JUSTIFICATION AND PRE-FEASIBILITY STUDY OF AN ELECTRICAL INTERCONNECTION FOR ST. KITTS AND NEVIS

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ABSTRACT

The Federation of St. Kitts and Nevis fully depends on petroleum imports for its electricity supply. However, renewable energy resources are abundant and provide the opportunity to diversify the energy mix and decrease the negative impact of high oil prices. This research comprises an energy analysis and an interconnection assessment as part of a pre-feasibility study for an electrical interconnection for St. Kitts and Nevis.

The energy analysis revealed that the implementation of four Renewable Energy Projects (REPs) - one biomass, one geothermal and two wind projects - matches the future demand for both islands independently and collectively. Multiple Linear Regression (MLR), proved to be a successful tool to forecast monthly electricity demand in Nevis. For St. Kitts an existing study was used to make the necessary demand projections, as the available dataset could not be applied satisfactorily in a multiple regression analysis.

The study found that electrical interconnection between St. Kitts and Nevis is justifiable and should ease the strained energy supply systems of both islands by adding extra capacity. Additionally, as St. Kitts encounters an electricity deficit, Nevis will produce more electricity than demanded. A cross border interconnection beyond the Federation's territory might not be an attractive option as the total operational capacity will not be sufficient to service the nations peak demand after 2015, 2016 or 2018, depending on the demand-ratio. This under the assumption that conventional electricity supply will be phased out, the capacity of the REPs will not be expanded, and no new REPs will enter the field.

The construction of a submarine cable between St. Kitts and Nevis is a viable alternative, which should not encounter large geographical and regulatory difficulties. The institutional framework should be transparent and close cooperation between the stakeholders involved will be indispensible to make the REPs successful and sustainable.

1. INTRODUCTION

1.1 Background and Problem Definition

The Federation of St. Kitts and Nevis is a Small Island Developing State (SIDS) located in the north-eastern Caribbean region. The two islands are geographically separated by a two mile stretch of water. St. Kitts is the largest island and covers an area of 65 sq. miles. The population on St. Kitts is approximately 30,000 with a population density of 186 persons per square miles. Nevis at 36 sq miles is somewhat smaller. The population is estimated to be 12,000 and the population density is lower than St. Kitts'; 111 persons per square mile.[1] The economy of the St. Kitts and Nevis is characterized by agriculture[2], tourism and light manufacturing industries.

Currently all electricity is produced by diesel fueled generators. This places St. Kitts and Nevis in a vulnerable position as the islands are fully dependent on imported fossil fuel for their electricity generation and transportation fuel. The price for electricity has been kept artificially low, primarily through a subsidy scheme initiated by the government. However, the increase in the price of oil in recent years prompted the government to initiate a fuel surcharge in October 2005 in St. Kitts. Nevis followed suit two months later in December 2005. Oil prices have continued to increase, since implementation of the fuel surcharge, and as a result, retail prices for electricity have doubled from late 2005 to August 2008.

This dependency on fossil fuels not only results in unreliable and currently high energy prices, it also contributes to global climate change. The associated projected sea level rise can have severe implications for coastal communities like St. Kitts and Nevis. Moreover, higher ocean temperatures will likely increase the intensity of hurricanes with increased wind speeds and more precipitations (IPCC, 2007). Obviously, the individual contribution of St. Kitts and Nevis to global energy consumption is marginal. Nevertheless, St. Kitts and Nevis can become an example of how energy supply diversification towards indigenous renewable resources can stimulate the economy and create new jobs.

Despite the difficulties small island developing states like St. Kitts and Nevis encounter in supplying their energy needs; the opportunities for generating electricity and producing transportation fuel from renewable resources seem abundant. The efforts to diversify the energy portfolio of St. Kitts and Nevis started in 2001. As a result of the on-going work of the Organization of the American States (OAS) and other institutions, there has been significant progress in the development of renewable energy alternatives in St. Kitts & Nevis. These resulted in the following Renewable Energy Projects (REPs) that are currently under government review or are in development:

[1] US Department of State, 2008. Available from http://www.state.gov/r/pa/ei/bgn/2341.htm
[2] From 1640 onwards, sugar was the primary export product. However, due to the rising production costs and low market prices the government decided to shut down the state owned sugar companies at the end of July 2005 (Ibid).

- A 5 MW biomass pyrolysis system in St. Kitts;
- A 10 MW wind park in St. Kitts, with the possibility to extend to 20 MW;
- A geothermal project in Nevis with an installed capacity of at least 34 MW; and
- A 1.1 MW wind park in Nevis, with the potential to grow to 10 MW.

This additional renewable energy capacity is large considering the current peak demand, which amounts to 25.3 MW in St. Kitts and 9 MW in Nevis. There is a possibility that energy demand may increase, as St. Kitts and Nevis switches from an agriculture-based economy to a high-end tourism based economy. However, stakeholders expect that the price of electricity will drop once these REPs are online attracting other (energy intensive) sectors. This may be an opportunity to diversify the economy by attracting light manufacturing industries, for instance.

Implementation of the REPs requires extensive planning of the development of the energy supply system and its associated infrastructure. At the moment, the electricity systems of St. Kitts and Nevis are operated independently. Electrical interconnection, transporting electricity from one island to the other, seems indispensable in making the REPs profitable. Besides the facilitation of REPs, integrating regional energy systems has more advantages. In a case study for Africa, the World Energy Council (2005) identified three additional major benefits: improved security of supply; better economic efficiency; and enhanced environmental quality.

1.2 Research Question

In the coming years, the electricity supply system of St. Kitts and Nevis will undergo several changes. On the one hand the electricity supply portfolio will be diversified and the total installed capacity will increase. The REPs will decrease the dependency on foreign fuel and lower electricity prices. This might, on the other hand, lead to an increase in the demand for electricity. Less expensive electricity will make St. Kitts and Nevis a more attractive place for (energy intensive) industries. Furthermore, the tourism sector will continue to expand given the government stimulus, and more a reliable and cheaper electricity supply.

At first glance the demand and supply for electricity seem to counterbalance. This cause-effect development however, merits further explanation, as the location of surplus electricity is likely to be Nevis because of the large geothermal potential, while St. Kitts has currently and will continue to have the higher electricity demand.

This study investigates how the electricity supply and demand can be matched spatially and temporally, while taking into account the perspectives of the parties involved i.e. governments, departments, utilities and project developers. The following research question has been defined:

How can all planned renewable energy projects be introduced into the small-scale distribution network(s) of St. Kitts and Nevis?

The remaining sections give an overview of the energy situation in St. Kitts and Nevis, including an energy analysis, an interconnection assessment, a description of the methodology applied, and the results obtained.

2. ELECTRICITY GENERATION AND DISTRIBUTION

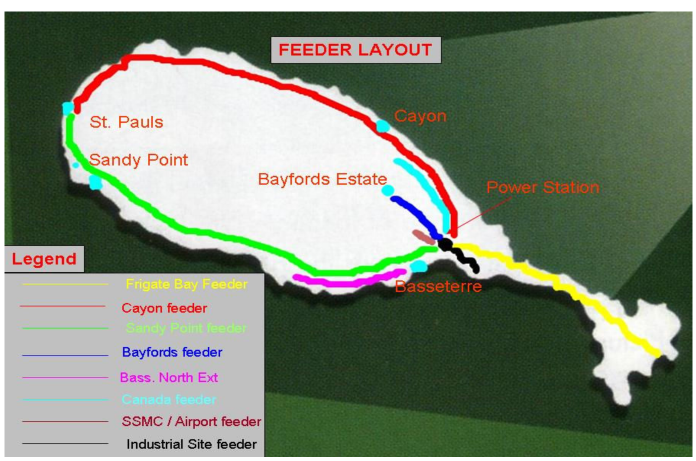
The island's power systems are currently operated independently and are not interconnected. The St. Kitts Electricity Department (SKED) is headquartered in Basseterre and the Nevis Electricity Company Limited (NEVLEC) is headquartered in Charlestown. Details on the operations and structure of each are provided below.

2.1 St. Kitts Electricity Department

Currently, electricity production and distribution in St. Kitts is managed by the state owned SKED. The installed capacity of the eight diesel generators amounts to 37.5 MW while the current available capacity is 34.5 MW. This services a peak demand of 25.3 MW (J. Channer, personal communication, August 12, 2008). The operational capacity corrects the available capacity by excluding generators passed the lifetime of 20 years and incorporates a safety margin by excluding the largest generator amounts to 18.9 MW. The spinning reserve[3] is of 8 MW and there is a back-up capacity of 1.5 MW from the Marriot Hotel. The engines suffer multiple brown-outs and outages (Ibid).

The supply is distributed throughout the island by 13, 11 kV/60 Hz radial feeders originating from the power station (Figure 1). It comprises both underground and overhead feeders, of which 90% of the latter was upgraded recently. The Canyon feeder and the Sandy point feeder in the NE part of St. Kitts are not connected (N. Greaux, personal communication, August 12, 2008).

Figure 1
Feeder layout of the St. Kitts Electricity Department[4]



[3] Spinning reserve is defined as any back-up energy generation capacity which can be made available to a distribution system with ten minutes notice and can operate continuously for at least two hours once it is brought online (Energyvortex, 2008).
[4] Source: N. Greaux, personal communication, August 12, 2008

In St. Kitts, the retail price for electricity has remained constant through government subsidies. Domestic consumers have been paying 0.37 EC$/kWh[5] and industrial and commercial consumers 0.43 EC$/kWh[6] for the last decades. A fuel surcharge[7] applied since October 2005 increased electricity prices by 0.15 - 0.30 EC$/kWh. The fuel surcharge is calculated on the first day of every month (D. Edmeade, personal communication, August 12, 2008).

Currently, the SKED is still a department within the Ministry of Public Works, Utilities, Transport and Post of the federal government. A corporation process, initiated in July 2007, should eventually lead to a fully federal government owned electricity utility (L. Queeley, personal communication, August 13, 2008).

2.2 Nevis Electricity Company Limited

The private/state owned NEVLEC produces and distributes electricity in Nevis. The diesel fueled generation units have an installed capacity of 13.2 MW. However, the largest unit with a capacity of 2.7 MW is not online and another 2.5 MW unit is not reliable. Hence NEVLEC needs all engines to service a peak demand of 9 MW (C. Farell, personal communication, August 14, 2008).

The operational capacity includes only the engines within the lifetime of 20 years and applies a safety margin by not counting the largest engine amounts to 6.7 MW. There is neither spinning reserve nor back-up capacity. In order to increase their production capacity, NEVLEC is currently reviewing several proposals, including one from the Caribbean Development Bank, to purchase two 4 MW diesel engines. In view of the developments in the geothermal project, NEVLEC is considering the purchase of one 4 MW diesel engine instead (Ibid).

The distribution system comprises five 11 kV/60 Hz overhead feeders. Four feeders make up two rings; a larger one around the island and a smaller one in Charlestown. The fifth feeder is a dedicated feed to the Four Seasons resort (Figure 2). There are no substations and the distribution can be coordinated (turned on or shut off) by the use of hand switches. The last upgrade was performed in 1992 and NEVLEC has indicated that some structural improvements are necessary to upgrade some feeders (Ibid).

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[5] The domestic rate consists of an energy charge and a demand charge. The energy charge increases from 0.32 EC$/unit for the first 50 units, to 0.35 EC$/unit for the next 75 units to 0.37 EC$/unit for electricity consumed above 125 units. The demand charge increases with higher consumption; 7.20 EC$ for consumption up to 120 units, 12.50 EC$ for consumption between 120 and 240 units and 18.40 EC$ for consumption above 240 units.

[6] The industrial and commercial rate also consists of an energy charge and a demand charge. However, the energy charge decreases with higher consumption; 0.43 EC$/unit is the highest level of consumption and 0.39 EC$/unit is the lowest. The Standing charge amounts to 13.20 EC$ per 250 units.

[7] The fuel surcharge is imposed by the utilities when fuel prices reach over $3.38 per gallon. The fuel surcharges increases by one cent for each 12 cents increase above this level (D. Edmeade, personal communication, August 12, 2008).

NEVLEC has sold its subsidized electricity for 0.47 EC$/kWh[8] to domestic customers and 0.52 EC$/kWh[9] to commercial customers for several years. A fuel surcharge applied since December 2005 increased electricity prices by 0.21 - 0.66 EC$/kWh (A. Date, personal communication, August 14, 2008).

Figure 2
Feeder Layout of the Nevis Electricity Company Ltd[10].

3. METHODOLOGY

This research paper is divided into two parts: an energy analysis and an interconnection assessment. The energy analysis enlightens the size and location of the electricity generation surplus and indicates the necessity of an interconnection. The interconnection assessment on the other hand, points out the technical, regulatory and institutional aspects of an electrical interconnection between St. Kitts and Nevis and other islands in the Caribbean region.

On August 10, 2008 a delegation of the Department of Sustainable Development of the OAS travelled to St. Kitts and Nevis for a technical mission. One of the objectives was to collect historic and forecasting socio-economic statistics for the energy analysis. For the interconnection assessment the energy team consulted various stakeholders on the technical characteristics of electricity generation, transmission and distribution among the islands. The possible institutional and regulatory linkages for operation and management of the system were also discussed with the stakeholders.

[8] The domestic rate consists of the flat rate, the energy charge and de standing charge. The energy charge decreases from 0.51 EC$/unit for the first 50 units, to 0.49 EC$/unit for the next 75 units to 0.47 EC$/unit for the electricity consumed above 125 units. The standing charge increases with higher consumption; 7.20 EC$ for consumption up to 120 units, 12,00 EC$ for consumption between 120 and 250 units and 18,00 EC$ for consumptions more than 250 units.

[9] The commercial rate consists of an energy charge and a standing charge. The energy charge decreases with higher consumption; 0.52 EC$/unit as highest and 0.44 EC$/unit as lowest energy charges. The Standing charge amounts to 13.20 EC$ per 250 units.

[10] Source: C. Farell, personal communication, August 14, 2008

During this mission it was discovered that a consultancy firm had already been hired to perform a technical-economical analysis of the electrical interconnection (B. Tinsley, personal communication, August 14, 2008). In order to prevent overlap between these two studies, it was decided to switch the emphasis from the technical and economical requirements to the justification of the interconnection. Nevertheless, the technical, regulatory and institutional aspects were significantly emphasized.

3.1 Energy Analysis

The overview of the current energy situation given in the previous chapter pointed out that the electricity systems on both islands operate independently. Each island has its own factors influencing electricity supply and demand and conducting an energy analysis on the federal level would neither give the information necessary for the interconnection study, nor provide the methodology which can be followed by the electricity utilities. Consequently, the energy analysis was conducted separately for the island of St. Kitts and the island of Nevis. The supply and demand at the federal level was determined by merging the two energy analyses.

Electricity Supply

The project developers and key persons involved in the implementation of the REPs were consulted for an update on the developments of the energy supply site.

Electricity Demand

The electricity demand forecast for St. Kitts and Nevis was set up in a practical and manageable manner in order for it to be continued independently by the Ministries with energy in their portfolio. Moreover, it included parameters that was available on the islands; was reliable; and also affected electricity demand. Multiple Linear Regression (MLR) is a quantitative method used to examine the relationship between a single dependent variable such as electricity demand, and two or more independent variables. Moreover, MLR can be used as a forecasting tool. MLR is widely used in biological, financial and social sciences and has been successfully applied in several electricity demand studies around the world (Lorchirachoonkul, 2006). Because the input for this forecast methodology can easily be updated and the software package is free and compatible with Microsoft Excel, it is a suitable tool for the energy analysis.

When forecasting, the goal is to develop a formula for making predictions about the dependent variable, based on the observed and forecasted values of independent variables. The MLR forecast equation is defined as follows (Fisher, 2005):

$$\hat{y} = \hat{a} + \sum_{i=1}^{k} \hat{b}_i x_i$$

Where:

y = forecast for *dependent* variable, y

k = number of *independent* variables

x_i = ith *independent* variable, where $i = 1...k$

$\hat{a}$ = estimated intercept term for the line

$\hat{b}_i$ = estimated slope coefficient associated with variable x_i

First, a pre-selection of independent variables based on their availability and impact was made. The second step was to gather a dataset of the pre-selected variables as large, detailed and reliable as possible. The intention was that the dataset has the following observations for the dependent and all pre-selected independent variables:

- monthly based;
- representative of the period from 1980 to present;
- categorized as per consumer group;
- available for St. Kitts and Nevis, independent of each other.

Furthermore it should include forecasting data of the independent variables.

Subsequently, by means of a correlation analysis it was determined which independent variables influence electricity demand. Based on the number of observations[11], the quality of the dataset and the correlation between the independent and the dependent variable, a final selection was made.

Several models with different variable combinations and/or different level of detail were proposed. The validated model with the highest correlation and significance was used for the final energy analysis. Electricity supply and demand were matched spatially (per island) and temporally (in the period 2008-2020) to indicate the necessity of the interconnection.

3.2 Interconnection Assessment

First, geographical data such as distances and bathymetry[12] of the St. Kitts and Nevis territory and the Leeward Islands were collected. Then, a review of the literature on past experiences with submarine electricity cables was conducted. This gave an idea of the technological requirements for an interconnection between St. Kitts, Nevis and other islands in the Caribbean region.

Insights into the regulatory aspects of an interconnection were obtained during the mission to St. Kitts and Nevis where various stakeholders were consulted about their view on a possible (cross border) interconnection. Federal and international laws provided the framework for the institutional aspects of the (cross border) interconnection.

The interconnection assessment can be considered as a pre-feasibility study and should be followed up by a more detailed technical and economical feasibility assessment.

[11] There should be at least 10 to 20 times as many observations as variables, otherwise the estimates of the regression line are probably very unstable and unlikely to replicate (StatSoft, 2007).
[12] The measurement of the depths of oceans, seas, or other large bodies of water.

4. MATCHING ELECTRICITY SUPPLY AND DEMAND

4.1 Electricity Supply

The path from a Sustainable Energy Plan towards the aimed energy supply is long and marred with many obstacles that must be overcome; and as long as none of the four REPs are operational, it is impossible to say what their actual energy supply will be. Table 1 summarizes the planned implementation dates and capacities of the four REPs. Note that the time mentioned refer to the most optimistic planning. Moreover, electricity supply on St. Kitts and Nevis will be highly dependent on the interconnection between the islands and with other islands in the region. An interconnection will increase the delivery options for the project developers and the electricity utilities and therefore stimulate expansion of the current four REPs and/or the attraction of new REPs.

Table 1
Planned Capacity, Operational Capacity and Timing for the Four REPs on St. Kitts and Nevis.

		St. Kitts		Nevis	
		Wind	**Biomass**	**Wind**	**Geothermal**
Phase 1	**Capacity (MW)**	1 (0.42)	5 (3.5)	1.1 (0.46)	34 (30.6)
	Time	End 2008	Mid 2010	Beg. 2009	End 2009
Phase 2	**Capacity (MW)**	10 (4.2)		10 (4.2)	t.b.a
	Time	End 2009		t.b.a	t.b.a
Phase 3	**Capacity (MW)**	20 (8.4)			
	Time	t.b.a.			

It should be noted that there is a distinction between the installed capacity and the operational capacity. The first refers to the total installed capacity of the conventional and renewable energy turbines, whereas the latter corrects for the anticipated operating time and output of the turbines. In Table 1 the operational capacity is displayed with the numbers between the brackets. In order to realistically approach the actual electricity supply, the operational capacities instead of the installed capacities were used for this energy analysis.

The operational capacity for the REPs was determined as follows: wind energy is an intermittent resource and electricity generation depends heavily on the wind regime. Contreras (2008), calculated that the operational capacity of the planned wind project on Nevis will be 42% of the installed capacity. The same capacity factor has been used for the wind energy project on St. Kitts assuming the wind regime will be the same on both islands. In general, the capacity factor of geothermal plants varies around 0.9 depending on the type of geothermal system in place (Geothermal Energy Association, 2008). The capacity factor of the conventional power plant is 0.75 in St. Kitts (J. Channer, personal communication, August 12, 2008) and 0.74 in Nevis (C. Farell, personal communication, August 14, 2008). Bio-energy plants are assumed to have a capacity factor of 0.7 similar to conventional power plants (Azar, 2000).

The current condition of the electricity supply by conventional diesel engines was discussed in section 3. The following sections provide an overview of the capacity and planning of the wind, geothermal and bio-energy projects on St. Kitts and Nevis.

Bio-energy on St. Kitts

The bio-energy project in St. Kitts will use the former sugarcane lands on the Atlantic side of St. Kitts. The location of the bio-energy plant is not determined yet, but it will be selected in a way that allows for the shortest distance for transportation of feedstock. A fast growing bamboo-grass which can be harvested year round will be used as feedstock. It is estimated that 4,000 acres will produce about 120,000 tons of dry biomass per year. The majority of the feedstock will be used for the production of bio-oil for export or local use. The bio-energy project will have an installed capacity of 5 MW.

As soon as the project proposal is accepted by the federal government, the sugarcane growing wildly will be harvested, pelletized and shipped to Europe. Subsequently the bamboo-grass will be planted and the first harvest may occur after 18 months.

Wind energy on St. Kitts

In this project 0.9-1.2 MW wind turbines will be installed next to the Robert Llewellyn Bradshaw International Airport. The project consists of three phases. Phase one involves one wind turbine to be installed at the end of 2008. In phase two the installed capacity is increased to 10 MW in 2009/2010. In phase three the installed capacity is doubled to 20 MW. Initialization and timing of phase three will depend on future electricity supply and demand in St. Kitts and the possibility of an interconnection.

Geothermal energy on Nevis

In July 2008, the parliament of the Nevis Island Administration (NIA) accepted the geothermal bill delineating a regulatory framework for the implementation of geothermal energy on Nevis. The geothermal potential is positive and the geological data acquisition proceeding steadily. Two more exploration wells, in addition to the current two sites, will be drilled to provide more information about the extensions and other characteristics of the geothermal reservoir. The installed capacity of the geothermal plant will depend on the interconnection and the geothermal potential but it can be as high as 34 MW as inferred from presently available estimations to service both islands in their electricity demand. In case an interconnection with another island in the Caribbean region is economically and technically feasible, the production capacity may be further increased. The geothermal plant is expected to be in operation by the end of 2009.

Wind energy on Nevis

The project proposal for a wind turbine park along the Nevis coast is at the NIA for approval. Once accepted, the first phase of 1.1 MW installed capacity will be in operation in 6 months. The project may be extended to 10 MW in a second phase.

4.2 Electricity Demand

Pre-selection of Variables

In Multiple Linear Regression data of the independent variables (x) should be available and should have an effect on the dependent variable (y) - electricity demand. Table 2 provides an overview of variables used in previous load forecast studies.

Each MLR electricity demand forecast study reviewed selected different independent variables based on the specific characteristics of the investigated country/region. For example, in Northern Cyprus the tourism industry had a large influence on the electricity demand, while in New Zealand this variable had a smaller influence on the total national electricity demand and hence was not included in the study by Mohamad et al. (2004).

Moreover one can imagine that temperature has a large influence on electricity demand in countries with severe winters and electricity-based heating systems. On the other hand, in tropical countries with little seasonal variation the temperature has less impact on electricity demand.

Table 2
Independent Variables used in previous MLR Electricity Demand Forecast Studies

Theme		Location	Author
Wealth	Real GDP	New Zealand	Mohamad et al., 2004
			Fatai et al., 2003
	GDP per month	Thailand	Lorchirachoonkul, 2006
	Per Capita Income	Northern Cyprus	Egelioglu et al. 1999
Power Tariff	Electricity Price	New Zealand	Mohamad et al., 2004
			Fatai et al., 2003
		Thailand	Lorchirachoonkul, 2006
		Northern Cyprus	Egelioglu et al. 2001
Weather	Temperature	New Zealand	Fatai et al., 2003
Number of Users	Population	Thailand	Lorchirachoonkul, 2006
		New Zealand	Mohamad et al., 2004
	Customers	Northern Cyprus	Egelioglu et al. 2001
	Number of tourists	Northern Cyprus	Egelioglu et al. 2001

Based on the previous studies discussed above and the demographic, geographic and economic characteristics of St. Kitts and Nevis it has been decided to pre-select the independent variables as follows: GDP; Electricity price; Population; and the Number of Tourists, for the St. Kitts and the Nevis case study.

Sources of Data - St. Kitts

The historical analysis period range from January 1998 to December 2004 and was determined by the total monthly electricity sales data obtained from (Stanley Consultants, 2002; 2005). Sales for the last five months of 2001 were interpolated as these data were lacking. The electricity retail price—which has been constant for decades due to governmental subsidies (J. Channer, personal communication, August 12, 2008)—and the monthly fuel surcharge from January 2006 to July 2008 were obtained courtesy of (D. Edmeade, personal communication, August 12, 2008). Both midterm population estimates in the period 1997-2004 and monthly tourism stay-overs in the period January 1999 to June 2007 were provided by (B. Harris, personal communication, August 26, 2008). The monthly tourism stay-overs of 1998 were extrapolated.

Sources of Data - Nevis

The historical analysis period range from January 2001 to February 2008 based on the total, monthly electricity sales that were obtained from (C. Farrell, personal communication, August 14, 2008). Data on electricity retail price, which had been constant for decades due to governmental subsidies (Ibid), and data on monthly fuel surcharge from December 2005 to August 2008 were obtained from (A. Date, personal communication, August 14, 2008). Mid-term population estimates from 2001 to 2006 were reported in the Nevis Statistical Digest 2006. Monthly tourism stay-over's in the period January 1999 to December 2007 was provided by (B. Harris, personal communication, August 26, 2008).

As a general note, GDP as reported in the world economic outlook database of the IMF (2008) is only available at the federal level and per year. Hence, this is the only variable where there is no distinction between the two islands. Furthermore, in this study it is assumed that the federal GDP and the population grow in a linear fashion. In this way yearly data has been refined to monthly data, enabling to continue the energy analysis on this detailed level.

Proposed Model

The proposed Multiple Linear Regression model to fit historical data and forecast future electricity sales is:

$$Ed = a + b_1 Price + b_2 Pop + b_3 T + b_4 GPD + u$$

Where:	Ed	=	Electricity sales (MWh/month, MWh/season or MWh/year)
	a,b	=	Regression coefficients
	Price	=	Price of electricity (EC$cents/kWh)
	Pop	=	Population (#)
	T	=	Number of tourists (#)
	GDP	=	Current GDP in million EC$
	u	=	Disturbance term

Several statistical tests were used to select the independent variables of the final model and to eventually validate both the St. Kitts and Nevis forecast models. The adjusted R^2 determines how well the model explains actual electricity sales data. The Variance Inflation Factor (VIF) is a test to detect the severity of multi-collinearity in the model. Lastly, the F-test on a 0.05 significance level was used to determine overall significance of the model.

4.2.1 Results and Data analysis - St. Kitts

In St. Kitts the fuel surcharge was applied for the first time in October 2005. However, the available historical data set of the electricity demand dates from January 1998 to December 2004. This means that the price of electricity is constant for the entire period under analysis, resulting in a correlation with the independent and other dependent variables of '0'. Even though a change in electricity price will most probably affect the electricity demand, this aspect can not be taken into account because of the lack of historical data. Hence, the variable 'price of electricity' is excluded from further analysis.

Table 3 shows the adjusted correlation, the results of the statistical tests and dependency of the remaining and adapted independent and dependent variables. The F-ratio is larger than the critical value of 2.72 for a degree of freedom (3, 80[13]) suggesting the model is significant. In addition, the correlation between the dependent variable and the VIF values indicate there is no multi-collinearity. Unfortunately, the adjusted R^2 of 0.1834 indicates that the correlation between the variables is low.

Table 3
Correlation Matrix and Validity Test Results for St. Kitts

Model #1						
	pop	**T**	**GDP**			
Pop	1.0000				**Adjusted R^2**	0.1834
T	0.5231	1.0000			**F-ratio**	7.2147
GDP	0.9245	0.4674	1.0000		**$F_{critical}$**	2.7188
Ed	0.2399	0.0622	0.3706		**Df**	80
VIF	7.4199	1.3801	6.8961			

Subsequently, several models that manage the available dataset differently will be investigated in order to detect how the correlation can be increased while remaining statistically viable and significant.

Population data shows an unusual high growth between 1998 and 1999, followed by an unusual sharp decline during 1999-2000. This is a very remarkable trend compared to the steady growth in the years before 1999 and after 2000. Moreover, the population

[13] Where 3 is the number of independent variables (x) and 80 the number of observations minus the number of independent variables.

estimates of the IMF (2008) and the US Census bureau (2008) do not show this sharp increase and decrease in the period 1999-2000. In model #2 this unusual trend in population was smoothened to fit the other data sources and the past trend. However, this did not result in a better model (see Table 4), since the adjusted R^2 decreased to 0.123 and the problem of multi-collinearity is severe.

Table 4
Correlation Matrix and Validity Test Results for St. Kitts

Model #2						
	pop	**T**	**GDP**			
Pop	1.0000				**Adjusted R^2**	0.123
T	0.5002	1.0000			**F-ratio**	4.8804
GDP	0.9905	0.4674	1.0000		**$F_{critical}$**	2.7188
Ed	0.3566	0.0622	0.3706		**Df**	80
VIF	58.5127	1.4122	56.1370			

The electricity demand over time does not show a distinctive monthly pattern. Hence, in model #3 investigates whether the correlation increases once the monthly data is flattened to seasonal data. Table 5 shows the correlation matrix and the statistical test results of this seasonal model.

Table 5
Correlation Matrix and Validity Test Results for St. Kitts

Model #3						
	pop	**T**	**GDP**			
Pop	1.0000				**Adjusted R^2**	0.4443
T	0.5622	1.0000			**F-ratio**	7.9279
GDP	0.9166	0.4807	1.0000		**$F_{critical}$**	3.028
Ed	0.4114	0.2992	0.6029		**Df**	23
VIF	7.1138	1.4782	6.3279			

The significance and validity tests are positive and the adjusted R^2 increases substantially to 0.44. Nevertheless, this number does not prove that there is a clear correlation between the independent and dependent variable.

In model #4 the monthly data is flattened to yearly data. The number of observations decreases substantially and consequently the F-ratio, (indicating the significance of the model) dropped below the critical value. The other results of this model are summarized in Table 6.

Table 6
Correlation Matrix and Validity Test Results for St. Kitts

Model #4						
	pop	**T**	**GDP**			
Pop	1.0000				**Adjusted R^2**	0.361
T	0.7932	1.0000			**F-ratio**	2.1301
GDP	0.8670	0.8080	1.0000		**$F_{critical}$**	9.2766
Ed	0.2588	0.4640	0.6093		**Df**	3
VIF	4.4732	3.2001	4.7787			

None of the models described above shows a significant correlation between the electricity demand and population, the number of tourists and the GDP. Therefore, it must be concluded that MLR with the available dataset is not a useful tool to forecast electricity demand in St. Kitts. This lack of correlation can have several causes.

The first cause can be erroneous values in the available dataset. For example, metering mistakes in the electricity sales of the SKED can double count electricity sales, count electricity sales in the wrong month, or not count them at all. The St. Kitts model #3 tried to reduce the impact of such errors by grouping three months into one season. This increased the correlation substantially, but not enough to use this model for forecasting electricity demand.

A second cause for the lack of correlation can be related to the time period. The beginning of the period under analysis 1998-2004 is characterized by Hurricane Georges in September 1998 (and to a lesser extent Lenny in November 1999). According to the U.S. Agency for International Development (1998), Georges significantly affected among others, the tourism industry and destroyed 50% of the 1999 sugarcane harvest. As a result, GDP per capita showed a decreased growth from 1999 to 2003 (IMF, 2008). Another mismatch in the time period under analysis is the electricity demand, which shows a remarkably high peak in 2000. This does not correlate in any way to the decreased GDP, tourists and population (see St Kitts model #2). Attempts to exclude these unusual years (1998-2000) from the analysis did not result in better models. Running the model from January 2001, January 2002 or January 2003 to December 2004 resulted in the following adjusted R^2 and F-test results (See Table 7 below).

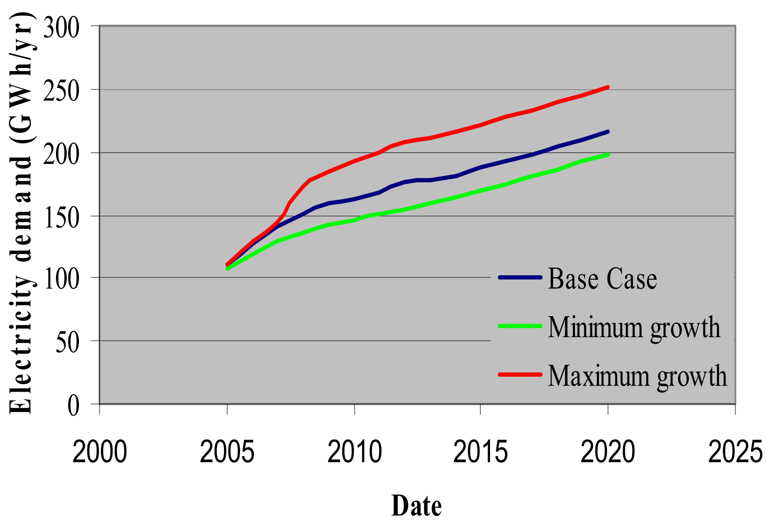
Table 7
Statistical Results of the St. Kitts Model #1 Excluding the Unusual Years 1998-2000

Analysis period	Adjusted R^2	F-ratio	Critical f	# of observations
2001-2004	0.1413	3.5774	2.8165	48
2002-2004	0.0598	1.7425	2.9011	36
2002-2004	-.01298	0.1189	3.0984	24

A third cause for the lack of correlation may be the selection of dependent variables. It is highly probable that there are other more important variables affecting the electricity demand in St. Kitts, than the population, number of tourists and GDP. However, these other variables may be occasional and therefore difficult to incorporate in the MLR model.

The energy analysis is a required component of the interconnection research, therefore in order to continue with the research the electric load analysis of the period 2005-2015 of Stanley Consultants (2005) was used instead. The forecasted load for the period 2016-2020 is extrapolated by following the trend of 2012-2015. Figure 3 shows a base case scenario and two sensitivity cases with a minimum and maximum growth.

Figure 3
Forecasted Annual Electricity Demand for St. Kitts[14]



4.2.2 Results and Data analysis – Nevis

The correlation matrix for Nevis, Table 8 below, shows the dependency of the independent and dependent variables to one another. The adjusted R^2 of 0.76 points out that a correlation between the variables is present, albeit not as clear as in other electricity demand forecast studies (Mohamad et al., 2004; Egelioglu et al. 1999; Lorchirachoonkul, 2006). The F-ratio is much greater than the critical value of 2.49 for degrees of freedom (4, 79), implying the model is highly significant. However, the correlation coefficient of GDP and population amounts to 0.9742, indicating that multi-collinearity exists in this situation. In addition, the VIF used to indicate the severity of multi-collinearity has passed the critical value of these variables.

[14] Source: Stanley Consultants, 2005

Table 8
Correlation Matrix and Validity Test Results for Nevis

Model #1						
	Price	**pop**	**T**	**GDP**		
Price	1.0000				**Adjusted R^2**	0.759
pop	0.8384	1.0000			**F-ratio**	66.356
T	0.4429	0.6087	1.0000		**$F_{critical}$**	2.4874
GDP	0.8859	0.9742	0.5813	1.0000	**Df**	79
Ed	0.5830	0.8379	0.5884	0.7650		
VIF	5.0230	21.5839	1.6295	28.6790		

A second analysis done by discarding population for Nevis, did not result in a better model. Even though the F-test showed significance and the remaining variables did not indicate multi-collinearity, the adjusted R^2 dropped to 0.57.

The third analysis, discarding GDP (Nevis model #3) below, proved to be the best model.

Table 9:
Correlation Matrix and Validity Test Results for Nevis

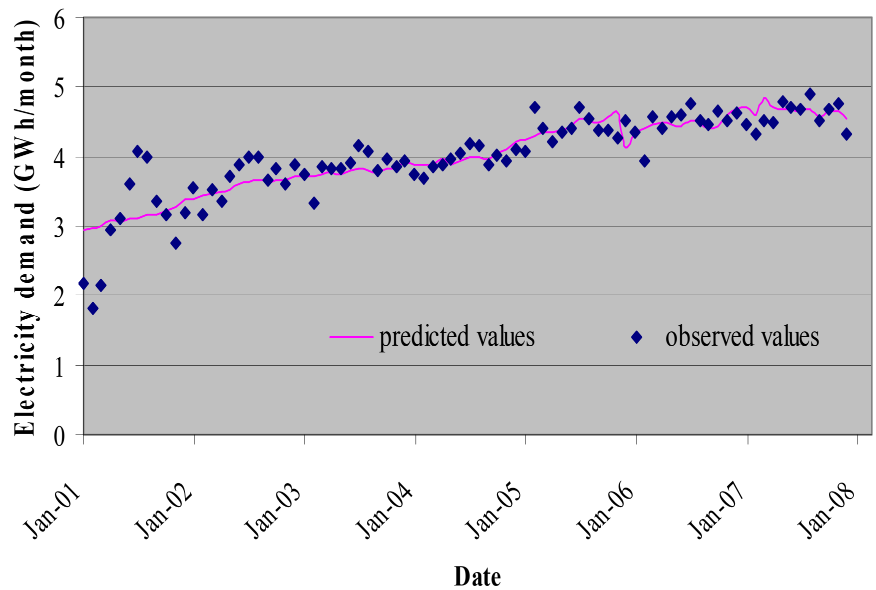
Model #3					
	Price	**pop**	**T**		
Price	1.0000			**Adjusted R^2**	0.7483
pop	0.8380	1.0000		**F-ratio**	83.234
T	0.4429	0.6079	1.0000	**$F_{critical}$**	2.7188
Ed	0.5830	0.8393	0.5884	**Df**	80
VIF	3.4388	4.3848	1.6245		

The adjusted R^2 decreased somewhat to 0.75 compared to Nevis model #1, but the multi-collinearity problem has been solved. Consequently, Nevis model #3 has been selected as final model for the energy analysis. The resulting model for Nevis is:

$Ed = -17001 + -1952.3P + 1.8688pop + 0.0713T$

Figure 4 shows the appropriate fit of the actual electricity demand along with the predicted values of Nevis model #3.

Figure 4
Observed and Predicted Electricity Demand in Nevis



The electricity demand model discussed above was used to forecast the electricity demand by variation of the independent variables (i.e. price of electricity, population and number of tourists). For this case study the change in electricity demand was calculated for the following three scenarios, but the model can be run with any kind of input.

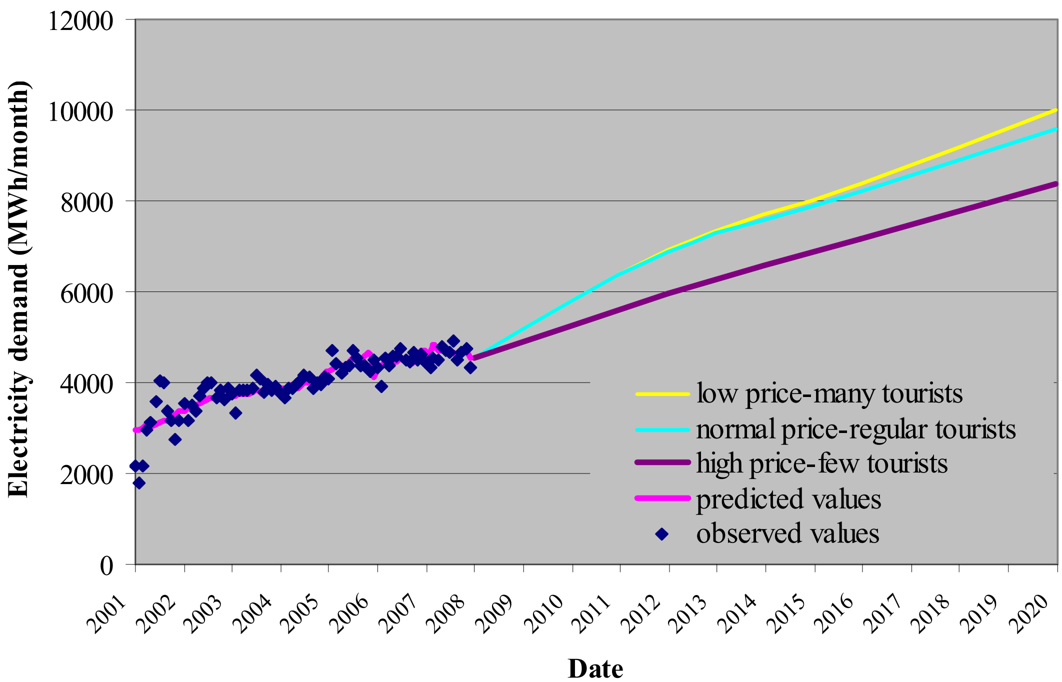
The electricity price in the "low price – many tourists" scenario will decrease to 0,20EC$/kWh in 2020. In the "normal price – regular tourists" scenario the electricity price will be the same as before the fuel surcharge. In the last scenario; "high price – few tourists" the electricity price will continue to rise towards 0,90 EC$/kWh in 2020. Population growth is assumed to be linear and the same in all three scenarios. However, it can be argued that the population will increase due to immigrant workers in the tourism industry. The tourism sector is expected to grow in all three investigated scenarios, albeit most dominant in the "low price - many tourists" scenario.

Table 10 and Figure 5 below display the observed, predicted and forecast electricity demand for the period 2001 - 2020. The thick and dark colored bars indicate the forecast value of each scenario. The thin and light colored bars indicate the 95% prediction interval (P.I.) of the associated scenario. Note that the electricity demand is measured in GWh/month instead of GWh/year, like in St. Kitts.

Table 10
Input and Output for the Three Scenarios for Nevis based on Model #3

		Input model			Output	Error	
Scenario	**Year**	**Price (EC$/kWh)**	**Pop (#)**	**Tourist (#)**	**Ed (MWh/m.)**	**95% P.I.**	**% of Ed**
low price-many tourists	2012	0.37	13,035	4,000	6,922	±811	12%
	2016	0.30	13,731	4,500	8,395	±1,036	12%
	2020	0.20	14,427	6,000	9,998	±1,310	13%
normal price-regular tourists	2012	0.37	13,035	3,330	6,874	±816	12%
	2016	0.37	13,731	4,000	8,222	±993	12%
	2020	0.37	14,427	4,800	9,580	±1,189	12%
high price-few tourists	2012	0.80	13,035	2,300	5,961	±675	11%
	2016	0.85	13,731	2,400	7,171	±787	11%
	2020	0.90	14,427	2,500	8,382	±934	11%

Figure 5
Electricity Demand Forecast for the Three Investigated Scenarios for Nevis

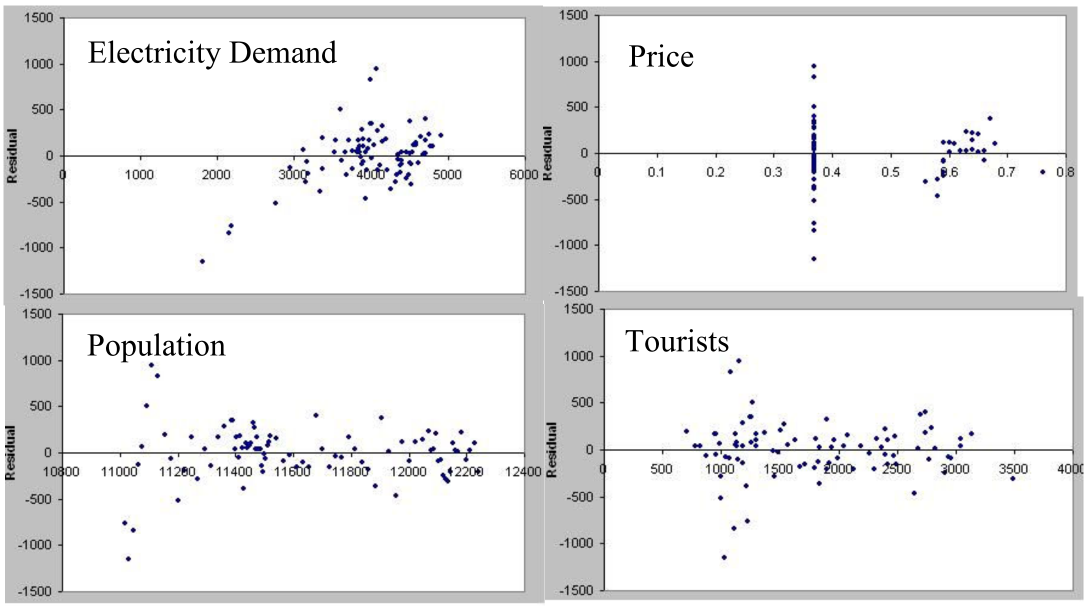


One of the major assumptions in MLR is that all relationships between the electricity demand and the independent variables are linear. This can be tested with bivariate scatterplots of the variables of interest, which for the Nevis model showed no curve for the variables price of electricity and number of tourists. The scatterplot of the electricity demand against the population on the other hand showed a slight curve. Fortunately, multiple regression procedures are not greatly affected by minor deviations from the assumption of linearity (Stafsoft, 2007).

A second assumption in MLR is that the residuals should be distributed normally. The performed F-test, which resulted positive, is quite robust regarding violations of this assumption. Residual plots can also indicate whether the final model can be considered appropriate. Figure 6 displays the residual plots of the final model for Nevis.

Figure 6

Plots of Residuals against the Electricity Demand, the Price of Electricity, Population and the Number of Tourists in Nevis



The lowest values of the residual plot of the electricity demand show a linear trend, but the higher values, which are consistent with the observations later in the analysis period, are random. The residuals of the price of electricity are characterized by the constant price for 59 of the 84 observations. The residuals of population and tourists are scattered randomly indicating the regression can be considered appropriate.

MLR is a top-down approach and therefore an appropriate methodology in macro-economic situations. However, these types of models have the tendency to have a rather pessimistic outcome compared to technology-based bottom-up models. In the Nevis case study this could mean that the actual electricity demand is higher than the forecast. Another implication with regard to applied forecast methodology is the relatively low total electricity consumption of Nevis. Since the island is small on the macro-economic level, developments like a new hotel have a relative large impact on electricity demand.

Even though there are some disadvantages with applying MLR in the Nevis case study, it still is an appropriate tool as the methodology fits well into the initially stated objectives. These include that the electricity demand forecast for St. Kitts and Nevis should be set up in a practical and manageable manner in order to be continued independently by the ministries of energy. Moreover, that it should include parameters that are available locally; are reliable; and obviously affect the electricity demand.

4.5 Justification of the Interconnection

The forecast peak demand in MW is an important parameter for the electricity utilities and REP developers to determine the additional operational capacity that is needed to service future demand. In addition, such forecasts can indicate the location and timing of a possible electricity supply surplus or deficit. This information is indispensible for the interconnection assessment.

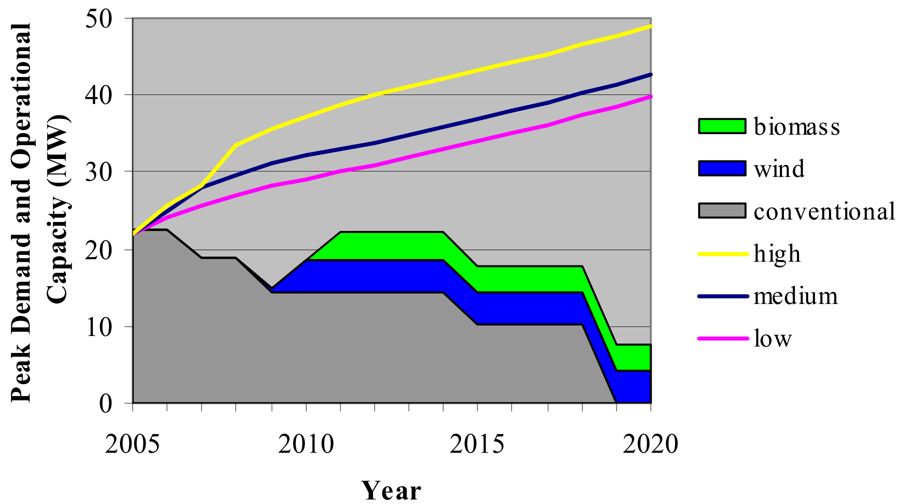
4.5.1 The Case for St. Kitts

Stanley Consultants (2005) forecasted, in addition to the electricity demand in GWh/yr (see Figure 3), also the peak demand in MW for the period 2005-2015. However, peak demand and electricity sales data prior to December 2005 was not available, which made it difficult to review the first years of the load projections of Stanley Consultants.

The diagram below shows the results of the forecasts made for St. Kitts using and extrapolating Stanley Consultants data from 2005 to 2020. The line diagrams show the results for the three energy demand scenarios. The area diagrams indicate the conventional and renewable operational capacity over time. According to Figure 7 there is a clear disparity between the line diagrams depicting the peak demand projection and the area diagrams depicting the operational capacity of the conventional diesel generators and the planned REPs. Thus demand is projected to surpass supply.

Note that the operational capacity differs from the available capacity (Section 2.1) and the latter is sufficient to service the current peak demand.

Figure 7
Peak Demand and Operational Capacity for St. Kitts for the period 2005-2020

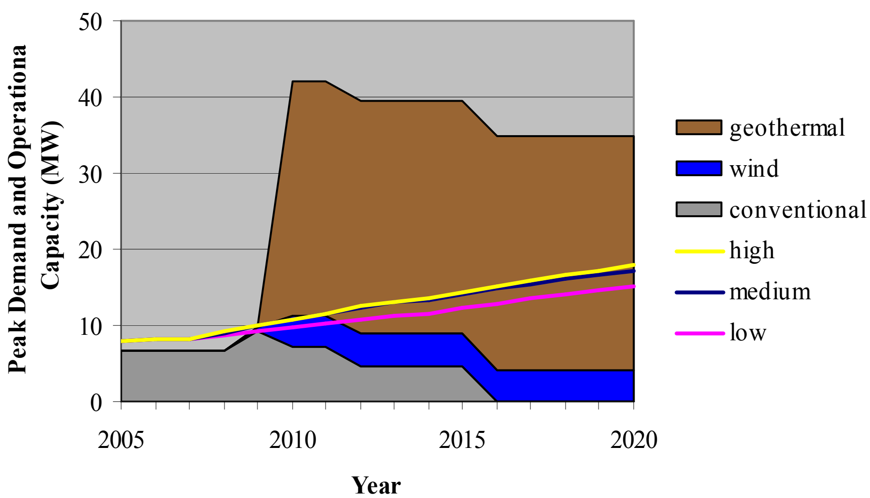


4.5.2 The Case for Nevis

To forecast peak demand for Nevis, MLR was used to calculate the electricity demand forecast in MWh per month (see Figure 5). The historical dataset (with 84 observations) indicated that 25% of the total energy production is not consumed by customers due to losses and own use. When converting the electricity demand in MWh/month to peak demand in MW there should be a correction for this gap. In this study the monthly sales are divided by the total hours of the allocated month and then divided by 75%[15].

In Figure 8 below, the line diagrams show the results for the three energy demand scenarios for the time period 2005-2020. The area diagrams on the other hand, indicate the conventional and renewable operational capacity over time. Currently, the operational installed capacity does not service the peak demand. A new diesel engine and the REPs will alleviate the pressure on strained generation systems assuming wind and/or geothermal energy is implemented as planned (see section 4.1). The geothermal plant will deliver the bulk capacity assuring sufficient supply for the long term.

Figure 8
Peak Demand and Operational Capacity for Nevis for the period 2005-2020



Figures 7 and 8 show that there will be an electricity production surplus in Nevis and an electricity production deficit in St. Kitts over the period 2005 to 2020. This outlook justifies an electrical interconnection between the two islands so that St. Kitts may benefit from Nevis' excess electricity.

A cross border interconnection (with other islands in the region) can become an attractive option if the Federation of St. Kitts and Nevis has a surplus electricity production during the projected timeframe up to 2020. Figure 9 shows the peak demand and operational capacity jointly, at the federal level (summing Figures 7 and 8).

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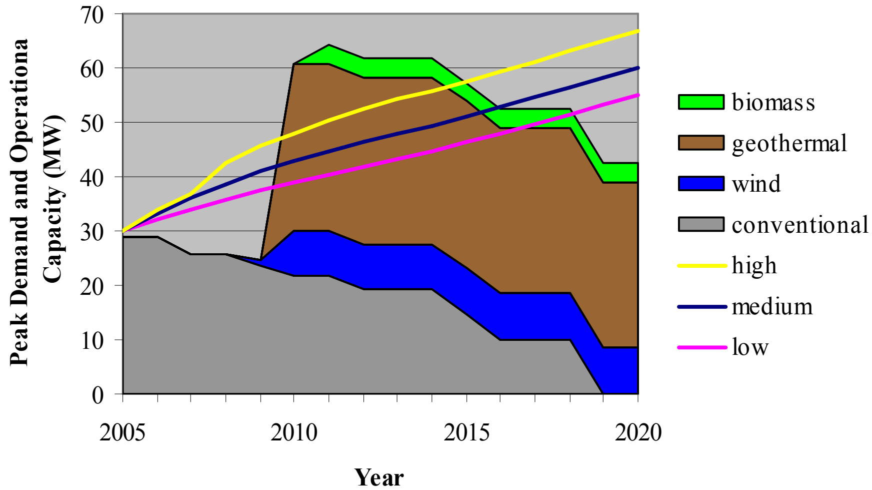
15 This factor has a standard deviation of 7.2%.

Figure 9
Peak Demand and Operational Capacity for St. Kitts & Nevis for the period 2005-2020



According to Figure 9, the operational capacity after implementation of the REPs will be sufficient to service the peak demand until 2015, 2016 or 2018, depending on the demand scenario. After these indicative dates however, the planned capacities of the REPs and the declining capacity of the conventional engines will not be sufficient to service peak demand. This under the assumption that demand continues to grow as projected, the conventional capacity is not replaced by new diesel engines, the capacity of the existing REPs is not extended and no other REPs are implemented. Considering these assumptions it can be stated that a cross-border interconnection with other islands in the region, is not an attractive option. This will be further examined in the subsequent paragraphs.

5. ELECTRICAL INTERCONNECTION

The energy analysis of section 4 has pointed out that in the short-term an electrical interconnection between St. Kitts and Nevis is necessary to meet supply electricity demand in St. Kitts and use electricity excess in Nevis. With the current planned capacity, exporting electricity to other countries in the Caribbean region does not seem as an attractive option in the long term. However, future capacity expansion, especially of the geothermal plant, can generate an electricity surplus at the federal level even in the long term. Hence, besides an interconnection between St. Kitts and Nevis, the possibility of a cross-border interconnection will also be considered.

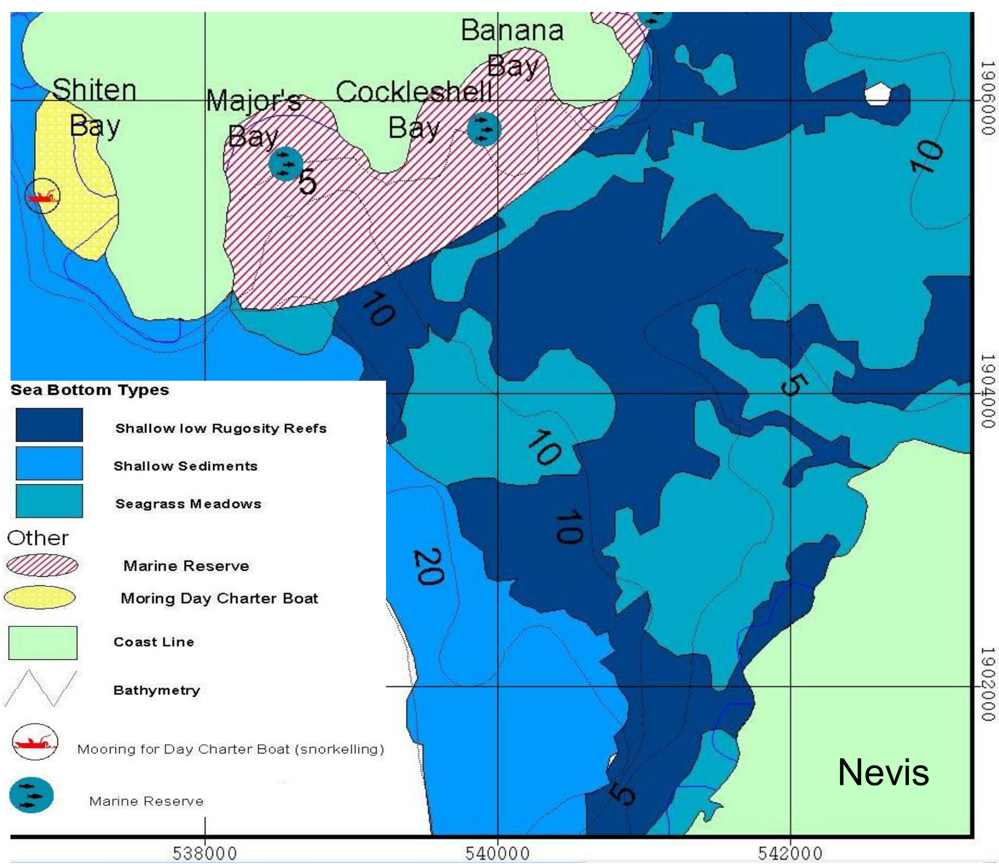
The options reviewed for an electrical interconnection take into consideration only submarine cables as this has proven to be commonly implemented technology, in view of the current system layout in St. Kitts and Nevis.

5.1 Geographical Characteristics

St. Kitts, Nevis and the Dutch island of St. Eustasius, are all located on the same bank. The shallow shelf is replaced by a steep slope 0.5 km to 5 km out of the shoreline (J. Simmonds, personal communication, August 15, 2008). The water depth between these three islands is at most 55 meters, while the water depths after the submarine slope are in the range of 0.6 km (Imray-lolaire, 1990).

The stretch of water between the St. Kitts SE Peninsula and Nevis is called *The Narrow* and is at the narrowest point 3.2 km long and at no point deeper than 11 meters. The sea bottom consists mostly of sea grasses, sand and minor coral reef. The *Major's Bay*, the *Cockleshell Bay* and the *Banana Bay* (see Figure 10) are important nurseries for fishes and other maritime life and has been designated a marine reserve. The Department of Fisheries initiated a procedure to officially protect the Narrow, however it is still unclear whether and when a maritime protection will enter into force.

Figure 10
Marine Habitat Map of the Water Stretch between St. Kitts SE Peninsula and Nevis[16]



[16] Modified from St. Kitts and Nevis GIS Atlas, 2002. (Water depths are in fathoms).

The stretch of water between St. Paul's in NW St. Kitts and St. Eustasius is at the narrowest point 13 km long and is no deeper than 55 meters.

An electrical interconnection between St. Kitts and Nevis and other islands in the Caribbean region -besides St. Eustasius- is more complicated because of the larger distances and water depths. The three islands St. Barthelemy, St. Martin and Anguilla are located on the Anguilla bank with St. Barthelemy (St. Barts) being the closest to St. Kitts and Nevis. Saba is the only island on the Saba bank and in the vicinity of St. Eustasius. The islands Antigua and Barbuda are located on the same bank east of St. Kitts and Nevis with Antigua the nearest. Montserrat is located in the south east direction of St. Kitts and Nevis with an uninhabited island in between. Continuation in the same direction leads to Guadeloupe, again the only island on its bank. Table 11 and Figure 11 provide an overview of the locations, directions, distances and water depths of the islands.

Figure 11
Satellite Image of the Leeward Islands (with the exception of the Virgin Islands)[17]

[17] The red ovals indicate the approximate locations of the banks. Source: Google maps

Table 11

Overview of the Water Depths and Distances of the Shortest Connection between the Adjacent Leeward Islands

Bank	From	To	Distance(km)[a]	Max. depth(m)[b]
St. Eustasius, St. Kitts and Nevis bank	Nevis	St. Kitts	3.2	11
	St. Kitts	St. Eustasius	13	55
Saba bank	St. Eustasius	Saba	26	838
	St. Kitts	St. Barthelemy	53	629
Anguilla bank	St. Barthelemy	St. Martin	19	24
	St. Martin	Anguilla	8	13
Montserrat bank	Nevis	Montserrat	49	790
Ariadne shoal	Nevis	Antigua	69	585
	Antigua	Barbuda	42	29
Guadeloupe bank	Nevis	Guadalupe	119	1121

[a] Distances are calculated with GPSvisualser.com based on the coordinates found in Google maps.
[b] Bathymetric information is read from map of Imray-lolaire (1990).

5.2. Previous Projects

High Voltage Alternating Current

High Voltage Alternating Current (HVAC) submarine cables are already in use in situations that are similar to that of the islands of St. Kitts and Nevis. The following examples provide some economic, technical, engineering and social insights on the construction of HVAC in the Caribbean region.

Firstly, in 1998 San Pedro on the Ambergris Caye Island was connected to the mainland of Belize by means of a 34.5 kV submarine cable. The 19.3 km submarine cable runs from the coastline at Bomba and Boca Chica to the southern tip of Ambergris Caye. Overhead transmission lines transport electricity to the power station in the center of San Pedro for another 9.5 km. Several feeders of the San Pedro distribution system were upgraded from 6.6 kV to 22 kV. The benefits for San Pedro include improved power quality (in terms of frequency and voltage control), a decrease in electricity price, and the ability to service rapid electricity demand on the island. The interconnection was financed jointly by the Caribbean Development Bank (CDB) and Belize Electricity Limited (BEL) at a total cost of US$ 9 million (SanPredroSun, 1998). San Pedro Town and a number of small villages and resorts on the island make up a population of around 10,000 (Ambergriscye, 2008).

Secondly, in 2001 a 12 km submarine cable installed in Grand Cayman, Cayman Islands was looped to connect the 69 kV cables and overhead lines on both sides of the North Sound lagoon. The benefits of this submarine loop include protection against hurricanes, salt and pollution and the preservation of the scenery. The shallow water of the North Sound is 2-6 m deep, obstructing the installation of the cable. The cable is coiled from the carrying ocean vessel on a pontoon from which the cable is laid (ABB, 2001).

High Voltage Direct Current

There are several successful High Voltage Direct Current (HVDC) interconnections world wide. First, in early 2008, Eemshaven in the Netherlands and Fedat in Norway were connected by a 580 km long, 700 MW, 450 kV DC cable. The maximum sea depth amounts to 410 m (Tennet, 2008). Second, a 400 kV DC, 500 MW transmission cable connected Otranto, Italy with the Aetos region in Greece in 2000. The submarine section stretches 163 km. The cable is laid at a depth of 1000m (George, 2000). Third, in the SArdegna PEninsola Italy (SA.P.E.I.) project the Sardinian transmission network was linked with the Italian main land. A bipolar configuration transmits 2x500 MW over 420 km. The maximum depth is 1650 m, the voltage in 500 kV DC (Prysmian, 2008).

However, not all projects are successful. For example, geothermal resource assessments on the major islands of Hawaii from 1978 onwards indicated that the youngest island, Hawaii, had a high geothermal energy capacity. With energy demand higher in the island of Oaha, where Honolulu is located, it was believed that an inter-island submarine cable would transmit electricity among the Hawaiian Islands. Multiple engineering feasibility studies were conducted from 1982 through early 1990 and indicated that a submarine cable connecting the larger Hawaiian Islands was technically feasible. The evaluated cables should withstand stresses of at-sea deployment, the undersea environment and would be in operation for at least 30 years. However, the costs indicated that the installation of the cable was not economically feasible. The cable was never built and the geothermal electricity production on the island of Hawaii is exclusively for own use (Thomas et al., 2002).

There are other HVDC examples ongoing in the Caribbean region. In a press release of August 2008, the governments of Columbia, Puerto Rico and the Dominican Republic agreed to initialize a feasibility study on an electrical interconnection. The proposed submarine cable will be 1000 km, the longest of the world. The cable, with an anticipated capacity of 1000 MW, should be finished in four years (Listindario, 2008).

Telecommunication Cables

In September 1995, St. Kitts was connected to 14 other island in the Caribbean region by the East Caribbean Fiber Optic System (ECFS) telecommunications network. This is a 1735 km long submarine cable that originates in Trinidad and travels along the chain of islands to St. Kitts. The landing point is in Frigate Bay. Nevis is connected to the international telephone system by a direct microwave radio relay link to St. Kitts. There was no Environmental Impact assessment required for this project. A second submarine cable -the South Caribbean Fiber (SCF)- was completed in mid 2007. It connects Antigua, St. Lucia, St. Kitts, St. Vincent, Barbados, Grenada and Trinidad, and is also interconnected with the Global Caribbean Network and the Middle Caribbean Network. An Environmental Impact Assessment was required as part of this project (Caribbeanpressreleases, 2006).

5.3 Technical, Regulatory and Institutional aspects

5.3.1 Technical Options

Submarine Cable

One option is to interconnect St. Kitts and Nevis with an 11 kV AC submarine cable. Both electricity distribution systems are operated at 11 kV AC. Hence, neither step-up and step-down transformers nor AC/DC converters are needed for the interconnection. On the other hand, transmission losses might be larger when operating at 11 kV than at higher voltages. Therefore, a second option is to increase the transmission voltage to 33 kV or 69 kV. Transmitting electricity at higher voltages reduces the transmission losses. However, it requires step-up and step-down transformers on both islands.

An AC interconnection can also have its disadvantages. First of all, the length of an AC cable is limited by the amount of reactive power produced by the cable as this reduces the carrying capacity of the conductor. This might restrict the usage of AC cables for the long-distance cross border interconnection. Second, if the AC transmission schemes of different electricity systems are not synchronized, a synchronizer and tight coordination is required to ensure “adequate stability margins” (Englund, 2003).

In order to overcome these issues, a third option is a HVDC interconnection. HVDC becomes cost-effective with longer transport distances when the smaller transmission losses and the reduced construction costs offset the AC/DC converter and transformer costs on each end of the line. HVDC allows controlled transmission between networks while retaining their independent operation: asynchronous grids can exchange electricity without the continuous real time adjustment of the relative phase of the two connected grids (Ibid, 2003).

A detailed techno-economic feasibility study should address the trade-offs mentioned above.

Connecting or Integrating the Grids

A submarine cable can connect the independent operating distribution networks of St. Kitts and Nevis with and without integrations of the networks. Advocates against a possible integration might argue that independent systems have the advantage that a failure in one island would not affect the other island. On the other hand, case studies of Srivastava et al (2003) in India and Gnansounou et al. (2004) in East China found that the integration of two (in the case of China) or five (in the case of India) integrated operating electricity markets have important advantages compared to independent systems. The benefits may arise from lower operating costs due to economic electricity exchange; delayed investment due to least-cost planning of available energy resources; increase in mutual energy reserves; and improvement of system reliability. In the case of St. Kitts and Nevis, both islands may have the benefits of cost savings from capital and operating costs reductions, and may mutually benefit financially from their net electricity excess. In practice, integration of the two distribution networks would require close cooperation between the SKED and NEVLEC.

5.3.2 Regulatory Requirements

Federal Level

Schedule 3 of the Environmental Control and Planning Act of St. Kitts and Nevis lists projects which require an Environmental Impact Assessment (EIA). Submarine cables are not listed, but comparable projects like i) hydro-electric plants and power plants and ii) gas pipelines demand an EIA. In addition, the federal government can demand an EIA when they consider it necessary. For example, an EIA was required for the construction of the SCF submarine telecommunication cable in 2007. All EIAs are reviewed by the Development Control and Planning Board (R. Edmeade, personal communication, August 13, 2008).

Past experience has taught that St. Kitts and Nevis does not have allocated landing points for submarine cables as the two telecommunication cables land at different points (C. McMahon, personal communication, August 15, 2008). Environmental barriers may arise when the submarine cable lands on the SE peninsula as the water around the Major's Bay, Cockleshell Bay and Banana Bay are important nurseries for fishes and other aquatic life (Simmonds, 2008). The Queen Conch is a protected specie living in these waters. This mollusk is recognized under Annex II of the SPAW Protocol and CITES which protects the conch from disturbance during the period of breeding (NOAA, 2008).

International Level

All countries in the Caribbean region, except the Dominican Republic and Venezuela have ratified the United Nations Convention on the Law of the Sea (UNCLOS, 2008). Thus, laying and operating a submarine cable outside the internal waters of St. Kitts and Nevis will not encounter international institutional barriers. Article 21 Part II, Article 58 Part V, Article 79 Part VI and Article 87 Part VII of the Law of the Sea, refer to the freedom to lay submarine cables in the Territorial Seas and Contiguous Zone, the Exclusive Economic Zones (EEZ), the Continental Shelf and the High Seas, respectively. In the territorial sea and contiguous zone (extending 12 nautical miles from the baseline)[18] innocent passage of submarine cables is permitted. In the EEZ (extending 200 nautical miles from the baseline) all countries are permitted to operate submarine cables (UNCLOS, 2008). In the Caribbean Sea all waters have been divided among the surrounding countries into EEZ.

5.3.3 Institutional issues

Ownership is an important issue in the construction and operation of a (cross-border) interconnection. NEVLEC is and in the short term SKED will become a private company, solely owned by the NIA and the Federal Government, respectively. Currently these electricity utilities are responsible for both the generation and distribution of electricity on the islands.

[18] The baseline is defined as the mean low water mark.

In a future with renewable electricity supplied from commercial project developers, SKED and NEVLEC might shift focus more towards electricity transmission and distribution. In this scenario, shared ownership of the St. Kitts and Nevis interconnection by SKED and NEVLEC is an option in assuring future business.

Supporters of the free market theory will argue that privatization of public utilities will eventually bring the lowest costs and hence the interconnection should be privately owned. However, a monopoly in electricity exchange within a federal state by a private company[19] might result in tensions between the company, the government and the consumers.

It should be noted that in the Nevis geothermal scenario, NEVLEC and the possible other electricity utilities in the Caribbean region, will be mutually dependent on each other. None of the parties involved can make this project profitable nor take full advantages of the benefits when there is no collaboration. Equally important is acknowledging that transparency is a key-factor when several actors with different interests are impelled to cooperate.

6. CONCLUSION AND RECOMMENDATIONS

In this study it was investigated whether the current conventional capacity, the planned REPs and future electricity demand result in a possible electricity shortage or surplus on local level and national level for St. Kitts and Nevis in the period 2008-2020. The results were used to verify whether an electrical interconnection between the islands and with other islands in the Caribbean region could be justified.

The electricity demand forecast for Nevis has been successfully modeled with MLR. As was proven, Model #3 performed satisfactorily in the statistical tests conducted, implying the considered independent variables are significant and valid. Thus NEVLEC, the Ministry with Energy in their portfolio and every other interested party will be able to make their own projections by choosing the independent variables in the model. It is recommended to update the model every year by importing the new monthly figures for electricity demand, the number of tourist stay-overs, population and the price of electricity, and reevaluating the coefficients of the model.

None of the proposed MLR models for St. Kitts produced the desired results. Consequently, an electric load analysis of Stanley Consultants (2005) was used to continue with the energy analysis. Completing the proposed model with more recent data might improve the quality of the model so that MLR can also be used for St. Kitts. To this aim, the SKED and the Statistics Department of the federal government should supply reliable monthly data of the proposed independent and dependent variables.

[19] In theory the NEVLEC and (in the near future) the SKED are private companies. However, as the governments are the only stakeholders it can be assumed that the objectives of these utilities differ from the objectives of a commercial privately owned utility which might focus more on profits. This argument is supported by the fact that electricity prices on both islands have been kept relatively low due to subsidies.

Currently, neither the *operational* capacity on St. Kitts (18.9 MW) nor on Nevis (6.7 MW) is sufficient to service peak demand (respectively 25.3 MW and 9 MW). The wind and bio-energy project on St. Kitts will not produce enough electricity to meet future demand and to compensate the declining conventional electricity supply. The deficit in the medium growth scenario amounts to -12 MW in 2012, -20 MW in 2016 and -35 MW in 2020. The wind and geothermal projects on Nevis by comparison, will result in a significant electricity surplus even with increasing demand and declining conventional capacity. The surplus in the medium growth scenario amounts to 27 MW in 2012, 20 MW in 2016 and 18 MW in 2020. An electrical interconnection between St. Kitts and Nevis can match the current and future electricity supply and demand misfit.

Electricity exchange between St. Kitts and Nevis with a submarine cable between the islands will not encounter large geographical difficulties as the water depths (max. 11 m) and the distances (min. 3.2 km) are small. A submarine cable from St. Kitts or Nevis to the adjacent Leeward Islands will be confronted with much larger distances (49-119 km) and greater depths (585-1121 m). A detailed techno-economic feasibility study should point out the trade-offs between the cable, converter and transformer, construction and maintenance costs of the various interconnection options.

There is no policy regarding the construction of submarine cables in place, but most likely the Department of Physical Planning will require an Environmental Impact Assessment (EIA). On the international level there are no difficulties expected with the construction and maintenance of such cables outside the territorial seas and contiguous zone.

Ownership is an essential element in the finance of the construction and maintenance of the submarine cable. A future (consortium of) owner(s) should be established in close and transparent cooperation between the project developers, the SKED, NEVLEC, the federal government and the NIA so all parties benefit from these renewable energy opportunities.

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