses with small areas of rubble. Within The Narrows, hard corals, algal hardground, gorgonian hardground, unconsolidated sediments and sand can be found, (see figure 4). Major’s Bay, Cockleshell Bay and Banana Bay, which are located at the South East Peninsula on St. Kitts, are important nurseries for fishes, the Caribbean queen conchs (*Strombus gigas*), Caribbean spiny lobsters (*Panulirus argus*) and other marine life. The Department of Marine Resources has made a proposal for this area to become a marine protected area (MPA) in the near future.



**Figure 4. Marine Habitat Map of The Narrows (From: Department of Physical Planning, St. Kitts)**

### **4.3 Analysis for the Justification of St. Kitts and Nevis Electrical Interconnectivity Project**

The prefeasibility study done by KEMA for OAS included an economic feasibility analysis of the St. Kitts and Nevis AC interconnection project. The economic feasibility analysis took into consideration the cost of a 3-miles AC submarine cable, the cost for submarine cable transport including unloading cable cost for 3 weeks, submarine cable installation, preparing and connecting the existing St. Kitts feeder, install terminations, substations and operation and maintenance (O&M) (ECPA/OAS, 2013). The total delivered cost of geothermal electricity to St. Kitts was combined with the cost of interconnection and the cost of the geothermal plant in order to derive the cost of energy. It was found from their study that the cost of energy from the St. Kitts and Nevis geothermal energy interconnectivity project will range from EC10.5¢/kwh to EC15.3¢/kwh (ECPA/OAS, 2013). The justification of this project is based on the fact that the cost of energy for the islands is more than EC27¢/kwh (ECPA/OAS, 2013). In 2012, domestic and commercial consumers in St. Kitts were paying EC37¢/kwh and EC43¢/kWh respectively. As a result, the geothermal interconnectivity project is deemed economical and is expected to substantially reduce electricity cost.

In their study of the justification and feasibility of the electrical interconnection of St. Kitts and Nevis, Brederode and De Cuba looked at forecast demand of energy in order to determine the additional operational capacity of REPs that would be needed to service future demands. They stated that the manifestation of an energy demand forecast can indicate the location and timing of a possible electricity supply surplus or deficit (2012). Data from Stanley Consultants was acquired and extrapolated to produce an energy demand forecast from 2005 to 2020 (Brederode and De Cuba, 2012), (see figure 5). In the

case of Nevis, a multiple linear regression diagram was produced using historical data to determine the energy demand forecast from 2005 to 2020, (see figure 6).

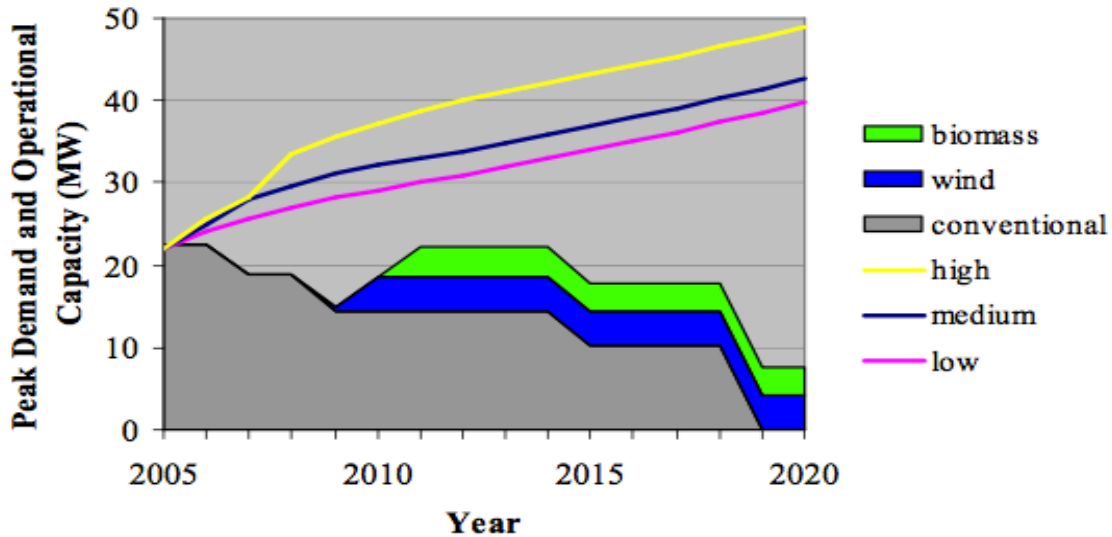


Figure 5. Peak Demand and Operational Capacity for St. Kitts for the period 2005-2020 (From: Brederode and De Cuba, 2012)

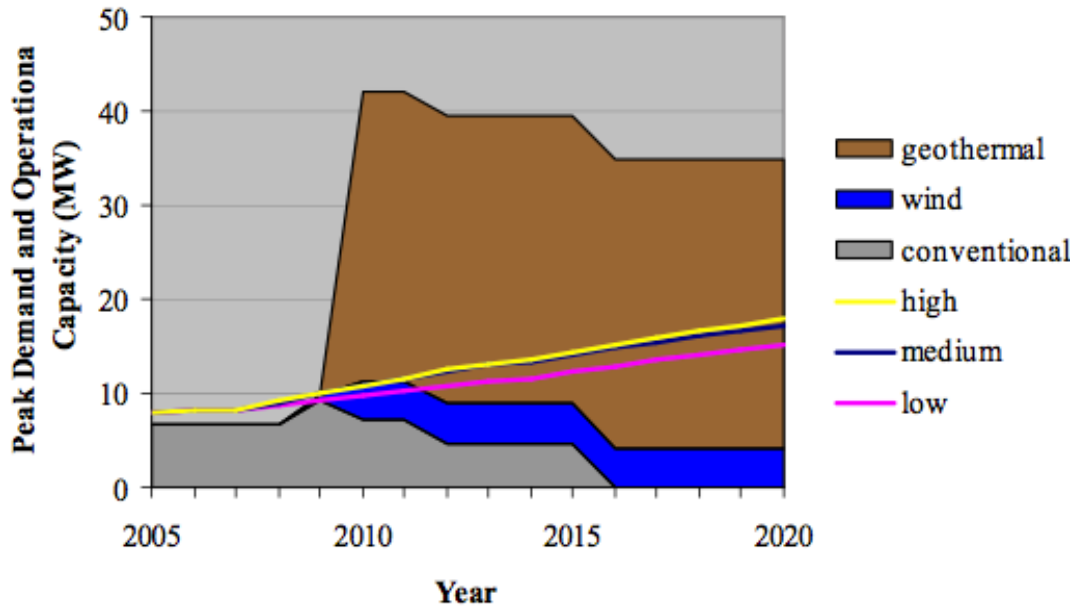


Figure 6. Peak Demand and Operational Capacity for Nevis for the period 2005-2020 (From: Brederode and De Cuba, 2012)

Figure 5 illustrates three energy demands, namely high, medium and low, each represented by lines. It also shows an area diagram that indicates conventional and REPs

operational capacity over time. The diagram shows a big difference between the peak demand projections, the operational capacity of the conventional diesel generators and the planned REPs of biomass and wind on St. Kitts over time. This shows that demand is projected to surpass supply over time. However, Nevis' peak demand and operational capacity diagram shows that the introduction of the REPs of geothermal energy and wind, along with the conventional diesel generator results in a surplus of energy. This result is mainly due to the proposed geothermal energy project. This was the main basis for the justification of the electrical interconnectivity project for St. Kitts and Nevis.

The studies done by KEMA for OAS, and Brederode and De Cuba, to justify the electrical interconnectivity project looked at two different but significant aspects for consideration. KEMA did an economic feasibility analysis, which is key in determining if the cost of power will be cheaper than the current cost of electrical energy produced by conventional diesel generators. The results show that the cost of energy from the geothermal energy interconnection project will be approximately EC14.93¢/kwh less than EC37¢/kwh that is being charged to consumers. On the other hand, Brederode and De Cuba produced an energy forecast for both islands from 2005 to 2020, which illustrates peak demands and operational capacity of conventional diesel generators and proposed REPs. This analysis was very important since it determined that St. Kitts will have an energy supply deficit while Nevis will have surplus supply. The excess energy that will be produced by the proposed geothermal energy project will be transferred to St. Kitts to facilitate its future supply deficit. Another factor to take into consideration is the increase of hotels that are expected to come on stream shortly that will increase the energy demanded. Kittitian Hill Resort, Hyatt Hotel, and the Pelican Bay Condominium Hotel

are multimillion-dollar ventures that are currently under construction in St. Kitts (Williams, 2014). The energy intensive manufacturing industry is also expected to increase with the implementation of the Brazil-Guyana-St. Kitts and Nevis Partial Scope Agreement (PSA). This agreement will give light manufacturing factories in St. Kitts duty-free access to potentially lucrative Brazilian markets (GoSKN, 2013). The expansion of the hotel and manufacturing sectors can result in the energy demand for St. Kitts and Nevis to be higher than the forecast produced from the study.

## **CHAPTER 5: OVERVIEW OF SUBMARINE ELECTRICAL CABLES**

### **5.1 Submarine Electrical Cables**

Submarine electrical cables are predominantly used today to transfer electricity between countries, as well as offshore installation such as renewable energy operation and oil platforms (Synder and Rondorf, 2011). The first submarine electrical cable was deployed in 1811 in Germany. Since then advancements have been made in the development of the efficiency of submarine electrical cables (Synder and Rondorf, 2011). There are two main types of submarine electrical cables, high voltage alternating current (HVAC) and high voltage direct current (HVDC). Both cable types are typically insulated by extruded plastic insulation of cross-linked polyethylene (XLPE) and ethylene propylene rubber (EPR), or by paper insulated and fluid filled insulation (World Bank/ Nexant, 2010). The demand for submarine electrical cables has increased drastically due to governments support for the increase use of renewable energy. This support stems from the high fossil fuel cost and the immediate need to reduce carbon emission to mitigate the negative impacts of climate change.

### **5.2 HVDC vs. HVAC Submarine Electrical Cables**

One of the first steps in any submarine electrical cable installation project is deciding between HVAC and HVDC. There are many aspects that determine the choice between both cables but the major aspect to consider is the length of the cable required. The sea depth, cost of cables and cost of additional facilities such as converters are also considered to determine which type of cable is most suitable for a particular project.

The capacitance of the cable plays an important role in the relationship of cable length to the choice of DC or AC. As the length of AC cables increases, the capacitance charging current also increases proportionately and eventually consumes all of the available real current (World Bank/ Nexant, 2010). As a result of this, DC cables are favored over AC cables with respect to long distances. AC cables are normally used for short to medium length interconnectivity projects. DC submarine cables will also be favored over its counterpart when the power transfer requirement is greater than 150-300 MW, the required length is 25 miles or greater, and it is also favored when AC transmission networks power transfer control, potentially may have serious problems (World Bank/ Nexant, 2010).

In relations to sea depth, submarine cables have to be sturdy enough to support the weight of the length of a cable to the depth it is deployed. This principle is very important for repair purposes, because the cable material must be strong enough to support the cable as it is being pulled from a particular depth. AC submarine cables have a guideline limit of 1000m in depth, while DC cables are able to be deployed in water depths of 1500m (World Bank/ Nexant, 2010).

### **5.3 St. Kitts -Nevis and Nevis-Puerto Rico Interconnection**

Due to the short 3 miles distance an AC submarine electrical cable has been proposed for the St. Kitts- Nevis interconnection. The use of a DC cable would have been more expensive due to the cost of converters needed to change AC to DC and DC back to AC (World Bank/ Nexant, 2010). As mentioned earlier, the depth of The Narrows is only 11m. This means that the present day technology is available to carry out this project



since the longest installed AC submarine cable is the Isle of Man- UK Mainland link, which is 105km (World Bank/ Nexant, 2010). However, a DC cable was chosen for the proposed interconnection project with Nevis and Puerto Rico. The use of a DC submarine electrical cable is favored because of the long distance of 280 miles and the depth of the St. Croix Valley of 1600m through which the submarine cable will pass. Present day technology is available since the deepest installation of a DC submarine cable recorded is the SAPEI (Sardinia-Italy) of 1650m (World Bank/ Nexant, 2010).

#### **5.4 Impacts of Submarine Electrical Cables on the Marine Environment**

The installation of submarine electrical cables can affect the marine environment by laying the submarine cable directly on the seabed, and by the vessels and machineries used during the installation and maintenance of the submarine cable. Some of the impacts caused by the interaction of the submarine electrical cable on the seabed are seabed disturbance causing displacement or disturbance of flora and fauna, increase turbidity, release of contamination and the alteration of sediments.

The diameter of these submarine electrical cables is 15 centimeters (cm) in width on average, and they are sometimes buried into the seabed to be protected from damage from anchors and fishing gears, or laid on top of the seabed (OSPAR, 2009). The laying of the submarine cable on the seabed can potentially affect benthic organism by disturbing the seabed, and by thermal radiation generated from the passing of electricity through the cable. Marine mammals and sensitive benthic organism can also be affected from electromagnetic fields and noise produced by the submarine electrical cable during operation, which can cause them to become disoriented (OSPAR, 2009). Turbidity

caused during the installation of the submarine cable can cause adverse effects on sensitive organisms that depend on a filtration mechanism like coral reefs and sea grass beds that require clear water for light to pass through for their survival. Protection of the submarine cables sometimes requires the introduction of a hard substrate that helps to protect the cable. This substrate may cause colonization of non-local flora and fauna on the seabed, which can cause instability to the natural benthic communities. Contamination caused by submarine cables only occurs when they are out of service, damaged and is left on the seabed for long periods of time, which allows certain chemicals to contaminate the marine environment (OSPAR, 2009).

The vessels that perform the installation of the cables can potentially cause noise pollution and visual disturbances. The noise and visual disturbances tend to affect seabirds that forage and rest close to the area where these cables are laid (OSPAR, 2009). These vessels also discharge waste and emission into the marine environment during their operations. Even though this is a temporary impact, it can still have adverse effects on certain organisms, such as seabirds, if cable installations are done when the seabird species are most sensitive towards changes, especially during mating season.

## CHAPTER 6: ANALYSIS OF THE ST.KITTS AND NEVIS GEOTHERMAL INTERCONNECTIVITY PROJECT

### 6.1 SWOT Analysis of the Geothermal Energy Interconnectivity Project

The purpose of the SWOT Analysis is to get a better understanding of the St. Kitts and Nevis Geothermal Energy Interconnectivity Project by identifying and analyzing its strengths, weaknesses, opportunities and threats. This analysis helps to highlight the most important issues and decision-making factors that should be taken into account for the development of the project.

**Table 3. St. Kitts and Nevis Geothermal Interconnectivity Project SWOT Analysis**

Strength	Weaknesses
<p>Internal factors:</p> <ul style="list-style-type: none"> <li>• Large geothermal resource reservoir with potential of 500MW</li> <li>• Geothermal resources are shallow</li> <li>• Potential to distribute energy to other nearby islands</li> <li>• Short and shallow interconnection distance</li> <li>• President and CEO of NREI, Mr. Thomas Drolet has 43 years of experience in public utility infrastructure (geothermal, natural gas, hydroelectric energy, nuclear and solar energy generation)</li> <li>• Experienced staff</li> <li>• Available present day technology</li> <li>• Available information from previous studies</li> </ul>	<ul style="list-style-type: none"> <li>• Small market demand</li> <li>• Lack of financing to complete project</li> <li>• Unstable political support from Federal Government</li> <li>• Uncertainty of environmental and social impacts</li> <li>• Lack of local policy and legislation for the fostering of renewable energy development</li> </ul>
Opportunities	Threats
<p>External factors:</p> <ul style="list-style-type: none"> <li>• Potential to transfer energy to neighboring Caribbean islands</li> <li>• Providing electrical energy to a bigger market</li> <li>• Collaboration with international organizations (EU, OAS)</li> <li>• Opportunity to be the first completely green country</li> <li>• Global influence (Climate Change)</li> </ul>	<ul style="list-style-type: none"> <li>• Competition from other renewable energy resource</li> <li>• Development of geothermal energy on St. Kitts</li> <li>• Change of government</li> <li>• Economic down turn</li> <li>• More profitable interconnectivity project</li> </ul>

### 6.1.1 Evaluation of SWOT Analysis

**Table 4. Ranking of strengths**

Strength	InS.	Mi.	Ma.	C
Large geothermal resource reservoir with potential of 500MW				✓
Geothermal resources are shallow			✓	
Short and shallow interconnection distance			✓	
Experience of CEO and staff		✓		
Available present day technology				✓
Available information from previous studies	✓			

Critical (C): Fundamental to the development of the Project

Major (Ma.): Important for cost and viability

Minor (Mi.): Minimal impact on project outcome

Insignificant (InS.): No major impact on the project

**Table 5. Ranking of weaknesses**

Weaknesses	InS.	Mi.	Ma.	C
Small market demand			✓	
Lack of financing to complete project				✓
Unstable political support from Federal Government				✓
Uncertainty of environmental and social impacts			✓	
Lack of local policy and legislation for the fostering of renewable energy development		✓		

Critical (C): Project cannot commence unless it is addressed

Major (Ma.): Project can carry on but may experience limited success

Minor (Mi.): Small inconvenience to the project

Insignificance (InS.): negligible impact on the project

**Table 6. Ranking of opportunities**

Opportunities	InS.	Mi.	Ma.
Potential to transfer energy to neighboring Caribbean islands		✓	
Providing electrical energy to a bigger market			✓
Collaboration with international organizations (EU, OAS)		✓	
Increase government revenue			✓
Opportunity to be the first completely green country (Branding)	✓		
Global influence (Climate Change)	✓		

Major (Ma.): Significant potential increase in the success of the project  
Minor (Mi.): Small potential increase in the success of the project  
Insignificant (InS.): no potential increase in the success of the project

**Table 7. Ranking of threats**

Threats	Mi.	Ma.
Competition from other renewable energy resource	✓	
Development of geothermal energy on St. Kitts		✓
Economic down turn		✓
Change of government	✓	
More profitable interconnectivity project		✓

Major (Ma.): Potential to halt the project  
Minor (Mi.): potential to cause small disruption in the project

### 6.1.2 Critical Issues

The evaluation of the SWOT Analysis identified the important issues that must be taken into consideration for the development of the project. In terms of strengths, the large geothermal energy potential of 500 MW on Nevis and available present day technology were identified as the critical strengths of the project. Nevis is fortunate to have numerous thermal wells and a large hydrothermal alternation on the western and

southern side of the island (Balocletti and Lawrence, 1999). West Indies Power drilled three slim holes in 2008 that showed that the geothermal reservoirs are very shallow. Temperatures of 260 Celsius (°C) were found as shallow as 732m (Maynard-Date and George, 2013). These resources and conditions are fundamental for the development of the project.

The two critical weaknesses identified are lack of financing for the completion of the project and unstable political support from the federal government. West Indies Power was initially contracted for the development of the geothermal project, but has since been replaced by the NREI. The former NIA stated that they were displeased with the delays in the project development, and that the company did not have the necessary financial resources. Financial support is crucial to the project since large sums of capital are needed at the initial stages. The small market size however, makes it difficult to attract the necessary investment capital. The project was initially slated to start in 2011, but is now expected to come on stream in the near future. Another critical weakness is the unstable federal government support towards the geothermal interconnectivity project. The federal government has to sign a purchasing power agreement (PPA) with NREI. If the federal government does not support this, the geothermal interconnectivity project will not take place.

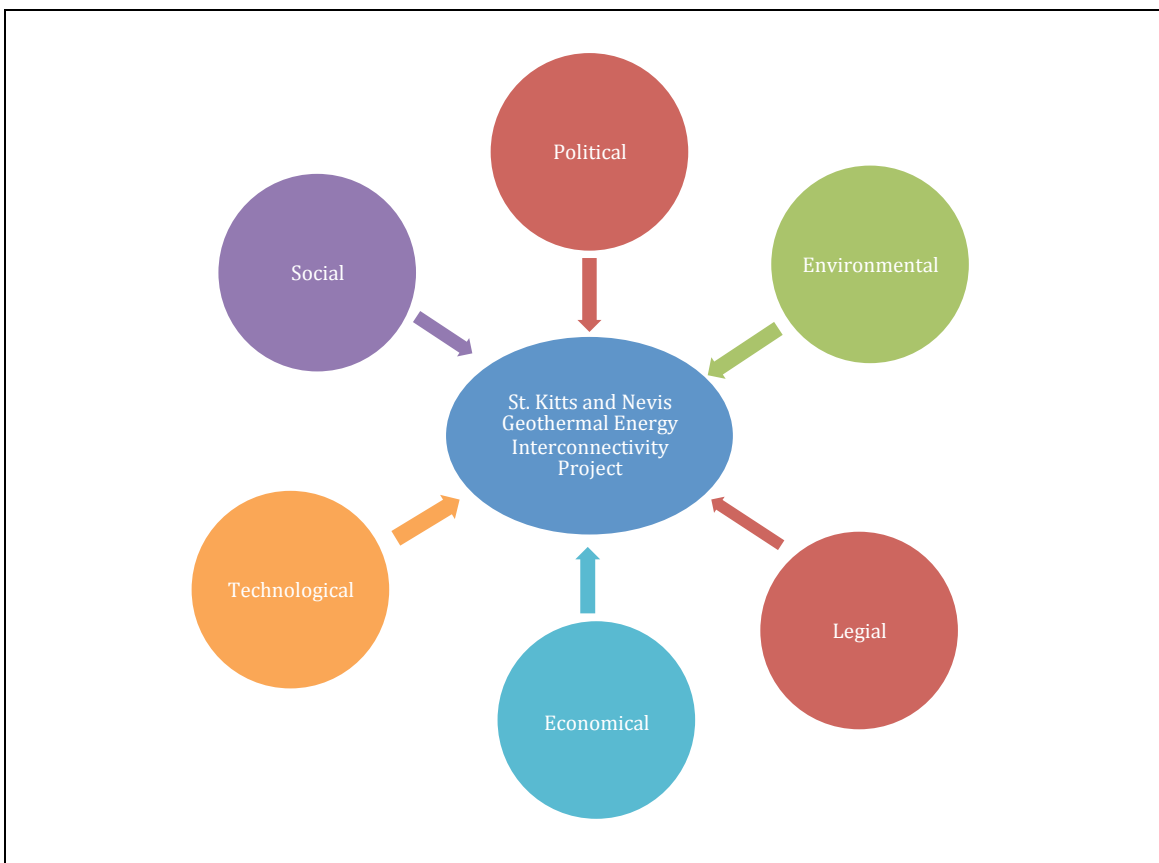
The opportunity to distribute energy to other nearby Caribbean islands, to provide energy to a large market and potential to increase government revenue are the major opportunities identified from the SWOT Analysis. The large geothermal energy potential on Nevis makes it possible for the distribution of power to nearby islands. Possible interconnection projects with Saba, USVI and Puerto have been taken into consideration.

Selling power to these islands increases the market size, which increases the potential of attracting investment capital. Nevis is expected to benefit from increased government revenue if the prospective projects are developed.

There are number of external threats to the St. Kitts and Nevis interconnection project. The Federal government is considering the possibility of developing its own geothermal energy project on St. Kitts. Thermal springs can be found along the western shoreline of the island, as well as moderately large areas of steaming ground in the center of Mount Liamuiga (Balocletti and Lawrence, 1999). The Clinton Foundation Climate Initiative recently visited St. Kitts to evaluate the prospect of renewable energy on the island including geothermal energy (“St. Kitts and Nevis focus”, 2014). If St. Kitts developed geothermal energy, there will be no need for an electrical interconnectivity project. Economic down turn, was also identified as a major threat. The recent economic situation impacted the investment climate, resulting in many unfinished projects worldwide. This is a serious threat to the project, since it is heavily dependent on investment capital. The St. Kitts and Nevis interconnectivity project can experience competition from other islands that are willing to transfer electrical energy. Dominica recently developed a small geothermal plant for domestic purposes, and has launched the development of 100MW geothermal plant for exporting power to Guadeloupe and Martinique (Brown, 2013). If it is more economical for St. Kitts and Nevis to link to Dominica, then this probably will result in the abandonment of the project.

## 6.2 PESTLE Analysis of Geothermal Energy Interconnectivity Project

The PESTLE Analysis helps to analyze the general environment of the St. Kitts and Nevis geothermal energy interconnectivity project. The general environment in this case includes the subcategories of political, social, economic, legal and technological, (see figure 7). There are potential implications that can arise caused by the influence of the electrical interconnectivity project and the general environment on each other. The results from the PESTLE Analysis provide key inputs to assist decision makers with future decisions and strategies in relation to the electrical interconnectivity project.



**Figure 7. All the external environmental factors (PESTLE factors)**



**Table 8. PESTLE Analysis for the Geothermal Interconnectivity Project**

<b>Political</b>	<b>Social</b>
<ul style="list-style-type: none"> <li>• Political Instability (Call for Secession by Nevis from St. Kitts)</li> <li>• Policies of political parties</li> </ul>	<ul style="list-style-type: none"> <li>• Displacement of fishers and Dive tour operators who operate within The Narrows</li> <li>• Creation of new jobs, and expertise in the field of geothermal energy production</li> <li>• Impact of increase transmission lines on the health of civilians</li> <li>• More funds to invest in social development</li> <li>• Increase wages and salaries</li> <li>• Decline of traditional culture and practices</li> </ul>
<b>Economical</b>	<b>Technological</b>
<ul style="list-style-type: none"> <li>• Inflation</li> <li>• Expansion of the tourism and light manufacturing industry</li> <li>• Increase of small business</li> </ul>	<ul style="list-style-type: none"> <li>• Availability of Technology for the development of the project</li> <li>• Nevis can become the lead example for the development of geothermal energy</li> <li>• Increase technological transfer and change</li> </ul>
<b>Environmental</b>	<b>Legal</b>
<ul style="list-style-type: none"> <li>• Impact of submarine cable on seabed</li> <li>• Impact of submarine cables coastal landing sites</li> <li>• Lack of attention to environmental protection ministries</li> <li>• Increase coastal stress on the environment due to increase coastal development</li> <li>• Increase presence of submarine cable maintenance ships</li> <li>• Increase pollution</li> <li>• Natural Disasters</li> </ul>	<ul style="list-style-type: none"> <li>• Development of laws to facilitate the sustainable development of REPs</li> <li>• Requirements for laying submarine cables on nearby countries continental shelves</li> </ul>

### **6.2.1 Political**

Historically, the political parties on Nevis, namely the Nevis Reformation Party (NRP) and the Concern Citizen Movement (CCM) were formed on the agenda of secession. Chapter 10, Article 113 of the constitution of St. Kitts and Nevis makes provisions for secession for Nevis (Constitution Order, 1983). On two occasions, Nevis attempted to disassociate from St. Kitts. The first was in 1977 when the NRP spear headed a referendum, which resulted in a 99% vote for secession, but was ruled an unofficial referendum (Byron, 2010). The second referendum was held in 1998, spear headed by the CCM, which resulted in a majority vote of 62%, 5% short of the 67% required from secession (Byron, 2010). If Nevis becomes financially stable as a result of the success of the geothermal energy interconnection project, it can cause political instability. This might result in another referendum for secession, or increase calls for more autonomy for the NIA to manage the affairs of Nevis.

The successful development and operation of the St. Kitts and Nevis geothermal energy interconnectivity project can shape national energy policies as well as policies of political parties. The interconnectivity project allows the decision makers to see gaps, and areas where efficient regulations must be imposed and is therefore helpful towards policy making. High cost of electricity has been a burden on the population. The introduction of the geothermal energy interconnectivity project will encourage political parties to incorporate more renewable energy alternatives in their bid to reduce the cost of electricity. The issue that can arise from this is the fact that politicians tend to rush policies in order to gain popularity without listening to arguments from the proponents and critics. This sometimes results in negative outcomes from the implementation of poor policies. In the case of the European Union (EU) and United States, biofuel policies were

made to promote the production of corn and palm oil. These policies were in effort to reduce CO<sub>2</sub> emission, assist corn farmers and palm oil plantation owners. However, these policies resulted in negative outcomes such as increase of food prices and land usage changes where grasslands and forests were transformed into agricultural lands (Papier, 2008).

### **6.2.2 Social**

The introduction of the submarine cable in The Narrows will disrupt fishing and dive tour operations within the area. Fishers damage submarine cables 100-150 times per year (Drew and Hopper, 2009). Submarine cables are normally damaged by anchors, and fishing gears such as fish pots, trawl lines and the anchors of fish aggregating devices (FADs). The disruption of power cables can be extremely lethal since they carry up to 500,000 volts of electricity (Drew and Hopper, 2009). It is also dangerous to fishing vessels since lifting a submarine cable can cause the vessel to capsize. The St. Kitts and Nevis fisheries sector in 2012 recorded fish landings valuing US 2.5 million (GoSKN, 2013). It will be great financial risk if fishing continues in this area, since cable repairs in shallow water can cost at least US \$1 million (Drew and Hopper, 2009).

The successful development of the geothermal energy interconnectivity project is expected to increase jobs. The diversification of the energy portfolio with the introduction of other REPs makes opportunities for job creation, especially if the materials and infrastructure needed for the development of the REPs are manufactured locally (Akella, Saini and Sharma, 2009). Increased government revenue, as a result of the geothermal energy interconnection project can contribute to reducing the large national debt and improving social development such as healthcare, housing and

education. Increase of government revenue can also result in increase of wages and salaries. In relations to St. Kitts and Nevis, due to the success of the debt-restructuring program and its CBI Program, the government has recently increased minimum wage by 12% and minimum wage social security benefits by 7.5% (McCall, 2014). The increase in economic development and wages can also erode existing traditional values and culture of St. Kitts and Nevis. In a world value survey on culture change, it was concluded that economic development is associated with pervasive, and to some extent predictable, cultural change (Inglehard and Baker, 2000).

The geothermal energy interconnectivity project will potentially increase the number of transmission lines to provide cheap energy to the expanding residential, industrial and resort tourism areas. The increase of transmission lines can have a negative impact on humans who live in close proximity to them. Extremely low frequency electromagnetic fields (ELF-EMFs) can affect the nervous system of people at high exposure, and affect memory, cognition and other brain functions at low exposure (Ahmadi, Mohseni and Akmal, 2010). This is a cause for concern due to the large amount of uncertainty surrounding this issue, and because exposure to EMF from transmission lines has been acknowledge for potentially causing childhood and adult leukemia, breast cancer, decrease in blood sugar and neuropsychological disorder (International Commission on Non-Ionizing Radiation Protection (ICNIRP), 1998). As more transmission lines are constructed to facilitate the expected growing tourism, manufacturing industry and the expansion of residential areas, the impact of transmission lines on the health of the population should be taken into consideration in the future.

### **6.2.3 Economical**

St. Kitts and Nevis is expected to experience economic growth as a result of the geothermal energy interconnection project. The reduction in expenditure on fossil fuels for energy generation, creation of new jobs, increase of wages and salaries will encourage the multiplier effect which induces spin offs in other sectors such as the creation of small business, restaurants and factories (Akella et al., 2009). The downside to economic growth is the issue of inflation, where the growing demand for resources is more than the supply causing prices to increase. Inflation can potentially have a negative impact on the population, especially the low-income earners. The rise in economic growth can also cause increased disparity between the low income and high-income earners, where those holding top positions benefit more financially.

The availability of cheap power from the geothermal energy interconnection project on St. Kitts and Nevis will have the potential to attract foreign investments for the development of hotels and light manufacturing operations. The expansion of the tourism and light manufacturing sectors can elevate pollution and stress on the marine environment. Economic growth also encourages the increased use of natural resources such as fresh water and marine resources. The resultant development of small businesses, hotels, restaurants and factories will increase the demand for fresh water supply, which can become a very serious issue if a water shortage develops.

### **6.2.4 Technological**

The technology needed for the development of the St. Kitts and Nevis geothermal energy interconnectivity project is available. The depth and length of the Narrows are within the limit that allows for the utilization of present day technology. One of the goals

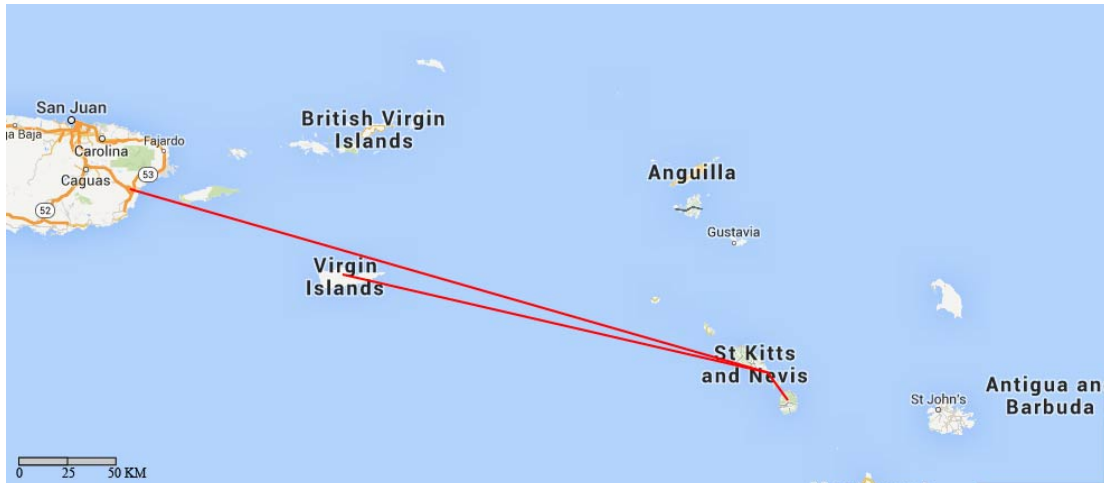
of the project is to provide technology transfer and training in the areas of geology, modeling, well design and drilling, power plant development, operation, maintenance, and technical and financial risk assessment (“Nevis Island Partners”, 2013). However, one issue is whether or not the submarine power cable will be deployed on the seabed with or without armor, or be buried for protection. The use of armor that runs along the length of the submarine cable and burial of the submarine cable can cause negative impacts on the ecology of The Narrows. Environmental issues associated with the use of technology will be discussed further in the environmental section.

In relation to the Nevis–Puerto Rico interconnection, the project has been deemed technologically feasible since submarine electrical cables have been deployed at longer length and similar depths. However, the main technological issue is that at 95 miles on the proposed route, the submarine electrical cable will have to weave through underwater peaks at depths of 900-1850m. These peaks can be dangerous for deployment of the cable. Another issue is that the submarine power cable to Puerto Rico will cross six other submarine cables on its route. There is an uncertainty on how the crossing of a submarine power cable with a telecommunication cable can affect each other.

### **6.2.5 Legal**

The main legal issue surrounding the St. Kitts and Nevis geothermal energy interconnectivity project originates from the Nevis-Puerto Rico interconnection. The submarine power cable will potentially pass through territorial waters of St. Eustatius, the United States Virgin Islands and British Virgin Islands, (see figure 8). Under the United Nations Convention on the Law of the Sea (UNCLOS), coastal states in archipelagic waters and the territorial sea have the right to exercise sovereignty and may establish

conditions for the passing of submarine cables (Carter, Burnett, Drew, Marle, Hagadorn, Bartlett-McNeil and Irvine, 2009). Legal provisions will have to be made in order for this interconnection to be done.



**Figure 8. Showing paths of the submarine electrical cables through archipelagic waters of a section of the Eastern Caribbean**

### **6.2.6 Environmental**

Environmental issues associated with the St. Kitts and Nevis geothermal energy interconnectivity project stem from the economic growth and development, and the deployment of the submarine power cable on the seabed. The availability of cheap power from the geothermal energy project will create an atmosphere good for foreign investments. It will attract investors who are interested in developing hotels and manufacturing operations. Hotel developers are keen to develop their structures on the coastline near to beaches and therefore the introduction of more hotels in the coastal regions will increase pressure on the marine resources. Terrestrial biodiversity and habitats will also be affected as a result of large clearing of lands to accommodate the massive hotels and factories. More hotels and factories indicate an expected increase in pollution and pressure on the waste management institutions on both islands.

The deployment of the submarine electrical cable will also have an impact on the marine environment. Coral reefs and sea grasses, which are indispensable for supporting marine life, are present within The Narrows. The introduction of the submarine cable laid on the seabed can smother organism, damage coral reefs and sea grasses if the cable become in contact with them. If the plan is to bury the cable, then sedimentation and turbidity will become an issue for filter-feeding organisms and light-dependent organisms. The submarine cable can cause the development of hard and soft substrates that attract foreign marine life to the area. This can cause the original ecosystem and biodiversity present to become affected. During operation, the EMF emitted from the cable will affect organisms in close proximity. There is also visual and noise pollution due to the rise of the presence of ships to perform deployment, and operation and maintenance procedures.

The submarine electrical cable can be affected by natural occurrences such as earthquakes, volcanic eruptions and in the long term, climate change. These occurrences can damage submarine cables causing disruption to operations. St. Kitts and Nevis is no stranger to volcanic eruptions and earthquakes with St. Kitts having four volcanic centers, and Nevis being described as one large volcano (Simpson and Shepherd, 2001). There are two unsubstantial reports of volcanic eruptions on St. Kitts in 1692 and 1983 (Simpson and Shepherd, 2001). St. Kitts and Nevis continues to experience earthquakes. Most recently in 2013, an earthquake of the magnitude of 5.3 occurred near the Federation. In 1974 a 7.5 magnitude earthquake struck the Federation causing major damage to the islands (“Earthquake strikes near St. Kitts”, 2013).



Another potential issue is the neglect of important environmental departments as a result of focusing on economic development. St. Kitts and Nevis has been suffering from a large national debt for a very long time, and has thus placed more focus on industries such as tourism, manufacturing, and the CBI Program since they generate important revenue. Quite often, essential environmental protection government departments get little attention and funding to pursue programs. It is possible that the economic success of the St. Kitts and Nevis geothermal energy interconnection project might become the major focus by the government causing those environmental oriented departments to become neglected. This can result in detrimental environmental impacts due to lack of environmental monitoring and programs.

## **6.3 Discussion**

This discussion will take a marine focus, taking into account the issues related to the direct and indirect impacts of the St. Kitts and Nevis geothermal energy project. In two sections, the impact of the submarine cable on the marine environment and the marine environmental impacts caused by the increase of resort tourism and light-manufacturing industry will be discussed.

### **6.3.1 Impact of Submarine Electrical Cable on the Marine Environment**

The deployment of the submarine power cable within The Narrows will potentially cause disturbances to the seabed. The level of the impact depends on the proximity of the deployment site to benthic organism, and other marine habitats. Submarine cables can smother the flora and fauna on the seabed. During deployment and repairing of the cable, the bottom is being disturbed causing suspension of sediments. This increases turbidity of the water, which can affect light-dependent organisms, as well as filter-feeders. The deployment of the submarine cable can also release contaminants and alter sediment movement. These disturbances mentioned are temporary, and quite often only affect sensitive environments and specific species.

EMF is generated by the interaction between the magnetic field around the cable and the ambient salt water (OSPAR, 2009). The EMF generated from the submarine cable can impair the orientation of marine fish species (OSPAR, 2009). Research has shown that marine bony fishes exhibit physiological reactions towards EMF of  $7\text{mV}^{\text{m}^{-1}}$  and behavioral responses at  $0.5\text{-}7.5\text{ V}^{\text{m}^{-1}}$  (OSPAR, 2009). An HVAC submarine cable has been proposed of the St. Kitts and Nevis interconnection project, AC submarine

cables produce weaker EMF than DC cables. This is another benefit of using an AC submarine cable in relation to the impact of EMF on the marine environment.

Lost heat energy from submarine power cable during electrical transfer increases the temperature of its surroundings. The rise in temperature of the surrounding ambient salt-water is dependent on the type of cable, transmission rate and characteristics of the surroundings (OSPAR, 2009). This temperature rise can affect marine species negatively. It is important to note that HVAC cables lose transmission heat more significantly than HVDC cables of equal transmission rates (OSPAR, 2009).

The impacts of submarine cables discussed are primarily localized. Only areas in close proximity to the submarine cable will be affected as opposed to the general area. The impacts associated with the deployment and burial of the cable are temporary, which allows for the affected flora and fauna to rejuvenate. However, submarine cables tend to produce hard and soft substrates if not buried. These substrates are able to attract foreign marine life, which potentially can change the marine ecosystem of the area (Lin and Yu, 2012; OSPAR, 2009).

### **6.3.2 Impacts of Coastal Development**

The successful construction and expansion of the St. Kitts and Nevis interconnectivity project is expected to produce cheap power. The pre-feasibility study of the project done by KEMA for OAS concluded that the cost of electricity is expected to range from 10.5¢ kWh to 15.3¢ kWh. This is considerably less than the 37¢ and 43¢ kWh that is now paid by consumers and commercial businesses respectively. The drastic decrease in the cost of power fosters a healthy investment climate for the Federation. The Caribbean region depends more on tourism to sustain livelihoods than any other region of

the world (Hebert and Christian, 2014). The Caribbean islands are able to attract foreign investment for the tourism sector due to their attractiveness of clear water, white sand beaches, warm tropical climate, and the spice of exotic calypso. However, the current high cost of electricity is a deterring factor for attracting investors. The availability of cheaper power will see the increase development of resort tourism near the coastal regions. These resorts require close proximity to coastal resources such as beaches, fresh water supply, skilled labour force, marine resources (fish) and cheap reliable energy. The increased construction of hotels and restaurants is directly proportional to the pressures on coastal resources. Currently, coastal development in St. Kitts is mainly attributed to the expansion of the tourism industry (Carter, 2010).

Sedimentation from runoff into the coastal areas is a major problem that is affecting marine life. Mangroves were cleared for the development of golf courses, road construction, and hotel construction on the island. Mangroves are very important habitats to the fisheries since they are nurseries for juvenile fishes, crabs and mollusks, and also help to reduce the impact of sedimentations on nearby coral reefs. Sand mining on the island has also caused negative impacts on the marine resources and fisheries. Sand is being removed from beaches for the manufacturing of cement, construction of settlements and mass tourism resorts. Large sand mining activities can disrupt and exacerbate erosion of coastlines, which increases the effect of sedimentation caused on the marine resources.

Sedimentation negatively impacts coral reefs and sea grass beds, which are important fish habitats. Sedimentation deprives coral reefs and sea grass beds of light that is important to their survival. Sediments quite often smother them and cause detrimental

habitat damage (Islam and Tanaka, 2004). Sedimentation is also associated with pollution, where the particles are contaminated with metals and phosphorous, which causes instant deterioration of the sea grass bed and corals reefs, fish kills, bioaccumulation in the fish stocks and eutrophication as a result of increased contaminants from sediments (Islam and Tanaka, 2004). Sedimentation stresses the coral reefs and makes them more vulnerable to coral diseases.

Increase in hotels and light manufacturing due to cheap power can put additional stress on the waste management system. The introduction of the St. Kitts Marriott Resort and the Royal Beach Casino in 2003 has placed an enormous burden on the St. Kitts Solid Waste Management Corporation (SWMC). The life of the landfill has been reduced since its inception. As of 2013, the garbage-holding cell at the landfill had reached its full capacity (Dixon, 2013). The current waste is wrapped and stored in hope to be converted into electricity when the proposed waste to energy plant is operational. The increase in hotels and light manufacturing will increase pressure to implement measures to accommodate the rise in waste. Marine pollution, caused by the improper disposal of garbage by tourists can be detrimental to the marine environment. This can become a serious issue since the tourism industry is expected to expand.

The demand for fresh water resources will also increase. The resort tourism sector utilizes large amounts of fresh water for their operations. St. Kitts and Nevis is fortunate to have a good water supply to service the local population. However, it is not enough to accommodate the growing tourism industry. The annual renewable water resource in St. Kitts amounts to  $1.66 \times 10^7 \text{m}^3$  and the annual renewable water production is  $9.13 \times 10^6 \text{m}^3$  (Chapman, Paul. Moise and Riley, n.d). This is sufficient to service the general

population and existing commercial entities. However, the present water supply is not enough to accommodate the Marriott Beach Resort and Royal Beach Casino, which demands 109984624m<sup>3</sup> daily (Chapman, et al., nd). A desalination plant produces Marriot's water supply. The hotel's demand for fresh water would have been a burden on the island's fresh water supply. What is important to consider, is how the newly constructed hotels will get fresh water? If the new hotels utilize desalination plants, it is important to consider the marine impact of the plants. In relation to the open water intake desalination plants, like the one at the Marriot, they can cause impingement of marine species caused by the intake screens, and entrainment of marine species within the plant (Dawoud and Al Mulla, 2012). Desalination plants can potentially disturb the seabed, which causes high turbidity due to suspension particles, nutrients and pollutants that can affect marine life (Dawoud and Al Mulla, 2012). They can also alter sediment transport along the coastline, and the brine produced, if discharged into the sea, can increase salinity in very sensitive ecosystems causing harmful impacts. The cumulative effect of multiple desalination plants by the new hotels can potentially have a negative synergistic impact on the marine environment.

Marine transport is critical for St. Kitts and Nevis, as it relies heavily on importation, tourism and fossil fuel. St. Kitts is the leading exporter to the United States in the Eastern Caribbean (Williams, 2014) and has experienced an increase of 9.4% of the export of electronic components to the United States (GoSKN, 2013). Despite the success of the manufacturing industry, St. Kitts is still hoping to expand its manufacturing industry through the Partial Scope Agreement with Brazil. The availability of cheap power can result in dramatic growth of the manufacturing industry, hence increasing

marine transport. The expansion of the tourism industry can also lead to an increase in cruise ship berths. St. Kitts and Nevis is projected to pass the 650,000 passenger arrival mark for 2013-2014 season, with an expectation of over 700,000 passengers in 2014-2015 (GoSKN, 2013, p.14). The mega yacht marina that is under construction at Christophe Harbour is also expected to boost marine transportation. The increase in marine transportation can increase sea traffic, visual pollution to local residents, pollution caused by the discharge from oil and other substances. In relation to the fisheries sector, the federal government has been promoting the use of fish aggregating devices (FADs) to aid fishers in capturing commercial fish. However, the rise in marine transport can be a threat to these devices through collision with ships. The introduction of invasive species caused by the discharge of ballast water from ships can also be a threatening issue to the marine environment.

The expected increase in the number of hotels on the islands will heighten the demand for marine resources. Currently, there is a heighten demand for fish products on the islands. This is evident of the high level importation of fish. St. Kitts and Nevis imported 804 037 kg of fish in 2009 (Masters, 2010). This number is expected to increase as the local fish catch declines (GoSKN, 2013). The increase demand for fish can exacerbate overfishing in coastal areas, and cause fish prices to increase and become unaffordable for the local population.

Increased user conflict issues are expected to develop as more hotels and restaurants are constructed on the coast. There will be competition for the use of marine space. The expected increase of tourists in the coastal areas can also affect other users such as local residents who use the beaches for recreational purposes, fishers and dive

tour operators. To resolve user conflict issues, it is necessary to have a concerted well-considered holistic and coordinated integrated management and planning approach (Kay and Alder, 2005). St. Kitts started its integrated management approach by participating in a public survey spear headed by The Nature Conservancy that led to the development of a marine zoning plan. This plan is in the hopes of mitigating user conflict issues and fostering sustainability of the marine environment. However, the marine zoning design from this project has not been implemented.



## **CHAPTER 7: CONCLUSION AND RECOMMENDATIONS**

### **7.1 Conclusion**

This study performed an assessment of the socio-economic and marine environmental impacts to determine if the St. Kitts and Nevis geothermal energy interconnectivity project is environmentally and socially sustainable. It also took into account the proposed Nevis-Puerto Rico electrical interconnection, which is the final stage of the proposed geothermal energy project.

Results from the SWOT analysis shows that there are very important strengths and opportunities of the project. These strengths and opportunities can be used to address the critical weaknesses and threats that the project faces. For instance, lack of funding that was identified, as a critical weakness of the project can be address by increasing the market size through sale to nearby islands. The increase in market size will be able to attract investment capital to support the project.

The PESTLE analysis investigated the general environment of the project, by looking at potential issues that can affect the country due to the development of the project. The assessment shows that there are a number of issues that can arise from the project. In the social context, the effects of increased transmission line on humans, and the displacement of fishers and dive tour operators, are two of the main issues. The impact of transmission lines on humans is still an indecisive study that requires continued research and monitoring. However, measures to mitigate a problem of this nature can be resolved with proper planning. The introduction of a submarine cable definitely will affect fishers who fish in The Narrows. These fishers and drive tour operators may be

displaced, or their operations modified to reduce the risk of damaging the submarine cable. These issues can be tackled early through proper planning and management.

The potential economic issues analyzed showed that the geothermal energy interconnectivity project can indirectly affect the marine environment through economic growth. Increased coastal development, marine transport, and pollution are some of the identified marine environmental impacts indirectly caused by the geothermal electrical interconnection project. The issues stemming from economic growth and development can all be mitigated and resolved in some cases to ensure sustainability of the marine environment.

The potential direct impacts of the deployment of the submarine cable are local. Marine species that are in close proximity to the cable will be affected to some degree. In relation to disturbances of the seabed, they are temporary and will allow affected flora and fauna to recover. Ships for deployment and repair of the submarine cable will be in the area temporarily hence there will not be constant visual and noise pollution.

From the study, a simple conclusion can be drawn. St. Kitts and Nevis geothermal energy interconnectivity project is socially and environmentally sustainable, however measures to mitigate social and marine environmental impacts must be implemented.

**Table 9. Summary of Benefits and Negative Effects of the St. Kitts and Nevis Geothermal Energy Project**

<b>Categories</b>	<b>Benefits</b>	<b>Negative effects</b>
<b>Socio-Economic</b>	<ul style="list-style-type: none"> <li>• Lower cost of electricity</li> <li>• Less imported fuel (cleaner environment)</li> <li>• Increase government revenue</li> <li>• Increase funding for Social Development (Improve standard of living)</li> <li>• Transfer of high technological knowledge</li> <li>• Multiplier effect (increase agriculture, fishing, manufacturing, small business)</li> <li>• Branding as a green country</li> </ul>	<ul style="list-style-type: none"> <li>• Erosion of traditional culture</li> <li>• Increase disparity between high and low income earners</li> <li>• Displacement of fishers and dive tour operators</li> <li>• Increase user conflict for coastal areas</li> <li>• Health issues from increase transmission lines</li> <li>• Inflation</li> </ul>
<b>Marine Environmental</b>	<ul style="list-style-type: none"> <li>• Reinvestment of funding from polluter pay schemes and fees back into taking care of the marine environment</li> <li>• Encourage development of MPAs close to electrical connection</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of focus on marine environment</li> <li>• Localized impact of submarine cable on flora and fauna</li> <li>• Increase demand on natural resources (freshwater and marine resources)</li> <li>• Increase marine pollution from ships, and garbage produce as a result of tourism expansion</li> <li>• Increase stress on coastal areas from development</li> </ul>

## **7.2 Recommendations**

The principles of ocean governance in good marine management practice, as identified in contemporary literature are best environmental practice, public participation, polluter pay, precautionary approach, adaptive management, access to information and careful decision-making (Gupta, 2010). Incorporation of these principles can solve the solutions to the problems that have been identified. The availability of cheap power has the potential to cause devastation to the marine environment, hence the government and other decision makers should exercise these principles in the decision making process.

### **1) Principle of best environmental practice**

It is important to incorporate the principle of best environmental practice. This project was able to identify potential social and marine environmental issues associated with the geothermal energy interconnection project. However a thorough social and environmental impact assessment should be done in accordance with the National Conservation and Environmental Protection Act, no.5 1987 of St. Kitts and Nevis. This type of assessment is helpful to the government and other decision makers since it thoroughly assess all the potential social and environmental impacts of the project.

### **2) Principle of public participation**

The electrical interconnection project can potentially affect fishers and dive tour operators. It is important for the government to utilize the principle of public participation. Public consultation with stakeholders is important, as they should be involved at the earliest stages of the development of the project. Stakeholders have valuable contribution towards management needs, and their support towards the project helps to assist smooth implementation and development. Stakeholder meeting and

consultation to find solutions can also resolve user conflict issues that can arise from the increase in competition for marine space.

Politics was identified as a critical weakness of the electrical interconnection project. Talks of secession can be detrimental to the development of the project. The principle of public participation is important in a process of this nature, because the population must be aware of the consequences of their decisions and participation. This helps to maintain stability within both islands and foster a good investment climate in the long run.

### **3) Polluter pay principle**

The study shows that most of the potential marine environmental issues assessed were indirectly caused by economic growth and development of tourism and other industries. For this situation it is important to utilize the polluter pay principle. Users of the marine environment, including fishers, diver tour operators, hotels and restaurants should pay towards the cost of measures to prevent, control and reduce damage to biodiversity and coastal landscape. The utilization of a fund that collects fees and donations from various users and government can be an effective mechanism since the funds will be invested towards improving the sustainability of the marine environment.

### **4) Precautionary principle**

The potential increase of marine transport will result in the presence of more and larger cargo and cruise ship vessels. The government should take into account the precautionary principle to anticipate the problem of lack of accommodation to support the increased marine transport. The decision to build a new port and pier expansions are a few alternatives to resolve this potential issue. The principle applies for the country to

boost preparation and safety precautions for unfavorable vessel accidents that can cause wide spread marine environmental damage such as an oil spill. The government and other decision makers should also anticipate the potential water shortage caused by the expansion of the tourism and manufacturing sector. The necessary measures such as the importation of water should be put in place to support these industries.

The precautionary principle should also be considered for the diminishing of fish stocks and marine life caused by habitat damage and overfishing. The introduction of a MPA reflects this principle, as it is able to protect biodiversity and species abundance. Despite the high level of uncertainty of how economic growth will affect the marine environment, and lack of scientific data, the implementation of a MPA will help to conserve the marine environment. It is also important for the human capacity in the environmental department to become more comprehensive to deal with the complex marine environmental issues.

#### **5) Adaptive management principle**

The Fishers Act 1995 does not include the development of MPA, submarine cable installation and aquaculture. It is important that the fisheries management plan is updated to reflect the adaptive management principle. This allows decisions to be made to reduce uncertainty overtime with the use of best scientific information available from systemic monitoring. As new information is collected on the state of the marine environment, the management plan should be able to effectively resolve new problems that manifest over time.

## **6) Principle of public access to information**

As marine related issues become more complex, and require more integration and collaboration, the principle of public access of information is crucial to the decision making process. This principle helps to enhance coordination between various government agencies, and the general public as everyone is aware of what is going on. This helps to foster two-way communication between government agencies and communities, which makes implementation and enforcement of a project more successful. The management of the FAD fishery in St. Kitts and Nevis can be enhanced by this principle through increasing communication and sharing of information between fishers, government agencies and vessel operators on the positions of these devices. This will help to reduce the direct collision of ships on these devices and the loss of expensive FAD construction materials.

## **7) Principle of careful decision-making**

The government should take into account the principle of careful decision-making. It is important that decisions be made in stages as the best available information becomes available. The incorporation of economic, environmental and social sound measures in the decision making process will help with the conservation and sustainability of the marine environment.

## REFERENCES

- Agostini, N.V., Margles, W.S., Schill, R.S., Knowles, E.J., & Blyther, J.R. (2012). Marine Zoning in St. Kitts and Nevis: A Path Towards Sustainable Management of Marine Resources. *The Nature Conservancy*
- Ahmadi, H., Mohseni, S., & Akmal, A.S.(2010). Electromagnetic Fields Near Transmission Lines: Problems and Solutions. *Iranian Journal of Environmental Health Science & Engineering*, 7(2), 181-188. Retrieved from <http://ijehse.tums.ac.ir/index.php/ijehse/article/view/246>
- Akella, A.K., Saini, R.P., & Sharma, M.P. (2009). Social, economical and environmental Impacts of renewable energy systems. *Renewable Energy*, 34 (2009), 390-396. Retrieved from [http://www.greenenv.blog.com/files/2009/06/akella\\_2009\\_renewable-energy.pdf](http://www.greenenv.blog.com/files/2009/06/akella_2009_renewable-energy.pdf)
- Bacchus, C. (2014, August 13). Nevis Pursuing Waste to Energy, Retrieved from, West Indies News Network website, <http://www.winnfm.com/press-releases/9379-nia-announces-partnership-with-us-based-company-to-convert-waste-to-energy-on-nevis>
- Balloccetti, L., & Lawrence, B. (1999). Geothermal Resources in Latin America and Caribbean. 1-214
- Brederode, K.E, and De Cuba, K. (2012). Justification and Prefeasibility Study of an Electrical Interconnection for St. Kitts and Nevis. 1-33  
Retrieved from: <http://www.oas.org/usde/reia/Documents/St.%20Kitts%20-%20RenewableEnergyProjectsandInter-connectionAssessment.pdf>
- Brown, D. (2013, December 19). Nevis Embarks a Geothermal Energy Journey. Inter Press Services News Agency. Retrieved from <http://www.ipsnews.net/2013/12/nevis-embarks-geothermal-energy-journey/>
- Bruckner, A., & Williams, A. (2012). Assessment of the Community Structure, Status, Health and Resilience of Corals Reefs off St. Kitts and Nevis. June 2011. Khaled bin Sultan Living Oceans Foundation, Landover MD, pp.64
- Byron, R. (2010, March 26). Historical Repeat Itself Dramatically in Nevisian Politics. The Observer. Retrieved from, <http://www.thestkittsnevisobserver.com/2010/03/26/byron.html>
- Carter L., Burnett D., Drew S., Marle G., Hagadorn L., Bartlett-McNeil D., and Irvine N. (2009). Submarine Cables and the Oceans – Connecting the World. UNEPWCMC Biodiversity Series No. 31. ICPC/UNEP/UNEP-WCMC. Retrieved from <https://www.iscpc.org/publications/>



- Carter, S.S. (2010). National Environmental Summary Federation of St. Kitts and Nevis 2010: United Nations Environment Programme. Retrieved from <http://www.pnuma.org/publicaciones/Final%20NES%20St%20Kitts%20Nevis%20Nov%202010-%20edited.pdf>
- Chapman, I., Paul, D., Moise, G., & Riley, A. (nd). Wastewater Production, Treatment and Use in St. Kitts. Retrieved from [www.ais.unwater.org/ais/pluginfile.php/378/mod.../ST.\\_KITTS.pdf](http://www.ais.unwater.org/ais/pluginfile.php/378/mod.../ST._KITTS.pdf)
- CREDP/GIZ. (2013). A Review of the Status of Interconnection of Distributed Renewables to Grid in CARICOM Countries.
- Dawoud, A.M, & Al Mulla, M. (2012). Environmental Impacts of Seawater Desalination: Arabian Gulf Case Study. *International Journal of Environment and Sustainability*, 1 (3), 22-37. Retrieved from <https://www.sciencetarget.com/Journal/index.php/IJES/article/download/96/25>
- De Cuba, E.K. (2006). Towards a Sustainable Energy Plan for St. Kitts and Nevis. *Longterm electricity production cost assessment of electricity supply scenario For promoting the introduction of renewable energy technologies on SIDS in Caribbean, The St. Kitts Experience. 1-161*  
Retrieved from: <http://www.gseii.org/PDF/NWS-E-2006-21.pdf>
- Dixon, L. (2013, September 29). Conaree Dump Overflows, Retrieved from, SKNVibes News Website, <http://www.sknvibes.com/news/newsdetails.cfm/79514>
- Drew, S.C., & Hopper, A.G. (2009). Fishing and Submarine Cables. International Cable Protection Committee. Retrieved from <https://www.iscpc.org/publications/>
- Earthquake strikes near St. Kitts. (2013). Retrieved September 27, 2014, from the Caribbean 360 News website, [http://www.caribbean360.com/news/st\\_kitts\\_nevis\\_news/5-3-magnitude-earthquake-strikes-near-st-kitts](http://www.caribbean360.com/news/st_kitts_nevis_news/5-3-magnitude-earthquake-strikes-near-st-kitts)
- ECPA/OAS. (2013). ECPA Caribbean Initiative. *St. Kitts and Nevis AC Interconnection Pre-Feasibility Study*.
- ECPA/OAS. (2013). ECPA Caribbean Initiative. *St. Kitts and Nevis Puerto Rico DC Interconnection Pre-Feasibility Study*.
- Fridleifsson, I.B. (2001). Geothermal Energy for the Benefit of the People. *Renewable Sustainable Energy Review*, 5 (2001), 299-312
- Government of St. Kitts and Nevis (GoSKN). (2006). Adaptation Strategy in Response to The New EU Sugar Regime 2006-2013. *Document of Government*

- Government of St. Kitts and Nevis (GoSKN). (2010). Draft National Energy Policy and Action Plan St. Kitts and Nevis. Retrieved from [http://www.sknlst.com/Archive/SKN\\_Draft\\_NEP%20latest.doc](http://www.sknlst.com/Archive/SKN_Draft_NEP%20latest.doc)
- Government of St. Kitts and Nevis (GoSKN). (2013). Realizing the Gains of Fiscal Responsibility, Real Growth and Continued Opportunities. *2013 Budget Address*. Retrieved from [http://caribbeanelections.com//eDocs/budget/kn\\_budget/kn\\_budget\\_2013.pdf](http://caribbeanelections.com//eDocs/budget/kn_budget/kn_budget_2013.pdf)
- GSEII/ESG/OAS. (2007). Background Discussion Paper on Bio-energy Potential for St. Kitts and Nevis
- Griffith, A.L & Nerenberg, K. (2005). *Handbook of Federal Countries*. Quebec: McGill-Queen's University Press
- Gupta, M. (2010). *Indian Ocean Region: Maritime Regimes for Regional Cooperaton*. New York, NY: Springer
- Herbert, B., & Christian, C.S. (2014). Regional Tourism at the Cross-Roads: Perspectives of Caribbean Tourism Organization's Stakeholders. *Journal of Sustainable Development*, 7 (1). Retrieved from <http://www.ccsenet.org/journal/index.php/jsd/article/download/30453/19116>
- Hewlett, L.K. (2013, September 20). St. Kitts Launches Region's First Solar Energy Farm. The Observer. Retrieved from, <http://www.thestkittsnevisobserver.com/2013/09/20/solar-energy-farm.html>
- Hohmeyer. O., & Tritton.T. (2008). IPCC Scoping Meeting on Renewable Energy. Retrieved from <https://www.ipcc.ch/pdf/supporting-material/proc-renewables-lubeck.pdf>
- Huie, A. (2014, January 9). NIA Defends Decision to Choose NREI for Geothermal Energy. Retrieved from, West Indies News Network (WINN) website, <http://www.winnfm.com/news/local/6844-nia-defends-decision-to-choose-nrei-for-geothermal>
- ICNIRP. (1998). Guidelines for limiting Exposure to Time Varying Electric, Magnetic and Electromagnetic (Up to 300 GHZ). *Health and Physics*, 74(4), 494-522. Retrieved from <http://www.emclab.it/attachment/ICNIRP.Guidelines.PDF>
- International Monetary Fund (IMF). (2011). IMF Country Report No.11/270: *St. Kitts and Nevis*. Retrieved from <http://www.imf.org/external/pubs/ft/scr/2011/cr11270.pdf>
- International Monetary Fund (IMF). (2014). IMF Country Report No.14/7: *St. Kitts and Nevis*. Retrieved from <http://www.imf.org/external/pubs/ft/scr/2014/cr1449.pdf>

- Inter-American Development Bank (IDB). (2013). Energy Matrix Country Briefings. Retrieved from <http://publications.iadb.org/bitstream/handle/11319/4547/RG-CC1058%20Component%20I%20-%20Final%20Report%20Energy%20Matrix%20Country%20Briefings.pdf?sequence=1>
- Inglehard, R., & Baker, E.W. (2000). Modernization, Cultural Change, and the Persistence of Traditional Values. *American Sociology Review*, 65, 1. Retrieved from <http://my.fit.edu/~gabrenya/cultural/readings/Inglehart-Baker-2000.pdf>
- Islam, I., Tanaka, M. (2004). Impacts of pollution on coastal and marine ecosystems Including coastal and marine fisheries and approach for management: a review and Synthesis: *Marine Pollution Bulletin*, 48, 624-649. Retrieved from <http://teaching.ust.hk/~bisc529/HK/MPP2004v48n7-8p624-649%20islam%26tanaka.pdf>
- Jennifer, S., & Rondorf, N. (2011). About Submarine Power Cables [Power Point Slides] Retrieved from International Cable Protection Committee (ISCPC) Ltd website, <https://www.iscpc.org/publications/>
- Kay, R., & Alder, J. (Coastal Planning and management. USA & Canada: Taylor Francis
- Koon Koon, R. R. (2012). Geothermal Energy Prospecting for the Caribbean Islands of Nevis and Montserrat. Retrieved from <http://geoheat.oit.edu/bulletin/bull31-2/art5.pdf>
- Lin, L., & Yu, H. (2012). Offshore wave energy generation devices: Impacts on ocean Bio-environment. *Acta Ecologica Sinica*, 32, 413-434.
- Lund, W.T., & Freeston H.D, Boyd, L.T. (2010). Direct Utilization of Geothermal Energy. Retrieved from <http://geotermia.org.mx/geotermia/pdf/WorldUpdateDirect2010-Lund.pdf>
- Masters, J. (2012). CRFM Statistics and Information Report-2010. Retrieved from [http://www.crfm.net/~uwohxjxf/images/CRFM\\_Statistics\\_and\\_Inormation\\_Report\\_2010\\_revised\\_June\\_2014\\_for\\_website.pdf](http://www.crfm.net/~uwohxjxf/images/CRFM_Statistics_and_Inormation_Report_2010_revised_June_2014_for_website.pdf)
- Maynard-Date, A., & George, A. (2013). Geothermal Status, Progress and Challenges in the Eastern Caribbean Islands. <http://www.os.is/gogn/unu-gtp-sc/UNU-GTP-SC-16-05.pdf>
- Maynard- Date, A., & Farrell, C.N. (2011). Geothermal Activity and Development in Eastern Caribbean. Retrieved from <http://www.os.is/gogn/unu-gtp-sc/UNU-GTP-SC-12-07.pdf>

- McCall, T. (2014, September 19). Increased minimum wage electricity debt forgiveness announced by PM. SKNVibes News. Retrieved from <http://www.sknvibes.com/news/newsdetails.cfm/88855>
- Nevis Island Partners. (2013). Retrieved September 27, 2014, from the PR Newswire Website, <http://www.prnewswire.com/news-releases/nevis-island-partners-with-nrei-to-develop-geothermal-energy-plant-232907871.html>
- NRSL/OAS. (2012). Energy Policy and Sector Analysis in the Caribbean 2010-2011. Retrieved from [http://www.ecpamericas.org/data/files/Initiatives/lccc\\_caribbean/LCCC\\_Report\\_Final\\_May2012.pdf](http://www.ecpamericas.org/data/files/Initiatives/lccc_caribbean/LCCC_Report_Final_May2012.pdf)
- OSPAR Commission, (2009). Assessment of the Environmental Impacts of Cables. *Biodiversity Series*. 1-19  
Retrieved from: [http://qsr2010.ospar.org/media/assessments/p00437\\_Cables.pdf](http://qsr2010.ospar.org/media/assessments/p00437_Cables.pdf)
- Papier, R. (2008). The Politics of Renewable Energy: Unintended Consequences of Biofuel. *E- International Relations*. Retrieved from <http://www.e-ir.info/2008/02/10/the-politics-of-renewable-energy-unintended-consequences-of-biofuel-policies/>
- Saint Christopher and Nevis Constitution order, 1983, Statutory Instruments 1983 No.881  
Retrieved from <http://pdba.georgetown.edu/Constitutions/Kitts/kitts83.html>
- Simpson, K., & Sheperd, J.B. (2001). Volcanic-hazard assessment for St. Kitts, Lesser Antilles. Seismic Research Unit, The University of the West Indies. Retrieved from [http://www.oas.org/pgdm/hazmap/volcano/stk\\_volc.htm](http://www.oas.org/pgdm/hazmap/volcano/stk_volc.htm)
- St. Kitts and Nevis History. (n.d). Retrieved September 10, 2014 from The Commonwealth website, <http://thecommonwealth.org/our-member-countries/st-kitts-and-nevis/history>
- St. Kitts and Nevis focus on Renewable Energy. (2014). Retrieved September 20, 2014, from Caribbean News Now website, <http://www.caribbeannewsnow.com/headline-St-Kitts-Nevis-focuses-on-renewable-energy-20801.html>
- St. Kitts and Nevis Profile. (n.d). Retrieved September 15, 2014, from the Global Sustainable Energy Islands Initiative website (GSEII), <http://www.gseii.org/islands/st-kitts-nevis.html>
- Synder, J., & Rondrof, N. (2011). About Submarine Cables: IPCC

- Taiwanese Solar Panel. (2013) Retrieved September 17, 2014, from the Caribbean Journal website, <http://www.caribjournal.com/2013/06/27/taiwanese-solar-panel-manufacturing-plant-opens-in-st-kitts/>
- Wind Farm Initiative. (2014). Retrieved September 17, 2014, From the SKNvibes News website, <http://www.sknvibes.com/news/newsdetails.cfm/72778>
- Williams, E. (2014). Caribbean Journal says St. Kitts is undergoing a hotel development Boom, Retrieved from, SKNvibes News website, <http://www.sknvibes.com/news/newsdetails.cfm/88163>
- William, E. (2014). St. Kitts and Nevis leads the OECS in exports of goods and services to the US in 2013, first three months of 2014, retrieved from, SKNvibes News website, <http://www.sknvibes.com/news/newsdetails.cfm/87347>
- World Bank/Nexant. (2010), Caribbean Region Electricity Generation, Interconnection and Fuel Supply Strategy. *Interim Report*. Retrieved from: [http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2011/02/08/000112742\\_20110208142646/Rendered/PDF/594850Final0Report.pdf](http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2011/02/08/000112742_20110208142646/Rendered/PDF/594850Final0Report.pdf)
- World Energy Council. 2010. Surrey Energy Resources 2010. London, U.K  
Retrieved from: [http://www.worldenergy.org/documents/ser\\_2010\\_report\\_1.pdf](http://www.worldenergy.org/documents/ser_2010_report_1.pdf)

## Appendix

**Table 10. Energy consumption forecast for St. Kitts and Nevis (From: ECPA/OAS, 2013)**

Year	Annual energy (mwh)					
	Base growth rates			Low growth rates		
	St Kitts	Nevis	Combined	St Kitts	Nevis	Combined
<b>2011</b>						
Base load	130,000	60,000	190,000	130,000	60,000	190,000
Marriott	9,000	0	9,000	9,000	0	9,000
Christophe	3,000	0	3,000	3,000	0	3,000
Total	142,000	60,000	<b>202,000</b>	142,000	60,000	<b>202,000</b>
<b>Growth rate</b>	2.90%	5.20%		1.45%	2.60%	
<b>2012</b>	142,000	60,000	202,000	142,000	60,000	202,000
<b>2013</b>	142,000	60,000	202,000	142,000	60,000	202,000
<b>2014</b>	142,000	60,000	202,000	142,000	60,000	202,000
<b>2015</b>	142,000	60,000	202,000	142,000	60,000	202,000
<b>2016</b>	146,118	63,120	209,238	144,059	61,560	205,619
<b>2017</b>	150,355	66,402	216,758	146,148	63,161	209,308
<b>2018</b>	154,716	69,855	224,571	148,267	64,803	213,070
<b>2019</b>	159,202	73,488	232,690	150,417	66,488	216,904
<b>2020</b>	163,819	77,309	241,128	152,598	68,216	220,814
<b>2021</b>	168,570	81,329	<b>249,899</b>	154,811	69,990	224,800
<b>2022</b>	173,459	85,558	259,017	157,055	71,810	228,865
<b>2023</b>	178,489	90,007	268,496	159,333	73,677	233,009
<b>2024</b>	183,665	94,688	278,353	161,643	75,592	237,235
<b>2025</b>	188,991	99,611	288,603	163,987	77,558	241,544
<b>2026</b>	194,472	104,791	<b>299,263</b>	166,365	79,574	<b>245,939</b>
<b>2027</b>	200,112	110,240	310,352	168,777	81,643	250,420
<b>2028</b>	205,915	115,973	321,888	171,224	83,766	254,990
<b>2029</b>	211,887	122,003	333,890	173,707	85,944	259,651
<b>2030</b>	218,031	128,347	346,379	176,226	88,178	264,404
<b>2031</b>	224,354	135,022	359,376	178,781	90,471	269,252
<b>2032</b>	230,861	142,043	372,903	181,373	92,823	274,196
<b>2033</b>	237,556	149,429	386,984	184,003	95,237	279,240
<b>2034</b>	244,445	157,199	401,644	186,671	97,713	284,384
<b>2035</b>	251,534	165,374	416,907	189,378	100,253	289,631
<b>2036</b>	258,828	173,973	432,801	192,124	102,860	<b>294,984</b>