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ROAD MAP ON BUILDING A GREEN ECONOMY for SUSTAINABLE DEVELOPMENT in Carriacou and Petite Martinique, Grenada

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Road Map on Building a Green Economy for Sustainable Development in Carriacou and Petite Martinique, Grenada

Division for Sustainable Development of the
United Nations Department of Economic and Social Affairs
In cooperation with the
Ministry of Carriacou and Petite Martinique Affairs
And the
Ministry of Environment, Foreign Trade and Export Development of Grenada

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FOREWORD

This publication is the product of an international study led by the Division for Sustainable Development (DSD) of the United Nations Department of Economic and Social Affairs (UNDESA) in cooperation with the Ministry of Carriacou and Petite Martinique Affairs and the Ministry of Environment, Foreign Trade and Export Development of Grenada. The completion of this first *Road Map on Building A Green Economy for Sustainable Development in Carriacou and Petite Martinique*, *Grenada* is the result of an intensive effort by experts from Grenada, consultants and personnel from the United Nations who actively have participated in meetings, workshops, field trips, data collection and analysis since 2010. The study is part of a larger project being conducted by the DSD on “Integrating Climate Change into National Sustainable Development Strategies and Plans in Latin America and the Caribbean.” The idea of conducting this Road Map for Carriacou and Petite Martinique originated from the preliminary research carried out during the first stages of the implementation of this project in Grenada.

The framework, systematic approach and project proposed in this study represent an attempt to move forward with the practical implementation and demonstration on how integrated systems can be designed to construct Road Maps for greening the economies of Small Island Developing States (SIDS). The study supports the global efforts on defining national strategies for sustainable development and on addressing one of the major themes of the 2012 United Nations Conference on Sustainable Development (Rio+20 Conference) of a “Green Economy in the Context of Sustainable Development and Poverty Eradication.”

No study for building a green economy for sustainable development can be final and definitive. To be useful, the assessment process must evolve over time to fit ever-changing conditions, priorities and national sustainable development criteria. This publication summarizes initial analysis, findings and proposals. The study serves as a starting point for the development of a more in-depth, systematic assessment for designing green economies in SIDS. It is hoped that the experiences and lessons learned from this study will provide valuable information and knowledge to other countries interested in transforming their economies and achieving progress towards nationally defined sustainable development goals and objectives. It is also hoped that future studies will contribute to refinements in the proposed assessment and approach adding their own unique perspectives to what has been learned herein.

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Note:

TABLE OF CONTENTS

1. Introduction

Greening the economy is a strategy under consideration by countries to enhance the quality of life of their citizens and to pursue sustainable development goals. The transformation of traditional economies into green economies is based on making investments in technologies, systems and infrastructures that enhance productive economic activities while optimizing natural resource utilization and minimizing environmental impacts. The objective is to foster investments supporting social and environmental goals that would act as drivers for, instead of barriers to, sustainable economic growth.

The transition to greener economies implies the formulation of an overarching integrated approach that links social, economic and environmental policies and actions designed to ensure sustainable development and poverty eradication. Green growth strategies in developing countries need to be undertaken within this context and should ultimately address major priorities such as: providing basic education, housing and employment; ensuring food security and health coverage; and delivering essential services such as access to modern energy, water, sanitation, waste treatment and transport.

Designing a national green growth strategy represents a major endeavor in which complexity increases with the size of the country being considered. Small isolated communities with clearly identified priorities and challenges could represent excellent settings for pilot projects for designing and demonstrating effective strategies for the transformation of their traditional economies into green economies. Many Small Island Developing States (SIDS) are facing specific sustainable development and climate change challenges that can benefit from the implementation of green economy strategies.

Carriacou and Petite Martinique, which are the second and third largest islands of Grenada with around 9,000 inhabitants, are ideal microcosms for demonstrating how to build a green economy. Carriacou and Petite Martinique represent small islands with typical problems and limitations and with natural resources similar to other SIDS. Development challenges include: limited water resources, expensive energy and transport systems fully based on imported fossil fuels, lack of sewage treatment systems, and limited economic development and employment sources. Problems becoming more acute due to climate change are rising sea levels, beach erosion, declining agricultural output, increasing salinity in wells, lower precipitation, and more intense dry seasons. However, Carriacou and Petite Martinique have ample renewable energy resources including wind and solar along with potential tourism revenues for economic development. Currently, the Government is actively seeking innovative solutions to the islands' major sustainable development and climate change challenges.

The primary objective of this study is to design an integrated strategy, based on government criteria and expert assessment, for the transformation of the economy of Carriacou and Petite Martinique into a greener and more sustainable economy. The study seeks to design an approach for a transition to sustainable development for Carriacou and Petite Martinique according to criteria specified by government representatives and national experts. The experiences and lessons learned from this study will provide valuable information and awareness for other SIDS.

The study will generate substantive knowledge about the most important development blocks necessary for sustainable economies of SIDS with similar challenges and objectives.

The study is being conducted by the United Nations Department of Economic and Social Affairs (UN-DESA) in cooperation with the Ministry of Carriacou and Petite Martinique Affairs (MOCPMA) and the Ministry of Environment, Foreign Trade and Expert Development of Grenada. It addresses relevant priority areas on green economy, environmentally sound technologies, technology transfer, sustainable development, climate change and national energy profile assessments.

The effort represent an attempt to formulate a "green economy road map" for the transition towards sustainable development in a time frame of one or two decades. The study assesses and presents proposals for change in major development blocks including: energy, water, education, employment, transport, agriculture and food security, ecotourism and environmental issues.

1.1 Islands as Microcosms

One of the most famous quotes about the human capacity to change the world comes from Margaret Mead, who promoted the idea of "The Island Earth". In her anthropological classic *Coming of Age in Samoa,* Margaret Mead was struck by what a small community could do. She wrote: "Never doubt that a small group of thoughtful, committed citizens can change the world; indeed, it's the only thing that ever has," (Mead, 1930).

The challenge of sustainable development has persisted for decades as a critical example of how global negotiations can stress the need to take action, yet conflicting motivations, financial and other pressures, and risks can prevent action. To some, the primary challenge concerns access to energy and the resources for development. To others the critical issue is climate change. To yet others, the main question is about inequity in resources and opportunities available to different individuals and communities around the planet.

While this debate has raged – to act or not to act, who should lead, who should pay – one community has clearly and consistently highlighted that sustainable economic growth, sustainable communities, and sustainable ecosystems are all linked in an immediate and directly visible system. That clear voice has been island communities and nations. The Alliance of Small Island States (AOSIS) has carried this message forcefully at international climate meetings, development meetings, and conferences on international aid and development.

Island communities face the reality of limited land area, limited populations, direct and visible limitations of local agricultural productivity and of infrastructure. The sharp demarcation of island systems – even those with rich ocean resources – has made citizens and governments of islands more sensitive to the lack of global action than the international community has been.

Lessons from island communities are very important not only because they are directly threatened by inaction, but because global inaction to date is in many ways related to the tragedy of the commons: environmental change when viewed at a global scale can seem highly complex, with successful cooperation dependent on too many diverse and disparate groups agreeing to put their individual goals into a larger context. Islands do not have that luxury.

Islands present unique opportunities for cooperative action precisely because the human, economic, and ecological "webs" that connect seemingly different aspects of our existence – such as education with roads, farming with beaches, and rainfall with emergency preparedness – can all be brought into focus in a way that has proven challenging for citizens and leaders in larger cities, nations and regions. This has led to a focus on small islands as microcosms where many sustainable development issues are both clear to the local community and to the global community, and also where the impacts of more sustainable systems of energy, water, and land use can be most evident.

1.2 The Climate Crisis at the Island Scale

It is well known and confirmed by the Intergovernmental Panel on Climate Change (IPCC) in all of its assessments that SIDS – whether located in the tropics or higher latitudes – have characteristics that make them especially vulnerable to the effects of climate change (IPCC, 2007). These characteristics include their limited size, geographical dislocation, proneness to natural hazards and external shocks, high exposure of population and infrastructure and limited adaptive capacity. The vulnerabilities resulting from these characteristics are exacerbated by the effects of climate change, which include rising seas, acidification of oceans, coral bleaching, coastal erosion, flooding, loss of fresh water supplies, biodiversity loss and more frequent and intense weather events, including hurricanes.

Significant and sometimes severe impacts are already being experienced by islands. Coral bleaching has already led to a loss of roughly 16 percent of the world's coral reefs, with adverse effects on many islands. Intense tropical cyclones have become more frequent and stronger, and have caused much damage in the Pacific and Caribbean. Kiribati and the Maldives have already lost some of their islands to rising waters, and land losses have been reported in other Pacific Island countries as well as in the Caribbean. Shoreline erosion and flooding has caused major damage to roads, public utilities and households, and salt water damage to agricultural crops and the fresh water lens has caused severe food and fresh water shortages in a number of low-lying islands.

These impacts are predicted to intensify and worsen rapidly in coming decades. Sea levels will rise, compounding the effects of more intense tropical storms and threatening the territorial integrity and stability of political boundaries of many countries. In some cases the very existence of countries is in doubt. A report by the UN High Commissioner for Refugees (2007) to the United Nations Framework Convention on Climate Change (UNFCCC) indicated that a number of SIDS are now under threat of "statelessness", a situation which may occur long before rising seas inundate land.

Island nations will suffer some of the most severe consequences of climate change due to rising sea levels and storm intensification, among other impacts. Aware of their vulnerability, these nations have banded together to seek strong action on the part of all countries – the developed countries in particular – to fight climate change. The AOSIS, together with the Group of Least

Developed Countries (LDCs), called for an agreement at the Copenhagen Climate Convention in December 2009 to place restrictions on global CO_2 emissions to limit global temperature rise to 1.5 degrees Celsius, with emissions peaking by 2015 and rapidly declining thereafter (UNFCCC, 2009). The potential impacts of climate change on island nations include more frequent and extreme weather events, ocean acidification, coral bleaching, coastal erosion, and changing precipitation patterns, in addition to sea level rise that is already being experienced. Efforts by the islands so far have included advocacy, awareness-raising, and local investigation of adaptation strategies.

The need to develop both a holistic perspective on development and climate change and a resilience to climate variability has produced a number of important methods and metrics to evaluate the dynamics of human impact on the planet, and the reciprocal impact of the planet on mankind.

One recent important approach to understanding the human impact on the planet, and the implications of that footprint, is the concept of "planetary boundaries" (Rokström, 2009). In this work, a series of key environmental indicators are utilized to measure the degree to which humanity is operating in what seem to be "safe", "marginal", or "clearly unsafe" regimes of environmental impact, or disruption. In the words of this interdisciplinary and international team:

> "Boundaries" define the safe operating space for humanity with respect to the Earth system and are associated with the planet's biophysical subsystems or processes. Although Earth's complex systems sometimes respond smoothly to changing pressures, it seems that this will prove to be the exception rather than the rule. Many subsystems of Earth react in a nonlinear, often abrupt, way, and are particularly sensitive around threshold levels of certain key variables. If these thresholds are crossed, then important subsystems, such as a monsoon system, could shift into a new state, often with deleterious or potentially even disastrous consequences for humans (Rokström, 2009).

The authors go on to identify Earth-system processes and associated thresholds which, if crossed, could generate dangerous and thus unacceptable environmental change. They identify nine such processes for which it is possible to define planetary boundaries: climate change; rate of biodiversity loss (terrestrial and marine); interference with the nitrogen and phosphorus cycles; stratospheric ozone depletion; ocean acidification; global freshwater use; change in land use; chemical pollution; and atmospheric aerosol loading. Importantly, the Rockström team concludes from the data that the global population has exceeded planetary boundaries for the first three and is approaching "danger points" for several more. Beyond this group, there is debate about what the boundary may be on a planetary scale.

For each of these indicators, however, examples can be found in island communities where a local equivalent – due to global change or local factors – has been exceeded. In many cases this local ecological impact is due to local forces such as sewage discharge into a river or a bay, burning of trash, and changes in soil quality or quantity due to erosion. These impacts are signs that the local island community is in need of immediate remediation in the form of mitigation to prevent further damage and adaptation to deal with the changes that have been experienced locally. At the same time, these impacts are more immediate and often easier to quantify on islands where many of the drivers of change can be assessed and removed from the equation.

Island nations are already on the front lines of the climate change war, having recognized the immediacy and severity of the consequences they face. There is a strategic opportunity for islands to serve as demonstration sites for the technologies and infrastructure that are needed to achieve climate stabilization and a transition towards green economies, while also meeting their sustainable development challenges. Renewable energy technologies, low-carbon transport systems, and sustainable food production methods could be developed and demonstrated on islands, providing blueprints for cities elsewhere and potential economic dividends for the islands. A lead-by-example strategy to convert islands to net-zero carbon economies or green economies by 2020 could catalyze significant sustainable development in other parts of the world while benefitting the island economies. Millions of tourists visit the islands each year, providing an opportunity to educate these visitors not only about the consequences of climate change but also green technology solutions.

The high cost of imported energy on most islands makes renewable energy and transport alternatives cost effective. The security angle is also important for countries that rely on imported energy. Tourism is already the principal industry in many of these countries and could be enhanced by making it more environmentally friendly through technology showcases for global leaders interested in transforming cities and regions to low-carbon alternatives. The demonstration of net-zero energy practices could become a tourist attraction. Private companies are already investigating alternative energy and transport solutions, including solar electricity and electric cars, for islands.

Island systems permit a second level of analysis that has proven much harder to quantify, and even harder to address politically: the positive and negative roles of engineered systems and of social systems. On islands, researchers can study the impact of a single new road, or a dock, or a compact in a valley to limit erosion, or an agreement around managing a shared resource such as fishing in a lagoon. The story does not end there. A considerable body of sociological and behavioral economics research relates to the dynamics (both cooperative and coercive) of how small groups can come to consensus (French, 1956; Laumann & Pappi, 1976; Friedkin, 1998). The key messages, then, are: (1) that island systems are microcosms of what nations, regions, and the planet already are facing and will face; and (2) that the inter-dependent biophysical, social and economic systems human beings impact, engineer, and act within, cannot be separated. Islands provide clarity on these linkages and opportunities to address pressing challenges on islands and to learn how to then deal with these challenges in larger systems.

1.3 A More Sustainable Future

This study looks at specific aspects of the island system – energy, transportation, water, agriculture, education, ecotourism, environmental issues and others – both in some sectoral detail and as part of wider interacting networks. Some aspects of the system on Carriacou and Petite Martinique are within the local boundaries of sustainability, and others are beyond it. These issues are explored in this Road Map by looking at different aspects of the island system and by assessing how these issues relate to global challenges.

This study assesses a number of actions to be implemented in the next decades to demonstrate how coherent and comprehensive policies as well as integrated systems and clean technologies could shift the course or future of small communities towards greener economies and sustainable development. It looks at potential actions that will enhance energy and food security, effective use of natural resources, environmental actions and ultimately the well-being of the population of Carriacou and Petite Martinique.

The study illustrates how integrated water-energy-waste systems could be designed to respond to basic needs of expanding residential, commercial, industrial and service sectors of the economy. It discusses the opportunity for the development of a major potential economic activity – ecotourism. It also outlines the importance of a domestic education programme that responds to the current challenges and great opportunities for the effective use of human capital in the building of its capacity for the development and management of its natural resources. The study stresses the need for the establishment of a practical and efficient low-carbon transport system that can facilitate communication and travel while ensuring economic security and minimum environmental impact. In addition, the Road Map addresses the need for emergency preparedness, especially in relation to water and energy needs immediately after natural disasters.

The study results in cumulative knowledge and analysis useful for further development of feasibility studies for the building of the necessary systems and infrastructure that could allow the movement towards a greener economy. It is hoped that the information will be useful in the preparation of proposals for financial, technical and human support. Although an attempt is made to show quantitative assessments, it is clear that more data are necessary, especially time-series data, for thorough evaluation of priority areas. Nevertheless, the limited data available, combined with the expert analysis and qualitative assessment, provide conclusive details about policies and actions for pursuing a more sustainable future.

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2. Background

2.1 Geography and Historic Context

Carriacou is the most southerly of the Grenadines, situated 20 miles north of Grenada, at latitude 12.5 degrees (Figure 2.1). It has an area of 13 square miles (34 km^2) and is the largest of the chain of islands between mainland Grenada and St. Vincent. Petite Martinique, which is the smallest of the Grenada Grenadines, lies about 2.5 miles from Carriacou and has an area of 2.7 km^2. The islands experience a low rainfall of about 100 cm annually. Over eighty percent of the days are without rain making the islands mostly sunny throughout the year.

Figure 2.1: Map of Grenada, Carriacou and Petite Martinique

The first settlers on the islands, the Amerindians, appropriately referred to Carriacou as the "Land of Reefs". Carriacou was first settled by the French between 1650 and 1655. In 1783 the British conquered the island. Today the majority of inhabitants are descendants of African slaves who have maintained many of the ancestral customs and practices. Some of these are seen in the Big Drum Dance and other festive traditions. Nonetheless, the British influences are obvious, while French influence remains and French names are still noticed, especially in the L'Esterre area. The current populations of Carriacou and Petite Martinique are about 8,000 and 1,000 respectively. The population of Grenada is estimated at about 100,000.

In the 19th century, Scottish boat builders settled at Windward in Carriacou and on Petite Martinique. The Scottish names and boatbuilding skills have been passed down through the generations and remain strong even today. As a result many locally built boats ranging from small fishing sloops to large trading schooners are seen in the seas around the Eastern Caribbean. Boat building is still carried out in the traditional way on the beaches but fewer have been built in recent years. Over the decades, Carriacou produced mostly cotton with some sugar, limes, coffee and cocoa production. Today the inhabitants grow corn and pigeon peas for their own consumption, and subsistence farming, livestock rearing, fishing and seafaring are the main occupations.

2.2 The Political Context

In 1833, Grenada became part of the British Windward Islands Administration and was administered by a British Governor until the 1950s. In 1958 Grenada joined the Federation of the West Indies that was short-lived and collapsed in 1962. After an unsuccessful attempt by the

British Government to form a small federation of the Eastern Caribbean, Grenada was granted full autonomy over its internal affairs in March 1967 in the form of a new governance arrangement called statehood. Full independence was granted on February 7, 1974. Grenada now has a modified Westminster parliamentary system based on the British model, with a governor general appointed by and representing the British monarch (head of state) and a prime minister who is both the leader of the majority party and the head of government. This governance model was temporarily suspended in March 1979, when the Government was overthrown by a Marxist -Leninist group with close ties to Cuba, the Soviet Union, and other communist-bloc countries. In October 1983, following a power struggle within the Government and a US-led invasion, a non-elected interim administration was established for two years, after which Grenada returned to its current governance structure.

Carriacou and Petite Martinique are administered through the Ministry of Carriacou and Petite Martinique Affairs (MOCPMA) under the responsibility of a Cabinet Minister. The MOCPMA has been in operation for the past 13 years and was established to provide a better level of service to the islanders. Its operations are financed from the central government. The structure of the MOCPMA is designed along the lines of a regular government ministry with a Permanent Secretary who reports to the Minister and directs the day-to-day activities. However, the MOCPMA, in its span of responsibilities, differs from other ministries in that it has responsibility for a varied range of functions decentralized from the ministries on mainland Grenada (MOCPA, 2011).

Matters relating to agriculture, fisheries, public works and sports are overseen directly by the MOCPMA. Some other areas like health, education and the treasury are controlled from the mainland with the MOCPMA having some on-the-ground oversight. This governance structure for Carriacou and Petite Martinique is still evolving. The constitution of Grenada provides for a Local Council for Carriacou and Petite Martinique. This was never implemented. However, the current government initiated the process to give Carriacou and Petite Martinique a form of local government by 2012. This would allow residents to have greater involvement in and control of matters relating to managing the environment. The new arrangement should make it easier to implement actions resulting from research activities in this field.

2.3 The Economic Context

The structure of the Grenadian economy has evolved over the last forty years, moving from being highly dependent on agriculture to being highly dependent on services. Over the past 15 years, the Government has emphasized an over-arching strategy of economic transformation in response to the inescapable external and internal forces that have an impact on the economy. The medium term economic strategy therefore emphasized key issues including sustained and robust economic growth, improved disaster preparedness, human resource development and improved environmental management. The new government that took office in 2008 outlined an overall strategy of economic transformation by designating five transformational sectors: health, education and wellness; tourism and hospitality services; agro-business; energy development; and information communication technology.

Agriculture, which accounted for about 20% of GDP during the 1970s, accounted for less than 10% by 1995 and was estimated to be about 5.2% in 2011. This reduced contribution from agriculture was due to its vulnerability to natural hazards, the impact of pest and diseases, and shifts in the global economic climate associated with the changing trade arrangements for crops such as sugar and bananas.

The impacts of natural hazards were demonstrated by the damage caused by Hurricane Ivan in 2004 and Hurricane Emily in 2005. In particular, Hurricane Ivan completely destroyed the agricultural sector, prior to which the prolonged effects of moko disease were already adversely affecting the banana industry.

By 2009, services inclusive of tourism accounted for more than 80% of output. This sector is also vulnerable to natural hazards and is affected by developments in the source market for tourists. In 2004, Hurricane Ivan destroyed the tourism infrastructure resulting in a contraction in tourist arrivals. Consequently, value added in the hotel and restaurant sector, an indicator of developments in the tourism industry, contracted by 42% in 2005. The sector rebounded and expanded by 38% in the subsequent year as hotels, previously closed for renovation, were reopened.

Thereafter, the tourism industry was negatively affected by the global financial and economic crisis which began in 2008. Since 2009, the tourism sector has contracted significantly with stay over arrivals declining by 3.0% in 2008, 11.6% in 2009 and 3.0% in 2010. To stimulate the sector and in response to the constraints of limited airlift, the government subsidized some of the flights originating from major markets that serve the tourism sector.

Carriacou and Petite Martinique suffer equally or even more than the mainland as tourism on these two smaller islands is generally a spillover from tourism on mainland Grenada. Therefore, the ongoing world economic recession presents further challenges to the Government's efforts to stabilize and grow the economy and delays the effort by the MOCPMA to establish a resilient economy in Carriacou and Petite Martinique. In this environment, the fiscal position of the Government has been challenging. Despite efforts at containing the growth in current expenditure, the decline in current revenue of 13% in 2009 contributed to a current account deficit and a reduction in capital expenditure. This has limited the scope for expenditure on infrastructure development and other development projects. Moreover, projections show a fiscal surplus materializing no earlier than 2014 (Government of Grenada, 2011).

The economy of Carriacou and Petite Martinique is similarly structured to that of the mainland except that fishing and services are of greater importance. Petite Martinique accounts for over 60% of the national fish export. The services sector in Carriacou and Petite Martinique is dominated by tourism and auxiliary services. Tourism in Carriacou and Petite Martinique is less developed than in the mainland with a limited number of hotel-beds available, yet there are also a number of home stay facilities. Many of the visitors come from the other islands in the region. Tourism revenue is also derived from the occasional cruise stop over, yachting and the four festive seasons; carnival during February or March, string band and maroon festival in May, annual working boat regatta in August and the Parang festival in December.

Carriacou and Petite Martinique have experienced significant levels of migration over the last century, which has impacted the economic development of the islands. It is estimated that as of 2000, about 50% of the population had migrated. Carriacou and Petite Martinique is considered the least poor district in the country, (Kairi Consultants, 2009). This apparent "well-off" position of Carriacou and Petite Martinique is somewhat inconsistent with high levels of unemployment, yet can be explained by the high level of remittances through the extended family connections. There has been a strong network of extended families through which members of families working in developed countries regularly contribute to the financial upkeep of households on the islands. Over the past 40 years, remittances from North America and the UK were considered high and were estimated to be about 9.2% of GDP for Grenada, including Carriacou and Petite Martinique (World Bank, 2008). In Carriacou and Petite Martinique, remittances may account for more than 30% of the islands' GDP.

Remittances are used to meet the everyday subsistence needs of large numbers of families. They have also been expended on building, repairing, or enlarging residential dwellings; for acquiring prestigious foreign consumer amenities; for contemporary home furnishings and indoor plumbing facilities; for purchasing stereos and other electronic equipment; and for other symbols of modernization. The current global economic recession has impacted the current level of remittances and the lower rate of remittances is likely to continue since the number of returnees peaked during the mid-1990s and the level of migration has slowed due to lessening opportunities. Without migration and remittances, the economic situation is not sustainable and the population might be forced to change its system of production, alter social structures, and make other radical transformations in order to survive (Cultural Survival, 2011).

Economic performance data on Carriacou and Petite Martinique are not disaggregated from that of mainland Grenada. However, there is generally little difference between the economic performance of the mainland and the islands. The economies were adversely affected by the impact of the financial and economic crisis, particularly the fall in tourist arrivals and the decline in inflows of Foreign Direct Investment (FDI) and remittances. Consequently, Grenada's economy contracted by 5.7% and 1.3% in 2009 and 2010, respectively, and only modest growth was projected for 2011. The decline in economic activity was mainly associated with the contraction in the major sectors including tourism, construction and the wholesale and retail trade. The construction sector declined on average by 19% between 2009 and 2010 as major tourism related projects were halted. During that period, inflows of FDI fell from $300 million in 2008 to $101 million in 2010. The hotels and restaurant sector contracted, on average, by 9% between 2009 and 2010, reflecting the fall in stay over visitors. These developments had spill-over effects in the transport, communications and the whole sale and retail trade sectors which also contracted.

As a result of the weak economic performance, it is estimated that unemployment levels would have increased. Unemployment is high and is estimated to be over 30% in Carriacou and Petite Martinique. A number of projects geared at temporary employment for the youth have been implemented but this is not large enough to significantly reduce unemployment.

2.4 The Social Context for Enabling Greening

Many current social experiences of Carriacou and Petite Martinique are conducive to greening efforts. Some traditional practices which may appear old fashioned to a visitor, for example drying clothes on a line in the sun or using bathroom wastewater for irrigating the callaloo plot, are green activities. However, there are strong western influences which are quickly changing the traditional ways and are negative to the efforts of greening. For example, unlike 25 years ago when only a small number of primary school children drove to school, today children as well as adults use motor vehicles for travelling over very short distances. Islanders also use many processed foods as seen on television generating large volumes of waste from package material thereby creating a potential problem for land fill space in the future.

Carriacou and Petite Martinique are almost homogenous in ethnicity and the cultural tradition encourages wide community participation in communal activities. The songs and dances engender the concept of a participatory approach in local governance. Thus, efforts to greening the economy, which involves community ownership, are expected to receive overwhelming public support. Furthermore, the traditions encourage green practices.

Since the end of slavery people of working age have migrated in search of job opportunities. As a result it is almost inevitable that "the wish to leave" is acute among the rural youth and produces a "migration mentality" in which escape from the island is viewed as the only means of achieving anything in life. Today nearly every household has at least one family member overseas. The remittances from family members have resulted in a low level of poverty (below 10%) of the islands' population, making it possible for local financial support for initiatives that result in benefits. Nonetheless, a high level of unemployment remains among the youth. Although Carriacou has a low level of poverty it has benefited from a number of special social initiatives which were implemented during the 2005-2009 period of reconstruction and rehabilitation in response to hurricanes Ivan (2004) and Emily (2005). The important ones were safety-net initiatives involving the provision of work opportunities for the more vulnerable people (aged and economically challenged). Also, the Food Security (distribution) initiatives in response to the food crisis and hurricane impacts were notable.

In Grenada, persons over 65 years of age account for about 8.9% of the population (CIA, 2011), but this is higher for Carriacou and Petite Martinique. Due to the high number of returnees who have retired from the UK and North America, the proportion of elderly persons over the age of 65 is expected to reach 15% to 20% by 2020.

2.5 Education and Health

There are six pre-schools, six primary schools, two secondary schools and one post secondary college on the islands. Carriacou and Petite Martinque have sufficient school infrastructure to meet the demand of the school age population up to secondary school. The current school population is 1202 (52% primary students and 48% secondary) and many of the schools are under-populated. Education offerings are generally highly theoretical and the availability of vocational training and non-traditional courses are limited. As a result there is a mismatch between the skills of the population and the jobs available due to the nature of the training provided at the secondary schools. At the post-secondary, the T.A. Marryshow Community College, the subjects available are limited to business, social sciences and Information Technology (IT). There is, however, potential for physical expansion (Figure 2.2) at this college to provide more enrollments of students and to restructure the curriculum.

Figure 2.2: Unfinished facilities at T. A. Marryshow Community College

The health services in Carriacou are comprised of two hospitals (one public and one private) and four public medical clinics while Petite Martinique has one public medical clinic. At the public hospital, routine treatments up to minor surgeries are provided by two doctors who work on a rotating basis and a nursing staff of 14. All major medical treatment must be referred to the hospitals on mainland Grenada. The private hospital, which is outfitted with some modern equipment, is underutilized. A doctor who is supported by at least two nurses provides health services at the medical clinics at least once per week.

2.6 Sustainable Development as a Way of Life in Carriacou and Petite Martinique

During the 1950s and 1960s residents were almost self-sufficient in food supply and it was common for some households to be totally self-sufficient. Trees were routinely replanted for providing energy mainly in the form of firewood and charcoal. Drinking water came from communal cisterns, while water for other household uses came from a few dug wells and rainwater ponds. All these facilities were maintained and managed by the community and conservation became routine because of scarcity. Other practices that capture the concept of greening include the use of fishing boats that are powered by sails in the fishing villages of Windward and Dover, and solar drying of fish, meats and vegetables. Improved drying methods are now promoted by the Local Government

Figure 2.3: Solar drier for fish and fruits (locally constructed)

Unit at the MOCPMA for farmers and fishermen using a locally designed and constructed drier (Figure 2.3).

More recent initiatives of sustainable development and environmental management have come about through both non-government and governmental efforts. The earliest formal sustainable development initiative was undertaken by the Government in the late 1960s through a project "Carry a tree to Carriacou" which focused on reforestation. More recent initiatives included "the Integrated Physical Development and Environmental Management Plan for Carriacou and Petite Martinique" (Anon, 1998), which highlighted the need to manage the 100 hectares of mangroves and several hundreds of hectares of sea grass beds and coral reefs as part of a sustainable development strategy. The plan also proposed a Marine Protected Area (MPA), which was commissioned in 2010.

Other Government initiatives that enhanced environmental management and sustainable development included the development of a solid waste management strategy and the creation of a waste management system for Carriacou and Petite Martinique which is financed through a small tax on electricity bills. The solid waste management strategy seeks to maximize the diversion of waste from disposal through reducing waste generation, applying reuse, recycling and composting (Grenada Solid Waste Management Authority, 2003). Moreover this initiative is in response to Grenada's commitment to a number of regional and international agreements (e.g., Cartagena Convention, the Declaration of Barbados and Programme of Action for sustainable Development of SIDS and The St. Georges Declaration of Principles for Environmental Sustainability in the OECS), which address the management of waste. While there has been some success in terms of effective collection, the ability to recycle, reuse and composting has not been realized. Nonetheless there is an emerging opportunity for converting waste-to-energy at the Dumfries waste disposal site.

Non-governmental initiatives geared towards sustainable development include the Kido Foundation Project for protecting endangered species and their natural ecosystems and promoting environmental conservation education and training (KERS, 2008). The Carriacou Environmental Committee promotes environmental awareness through public education and community projects.

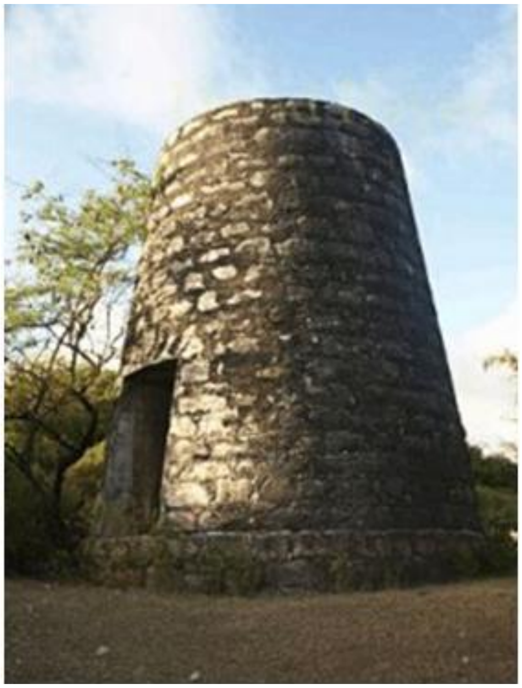

Figure 2.4: Relic of windmill used for grinding sugarcane in Carriacou

During the era of slavery and sugar production in Carriacou, wind power was used to grind sugarcane (Figure 2.4). During the 1950s, wind power was again used by a small number of homes for charging batteries for household lighting. Today, the use of alternative energy is gaining momentum. A few homes, hotels and the public hospital are using solar hot water systems in Carriacou and Petite Martinique. In Grenada, the Grenada Solar Power Ltd. (GRENSOL) has been marketing photovoltaic systems, five of which – with ratings up to 9 kW – have already been installed (GTZ, 2007).

In 2002, Grenada requested the assistance of the Global Sustainable Energy Islands Initiative (Tugwell, 2002) in developing a Sustainable Energy Plan (SEP) and promoted itself as the Green State (Roper, 2005). The only power company, Grenada Electricity Company (GRENLEC), is now looking at developing a wind farm site on government-owned land on Carriacou and has submitted a formal proposal. GRENLEC would like to generate 10% of its power from renewable energy from the wind farm by 2013 and 20% by 2017. Other examples of the use of wind energy can be seen in the neighboring Bequia where in 2008, Turbulence Ltd. of Grenada installed the first residential hybrid alternative energy system, which is a combination of solar panels and a wind turbine (Caribbean Compass, 2008). The Paradise Bay Hotel, situated at the southeast end of the island, installed an 80 kW wind energy conversion system from Netherlands-based Wind Energy Solutions BV (WES) in March 2007 (GTZ, 2007). A local church is also currently in the process of installing a wind turbine to provide its own power (Harbour Light of the Windwards, 2011). Notwithstanding, there are some barriers to the recent progress in renewable energy, as identified by Weisser, to shifting power production towards meaningful contributions from renewable energy, both in government and industry. Increasing numbers of successful demonstration projects would weaken or eliminate some barriers to the transfer of renewable energy technologies (Weisser, 2004).

In the hotel sector, 85% of the small hotels and guesthouses in Carriacou and Petite Martinique are following a trend that would contribute to sustainable development and are using solar heating and other renewable energy where possible. The Green Roof Inn, which has no air conditioning, uses solar water heating, reuses its grey water for irrigation and has installed water saving shower heads, leads the way in efforts at reducing the impact on the environment and contributing to a green economy.

2.7 Government Policies and Plans for Creating Greener Environment

During the past decade, the Government of Grenada has been developing policies and plans towards sustainable development. The Government has demonstrated its commitment to environmental management and conservation through policy initiatives such as the Carriacou and Petite Martinique Integrated Physical Development and Environmental Management (1998); the Forest Policy and Action Plan (2000); the Biodiversity Strategy and Action Plan (2000); the National Environmental Management Strategy; the National Communication on Climate Change (2000); the National Physical Development Plan (2003); and the Draft Policy on Renewable Energy (2002). These policy documents were developed through consultative and participatory approaches in the planning stages and with implementation that involved a wide array of vested interests. Collectively these policies and plans provide an enabling environment for the creation of a green economy.

In respect to energy, the Draft Policy on Renewable Energy (Government of Grenada, 2002) articulates the actions that the Government is committed to in setting up the enabling environment for sustainable energy management. These include initiatives on grid-tied renewable energy, independent renewable energy, energy efficiency and interventions in the transportation sector.

The Government is promoting capitalization of its natural resources through the use of renewable energy and has identified the main potential sources as solar, wind and biomass. It offers incentives for the use of renewable energy in that alternative energy products, including solar and wind energy systems, are exempted from the general consumption tax. The Government is committed to supporting wind energy for Carriacou and Petite Martinique. At the international level, Grenada has taken the lead in calling on developed countries to provide significantly reduced costs of renewable energy technologies to small island states (Caribbean News, 2011).

The National Forestry Policy and Action Plan (Thomas, 2000) was initially intended to reforest and stabilize forest areas. The general public made it clear that the conservation aspects of forests were more important than timber production, and the Forestry Department has since been focusing on multiple-use aspects of forest management such as conservation and recreation (Ministry of Finance, 2008). Carriacou and Petite Martinique are therefore recording reduced deforestation as the policy is being implemented on the islands.

Policies and plans specific to Carriacou and Petite Martinique include the Carriacou and Petite Martinique Integrated Physical Development and Environmental Management (Anon, 1998). The aim of the plan is to achieve “an integrated planning framework” for rational spatial and sound environmental management that will lead to sustainable development of the islands. The plan addresses a range of relevant areas including land use, population and settlement, environmental management, economic development, housing and community facilities. Since its completion, a number of activities have been undertaken to implement the plan.

In addressing the high levels of poverty in Grenada, the Government has identified areas for project development that can be aligned to the concept of a green economy inter alia:

- Disaster Management and Preparedness;
- Food Security Project;
- Biodiversity Conservation and Protection;
- Climate Change and Climate Vulnerability;
- Project to Combat Land Degradation;
- Infrastructure and Road Programme;
- Renewable Energy Project; and
- Solid Waste Management Project (Ministry of Finance, 2008).

2.8 Corporate Plan for the Ministry of Carriacou and Petite Martinique Affairs (MOCPMA)

Corporate planning is absent in many ministries of Government. Although the MOCPMA is a recently established ministry, it is leading the way in developing a corporate planning culture. It has adapted the mission statement: “to co-ordinate and facilitate all Government related activities and programmes for Carriacou and Petite Martinique through high quality services, shared responsibility, participation, increased productivity and appropriate technical support”. Senior officials of the MOCPMA have agreed that an updated corporate plan would place greater emphasis on using the "green economy" concept as central to the plan. Nonetheless, the current corporate plan recognizes the opportunities to "foster the spirit of partnership between NGO's, private and public sectors in Carriacou". There are many opportunities for the MOCPMA to take a green approach to its proposed infrastructure development.

2.9 Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis

A SWOT analysis of Carriacou and Petite Martinique (Table 2.1) was carried out to highlight some of the strengths, weaknesses, threats and opportunities that can influence the ability of the islands to be transformed into a green economy. While the analysis is not exhaustive it provides a list of possibilities.

Table 2.1: SWOT Analysis

Strengths	**Weaknesses**
• Small area and population which is conducive to micro projects • Low level of poverty • Tends to recover from natural disasters faster than mainland Grenada • Establishment of rainwater harvesting (RWH) technology and unanimous acceptance of the technology by islanders • Relatively crime-free community	• Lack of land use polices and plans • Small market for renewable energy • Relatively inaccessible • High energy costs (highest fuel and electricity costs in the country) • High land transport costs (20% higher than mainland Grenada) • Limited natural water resources • High inter-island ferry costs • Limited opportunities for youths • Large portion of elderly persons • High dependence on remittances • Lack of facilities for training programmes • Limited data for planning • High cost of living • High unemployment
Opportunities	**Threats**
• To promote renewable energy • To improve efficiency of transportation • To develop high-income residential luxury ecotourism through the promotion of retirement homes • To develop training facilities for education in sustainable development • To enhance RWH systems • To improve efficiency of water use by the use of low energy technologies that are now emerging • To market Carriacou and Petite Martinique as a green tourism destination • To develop a resilient economy	• High levels of migration • Decrease in remittances • Prolongation of the global economic and financial crisis • Western consumption-type influences • Natural disasters, particularly hurricanes and droughts • Impact of sea level rise and climate change on coastal erosion and water resources

2.10 Conclusions

The geographic, economic and social factors that exist in Carriacou and Petite Martinique provide for a repositioning of these small islands on a path to a green economy. As small islands which are relatively isolated and have limited natural resources, small population and negligible population growth over the last five decades, Carriacou and Petite Martinique are poised for developing an economy that can maximize the available renewable energy sources, such as solar and wind, in order to reduce the price of energy, which is critical to the development of sustainable tourism. The SWOT analysis shows that there are a number of opportunities for the use of green technologies that can improve the lives of islanders in a sustainable manner and can provide job opportunities that are not now available. The growth of new opportunities for local employment is important in reducing the migration of young people; however, the economic support from remittances is likely to decline. Furthermore, many small islands such as Carriacou and Petite Martinique are now under the threat of climate change and sea level rise and must adapt to these threats to avoid poverty and underdevelopment. Carriacou and Petite Martinique are in a unique situation to be successfully transformed into a green economy such that they can become models of possibilities for other small islands.

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3. Energy Resources and Technologies

3.1 Introduction

Energy is a vital component of sustainable development and poverty eradication. Access to energy has been shown to have a strong link to bringing health and educational services to under-served communities as well as to poverty reduction through expanded economic opportunities for the poor (Prull, 2008). The islands of Carriacou and Petite Martinique in Grenada rely almost entirely on imported oil for energy generation in both the stationary power and transport sectors. The 2007 / 2008 global financial crisis coupled with record high oil prices had a negative effect on the economies of most Caribbean island countries (Government of Grenada, 2011). This effect was exacerbated by the drop in travel and tourism, an industry which drives the economy of Grenada. In addition, these islands are also highly exposed to the environmental impacts associated with fossil fuel consumption such as sea level rise and increased strength and frequency of hurricanes (General Secretariat of the Organization of American States, 2006). Transitioning from fossil fuels to renewable resources for power generation not only alleviates these issues, but can also create local industry and help strengthen the economy.

This chapter discusses the potential for Carriacou and Petite Martinique to utilize renewable energy technologies for stationary power generation[1]. A summary of the current electricity system is provided along with a discussion of specific paths to utilizing the islands' exceptional renewable resources. A model of each island's power grid is presented using HOMER optimization software developed by the U.S. National Renewable Energy Laboratory (NREL). These models are used throughout the chapter in order to quantify the reduction each suggested renewable energy project would have on the island's fuel use and harmful greenhouse gas emissions. In addition to utility scale projects, this chapter provides a discussion on how smaller distributed renewable energy systems could positively impact homes, agriculture, water distribution and other sectors of Carriacou and Petite Martinique's infrastructure.

3.2 Electricity Supply in Grenada

3.2.1 Grenada's Electric Utility

Grenada Electricity Services Limited (GRENLEC) provides electrical generation, transmission and distribution services to the three-island state of Grenada, Carriacou and Petite Martinique. GRENLEC was established as the sole provider of electricity services for a period of 80 years from 1961 (GRENLEC, 2012). GRENLEC was originally structured as a subsidiary of the Commonwealth Development Corporation (a British development organization owned by the UK government), with the government of Grenada as a shareholder. In 1982, the government of Grenada became the sole owner of the utility. GRENLEC remained government-owned until 1994, at which point the Grenadian authority elected to divest a portion of its shares. The aim of

[1] All costs are presented in U.S. dollars (USD) unless otherwise stated. It is assumed that 1.0 USD is equivalent to 2.7 eastern Caribbean dollars (XCD).

the divestment was to introduce capital into GRENLEC for development projects, to ease the burden on public funds, and to encourage a transfer of technologies from more developed countries (GRENLEC, 2012). 50% of shares in GRENLEC were sold to WRB Enterprises Inc. (of Florida, USA), 21% kept by the Grenadian government and 29% sold to regional and national shareholders (GRENLEC, 2009). At this time, the Electricity Supply Act of 1994 was established, extending GRENLEC's rights as sole electricity provider to the Islands until 2073.

3.2.2 Electricity Generation, Consumption and System Losses

Electricity in Grenada, Carriacou and Petite Martinique is generated by diesel-fired generator sets. Each island has its own power station, transmission and distribution grid. The main island of Grenada has a power station at Queen's Park consisting of seven operational generator sets with an aggregate installed capacity of 45.9 MW as of August 2011 (GRENLEC, 2011). Carriacou's Beausejour power station consists of four generator sets with an aggregate capacity of 3.2 MW. Petite Martinique has two operational generator sets at its power station with a total installed capacity of 512 kW. In 2006, Grenada signed the Petro Caribe Agreement to receive diesel fuel from the Venezuela state company, Petroleos de Venezuela (PDVSA). Under this long-term agreement, petroleum products are accessible to signatories on a concessionary loan-financed basis (Government of Grenada, 2011).

The total gross generation of electricity in Grenada, Carriacou and Petite Martinique in 2010 was 209 GWh (GRENLEC, 2010). The total energy available for sale was 201 GWh, with the remaining 7.32 GWh (3.5%) being consumed on-site by generator auxiliaries. Electricity sales totaled 185 GWh, thus resulting in an estimated system loss of 16 GWh (8.2% of energy available for sale). Overall availability of the generators in 2010 was reported as 92%.

Total system loss reported between 2006 and 2010 ranges from 7.5% to 9.6% and appears to be uncorrelated with the growth in consumption (sales). GRENLEC has been exploring a number of initiatives to improve service quality and reduce technical losses. In its 2010 annual report, GRENLEC also highlights commercial losses from domestic and commercial customers as a significant challenge (GRENLEC, 2010).

3.2.3 Electricity Sales

In 2010, GRENLEC provided electrical service to an estimated 41,000 consumers (Government of Grenada, 2011). Total sales of electricity grew an average of 5% per year between 2006 and 2010. The majority of electricity sales are in the domestic and commercial sectors, which accounted for 39% and 55% of total sales in 2010, respectively. These two sectors also accounted for the majority of the growth in consumption between 2006 and 2010 (20% average annual increase for domestic customers, 24% average annual increase for commercial customers).

GRENLEC reported spending $32 million on diesel fuel in 2010 at an average fuel cost of $0.61 per liter (GRENLEC, 2010). Based on these figures, the total diesel fuel consumed by GRENLEC's power plants in 2010 was approximately 49 million litres. Purchases of diesel fuel represented 58% of GRENLEC's 2010 operating expenses. These prices are passed on to consumers as a fuel charge.

Table 3.1 shows the monthly price of diesel fuel and the resulting fuel charges in 2009 and 2010 as reported by GRENLEC. The average fuel charge increased from $0.13/kWh in 2009 to $0.17/kWh in 2010. This is a percentage increase of over 27% in one year. This fuel charge represents 47% of the average price of electricity in 2010 of $0.35/kWh (GRENLEC, 2010).

	Price of Fuel		**Fuel Charge**	
	2009 $/litre	**2010 $/litre**	**2009 $/kWh**	**2010 $/kWh**
January	0.42	0.57	0.15	0.16
February	0.38	0.57	0.13	0.16
March	0.38	0.60	0.11	0.16
April	0.42	0.64	0.11	0.16
May	0.44	0.60	0.11	0.17
June	0.51	0.59	0.11	0.17
July	0.48	0.58	0.13	0.17
August	0.55	0.59	0.13	0.16
September	0.51	0.60	0.14	0.16
October	0.56	0.65	0.14	0.17
November	0.58	0.67	0.15	0.17
December	0.57	0.70	0.15	0.18
Average	**0.48**	**0.61**	**0.13**	**0.17**

Table 3.1: Monthly Price of Fuel and Resulting Fuel Charges in 2009 and 2010 (Grenlec 2010)

3.2.4 Baseline HOMER Model for Petite Martinique

A model of the current electric power system on Petite Martinique was created using HOMER optimization software. Key assumptions and results are presented below.

The electricity demand profile for Petite Martinique was modeled based on daily generation records provided by GRENLEC for 2010. For this analysis, it was assumed that the demand is equivalent to the gross generation less generator auxiliaries. Based on 2010 data, Petite Martinique's average annual demand of 91 kW remains fairly constant from month-to-month. The estimated total annual consumption in 2010 was 796 MWh. Generator auxiliaries accounted for an additional 23 MWh.

Electricity is generated on Petite Martinique via two diesel-fired generator sets: a 251 kW-rated Caterpillar unit and a 261 kW-rated Lister ES2 unit. The performance of these generator sets was modeled in HOMER by creating fuel curves based on manufacturer-published datasets. These generator sets are used one-at-a-time and are switched approximately every 10-14 days.

Simulation results from the HOMER baseline model for Petite Martinique are summarized for 2010 in Table 3.2. Modeled data for the fuel's average lower heating value (42.5 MJ/kg) and density (854 kg/m^3) were obtained from GRENLEC. The simulation results show a total estimated annual energy production of 819 MWh and a corresponding fuel consumption of 308,600 litres.

	Lister Generator Set	Caterpillar Generator Set	Units
Electrical production	512,118	307,271	kWh/yr
Mean electrical output	93.5	93.5	kW
Min. electrical output	79.1	79.1	kW
Max. electrical output	120	120	kW
Fuel consumption	193,747	114,814	L/yr
Specific fuel consumption	0.378	0.374	L?kWh
Fuel energy input	1,957,940	1,160,271	kWh/yr
Mean electrical efficiency	26.2	26.5	%

Table 3.2: Petite Martinique HOMER Baseline Model Simulation Results (2010)

The combustion of diesel fuel in a thermal power system creates many different pollutants which contribute to global warming and respiratory illness. The modeled greenhouse gas (GHG) emissions from Petite Martinique's current generation system are presented in Table 3.3. In addition, the assumed Global Warming Potential (GWP) of each pollutant is shown for reference. The GWP is a relative scale which compares each gas to an equivalent mass of CO_2. Multiplying each pollutant by its GWP and summing them together gives an estimate of the total emissions in CO_{2e} (carbon dioxide equivalent) from combustion. The total estimated emissions are 1,866 tons of CO_{2e}.

Pollutant	**GWP**	**Total Emissions (tons)**	**CO_2 equivalent (tons)**
Carbon dioxide	1	743	743
Carbon monoxide	3	0.52	1.52
Unburned	11	0.19	2.13
hydrocarbons	680	0.11	71
Particular matter	0.075	0.65	0.05
Sulfur dioxide	310	3.38	1,047
Nitrogen oxides			
			TOTAL 1,866

Table 3.3: Annual Greenhouse Gas Emissions from Petite Martinique Baseline Model (2010)

3.2.5 Baseline HOMER Model for Carriacou

At the time of this study, a full year of detailed electricity demand data was not available for Carriacou. However, GRENLEC provided a summary of generation statistics for Carriacou and Petite Martinique for the months of January 2011 to July 2011. These data were used to test for a correlation between the demands for electricity on the two islands. The monthly net generation datasets shown in Table 3.4 are indeed strongly correlated, with a calculated correlation coefficient of 0.93. On average, the monthly net generation on Carriacou is roughly ten times greater than on Petite Martinique. Thus, the annual electrical demand on Carriacou was modeled by multiplying the data for Petite Martinique by a factor of 10. The resulting modeled demand has a peak of 1,172 kW and an estimated annual consumption of 7,960 MWh.

Electricity is generated on Carriacou via four diesel-fired generator sets: three 640 kW-rated units and one 1280 kW-rated unit (Caribbean Renewable Energy Development Program, 2011).

The smaller units are run in parallel (typically two at a time) to meet peak loads. The fourth, larger unit is used primarily for backup power generation.

	Net generation (kWh)	
	Carriacou	**Petite Martinique**
Jan- 2011	671,389	66,629
Fen-2011	586,464	56,732
Mar-2011	661,856	66,023
Apr-2011	634,132	64,822
May-2011	687,640	67,951
Jun-2011	654,533	66,308
July-2011	684,533	66,283

Table 3.4: Monthly Net Electrical Generation from January 2011 to July 2011

Simulation results from the HOMER baseline model for Carriacou are summarized for 2010 in Table 3.5. The simulation results show a total estimated annual energy production of 8193 MWh and a corresponding fuel consumption of approximately 2.6 million litres.

	Generator Set 1	Generator Set 2	Generator Set 3	Units
Electrical Production	2,731,302	1,730,249	3,732,339	kWh/yr
Mean electrical output	468	269	639	kW
Min. electrical output	192	192	599	kW
Max. electrical output	640	564	640	kW
Fuel consumption	863,781	606,994	1,120,593	L/yr
Specific fuel	0.316	0.351	0.3	L/kWh
consumption	8,729,084	6,134,076	11,324,339	kWh/yr
Fuel energy input	31.3	28.2	33	%
Mean electric				
efficiency				

Table 3.5: Carriacou HOMER Baseline Model Simulation Results (2010)

The modeled GHG emissions from Carriacou's current generation system are presented in Table 3.6. The results in Tables 3.3 and 3.6 show that the power systems on Petite Martinique and Carriacou emit a combined 20,000 tons of CO_{2e} per year.

Pollutant	GWP	Total Emissions (tons)	CO2 Equivalent (tons)
Carbon dioxide	1	7,127	7,127
Carbon monoxide	3	4.85	15
Unburned hydrocarbons	11	1.86	20
Particular matter	680	1.01	685
Sulfur dioxide	75	6.27	470
Nitrogen oxides	310	32	10,042
			TOTAL 18,359

Table 3.6: Annual Greenhouse Gas Emissions from Carriacou Baseline Model (2010)

3.2.6 Electricity Access

Access to electricity in Grenada is very high in comparison with neighboring island nations. In 2010, GRENLEC reported that 99.5% of communities in Grenada, Carriacou and Petite Martinique are electrified (GRENLEC, 2012). According to a recent study done by the International Energy Agency, Grenada has the second highest electrification in the Caribbean, falling only slightly behind the Netherlands Antilles. By comparison, Haiti has the lowest electrification rate in the region, at less than 40% (IEA, 2009).

3.3 Renewable Energy Policy and Incentives

3.3.1 Summary of Grenada's National Energy Policy

The Grenadian Government has taken modest steps towards involving itself in the control of the island's electricity utility. Since late 2003, the Ministry of Agriculture, Land, Forestry, Fisheries, Public Utilities and Energy as well as the Marketing and National Importing Board have taken responsibility for the energy sector and the formulation of policies. This makes Grenada one of the few countries in the Eastern Caribbean with a specialized energy desk within the Government (Loy & Farrell, 2005). The Ministry of Finance and Planning has begun the process of developing a National Energy Policy. In November 2011, the Government of Grenada released the National Energy Policy (NEP) document outlining initiatives for low carbon development in Grenada, Petite Martinique and Carriacou. Key objectives of the NEP are summarized below (Government of Grenada, 2011):

- "Prioritize the use of Grenada's indigenous <u>renewable energy</u> sources to provide maximum economic performance and growth"
- "Reduce the national <u>carbon footprint</u>"
- "Position Grenada to create sustainable jobs and build resilience in its economy"
- "Ensure the creation of required legislation for the management of <u>geothermal power</u> development and use and channel resources to materialize its deployment"
- "Engage into collaboration with similar ongoing geothermal development activities in the region to secure required technical assistance and financing"
- "Assess the potential for a <u>waste to energy</u> facility for Grenada"
- "Encourage the investigation of the potential to produce <u>alternative liquid fuels</u> from municipal solid waste and agricultural wastes"
- "Assess the enforcement of mandatory installation of <u>solar water heaters</u> on all new public-sector buildings, hotels and all other buildings having a commercial demand for hot water"
- "Review the existing state of <u>wind power</u> assessments island-wide and ensure continuance"

The most tangible objective of the NEP is to meet 20% of energy consumption in the stationary power and transportation sectors with renewable sources by 2020 (thereby also reducing GHG emissions by 20%). These targets follow the European Union's goal of increasing energy from renewable sources 20% by 2020 (BP, 2011). As such, GRENLEC and the government of Grenada are evaluating the potential for integration of a number of mature renewable energy technologies, including wind, photovoltaics, and waste-to-energy (GRENLEC, 2010). The NEP outlines the following specific steps to achieve its goal of 20% renewable energy by 2020 (Government of Grenada, 2011):

- “Complete feasibility analysis and construction of a 20 MW geothermal plant”
- “Explore expansion to 40 MW of geothermal”
- “Construct a 2.5 MW wind turbine for Carriacou”
- “Achieve 10% Electricity Generation by wind & solar PV”
- “Establish vehicle fuel efficiency standards”
- “Achieve 20% market penetration with hybrid and electric vehicles”

The NEP also suggests to reach a target of “70% renewable energy for electricity production in Carriacou and Petite Martinique” by 2013. In a 2011 budget statement (GOG, 2011), the Government of Grenada states that it has completed a funding request along with GRENLEC to the European Union Energy Initiative to support a proposed wind-diesel system for Carriacou. The project would include the installation of 2 – 2.5 MW of wind energy, use of back-up diesel generators, battery storage, desalination and ice making/storage (an additional economic benefit to the indigenous fishing communities). Estimated capital costs for this project are $4.5 million (GOG, 2011). Other than the suggested 2.5 MW wind turbine for Carriacou, the NEP does not list specific projects to meet their 70% target.

3.3.2 Current Renewable Energy Incentives

The Government of Grenada (GOG) currently offers incentives for renewable energy products in the form of a tax exemption. Equipment deemed eligible by the GOG, including wind and solar systems, are exempt from the general consumption tax (GCT). At a current GCT of 10%, this represents a notable savings in capital equipment costs. However, increased adoption will require more attractive incentives and subsidies, as echoed in the recent NEP.

3.4 Renewable Energy Potential of Carriacou and Petite Martinique

There are many commercially available technologies for renewable power generation. The generation options which are the best fit for a given project depend on the scale, economics and renewable resources available for that specific location. The islands of Carriacou and Petite Martinique present a unique opportunity for implementing many of these technologies, due to their tropical climate and high fuel costs. On the other hand, there are many hurdles to face in adopting any new technology. The limited land area available, sensitive ecosystems and visual impact of each option is of concern as well as the availability of materials, limited skilled local labor and remote location of the islands. The following section discusses the potential for integrating renewable energy technologies into the existing diesel power grids on Carriacou and Petite Martinique.

3.4.1 *Wind Resource on Carriacou and Petite Martinique*

With the threat of climate change and rising oil prices, wind power is becoming an increasingly viable alternative for electricity generation in many parts of the world. Global installed wind capacity has grown on average 27% per year between 2005 and 2010. In 2010, for the first time, the majority of this new wind power capacity was added in developing countries and emerging markets. This growth was due in part to the growing popularity of community-based projects and distributed, small-scale grid-connected turbines (REN21, 2011). As island countries like Grenada adopt clean energy policies, power generation from wind turbines is becoming more widespread.

In 2010, GRENLEC installed 50 meter met towers to better quantify the wind resource on Grenada (at Clozier, a mountainous site) and Carriacou (near Top Hill) (Caribbean Renewable Energy Development Program, 2011). Table 3.7 shows the monthly average wind speeds recorded at Top Hill from December 2010 to November 2011. The annual average wind speed measured at 50m is 7.74 m/s, which corresponds to an NREL Class 5 wind regime. Historically, utility scale wind projects are economically viable for sites with Class 5 winds or higher. However, low-wind speed turbines have been developed recently to take advantage of sites with Class 3-4 winds.

Month	Mean Wind Speed (m/s)
Dec-10	7.7
Jan-11	9.6
Feb-11	9.7
Mar-11	8
Apr-11	7.6
May-11	7.4
Jun-11	9
Jul-11	7.5
Aug-11	6.3
Sep-11	6.1
Oct-11	7.3
Nov-11	6.7

Table 3.7: Top Hill Wind Speeds

The data in Table 3.7 was used to create a model of the wind resource on Carriacou and Petite Martinique. The modeled distribution of wind speeds was based on data obtained from (Weisser, 2003). The simulated wind speed distribution at 50 m is shown in Figure 3.1. It has also been shown that for coastal sites, there is a strong diurnal pattern, with the highest wind speeds occurring between 09:00 and 16:00 (Wright, 2001). This pattern matches data collected on Grenada in (Weisser, 2003), as shown in Figure 3.2. These monthly and diurnal patterns are key for integrating wind power into an existing diesel grid. Finally, the simulated monthly average wind resource is shown in Figure 3.3.

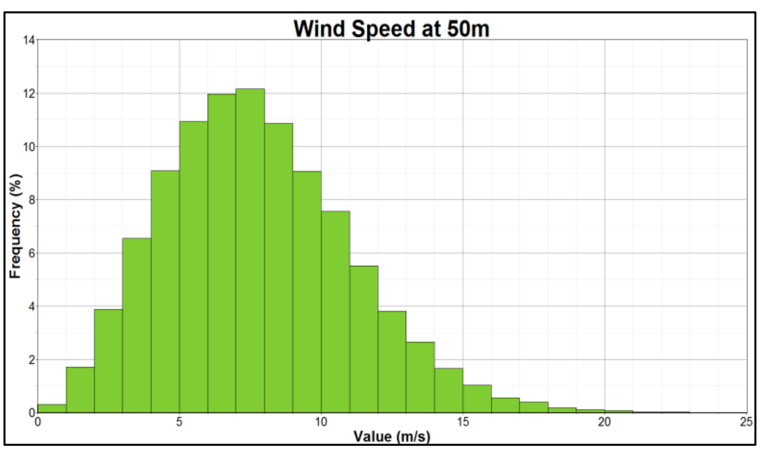

Figure 3.1: Simulated wind speed distribution, 50 m

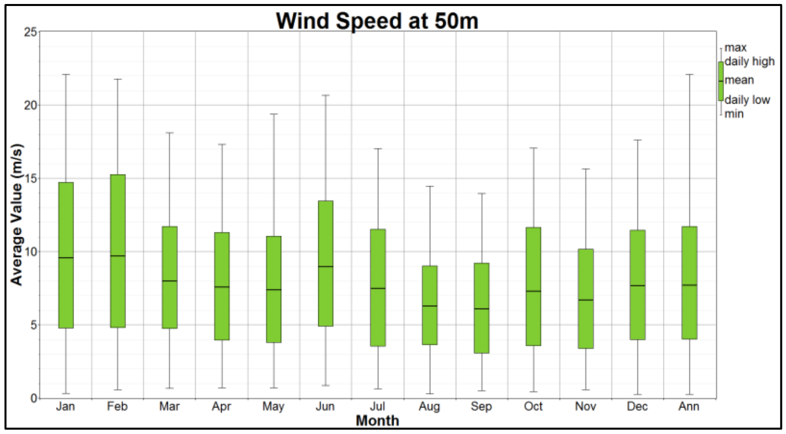

Figure 3.2: Measured Diurnal Wind Pattern on Grenada (Weisser, 2003)

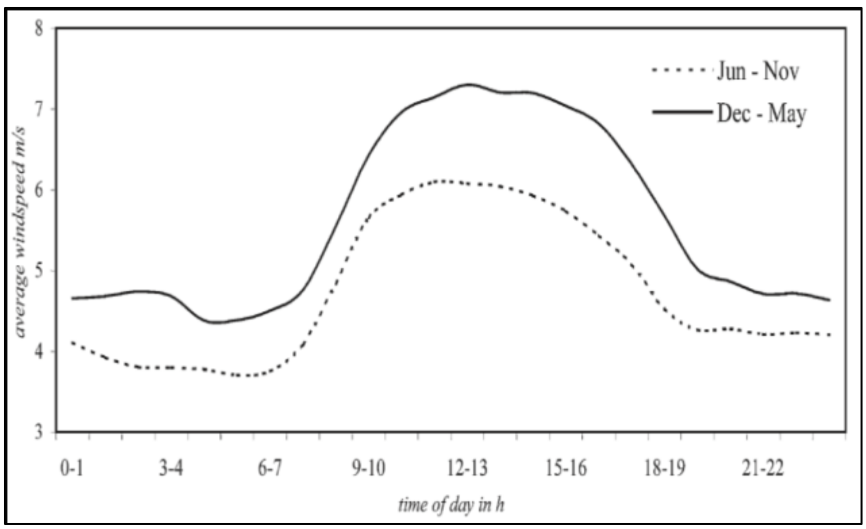

Figure 3.3: Simulated Monthly Average Wind Speed at 50 m

Wind Diesel Systems

A wind turbine installed on Carriacou or Petite Martinique would likely be integrated with the existing diesel generator sets in what is commonly referred to as a wind-diesel hybrid power system (aka wind-diesel system). The primary goal of a wind-diesel system is to obtain a maximum contribution from the renewable wind generation to the total energy produced, while maintaining system stability. The architecture of wind-diesel systems varies depending on the desired percentage of energy to be produced from wind (known as the wind penetration).

Wind turbines are commonly split into three classifications based on their rated power output: small, medium and large scale. The market for small (0.1 -10 kW) turbines ranges from remote off-grid locations to residential systems. These smaller designs are typically far too expensive on a per watt basis to consider for utility-scale applications. Medium-scale turbines (50 kW -1 MW) have all the infrastructure needs of their larger counterparts, but also tend to be more expensive per watt. By increasing turbine size from 250 kW to 1 MW machines, site construction costs can be reduced by up to 30% (Wright, 2001). Thus, the current trend in the wind industry is to move away from the medium scale turbines toward the larger, taller multi-megawatt machines. Due to this trend, few companies are still manufacturing these medium scale turbines. One of the few remaining markets for medium scale turbines is for island systems, where turbines are appropriately sized to integrate with existing diesel generator sets (which are commonly in the hundreds of kilowatts to megawatt range).

One medium scale wind turbine that has had notable success in island systems is the 275 kW-rated GEV MP wind turbine manufactured by Vergnet. The GEV MP was designed with a two-blade rotor and hinged tower that allows the turbine to be lowered to the ground and strapped down in the event of a pending tropical storm. On August 16th, 2007, with hurricane Dean approaching, Vergnet was able to safely lower and tie-down 216 wind turbines located throughout 15 wind farms in Guadeloupe, Martinique and Cuba within 14 hours. Although this violent cyclone caused much material damage and induced a power outage of more than 50% of the electric distribution system in Martinique, no damage was reported to the turbines.

Wind-Diesel HOMER Model

The Vergnet GEV MP wind turbine was used to simulate the performance of a potential wind-diesel system on Carriacou. Figure 3.4 shows the simulated monthly average production of electricity for this wind-diesel power system given the following assumptions:

- 2010 electrical consumption as presented in Section 3.2.5
- Existing diesel system consisting of three (3) 640 kW diesel generator sets
- One (1) 275 kW Vergnet GEV MP turbine at a hub height of 55m

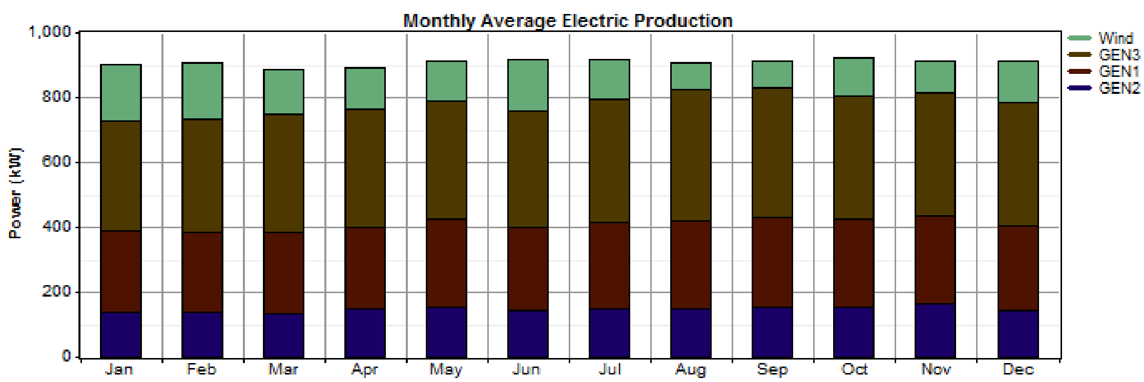

Figure 3.4: Simulated wind-diesel system with single vergnet GEV MP turbine on Carriacou (2010)

The modeled GEV MP turbine has an estimated annual production of 1,116 MWh. The energy generated by this single turbine would meet approximately 14% of the annual demand (2010) on Carriacou. The simulated peak instantaneous penetration from wind generation (wind farm power output ÷ electrical load) is ~35%. In this scenario, the penetration from wind power is low enough that energy storage and advanced controls are not needed.

Table 3.8 shows the modeled average and peak wind penetration for up to four wind turbines installed on Carriacou. As the number of wind turbines in the system is increased from 1 to 2, the peak wind penetration reaches 72%. This situation corresponds to a load factor on the active diesel generator set of 28%, which is below the recommended 30% minimum. However, Figure 3.5 shows that the peak penetration in this 2-wind turbine system peaks above 70% for significantly less than 1% of the year. Thus, this system could feasibly be installed on Carriacou without the need for energy storage or a dump load.

Number of GEV MP Turbines	Average Wind Penetration	Peak Wind Penetration
1	14%	36%
2	28%	72%
3	41%	107%
4	51%	143%

Table 3.8: Simulated peak and average wind penetration for 1-4 vergnet GEV MP turbines on Carriacou (2010)

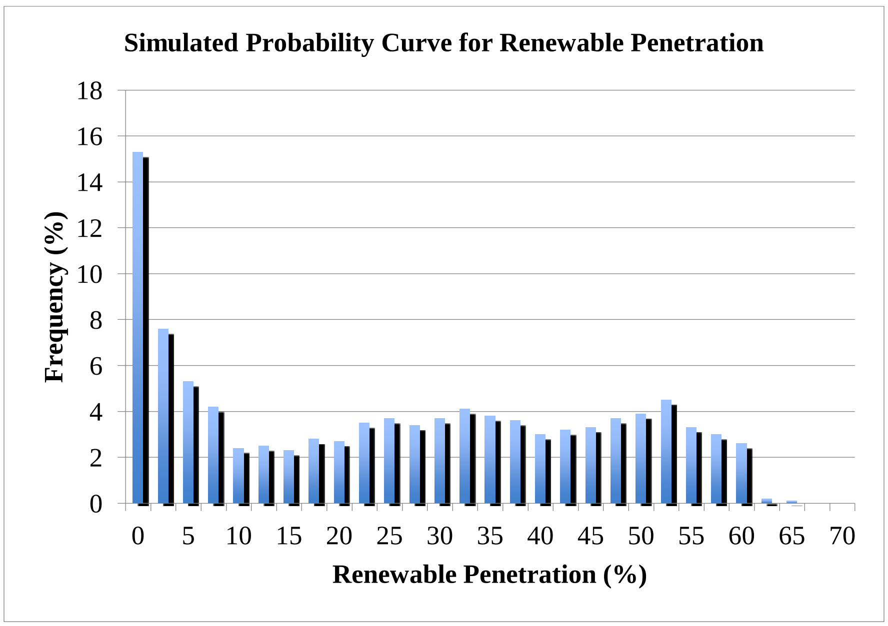

Figure 3.5: Simulated peak wind penetration for two Vergnet GEV MP turbines installed on Carriacou

As the number of wind turbines in the system is increased to three, the peak wind penetration is over 100%. In this scenario in order to maintain system control, either a dump load would be required to curtail any excess wind energy or energy storage would need to be added to the system.

A turnkey installation of the Vergnet GEV MP turbine is estimated to be on the order of 2200 €/kW ($2.93 per Watt) for remote locations. Thus, a single 275 kW machine would require a capital investment of ~ $806,000. Assuming an avoided cost of diesel fuel of $0.18/kWh, the simple payback can be calculated as follows:

- $806,000 ÷ (1,176MWh/yr × $0.18/kWh) ≈ 4 years

Finally, the modeled GHG emissions from Carriacou's current generation system with a single Vergnet GEV MP turbine installed are presented in Table 3.9. A comparison with the baseline model presented in Table 3.6 shows an estimated annual reduction of 2,029 tons of CO_{2e}. This represents a reduction of ~11% of the island's total estimated emissions from stationary power generation.

Pollutant	GWP	Total Emissions (tons)	CO2 Equivalent (tons)
Carbon dioxide	1	6,339	6,339
Carbon monoxide	3	4.31	13
Unburned	11	1.65	18
hydrocarbons	680	0.90	610
Particulate matter	75	5.58	418
Sulfur dioxide	310	29	8,932
Nitrogen oxides			
			TOTAL 16,330

Table 3.9: Annual Greenhouse Gas Emissions from Carriacou Baseline Model with One Vergnet GEV MP 275 kW Wind Turbine (2010)

3.4.2 Solar

In general, the solar resource throughout the Caribbean is excellent, with only minor variation due to island micro-climates that can increase local cloud formation. Despite this readily available resource, adoption of solar energy technologies has been slow in comparison with the U.S. and Europe. Commonly cited hindrances to adoption include high capital costs, high costs for implementation, lack of knowledge and acceptance, missing financial incentives, volunteers, rules and strict regulations (Schwerin, 2010). Despite these hindrances, many countries in the Caribbean including Grenada have begun to successfully integrate solar technologies into their electrical grids.

There are various technologies on the market today which harvest the energy in the sun's rays to create electricity:

- Thermal energy from the sun can be used to cost-effectively heat water in solar-hot-water systems. These systems are most efficient when the panels are co-located with the thermal demand, such as in homes with domestic water heaters. Solar-hot-water systems represent the most prevalent use of solar energy in the Caribbean thus far – with domestic and industrial use, as well as hotels and hospitals.

- Concentrated solar-thermal-electric (STE) devices typically use mirrored dishes to focus sunlight onto a pipe which carries some sort of high thermal conductivity working fluid. The fluid is then used to run a heat engine such as a Sterling engine to create electricity. In order for the heat engine technologies to be cost effective, STE systems are typically manufactured on the megawatt scale.

- Unlike STE devices, photovoltaic (PV) systems are modular in nature, and can be sized for any application. Photovoltaic systems can either be ground or roof mounted, and can either change their tilt to track the sun or be mounted at a fixed angle. Due to the excellent solar resource in the Caribbean, PV is an obvious choice for electricity generation. Unfortunately, no reliable estimation of the total installed capacity of PV in the Caribbean is available due to a considerable percentage of off-grid systems, with a lack in public authority monitoring (Schwerin, 2010). The majority of PV systems tied into the GRENLEC grid have been installed by Grenada Solar Power Limited (GrenSol), a local privately owned company. GrenSol has installed an aggregate capacity of ~300 kW, almost reaching the cap GRENLEC set for 1% of yearly electricity production.

Solar PV HOMER Model

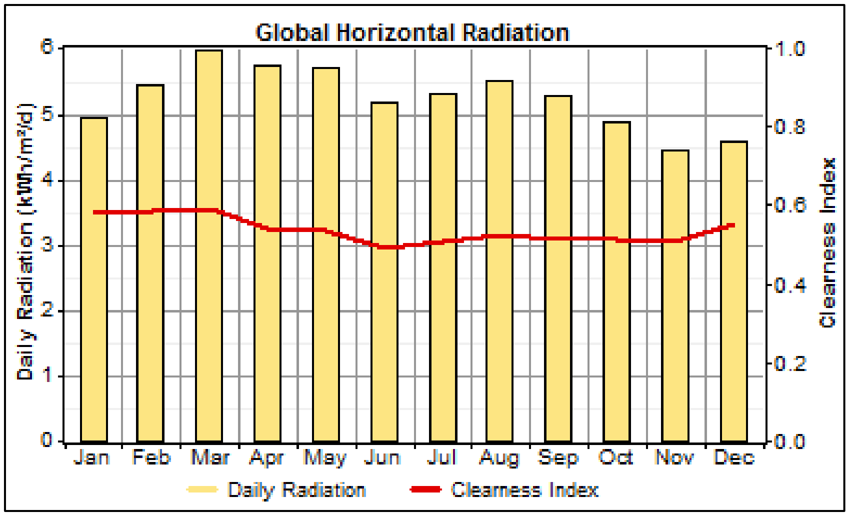

Figure 3.6: Modeled solar resource on Grenada

In this report, the solar resource for Grenada was estimated using NASA's Surface Solar Energy Data Set. This data set provides monthly average solar radiation data as well as an estimated clearness index across the earth. The solar resource data set for Grenada is shown for reference in the screenshot of Figure 3.6. Here, the "Daily Radiation" values represent the average daily global solar radiation incident on a horizontal surface, expressed in kWh/m^2, for each month of the year.

Quantity	Value	Units
Rated capacity	1.00	kW
Mean output	0.18	kW
Mean output	4.40	kWh/d
Capacity factor	18.3	%
Total production	1,605	kWh/yr

Table 3.10: Simulated Performance Summary of 1kW PV System on Grenada

A solar PV system model was created for Grenada in HOMER, given the solar resource shown in Figure 3.6. A panel efficiency of 18% was assumed – based on current commercially available silicon-PV technology. Likewise, a total system DC to AC conversion efficiency of 87% is assumed. A fixed-mount system was assumed for this model, with a panel tilt of 12° south above the horizon (roughly equivalent to the islands' latitude). A summary of the modeling results for a 1 kW PV system is shown in Table 3.10. The modeled 1 kW PV system has an estimated daily average energy production of 4.40 kWh.

Solar PV technologies have experienced a significant drop in cost over the past five years. The average global cost per module in 2010 was reported as $1.30 – 1.80 per Watt, which represents a decrease of 14% from 2009 figures (REN21, 2011). These reductions are primarily a reflection of the increased availability of polysilicon due to rapid expansion of manufacturing capacity – most notably in China. The drop in module cost has also translated into a drop in the overall installed price of new solar PV systems. In the U.S., best-in-class installed solar PV prices in 2010 were ~ $3 per Watt for utility-scale installations, with a total average of $3.80 per Watt across all sectors (DOE, 2012). These prices are also a reflection of the experience accumulated by developers, installers and regulatory bodies in the U.S. As a comparison, in 2010 the price range of solar PV systems installed in Grenada by GrenSol varied from $4,500 to $5,400 per kW depending on the system size (Schwerin, 2010). As more systems are installed in Grenada and throughout the Caribbean, the total system prices will likely begin to approach those currently seen in the U.S.

The payback for solar PV is unfavorable especially in comparison with wind energy. Fortunately, in February 2007, GRENLEC established a net metering rule governing the interconnection of distributed generation (DG) including PV. For systems less than 10kW, the policy provides for net metering at retail electricity rates. This is done to encourage the use of smaller distributed systems, but is subject to review as penetration increases. Systems over 10 kW will be net metered at a rate negotiated between GRENLEC and the installer. Solar PV installations become much more financially viable when under the 10kW net metering limit.

The modeled GHG emissions from Carriacou's current generation system with a 10 kW PV system installed are presented in Table 3.11. A comparison with the baseline model presented in Table 3.6 shows an estimated annual reduction of 30 tons of CO_{2e}. This represents a reduction of ~0.1% of the island's total estimated emissions from stationary power generation.

Pollutant	GWP	Total Emissions (tons)	CO2 Equivalent (tons	
Carbon dioxide	1	7,116		7,116
Carbon monoxide	3	4.84		15
Unburned	11	1.86		20
hydrocarbon	680	1.01		684
Particulate matter	75	6.26		470
Sulfur dioxide	310	32		10,025
Nitrogen oxides				
			TOTAL	**18,330**

Table 3.11: Annual Greenhouse Gas Emissions from Carriacou Baseline Model with 10kW of PV (2010)

Figure 3.7: Solar PV carport (source: www.domesticfuel.com)

Given the Government of Grenada's current net metering laws, the most economically viable solar PV systems will be 10 kW or below and installed on the customer side of the meter with a commensurate load. At ~65 ft^2/kW, the roof area needed for a 10 kW system is on the order of 650 ft^2. Larger industrial customers can take advantage of their roofs for mounting of both PV and solar-hot-water in lieu of space-intensive ground mounting. Solar PV carports provide another alternative to traditional ground mount systems. In addition, the panels provide shade from the sun for vehicles – keeping them cool. For example, the carport pictured in Figure 3.7 has shade for two vehicles and appears to have an installed PV capacity of ~ 3.2 kW. There are many locations where a solar PV carport could prove to be beneficial in both Carriacou and Petite Martinique. For example, the airport parking area in Carriacou is easily large enough for 10+ cars (or ~ 16 kW).

3.4.3 Geothermal

The archipelago of islands comprising the Eastern Caribbean is known for its geothermal activity. These islands have a total of 21 volcanoes, six of which have erupted within the past 400 years. Since the 1700s, people have visited these islands for the numerous hot springs thought to help with common ailments such as arthritis. Feasibility studies for geothermal power started in the area as early as the 1950s, although development has been slow. To date, Guadeloupe has the only operational geothermal plant, with a total installed capacity of 15.7 MW. In addition, Nevis, Martinique and St. Lucia have all had slim holes and/or exploratory wells drilled. Nevis and St. Lucia are expected to start drilling shortly with plans to install a 10 MW and 15 MW plants, respectively (Farrell & Maynard-Date, 2011).

Geothermal prefeasibility studies were done on the island of Grenada in 1981 and again in 1992. These studies revealed a medium enthalpy resource on Mt. St. Catherine, several small thermal springs in ravines radial to the central volcano and numerous relatively young phreatic explosion craters. Additionally, the sub-sea volcano “Kick-em-Jenny” lies only five miles off Grenada's north coast suggesting that the zone between it and central northeastern Grenada may hold geothermal potential (Huttrer, 2000). Grenada is estimated to have a geothermal resource potential of 1,100 MW.

GRENLEC submitted a geothermal development strategy to the Government of Grenada in 2009. If proven feasible, GRENLEC intends to begin installation of a 20 MW plant on Mt. St. Catherine by the end of 2013. In the long term, GRENLEC hopes this capacity could be increased to 40+ MW (Government of Grenada, 2011). In the NEP, the Government of Grenada highlights the importance of this geothermal resource with plans to create the required legislation to manage such developments, including the creation of a Geothermal Act.

Geothermal power has a strong advantage over other renewable energy technologies in that it can be used as a baseload resource, whereas wind and solar are variable. The exploration stage for geothermal development (including project mapping, permitting, thermal geophysical studies, rock / water sampling and drilling thermal gradient holes) is a costly and time-intensive process. Unlike wind or solar power, whose resources can be felt and seen prior to undertaking a feasibility study, the exploration stage of a geothermal project could yield unsatisfactory results. Thus, financing geothermal exploration is difficult and risky, most notably in areas which have no prior history of development.

To date, no geothermal feasibility studies have been done for Carriacou or Petite Martinique. However, due to the high resource potential elsewhere in the Eastern Caribbean (including the island of Grenada), financing should be made available to begin exploration.

3.4.4 Waste to Energy

With the limited land area available in many Caribbean island countries, dealing with waste accumulation is a common issue. Specific challenges include a high number of low-density collection points; high operating costs of traditional waste collection and treatment systems; small economies that limit the viability of recycling or alternative waste treatment systems; and availability for sanitary landfill activities due to competing land uses (de Cuba, 2008). As such, many Caribbean countries and utilities are exploring waste-to-energy systems as an alternative for both waste management and energy generation. In general, waste-to-energy processes produce electricity through direct combustion of waste, or through the generation of a combustible fuel such as methane or syngas.

The use of agricultural waste to create energy is explored in Section 3.5.4 of this report. In addition to agricultural waste, many waste-to-energy systems have been successfully implemented using municipal solid waste (MSW) and wastewater as a fuel source. Plans are underway to develop the Caribbean's first waste-to-energy plant in St. Kitts. The plant will combust municipal solid waste, with the ash byproduct being utilized to create cinder blocks for construction. It is estimated that this project will produce 7 MW of baseload power (Hewlett, 2011).

To date, Carriacou and Petite Martinique have no centralized wastewater system. Individuals and businesses use septic tank and soak-away systems and pit latrines. Without the existing infrastructure of a centralized wastewater system, gathering this resource for use in a waste-to-energy facility could prove to be economically unfeasible. However, as explored in Chapter 4 of this report, in the case of residences in a village, Community Wastewater Management Systems (CWMS) could be introduced.

In 2003, it was estimated that Carriacou generates over 1,900 tonnes of MSW a year (Government of Grenada, 2003). Typically, a ton of MSW will produce ~2,600 Nm^3 (Normal cubic meters) of syngas in a gasifier. If burned in a generator set, this volume of syngas will generate ~930 kWh of electricity (SWANA, 2008). Using these figures, the MSW from Carriacou could generate upwards of 1,767 MWh of baseload energy per year. This is equivalent to a power output of roughly 200 kW. The energy generated could offset 22% of the island's 2011 estimated annual demand of 7,960 MWh.

In order to account for increased production of MSW through time (and the possible addition of a waste stream from Petite Martinique), a 500 kW gasification plant could be installed on Carriacou. At an estimated \$3 capital cost per watt, the project would require approximately \$1.5 million. Assuming an avoided cost of diesel fuel of \$0.18/kWh, the simple payback can be calculated as follows: $\$1,500,000 \div (1,767,000 \text{ kWh/yr} \times \$0.18/\text{kWh}) \approx \underline{1 \text{ year}}$

Of equal importance when evaluating waste-to-energy is the assurance that the islands will maintain an integrated waste management strategy that balances the complex systems of waste reduction practices, recycling and land filling with energy production. Setting up this infrastructure could very well add to the capital cost shown above.

3.5 Distributed Energy Options

The electric power industry has evolved to produce low-cost electricity for high population densities by utilizing centralized generation facilities. Extension of transmission from large central grids is expensive to build and maintain, thus many isolated systems have adopted distributed generation (such as internal combustion engines, gas turbines, photovoltaics, fuel cells and wind-power) at or near the end-user to provide electric power (Prull, 2008). The Government of Grenada stressed the importance of distributed generation in its NEP, stating plans to formulate procedures and standards for system interconnection, reciprocal tariffs and streamlined project approval processes (Government of Grenada, 2011).

This section of the report explores the potential for using distributed generation for households, water distribution, community shelters and medical centers, agriculture, communities and ecotourism developments.

3.5.1 Alternative Renewable Energy Systems for Households

Renewable energy technologies are a natural fit for providing heat and/or electricity to a home or community due to their modularity and scalability. One of the oldest and most common uses of renewable energy for homes in the Caribbean is solar water heating. Grenada has seen a steady increase in the installation of solar hot water systems in the residential (domestic) sector. Table 3.12 shows imports of solar water heaters from 2000 – 2008 as reported by the Ministry of Finance, Planning, Economy, Energy & Cooperatives (Schwerin, 2010). This growth has prompted the Government of Grenada to assess the enforcement of a mandatory installation of solar hot water heaters on all new public-sector buildings, hotels and all other buildings having a commercial demand for hot water, although no firm policy has been set (Government of Grenada, 2011).

	Solar Water Heaters for Domestic Use	Other Solar Water Heaters
2000	182	25
2001	202	6
2002	118	4
2003	373	10
2004	736	30
2005	500	153
2006	509	95
2007	644	11
2008	799	122
Total	**4063**	**456**

Table 3.12: Solar Hot Water Heater Imports from 2000 – 2008 (Schwerin, 2010)

Flat plate solar thermal collectors are well suited for the Caribbean climate, where freezing temperatures are not an issue. Evacuated tube-type solar hot water systems are more efficient but generally much more expensive to install.

As oil prices continue to rise, more homeowners have also begun to install small renewable electricity systems (e.g. solar PV and wind turbines) to offset a portion of their usage. GRENLEC has a net metering policy that allows residential customers to get paid for excess generation at retail rates for systems up to 10 kW (which is significantly larger than the 2-5 kW needed to offset the usage of an average home). As shown in Section 3.4.2 of this report, this policy allows residential customers to achieve a very reasonable payback of about four to five years for a solar PV installation. Through the total 25 PV grid tied systems installed across the island (residential and small commercial), 123.82 KW are now administered under the GRENLEC net metering policy (GRENLEC, 2009).

Small wind turbines (such as the 1.2 kW Skystream by Southwest Windpower) also have great potential in offsetting a portion of a home's electrical usage. However, proper siting of a wind turbine has a massive effect on its productivity, as nearby obstacles (e.g. trees, buildings) will shield it from the wind. These grid-connected systems can also be coupled with a battery bank, allowing the home to remain electrified during a grid outage.

In addition to grid-connected renewable energy systems, homeowners can also take advantage of smaller off-grid systems to power pumps or other appliances. For example, in Chapter 4 of this report, solar-powered pumps are suggested as an alternative for homeowners to transport water from their cisterns to faucets. At ~$400 installed (assuming a capacity of 50 W), this pump would pay for itself in approximately eight years.

3.5.2 Renewable Energy Systems for Water Distribution or Generation

In section 4.4 of this report, the use of reverse osmosis (RO) for water desalination is discussed. It is suggested that Carriacou will require a new RO plant with a capacity of 379 m^3/day and a storage facility of 190 m^3. A similar facility may be required for Petite Martinique. A recent analysis done for a modern RO plant installation in the British Virgin Islands showed an energy demand of ~12 kWh per 1,000 gallons (3.17 kWh/m^3) of fresh water produced (Prull, 2008). Thus, assuming this same efficiency, the suggested RO plant for Carriacou would equate to an energy demand of 1,182 kWh/day, or 432 MWh/yr.

The added electrical demand on Carriacou's grid could be offset by the addition of renewable generation, in the form of solar PV, wind, etc. For example, in Section 3.4.1, it was shown that a single Vergnet GEV MP 275 kW wind turbine would generate an estimated 1,116 MWh/yr if installed on Top Hill. Thus, the proposed RO plant would only require ~37% of the estimated annual energy produced with the wind turbine – with the remaining serving other electrical loads (such as water distribution pumps) on the island grid.

The water storage for the proposed RO facility is fairly small – with the capacity to serve demand for only ~1/2 a day. If this storage capacity were to be increased significantly (to say 2-3+ days worth of storage), this would allow for the operation of the RO plant to be decoupled from the demand for fresh water. If installed along with the aforementioned wind turbine, the RO plant could be run at full capacity during times of high wind speeds. During times of low winds, the RO plant could be shut down, allowing the demand for water to be met by excess storage. In this sense, the RO plant and water storage facility are acting as a battery, thereby absorbing excess electrical generation from the proposed wind facility. Running the RO plant in this fashion can significantly reduce stress on the island's diesel system from the variable wind generation as well as lower fuel use (Prull, 2008).

Moreover, if the storage capacity of the RO plant was increased enough, it could feasibly be coupled along with the wind turbine as a stand-alone "off grid system". However, given the variability of the wind resource, the cost of the needed storage would likely be prohibitive.

3.5.3 Renewable Energy Systems for Shelters (Community Centers) and Medical Centers

Each year an average of ten tropical storms develop over the Atlantic Ocean, Caribbean Sea, and the Gulf of Mexico. Stronger storms can devastate towns, ripping buildings apart and causing disastrous flooding hundreds of miles inland. Grenada in particular was badly hit by hurricanes Ivan in 2004 and Emily in 2005. As a precaution, special buildings throughout Grenada have been designated as hurricane shelters for residents to gather during a potentially dangerous tropical storm. These buildings are typically chosen for their size and strength of construction. Shelters, along with designated medical centers and clinics, provide a vital service to the residents of Carriacou and Petite Martinique.

Figure 3.8: Backup diesel generator system at Carriacou's main hospital

The shelters on Carriacou and Petite Martinique are powered via the GRENLEC electrical grid, with the majority having no form of backup generation. One notable exception is the main hospital on Carriacou near Belair Park, which has a backup diesel generator system (shown in Figure 3.8). This generator is quickly started via an automatic transfer switch when there is a loss of power from the grid, providing emergency power to the hospital. Diesel generators are often used throughout the world as a source of emergency power for buildings with larger, more critical loads. These generators, if properly maintained, can be started fairly quickly and provide steady, reliable power.

As an alternative, onsite renewable energy generation can be used along with a battery to provide a simple and effective backup generation system for buildings with smaller, less critical loads. For example, a photovoltaic (PV) / inverter / battery grid-interactive system could both offset part of the building's energy use during normal operation and provide backup generation during a loss of power from the grid. During normal operation, a grid-interactive system behaves much like a normal grid-tie system. Electricity generated by the PV panels is used to power the building's electrical loads, with any excess (or deficit) being supplied by (or absorbed by) the grid. Meanwhile, the batteries are kept at 100% state-of-charge via a charge controller. Unlike a grid-tie system, during an outage the grid-interactive system will continue to supply power to the building via the battery storage. The PV panel will also continue to supply current to the batteries through the charge controller. When the grid is restored, the inverter/chargers help recharge the batteries to their full state of charge while the grid powers all AC loads. Once the batteries are recharged, the system returns to normal operation.

The hurricane shelter located at the community center (shown in Figure 3.9) is a simple, open structure with a modest electrical load from ceiling fans, overhead fluorescent lights and a small refrigerator. During our November 2011 site visit, the building's electrical meter read a load of 0.69 kW with a total recorded usage of 2576 kWh since January 2011.

Figure 3.9: Community center / Hurricane shelter

By combining the battery backup with grid-tied PV, the system pays for itself via the avoided cost of electricity from the grid. The estimated payback is ~14 years at an average price of electricity of $0.60 per kWh. In contrast, a backup diesel generator would never pay for itself, as it cannot back-feed the grid.

Each hurricane shelter or medical center may have specific electrical or heating requirements which would guide the design of a backup generation system. It is commonplace for buildings to have only critical loads and receive backup power by wiring them on a separate set of circuits. This allows for a smaller, more economical backup generator. In other situations, there may be a critical demand for thermal energy, for example, hot water. This emergency hot water demand could potentially be met by a solar-hot-water system. Alternatively, a backup diesel generator could be used to provide additional thermal energy by capturing the waste heat from combustion via a heat exchanger on the generator's radiator system. In each case, a key design consideration should also be the resilience of the renewable energy system. For example, diesel generators or batteries should be housed in a reinforced structure (e.g. concrete) that is able to withstand tropical storms. PV or solar-thermal panels should also be ground mounted with reinforced steel and concrete to reduce the effects of wind-loading.

3.5.4 Renewable Energy for Potential use in Agriculture

The islands of Grenada have a long history as agricultural producers, and this industry continues to be of key importance to the economy. Sustainability in the agricultural sector of Carriacou and Petite Martinique is discussed in Chapter 7 of this report. In this section, the potential symbiosis between agriculture and renewable energy is explored.

Renewable Energy for Irrigation

The current irrigation practice typically involves the pumping of rainwater from ponds and cisterns or the trucking of water to the farm. Both of these strategies can be energy intensive and thus expensive to the farmer.

For remote locations, pumps powered by on-site distributed generation are often a more financially viable option than extension of the grid. In the U.S., it has become commonplace to power remote water pumps directly with on-site solar PV systems. The pumps, if designed in conjunction with the solar PV installation, could be DC powered – thereby increasing overall system efficiency by removing DC-AC conversion losses. These solar PV powered pumps can also be configured with a battery to increase the availability of the pump. However, often energy storage is omitted, and the pump simply operates when the sun is shining. Solar PV pumping stations could be used in Carriacou and Petite Martinique to transport irrigation water from remote basins and ponds to crops. The potential for integrating these solutions into agricultural lands would need to be evaluated on a case-by-case basis, although the Government of Grenada and GRENLEC could become involved by offering incentives to farmers for utilizing distributed generation resources.

Renewable Energy from Agricultural Waste

Farming naturally produces agricultural waste (also known as biomass) – a byproduct that can potentially be utilized to create energy. This agricultural waste is typically disposed of off-site, generally at no economic benefit to the farmer. Moreover, at many locations in the Caribbean, biomass is burned, wasting the stored energy and causing harmful emissions.

Biomass can be used to generate both electrical and thermal energy via gasification. Gasification is a thermo-chemical process in which the biomass is cooked in an oxygen-starved chamber. By depriving the fuel of oxygen, the biomass does not burn, but gives off a hydrogen-rich syngas. This gas can then be captured, cleaned and burned in a generator set. The power produced from the generator set can be used to offset the electrical usage of the agricultural facility, or sold directly to the grid. As the biomass gives off syngas, the remaining material is transformed into charcoal and ash of approximately 1-5% of the volume of the original biomass fuel. This remaining material is known as biochar, and can be utilized as a soil amendment, adding valuable nutrients and carbon as well as stabilizing soil pH.

A central biomass gasification facility could be set up on Carriacou and/or Petite Martinique, servicing the agricultural waste from multiple farms. Having a centralized facility could potentially reduce capital costs (as opposed to multiple smaller units), increase throughput and create many local jobs – not only at the facility itself, but in the collection and transportation of the resource from the farms. The farmers could then be compensated for this resource, which could create a boost for the local economy.

Renewable Energy Generation on Agricultural Lands

Agricultural lands are typically located in remote areas. As such, these lands are often in very windy locations, making them a natural candidate for utilizing wind energy. In the U.S. and Europe, it has become commonplace for wind developers to lease active farmland to erect projects. One wind turbine uses only one-quarter acre of land, including access roads, and can provide royalties for the farmer of up to $2,000 per year (Union of Concerned Scientists, 2012). Co-locating the wind turbines with active farmland has proved to have no adverse effects on agricultural yield, and/or grazing. Moreover, the additional revenue stream for the farmers can be crucial in years with low production. In some cases, farmers have joined together to finance their own wind power developments in a cooperative. A detailed survey or GIS analysis of the wind resource throughout Carriacou and Petite Martinique would be needed to ascertain if such wind-rich farmlands exist. If they do, the wind power would have positive economic implications for both the utility and the farmers involved.

3.5.5 Integrated Renewable Energy / Wastewater Treatment Systems for use by Communities and Ecotourism Developments

Tourism is an integral part of the economy in most Caribbean island countries, including Grenada. Trends have shown that as many travelers are embracing a more sustainable lifestyle, they have begun to search for environmentally friendly destinations. Tourist destinations which take advantage of these ecotourism trends could see a significant boom in revenues. For example, in 2004, it was estimated that ecotourism was growing globally three times faster than the tourism industry as a whole. A key aspect to sustainable design is to understand the interaction among the different infrastructure subsystems.

Energy demands for wastewater treatment could feasibly be met by onsite renewable energy generation. For example, the electricity generated can be utilized onsite to power a reverse osmosis desalination system (as discussed in Section 3.5.2). This electricity could also be used for UV disinfection, distillation or photo-catalytic oxidation to destroy pathogens – depending on the architecture of the wastewater system (Argaw, 2004). Thermal energy from solar hot water or combustion of biomass can also be used for pasteurization and distillation. In windier locations, a wind turbine could be utilized to directly pump water for a wastewater system.

Wastewater treatment is in general a very energy-intensive process. For certain projects, the capital costs associated with the required renewable energy capacity could be prohibitively expensive. On the other hand, extension of services from the grid may not be an economically feasible option for many remote island locations. Therefore, every alternative system must be evaluated based on the local conditions and system sustainability issues.

3.6 Urban Planning Vision and Green Building Standards

In recent years, electronic devices and computers have become increasingly used. With this growing appetite for technology and more time being spent indoors, the demand for electricity in buildings and homes has grown significantly. This building energy use can be greatly reduced by creating more environmentally sustainable structures. Policies which encourage or require new construction to be energy-efficient are becoming commonplace in both the U.S. and Europe. These policies are being adopted at the city, county and state level. This has given rise to several voluntary sustainable building rating systems such as BREEAM (the UK’s Building Research Establishment’s Environmental Assessment Method), Green Star, Minergie, Green Globes and LEED (the U.S. Green Building Council’s Leadership in Energy and Environmental Design). In the LEED rating system, credits are awarded for a project applicant (e.g. new construction, retrofits to existing buildings, etc.) based on a variety of green design criteria. The project is then certified by the U.S. Green Building Council to be LEED Certified, Gold, Silver or Platinum – signifying the number of credits achieved in the design.

In the Caribbean, LEED has been the most widely recognized benchmark for sustainable building thus far, in part due to strong geopolitical connections with the U.S. (Newton, 2010). However, LEED was designed to rate projects in the U.S., and thus some of the criteria do not translate well to building in the Caribbean. One of the biggest differences between the two is in designing for thermal comfort. LEED, being designed for northern and southern temperate zones, has specific requirements for mechanical heating and rigorously airtight buildings. These requirements are not well suited for buildings in the Caribbean which generally need cooling year round, or significant natural ventilation and natural airflow. There are also socioeconomic differences between the U.S. and Caribbean which make the traditional LEED structure difficult to implement. The documentation required for application is extensive and requires coordination of drawings, specifications and codes. As such, LEED may be perceived by local designers as a barrier to meeting their project timeline (Newton, 2010). In addition, green building tends to have more heavy up-front costs (although these are paid back in time through increased efficiency). In the Caribbean, these long-term benefits may be overlooked in favour of the cheapest construction bid.

Irrespective of these hurdles, green buildings present a strong business case for developers, tenants and governments. Arguably, governments such as Grenada's could develop their own green building standards – borrowing from the most applicable components of LEED, BREEAM and other benchmarks.

3.7 Disaster Resilience of Energy Systems

With centralized diesel power plants and many overhead power lines, the electrical grids on Grenada are particularly vulnerable to natural disasters. As such, a strong storm could potentially damage power lines leaving much of the islands without power both during and after the event.

Distributed generation systems have many inherent qualities that could enhance the resilience of the current island electrical infrastructure. Mobile diesel and solar generators can be used after a disaster to provide emergency power for areas that have lost connection to the grid. In addition, grid-connected distributed generation systems provide an inherent redundancy in that they are geographically dispersed, thereby decreasing the probability of a complete outage. Many distributed generation systems are scalable and thus can be sized appropriately to meet emergency loads of a single building, shelter, etc. Many of these systems (e.g. diesel generators and solar PV systems with energy storage) have the ability to isolate themselves from the grid during a fault, in many cases providing an uninterrupted power supply for the area. These technologies are also designed with a level of autonomy which allows them to operate without the need for human supervision.

In addition to smaller distributed generation systems, utility scale renewable energy technologies could provide a much-needed level of resilience to the electrical grids of Carriacou and Petite Martinique. For example, a large solar PV installation typically consists of multiple inverters and panel arrays. If part of the system is damaged (e.g. a panel or sub-array), the rest of the system is able to continue providing power to the grid. The same can be said of a wind turbine farm, where the loss of a single turbine in a disaster will not affect the performance of the other turbines. However, it should be noted that in order to avoid reverse-power situations and to maintain control, utility scale renewable energy systems are often designed to disconnect from the grid in the event of a fault. In addition to the many advantages, distributed generation has many benefits for homeowners; the inherent disaster resilience warrants further investigation from both the Government of Grenada and GRENLEC.

3.8 Conclusions

With a new NEP, the Government of Grenada has begun to embrace the vast potential for renewable energy on its islands. Geothermal exploration on mainland Grenada has proven positive and should be expanded to include Carriacou and Petite Martinique. Wind energy is also a viable option for utility-scale energy generation based on data collected thus far on Carriacou. In the short-term, one to two medium scale wind turbines could feasibly be installed without the need for expensive energy storage and control systems. Waste-to-energy from biomass and MSW also hold potential, although the infrastructure for these systems is complex and does not exist elsewhere in the Caribbean. Distributed generation in the form of solar PV and solar water heating have wide applications for the domestic, water treatment and distribution and ecotourism sectors. Policies that encourage distributed solar technologies would also increase the resilience of the island grids to storms and other disasters. The Government of Grenada needs to work with GRENLEC to ensure that net metering continues and that renewable energy generation is given priority when evaluating development.

3.9 Possible Projects

Project 1: **Wind Turbine Installation on Carriacou, Top Hill**
Aim: *To reduce dependence on foreign oil and reduce harmful emissions*
Target: Carriacou GRENLEC grid
Description: French manufacturer Vergnet offers a 275 kW turbine that is specifically built for the marine island environment. A single turbine has an installed cost of ~$806,000. The energy generated if sited on Top Hill would offset 14% of the island's current annual electricity demand. The estimated payback for this system is about four years. In addition, a single turbine would reduce the CO_{2e} emissions from the island's stationary power plant by 11%. Up to two of the Vergent turbines could be installed on Carriacou without the need for costly energy storage.

Project 2: **Wind Resource Study on Petite Martinique**
Aim: *To assess the potential for wind energy on Petite Martinique*
Target: The Government of Grenada
Description: Installation of a wind monitoring system to evaluate the potential for wind energy generation on Petite Martinique. Estimated capital cost $10,000 - $40,000.

Project 3: **Geothermal Exploration on Carriacou and Petite Martinique**
Aim: *To assess the potential for geothermal energy on Carriacou and Petite Martinique*
Target: The Government of Grenada, GRENLEC
Description: Grenada has a known geothermal resource. Although exploration can be expensive, if a viable resource exists on Carriacou or Petite Martinique, a plant could easily supply the majority of the islands' electrical needs. Estimated cost $1,000,000 - $3,000,000 (including thermal gradient wells).

<u>Project 4:</u> Exploration of a Waste-to-Energy Plant for Carriacou
Aim: *To assess the potential cost / benefit of a waste-to-energy plant on Carriacou*
Target: The Government of Grenada, GRENLEC
Description: Explore the infrastructure costs for a waste-to-energy plant on Carriacou using MSW as a fuel. A 500 kW plant would have an estimated installed cost of ~$1,500,000, although there are numerous additional costs for setting up the required infrastructure.

<u>Project 5:</u> Renewable Energy Systems for Emergency Shelters
Aim: *Design / install grid-interactive distributed energy systems for all emergency shelters*
Target: The Government of Grenada
Description: A simple grid-interactive solar PV system (with batteries) for an emergency shelter would require a capital investment of ~ $14,000 - $20,000. The Government should explore grants to fund the installation of these systems for all nine emergency shelters on Carriacou and Petite Martinique as a matter of safety for residents.

<u>Project 6:</u> Develop Green Building Standards
Aim: *Create standards governing the efficiency of all new buildings*
Target: The Government of Grenada
Description: As a first step to adoption, Carriacou and Petite Martinique could mandate that all new government buildings be certified (to whatever benchmark is chosen). Commercial builders could be offered incentives for green buildings such as tax credits and expedited permitting. Explore mechanisms for creating rebates for homeowners who purchase energy efficient lighting and appliances, or to those who can reduce consumption by a certain percentage over their last year's usage.

<u>Project 7:</u> Solar PV Carport for Carriacou Airport
Aim: *To offset the electrical usage of the airport while providing shade for cars*
Target: The Government of Grenada
Description: A 16 kW carport would provide shade for roughly 10 cars. The installed cost of the system would be ~ $96,000 (assuming $6/Watt). However, since the system could connect on the customer side of the meter, it would offset $0.61/kWh electricity, thus having a payback period of only six years.

<u>Project 8:</u> Distributed Solar PV Systems for Households
Aim: To provide clean distributed energy for individual homes and businesses
Target: The Government of Grenada, GRENLEC
Description: GRENLEC currently allows net metering for renewable energy systems up to 10kW at retail electricity rates. Assuming an installed cost of $4.50/Watt, an applicable solar PV installation would achieve a simple payback of less than four years. These systems not only benefit the individual homeowner, but also reduce peak load on the GRENLEC diesel generation system due to daytime air conditioning. In addition to green building standards and incentives, the Government of Grenada would benefit from exploration of funding mechanisms to encourage more widespread adoption of solar PV and other distributed generation technologies.

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4. Water Resources

4.1 Introduction

Water is life therefore water management is one of the most pressing challenges facing society today. Efficient water resources management is essential for sustainable development. Experts predict that, if the current water management practices continue, the demand for water by humans could exceed the amount available by as much as 40% by 2030. In the Caribbean, water availability is threatened by population increase, urbanization, economic development and growth in tourism. Even a slight decrease in rainfall would constitute a serious pressure on water resources. Such pressure can be exacerbated by inexorable climate change during this century and specifically can have a great impact on the water resources sector on most islands**.** Climate modeling already indicates that temperatures in the Caribbean will continually rise, that seasonal dry periods will be extended, and that droughts will be more frequent. This scenario requires innovative responses, such as the concept of the green economy.

Sustainable development issues (such as health, food security, and poverty eradication), which are interwoven with a green economy, are fundamentally connected to water. In island states, poor water management can lead to pollution of surface and coastal waters and can negatively affect coastal livelihoods. In the case of Carriacou and Petite Martinique, a green economy and sustainable economic growth and development are supported by activities on the coast. Moreover, mitigating disaster risks (such as floods and droughts) and adapting to climate change are other important objectives of a green economy that require Integrated Water Resources Management (IWRM).

The need for IWRM was reinforced at the 2002 World Summit on Sustainable Development in Johannesburg. Integrated approaches to water management have been articulated for many years in Grenada and in Carriacou and Petite Martinique, and these are slowly being implemented and are having some positive impacts on the ground. An integrated approach to managing the water resources of Carriacou and Petite Martinique is an important pillar to the development of a green economy for these islands.

A Statement by UN-Water for the UN Conference on Sustainable Development 2012 (Rio+20 Summit) reinforces the point that the success of a green economy depends on sustainable, integrated and resource-efficient management of water resources and on safe and sustainable provisioning of water supply and adequate sanitation services (UN-Water, 2012). This approach must be reinforced by timely measurement of economic performance in terms of indicators of social and environmental sustainability. This chapter reviews the water resources and its management in Carriacou and Petite Martinique.

4.2 Precipitation

The islands of the Grenadines in the Eastern Caribbean have limited groundwater and no permanent stream flows; they depend almost exclusively on rainwater harvesting (RWH) for domestic and agricultural uses. Rainfall data have been collected in Carricaou since the 1920s. The average annual rainfall at Limlair and Belair (Figure 4.1) is 1088 mm and 1370 mm, respectively. In the Grenadines there are two distinct seasons – a dry season from February to June with about 26% of annual rainfall and a rainy season from July to January. The average rainfall in the dry and rainy seasons is shown in Table 4.1.

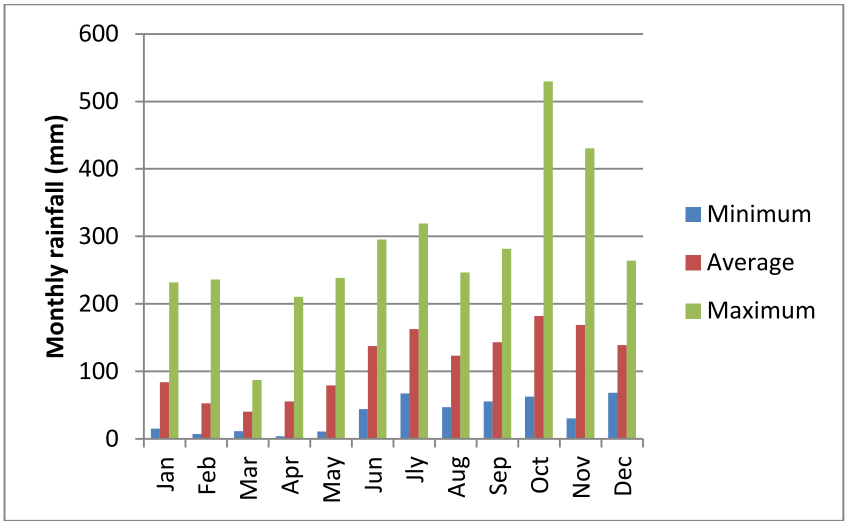

Figure 4.1: Historic rainfall data for Belair, Carriacou

Average Rainfall (mm)	**Limlair**	**Belair**
Annual	1088	1370
Dry Season	285	365
Rainy season	803	1005

Table 4.1: Rainfall distribution for two stations in Carriacou

4.3 Groundwater

There are 20 watersheds in Carriacou and Petite Martinique, some of which are small. The aquifers in the main watersheds shown in Figure 4.2 are small and shallow. During the post-slavery period, the exploitation of groundwater commenced with the establishment of dug wells. In 1891, a few wells were sunk at locations along the coasts, including at Tibeau (Figure 4.3), to obtain groundwater from the existing narrow freshwater lenses. Since then, there has not been significant progress in developing the limited groundwater source.

Figure 4.2: Watersheds of Carriacou and Petite Martinique

Figure 4.3: The first dug well at Tibeau, Carriacou

There are currently no programmes for monitoring groundwater in Carriacou and Petite Martinique and therefore reliable data on groundwater quantity or quality is limited.

Several of previous studies on the groundwater potential in Carriacou show that, where groundwater is present, the quality is usually poor (low palatability) with high quantities of dissolved salts and hardness levels of 300 mg/l to 500 mg/l (Lehner, 1939; Mather, 1971; Mente, 1985 and Barragne-Bigot, 1987). These studies estimate that the total groundwater potential is 270 to 334 m^3/day (Table 4.2). The one borehole in production yields 125m^3/day while the 28 dug wells have a combined yield of 27-36m^3/day (Parsram, 2011). During the drought of 2009/10 a local operator drilled a number of wells in the Hillsborough aquifer but the yields were small. In any event, these wells were in close proximity to the current main borehole and would have been drawing down water from the same cone of influence.

In 2010, the National Water and Sewerage Authority (NAWASA) considered improving the quality of the water from the borehole by installing a reverse osmosis (RO) plant at the borehole site. In 2011 the idea was abandoned, as it was then expected that technical assistance to be received from the Indian Government to install a desalination plant would make NAWASA's investment redundant.

The limited groundwater that is found in Carriacou and Petite Martinique is threatened by climate change and sea level rise. Most dug wells, which are shallow and within 100 m of the coastline, have shown increased concentrations of chlorides. This can ultimately lead to abandonment of some of these wells. Consequently salt-water intrusion is of great concern in Carriacou and Petite Martinique.

Watershed	Water quality	Potential availability (m^3/day)	Number of Dug-wells	Boreholes Current (potential)
Dover-Craigston	Good for livestock	55-75	3	2(1)
Hillsborough	potable	90-97	7	3(1)
Six Roads	Poor	38-57	2	1(2)
Harvey Vale	Poor	20-38	1	1(2)
Dumfries-Bellvue	Poor	undetermined	2	1(1)
La Ressource -Sabazan	Poor	20	1	2(0)
Grand Bay – Mt. Pleasant	Fair	38	4	2(2)
Limlair-Dover	fair	4	4	1(0)
Windward	Very poor	undetermined	2	0(0)
Petite Carenage	Brackish and poor	5	1	0(0)
Petite Martinique	Very poor	undetermined	3	0(0)
Total		**270-334**	**28**	**13 (9)**

Table 4.2: Groundwater resources in Carriacou and Petite Martinique (source GOG 2000)

4.4 Desalination

The first desalination plant was installed at Camp Carriacou in the 1970s for the Canadian-operated marine school on the southern tip of Carriacou. The school used this water to augment the supply from harvested rainwater. In 1998/1999, the Government of Grenada purchased three RO desalination plants to assist with the augmentation of water supply in Carriacou and Petite Martinique at a cost of about US$5.0 million. The Petite Martinique plant (Figure 4.4) had an output of 136 m^3/day while the Carriacou plant (Figure 4.5) had an output capacity of 454 m^3/day.

Figure 4.4: Derelict desalination plant at Petite Martinique subjected to harsh marine environment

Desalination may appear to be a good water augmentation option for the water-scarce islands of Carriacou and Petit Martinique, but poor plant site, lack of distribution infrastructure, mechanical problems, limited storage capacity and lack of enthusiasm by residents to use the water for drinking all contributed to their demise. In Petite Martinique the impact of the salt air on the coast was particularly harsh resulting in extreme corrosion of the structures housing the desalination plant as seen in Figure 4.4. It was found that there was generally little public education and awareness in the islands of Carriacou and Petit Martinique where the desalination plants have been operational. There are also other complications related to the fact that on these two water-scarce islands, rainwater harvesting (for which there is no information on monthly operational cost) is extensively practiced (UNESCO, 2006). The sustainability of such plants is also questionable since desalinated water was offered at EC $2/1000 gallons when the actual cost of production was closer to EC $18-20/1000 gallons (UNESCO, 2006).

Figure 4.5: Abandoned desalination plant at Carriacou

The future of desalination for Carriacou and Petite Martinique is currently not very clear. The request from the MOCPMA to the Indian Government to develop a water supply system for Hillsborough and its environs is being pursued. A technical report recommended a new RO plant with a capacity of 379 m^3/day and storage facility of 190 m^3. It is clear that, for the development of the tourism sector, rainwater harvesting must be augmented by a reliable source such as desalination. The opportunity to use integrated energy and emerging water technologies in the production of water is worth pursuing.

4.5 Residential Rainwater Harvesting

Residents on the islands have depended on rainwater harvesting. Rainwater storage systems in the Grenadines include underground and above ground concrete cisterns (average 30,000 litres), metal tanks (760-1,900 litres), plastic tanks (760-3000 litres), drums (170 litres) and wood barrels (130-150 litres). The first cisterns were built in the late 1700s for use by Europeans at the great houses. At Craigston estate a cistern with capacity of 190 m^3 (50,000 gallons) was built in 1785 of field-stone rubble with the inside lined with yellow brick and then plastered (Slade, 1984). This cistern is still in use. After the abolition of slavery, a few smaller cisterns with capacities of 10 m^3 to 15 m^3 were built by freed slaves from stone and white lime mortar (Figure 4.6).

Figure 4.6: Cistern built in the 1870s and currently in use

Figure 4.7: Modern RWH systems with overhead tank and internal plumbing

Modern household rainwater harvesting systems (Figure 4.7) consist of a rooftop water harvesting surface, a conveyance system for the harvested water, a cistern for storage and a means of distributing the water either by gravity, drawing using bucket and rope or a pumping and internal plumbing system. The collection systems are usually corrugated galvanized roofing material, concrete tiles, clay tiles, asphalt type shingles or wooden shingles. The runoff is collected by means of gutters which are mainly plastic. Very seldom are devices used to divert the first flush of water from the roof to waste or are there treatment devices to enhance water quality. The cisterns are usually sealed at the manhole and at the over flow with insect screens.

In the past thirty-five years, significant strides have been made in increasing the quantity of household water with an increasing number of households constructing larger cisterns (Figure 4.8). There has been a steady increase in the construction of household cisterns (Figure 4.9). The storage capacities of these cisterns have almost tripled in 25 years primarily due to the large number of returning nationals from North America and the United Kingdom who can afford to construct cisterns in order to maintain the water consumption level to which they are accustomed. Generally the improvement in the availability of rainwater harvesting systems (RWHS) for domestic purposes is due to rapid economic growth in Carriacou and Petite Martinique since the 1980s.

Moreover, the improvement in cistern stock and increased availability of water has led to an increased per capita use. During a year of average rainfall, the per capita water available for domestic use is 120 litres per day (Peters, 2006) which is adequate to meet household needs.

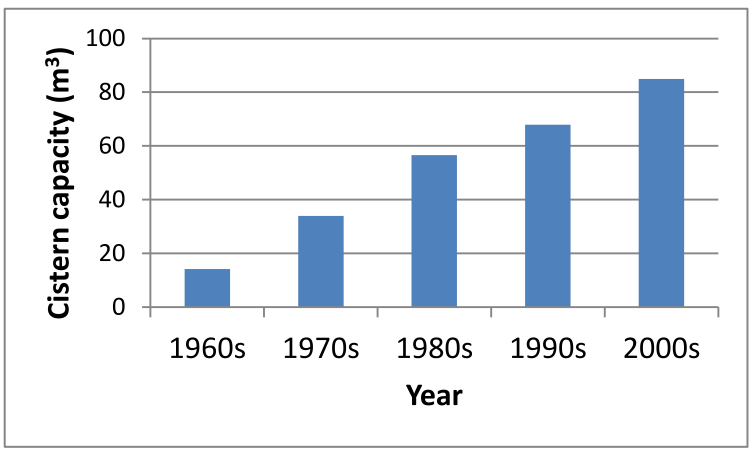

Figure 4.8: Average cistern size (1960 to present) in Carriacou (source Peters 2011)

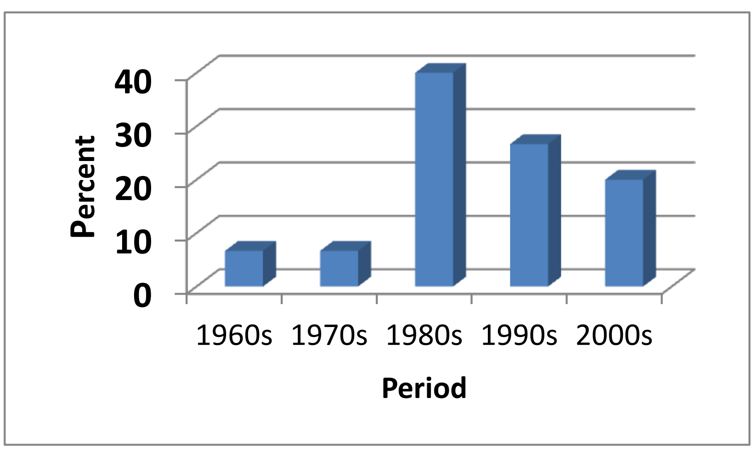

Figure 4.9: Cistern construction since the 1960s in the Carriacou and Petite Martinique (source Peters 2011)

An evaluation of the homes in Carriacou and Petite Martinique shows that for the wealthiest households, water consumption tends to be closer to that of the developed world. Currently, 91% of all households in Carriacou and Petite Martinique have concrete cisterns. In these households where cisterns provide the main storage, plastic tanks are used to supplement these cisterns or are used as overhead tanks to facilitate gravity flow in the internal plumbing systems. About 6% of the residents depend on polyvinyl chloride (PVC) tanks with a minimum capacity of 1.8 m^3 (400 gallons). The remaining residents still use drums and other smaller containers for RWH. The current total storage capacity of household cisterns is about 50,000 m^3. The status of residential RWHS in Carriacou and Petite Martinique is summarized in Table 4.3.

For RWHS in the islands, routine maintenance for gutters and tanks is carried out over periods of two to three years. Consequently, the two main concerns about residential RWHS relate to distribution (pumping systems) and quality (treatment systems).

Characteristic	**Percentage**
Households with cisterns	91
Households with storage over 4.5 m^3	94
Households with cisterns and internal plumbing	69
Some form of purification for the system	6
Biological control for mosquitoes	24
Use of chlorine tablets	15
Protection from wild life	25

Table 4.3: Characteristics of RWH systems in Carriacou and Petite Martinique

4.6 Communal Cisterns

Communal cisterns can be found at public buildings, schools (Figure 4.10), hospitals and medical clinics, churches, community centers and administrative offices. In Carriacou and Petite Martinique there are 33 communal catchments and 78 storage facilities for public use. Communal storage capacity is about 5,300 m^3 with additional public storage capacity of 4,430 m^3. In addition to providing water to the community when private cisterns were few, communal cisterns also have provided a meeting place where community members, particularly women and children, socialize.

In recent times the success of households' rooftop RWH in the islands has meant that the everyday need for communal cisterns has been reduced. This has resulted in the non operation of a number of these communal cisterns leading to neglect in many cases. The extent of the neglect of the communal cisterns was evident during the recent drought, when water from these cisterns was greatly needed but was in some cases unavailable or of such poor quality that it was not usable.

The communal cisterns, however, could remain central to disaster management particularly in the aftermath of hurricanes and droughts. The lessons learned from Hurricane Ivan suggest that communal rainwater storage systems, using schools and community centers, may be established to provide a reliable system for communities during the early periods after a hurricane disaster (Peters, 2010). Recognizing the unique benefit of RWHS in disasters, all efforts should be made to rehabilitate the current communal cisterns with a view to using available technology for improving quality, and to make such technology more accessible to the community. A second important role of the communal cisterns is that of an additional supply to schools and other public institutions that do not have sufficient capacity of their own. Currently, many public institutions depend on supplementation from donation by residences.

Figure 4.10: Communal cistern (roof catchment) at the Dover Government School, Carriacou.

4.7 Potable Water Quality Issues

While water availability may be problematic during severe dry seasons, generally the most pressing concern is the quality of drinking water at private residences and public places. In the islands, water which is harvested from rooftops and stored in concrete cisterns and plastic tanks is often presumed to be safe as it has not flowed on the ground and come into contact with any liquid or solid materials which can alter its quality (Peters, 2011). This presumption is considered reasonable as the detailed test results showed low levels of contamination of raw rainfall water samples and the excellent physical quality (negligible suspended solids and absence of color and odor) of stored drinking water in the islands. In cases where there are poor RWH practices, water quality can become a concern for drinking and food preparation purposes. Emerging technologies such as Solar Water Disinfection (SODIS) can be applied (Berney et. al, 2007 & Tamas, 2009). As SODIS results in positive health impacts and requires little capital investment on the part of end-users, it is thus appropriate for use by the very poor (WHO, 2007). SODIS is particularly suited for use at the household level and for rooftop RWH because of the low turbidity of rooftop RWH water. In public places, treatment of water for drinking and food preparation should be mandated and alternative methods like SODIS and Solar Water Stills (SWS) can effectively be promoted.

4.8 Water and Agriculture in Carriacou and Petite Martinique

A green economy requires the efficient use of natural resources to ensure food security. Agriculture can therefore play an essential role in achieving a green economy since it accounts for 70% of global water withdrawals and provides employment for 40% of the global population. In Carriacou and Petite Martinique, most agriculture is on small farms at the subsistence level. Nonetheless, smallholder farmers are essential in the transition towards a green economy as they can contribute to economic growth, poverty eradication and food security.

Historic documents suggest that sugarcane was grown and cultivated on the lower levels of the land. Irrigation channels were established in the late 1700s and used to direct rainwater from the hills for agriculture. In modern times, the potential for irrigation has not been exploited. Most of the current agriculture is rain-fed. Under a project for RWH, vegetable production was initiated recently through the use of 3,600 litres and 4,500 litres PVC tanks by 20 farmers, in support of the food security programme by the Ministry of Agriculture. Notwithstanding the current use of RWH, agriculture is still highly undeveloped.

The success of agriculture and livestock in the Grenadines has always depended on good rainfall. RWH ponds are the main supply of water for animals during the dry season. Small rain water ponds have been constructed throughout the islands and there are more than 25 ponds ranging in size that are currently in use for livestock production (Figure 4.11). Big Pond at Limlair (Figure 4.12) has been the main source of livestock water in the northern part of the island for over 100 years. Recently, a programme to construct micro dams at suitable locations can be used to increase the availability of water for both agriculture and livestock. Currently, using water from a small pond in Belair, Carriacou, has been beneficial in the production of fruits and vegetables and in maintaining a plant propagation centre (Figure 4.13). Carriacou has been using these irrigation systems to produce 85% of its planting material requirements since 2008.

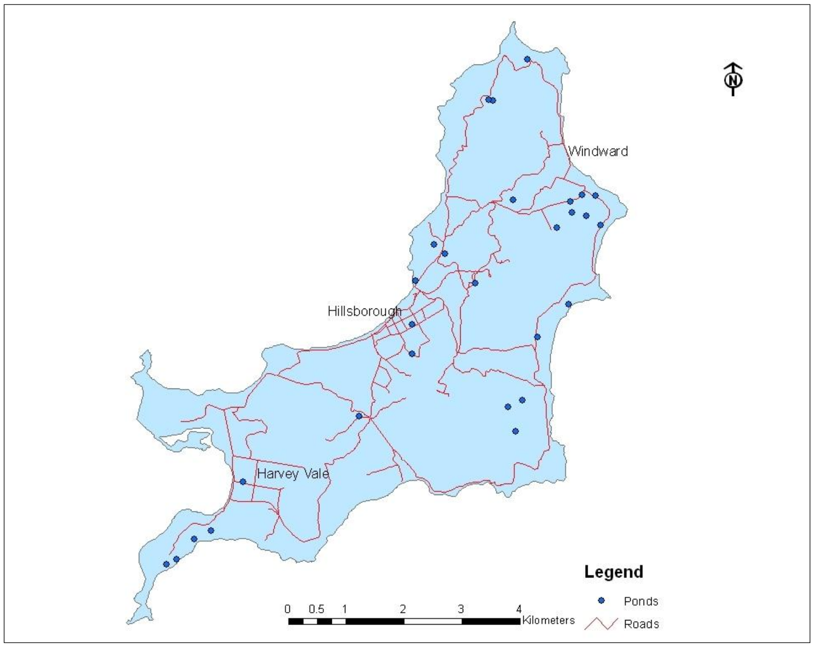

Figure 4.11: Map showing the location of ponds in Carriacou

Figure 4.12: RW micro dam (Big Pond), Limliar

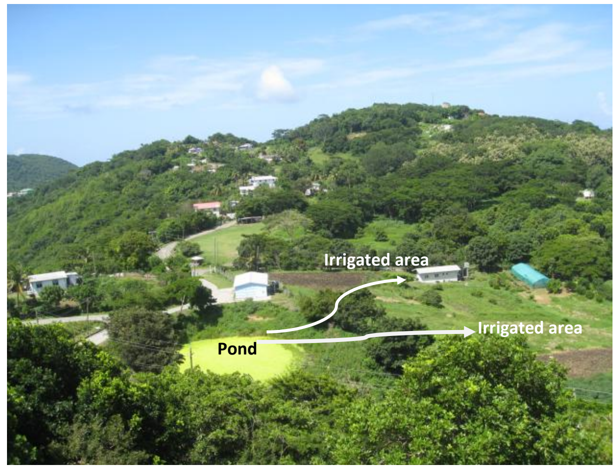

Figure 4.13: RW pond used for irrigation in Carriacou

4.9 Emergency Management and Preparedness

Figure 4.14: Cargo barge used to transport water from mainland Grenada to Carriacou

Carriacou occasionally experiences severe dry periods resulting in critical water shortages. Extremely low rainfall during the rainy season (June to January) is less frequent but can have severe impacts on crop and livestock production in addition to water shortages for domestic use. The islands, which account for 30% of the nation's livestock production, experienced 20% and 40% livestock losses due to the droughts in 1984 and 1992, respectively (UNFCCC, 2000). The rainfall during these two drought years was less than 75% of the annual average rainfall and 60% of the average dry season rainfall. The severity of the impact was partly due to the absence of predictability of these drought episodes so that residents were unprepared or commenced conservation measures too late. During the 2009/2010 drought, water was imported from mainland Grenada by using the ballast tanks of a cargo barge (Figure 4.14) and distributing the water to households using regular trucks with one or two tanks with a total capacity of 3.0m^3 to 3.8 m^3 (Figure 4.15). Based on this drought experience, Peters (2012) proposed a framework for monitoring droughts and water supply on the islands. This model uses the continuous computation of drought indices as a precursor to water availability at a particular time of the year. This model could now be made operational by the MOCPMA.

A key lesson from Hurricane Ivan is that households that practised rainwater harvesting and had even minimal storage capacities of around $4m^3$ were able to meet their needs during the first few weeks after the hurricane (Peters, 2010). Furthermore, the severity of the water shortages at emergency shelters was less in those shelters where there were water storage facilities that could be replenished from rooftop catchments.

Figure 4.15: Trucks being loaded with imported water for distribution during the 2009/10 Drought

In Carriacou and Petite Martinique there are few building fires. However, on occasions when there is a fire, the fire department is usually constrained in its operations due to lack of water, resulting in an almost complete destruction of the building. In this regard, some community cisterns could be designated and outfitted to allow easy access to fire tenders.

4.10 Flooding in Carriacou and Petite Martinique

The incidences of flooding in Carriacou and Petite Martinique are usually temporary and are not widespread. Floods tend to be localized to the Hillsborough area (Figure 4.16) and cause relatively insignificant material losses. However, there is much inconvenience and loss of productivity. The floods are likely to be more severe and regular due to climate change. In November 2011, the worst floods were reported in Carriacou when the two secondary schools, residences and businesses were affected.

Figure 4.16: Hillsborough Secondary School, Carriacou, flooded during a 2008 event

4.11 Wastewater Management and Sanitation

Carriacou and Petite Martinique have no centralized wastewater system. Individuals and businesses use septic tank and soak-away systems and pit latrines. Some households with internal plumbing and septic tank systems revert to pit latrines in the dry season or during severe dry periods in order to conserve on the use of the store water. In the case of pit latrines, the designs currently being used have not changed since the 1960s. In these latrines there are still problems with flies and odor. Pit latrines can be upgraded to Ventilated Improved Pit (VIP) latrines (Figure 4.17). These could be used in recreational areas for improving public washroom facilities.

Figure 4.17: A ventilated improved pit (VIP) latrine suited for the islands

The impact of septic tank soakaways and pit latrines on the groundwater, rainwater ponds, small dams and the wetlands (mangroves) has never been studied for Carriacou and Petite Martinique. In many cases, small hotels and guest houses situated within 50 m of the prime beaches use septic tank systems which were not strictly regulated at installation and may cause pollution of the beaches. Wetland infiltration systems (Figure 4.18) could be used for small hotels and guesthouses. In the case of residences in a village, Community Wastewater Management Systems (CWMS) could be introduced.

4.12 Water Governance

Figure 4.18: A small scale wetland infiltration system under construction

The regulatory framework associated with water resource management in Grenada is piecemeal, and the regulatory responsibility is embedded in various institutions. These legal instruments, due to the dispersion among the various institutions, require inter-sectoral coordination and cooperation for attaining the sustainable management of water resources (Government of Grenada, 2007). The National Water and Sewerage Authority (NAWASA) was established to provide the integrated approach to the management of water resources. The functions of NAWASA are:

- To provide water supplies and the conservation, augmentation, distribution and proper use of water resources including preservation and protection of catchment areas; and
- To provide sewerage and the treatment and disposal of sewage and other effluents.

The regulatory framework that is well established on mainland Grenada is absent in Carriacou and Petite Martinique. NAWASA only has a small operation in Carriacou and no operation in Petite Martinique.

The management of public water supplies in Carriacou and Petite Martinique is essentially carried out by the MOCPMA. The MOCPMA is responsible for maintaining the community ponds and dug-wells and is strongly supported by the community. Communities typically provide labor for the maintenance of RWH ponds and dug wells through small projects undertaken on weekends. This role played by MOCPMA in water management is expected to be transferred to the Local Government when it is established. A water governance framework is required for water management across sectors. The governance framework should be based on a concerted and holistic effort, along with a long-term vision, that combines the actions of the different stakeholders and with the participation of islanders under the leadership of the Local Government.

4.13 Price of Water

The cost of water from the cisterns is negligible as indicated from the 1986 rates shown in Table 4.4 which have not changed over the years. The low prices charged for water from communal cisterns are not sustainable and do not engender valuing the asset in monetary terms.

Cost	**Quantity**
US$0.24 for 3 months	14 litres (1 pan) per day
US$0.12 for 2 months	14 litres every other day
US$0.06 for 1 month	14 litres every other day
US$0.36 for 450 litres of water	

Table 4.4: Water rates for Carriacou communal cisterns (source CEHI 2006)

Peters estimated the cost of household RWH over the lifetime of a RWHS in Carriacou and Petite Martinique at US$1.15/m^3 (Peters, 2006). This is about 55% more expensive for an average family than on mainland Grenada where water from public supply is estimated at US$0.74/m^3.

The price of water in Carriacou and Petite Martinique can increase significantly during a severe drought. During the 2009-2010 drought, the cost of water delivered to households was as shown in Table 4.5.

Water Source	**Price (US$/m^3)**
Dug well	14.76
Borehole (NAWASA)	16.32
Borehole (Private)	26.20
Barged water (Private)	35.50
Barged water (MCPMA)	24.72
Cistern (Private)	24.23

Table 4.5: Price of water during the 2009/2010 drought (source Peters 2010)

The wide range of water prices is a challenge for Carriacou and Petite Martinique. Overcoming this challenge is possible through the use of an IWRM approach on the platform of green economic development.

4.14 *Integrated Water Resources Management for Carriacou and Petite Martinique*

The future water demand based on a projected population of 10,000 in the next 10 years is estimated at about 470,000 m^3 per year (excluding any major tourism and agriculture demands). Table 4.6 shows that at least 66% of this demand can be met by RWH and the limited groundwater. The remainder must come from desalination and improved water uses. This requires an integrated approach to water management with wide participation of islanders. Although a programme of IWRM is beginning to be widely practiced in Carriacou and Petite Martinique, its implementation is expected to encounter challenges. Progress will take time as more consultation is needed to ensure prioritization by the political directorate and to reduce the fear of changing from old practices related to water use.

Source	**Potential Quantity (Annual) (m^3)**
Boreholes	45,000
Domestic cisterns	210,000
Dug wells	13,000
Miro-dams	30,000
Communal cistern	15,300
Total	**313,300**

Table 4.6: Potential quantities of water from the existing sources in Carriacou and Petite Martinique

On a positive note, communities have always been involved in some form of management of the community's water resources. At the household level, families are responsible for their decentralized household water systems. Farmers, who share community ponds and have a vested interest in the facilities, have traditionally demonstrated a cooperative spirit in the management of the community ponds. Whatever difficulties that may be encountered in managing the upper watersheds could be mitigated through the use of public education. The local Non-Government Organizations (NGOs), mainly the Grenada Community Development Agency (GRENCODA) and the Agency for Rural Transformation (ART), have spearheaded a number of public consultations on Upper Watershed Management and Integrated Land and Coastal Resources Management over the past 15 years. There is, however, a need for promoting a greater role for local community groups in Carriacou and Petite Martinique.

Furthermore, consideration should be given to:

- Increasing water supply by expanding RWH domestic storage capacity;
- Promoting the use of water saving devices;
- Increasing water from desalination sources and by optimizing the limited groundwater resource; and
- Managing watershed to reduce pollution of RWH ponds and dams.

To achieve the above, a water policy specifically for Carriacou and Petite Martinique should be developed. The mix of water resources for sustainability in Carriacou and Petite Martinique is different than that of mainland Grenada.

4.15 Conclusions

Although drinking water and sanitation services improved in Carriacou and Petite Martinique over the last decades, there are still limitations in water quality and quantity. These limitations can be lessened by enhancing the efficiency in the use of water and energy through investment in relevant green technologies and infrastructure. These investments are critical to achieving the Millennium Development Goals and building a green economy. Traditionally, Carriacou and Petite Martinique have been in a unique position as households and the communities invest in RHW, and only a small portion of the investments in water and sanitation is provided by the Government.

Rainwater harvesting development is very well advanced in Carriacou and Petite Martinique. The development of RWH is critical to a green economy in the environment of climate change, as it can be used in the different aspects of water resources management on the islands. Notwithstanding the apparent recent success in the establishment of household rainwater supply, continuous availability of water, for both household and business purposes, remains a major constraint for long-term development. Through the framework of a green economy, there are a number of initiatives that make use of emerging technologies in alternative energy, efficient water use applications, and high motivation and awareness of the islanders.

Investments in new RWH dams and ponds and in "green" irrigation models (drip irrigation) can help improve food security. Investments in small-scale projects aimed at improving the quality of drinking water through household water treatment, such as SODIS, would increase confidence in the safety of local water and reduce the growth of imported bottled water.

Households and businesses are individually responsible for installing and managing their own decentralized water systems. There is the need to augment the current RWH and groundwater sources by desalination particularly to meet the demands of the growing tourism sector. This requires new investments and a participatory approach to IWRM. The development of an IWRM programme must incorporate factors such as population growth, increasing consumption of water and the impact of climate change. Bold leadership and new approaches to business, investment and policy that are supportive of sustainable IWRM are key requirements for Carriacou and Petite Martinique to achieve a green economy.

Implementing an effective IWRM programme to handle the potential competition for water between households and the growing tourism sector requires better information. In this regard, data collection on the development and performance of the water sector in Carriacou and Petite Martinique is recommended.

To improve food security there is the need to establish a long-term plan for the sustainable management of water resources in agriculture. This should take into account aspects of climate change and the need for protection from floods and droughts.

Setting up an adequate regulatory framework to enable the Local Government would help ensure a sustainable system for providing good quality water that is cost effective and affordable to the poor.

In support of the recommendations and as part of the way forward, the following strengths, weaknesses, threats and opportunities (SWOT) analysis (Table 4.7) was undertaken for water resources management in the islands particularly in regards to developing a green economy. A number of projects that can be developed are also provided together with the concept of a pilot project for the development of a new type of communal cistern.

Table 4.7: SWOT Analysis

Strengths	**Weaknesses**
• Preference for rainwater for domestic purposes • Resilience to the impact on drinking water from hurricanes • RWH technology well understood	• Limited natural water resources • Limited research work on existing water systems • Lack of centralized distribution system • Absence of land use policy • Absence of water and sanitation policies • Lack of public toilet facilities at public recreational places
Opportunities	**Threats**
Agriculture • Improvement of irrigation efficiency in agriculture by increasing the use of small dams and rain water harvesting • Use of small scale irrigation technologies (e.g. solar pumps, drip irrigation techniques) • Investments in "green" irrigation models (drip irrigation) Wastewater treatment • Promotion of localized wastewater treatment techniques. Water supply • Save energy by optimizing the use of gravity water supply and solar energy pumping • Use solar energy for water quality improvement • Use new filtration technologies (such as nano-technology) • Improve the use of communal cisterns by including solar pumping for distribution • Provide consumer education and public awareness on water efficiency and water quality concepts • Develop an operational drought monitoring system for the islands • Rehabilitate the communal cisterns for supply during disasters	• Loss of communal cisterns due to poor maintenance • Over use of imported bottled water • Waste disposal problem from increased use of plastic bottles from imported bottled water • Reduced efficiencies of current storage facilities due to climate change • Increased severity of dry seasons • Cost of water becoming unaffordable during drought periods • Pollution of small RWH dams and ponds • Pollution of prime beaches from poorly operating septic tank systems

• Use solar water pumping of the dug wells to improve accessibility by the community Water quality • Provide consumer education and public awareness on water efficiency and water quality concepts • Test different types of water disinfection systems • Promote business in the distribution of solar disinfection Water resources management • Implement sound integrated water resources management Wastewater management and sanitation • Promote enhanced latrines • Provide a management framework for maintenance of the decentralized wastewater systems • Create green jobs to deliver water and to process wastewater for both individuals and businesses • Promote the use of energy efficient packaged wastewater treatment plants	

4.16 Possible Projects

Project 1: Carriacou and Petite Martinique Domestic Water Quality Improvement
Aim: *To promote the use of solar disinfection systems for drinking water*
Target: Schools, business places and households
Description: Government, through external funding, can use government buildings (schools, public office buildings, and medical clinics) for a pilot project in installing basic first flush systems on RWH systems plus SODIS equipment in order to improve the safety of drinking water. In addition the government would use incentives in the form of duty concessions on material for the construction of first flush systems for households. These would be assembled locally by local craftsmen. There would be tax concessions on the import of SODIS and similar equipment.

Project 2: Improvement in Household Water Delivery System
Aim: *To promote the use of solar powered pumps of households*
Targets: Households with internal plumbing
Description: Most houses that have indoor plumbing use electric pumps to pump water from the main cistern to an overhead tank or directly to the faucets. These pumps cost up to $400.00 on the local market. Their dependence on electricity makes them vulnerable to power outages. Use of a solar powered pump would eliminate the use of electricity from the grid.

Project 3: Water Use Efficiency Improvement
Aim: *To promote the use of water saving devices*
Target: Public buildings, selected households

Description: This project can be undertaken by MOCPMA with external funding. It would involve the installation of water saving faucets and other such devices in public institutions (schools, hospital, community centers, medical clinics, police station and administrative buildings). It would also distribute similar devices to selected households at subsidized prices or at least duty-free prices. Local plumbers would provide their services free of charge in exchange for receiving the devices for their own homes free of cost.

Project 4: Water Management for Drought
Aim: *To develop a simple forecasting tool that can be used to implement timely conservation of RWH systems*
Target: All households
Description: The model developed by Peters (2012) would be used to provide community advisory bulleting on a continuous basis on water consumption patterns. The analysis would be done by the Planning Unit in the MOCPMA.

Project 5: Desalination Plant for Petite Martinique
Aim: *To use renewable energy to provide a reliable water supply to the residents of Petite Martinique*
Target: All residents
Description: A reverse osmosis plant powered by wind or solar energy or in a combination would be installed. Consideration would be given to developing a distribution network for at least Hillsborough and the environs. This would provide water to augment the current RWH supply.

Project 6: Sanitation Facilities Improvement (VIP latrines)
Aim: *To upgrade the latrine designs used in Carriacou and Petite Martinique to reduce odor and flies*
Target: Low income households, schools (as an emergency sanitation facility), other public places (parks, key beaches and recreational facilities)
Description: The project would introduce new designs of pit latrines that are more hygienic. The old models of pit latrines would be replaced with VIP latrines. The installation of public toilets at some public places that can be managed by a designated community member would improve comfort during the use of public places like beaches and parks. Outcomes include improved hygiene among uses, reduced pollution of groundwater and RWH ponds and dams, and employment in the construction of these latrines.

Project 7: Sanitation Facilities Improvement (evaporation pond) /wetland infiltration
Aim: *To improve the management of septic tank systems in Carriacou and Petite Martinique*
Target: All households using septic tank systems in Carriacou and Petite Martinique
Description: In this project households would be encouraged to clean their septic tanks regularly at a recommended interval. The project would provide a small truck tanker and equipment for emptying these tanks. The waste would be taken to a constructed evaporation pond where the waste could be harnessed as organic fertilizer.

Pilot Project Concept

Although there is a decline in everyday use of the traditional communal cisterns in Carriacou and Petite Martinique, the importance of these facilities is recognized. A new concept of the communal cistern is required to meet the needs of a changing society. Traditional communal cisterns depend on capturing water from large concrete catchments or roof areas of public buildings. The high value put on land makes further use of this method unattractive. A new approach is needed and can be based on collecting the spills from residences into a centrally located storage facility. Such a concept would be particularly suited and can be included in future housing projects where buildings are in close proximity. The proposed introduction of private and public housing developments, in particular the proposed Chinese funded housing development for Belview South in Carriacou, provides the opportunity to develop this new concept. A pilot project is suggested that can complement the Chinese funded project.

This pilot project is aimed at creating a new type of communal cisterns for a housing development. The objectives are:

- To optimize rooftop rainwater harvesting for a specific community;
- To promote the use of communal cisterns using a new approach of development; and
- To provide water for a housing development during disasters and to meet fire needs.

Overflows from individual cisterns attached to each residence would be channeled through a network of pipes to a central storage facility. Water from the central facility can be pumped to households based on needs during water shortages. Since it is unlikely that all households would use the system at the same time, the need for large pumping can be avoided, and pumping using renewable energy can be adequate.

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5. Education and Jobs

5.1 Introduction

Education as a human right is an essential factor for the well-being of any society. Through education, people acquire and develop skills and knowledge, and customs and values are passed on from one generation to the next. It is possible to exploit various job opportunities only through education. The educational opportunities that are available and affordable in developing countries are, in general, limited in comparison to those available in developed countries. Education in Small Island Developing States (SIDS) is especially limited due to geographic isolation and restrictions in financial and human resources. Development issues that are faced by SIDS are unique and therefore need the use of policies and technological advances that are designed to tackle specific environmental, social, economic and political priority areas. Providing appropriate education is the first step in addressing critical local issues which might be very different than those in other countries.

Educational opportunities that lead to the development of professional skills in critical areas of SIDS will increase the human capacity for meeting local needs and will lead to the generation of "green jobs", which will ultimately help the economies prosper. As defined by UNEP, a green job is "work in agriculture, manufacturing, research and development (R&D), administrative and service activities that contribute substantially to preserving or restoring environmental quality. Specifically, but not exclusively, this includes jobs that help to protect ecosystems and biodiversity; reduce energy, materials, and water consumption through high efficiency strategies; de-carbonize the economy; and minimize or altogether avoid generation of all forms of waste and pollution" (Worldwatch Institute, 2008).

There are a number of opportunities for using green technologies that can improve the lives of islanders in a sustainable manner and provide many jobs. The development of the human capital that will be able to provide knowledge for adaptation to climate change threats is critical. Also the availability of potential renewable energy in many SIDS, such as solar, wind and geothermal, represents a great opportunity for pursuing a more sustainable development. These resources can only be used to their full potential once the labor force is appropriately educated.

5.2 Current Education Situation

Primary and Secondary School Education

Grenada's educational system is modeled largely on the British educational system. Education is free and compulsory for children between the ages of 5 and 16. There are pre-school facilities which are optional. Primary education lasts for seven years and secondary education for five years. Post secondary education is mainly available through the National Community College, St. Georges University, and the University of the West Indies Open Campus Center. Public expenditure on education was estimated at 4.4% of GDP. The Ministry of Education has oversight of the education process from pre-schools to the Community College. The Ministry of

Social Development provides nurseries to children who are under the age of 3. The organization of services in education is based on districts with Carriacou and Petite Martinique representing one such district.

There are six preschools, six primary schools, two secondary schools and one postsecondary college on Carriacou and Petite Martinique. The islands have sufficient school places to meet the demand of the school age population up to secondary school. The current school population is 1,202 (52% primary students and 48% secondary) and many of the schools are under-populated. There is only one primary school on Petite Martinique and there are no secondary schools. There are two small boats for residential transportation which take 30 to 40 secondary school children from Petite Martinique to Carriacou every day. Education offerings are generally highly theoretical and the availability of vocational training and non-traditional courses is limited. At the end of the secondary education, students sit for the Caribbean Secondary Education Certificate (CSCE), administered by the Caribbean Examination Council (CXC) or the Cambridge General Certificate in Education (GCE). The School Leaving Certificate Examination is taken by students (+14 years) who did not attend secondary school. As a result there is an apparent mismatch between the skills of the population and the jobs available due to the nature of the training provided at the secondary schools. This contributes to people leaving the islands due to a lack of opportunities for studies or employment.

Post Secondary Education

At the post secondary college, the T.A. Marryshow Community College (TAMCC), the subjects available are limited to business, social sciences and Information and Communication Technology (ICT). The TAMCC campus on Carriacou only offers associate degrees in studies of arts, sciences, professional studies, applied arts and technologies, and continuing education. The college has 15 teachers and 120 students. GRENLEC is helping to fund the construction of a technical wing for the community college. There is a lot of open physical space for further expansion. The corporate actors (GRENLEC, Lime, National Insurance, and St. George's University) have assisted the educational system by providing financial assistance to students in need to pursue their education, and the government provides support through the Social Development Department.

Resource Centres

Resource centres have been established in the country to provide ICT access for the community. The centres also complement the limited ICT equipment in schools. There is one such centre each in Carriacou and Petite Martinique.

Challenges in the Education System

It is estimated that 40% of students perform at acceptable levels (Kairi Consultants, 2009). One challenge identified is that, although teachers are generally well qualified for the job, there is a low level of commitment. Other emerging problems relate to school violence and teenage pregnancies. Some of these problems are associated with poverty. In response to these challenges, the Government has implemented a number of social programs including:

- School feeding program: at least one hot meal is provided for students, particularly those from destitute households (51% primary school students and 5.3% of secondary school students).
- Free books program: books are provided free to students for the core subjects.
- Transport assistance: provided to children from low income families. Specifically in the case of Petite Martinique, children attending secondary school in Carriacou are transported free of cost.

5.3 Plans for Future Development of Education

A comprehensive programme seems necessary for modifying the curricula at primary, middle and high school levels and at the associate and bachelor's levels to incorporate critical issues such as natural resource management, green technologies, water management, environmental awareness, and climate change. The objective is to give priority to relevant issues for the country and for Carriacou and Petite Martinique to move towards a greener economy, sustainable development and enhanced well-being.

In the "Framework for the Sustainable Development of Carriacou and Petite Martinque" (Peters, et al., 2007), the current administration proposed the development of training programmes that would support ecotourism. Some of the proposed progammes include:

- A sailing school to facilitate sailing as a tourism attraction;
- A navigational school to provide skills and opportunities for youths;
- Training skills in snorkeling and scuba diving techniques; and
- Management training and support for entrepreneurs in ecotourism.

Community College

The TAMCC was founded in 1988 and is the national tertiary institution. The annual budget of US$9.5 million needed to operate is obtained from the Government's subvention and tuition fees. The college also has a working relationship with the St. Georges University. Most graduates leave with an associate's degree.

There are six main areas of study:

- School of Agriculture;
- School of Technical and Vocational Education;
- School of Applied Arts and Technology;
- School of Continuing Education;
- Teachers' College; and
- Nursing.

While the TAMCC has a campus in Carriacou, not all of its programmes are available at that campus. There is potential for physical expansion at the TAMCC and to expand enrollment of students and to restructure the curriculum. An introduction of the School of Technical and Vocational Education on the Carriacou campus would meet the needs of the Carriacou and Petite Martinique community, by providing appropriate programmes for technicians, electricians, engineers, natural resource specialists and environmentalists. These new programmes can allow the development of human capacities to respond to local priority issues such as water systems, electricity and renewable energy systems, environmental and ocean issues, agriculture and aquaculture. Specialized laboratories for sciences can be funded to study water quality in water catchment facilities, desalination plants and waste water processes, for example. These educational options will provide an incentive for the new generations of students to stay in Carriacou and Petite Martinique and contribute to its development rather than leave to study or work elsewhere. Some of the training could be short-term to respond to job opportunities.

Another benefit of having technical and vocational training to fit a green economy is associated with the Caricom Single Market and Economy (CSME). As part of this wider group, the Organization of the Eastern Caribbean (OECS) implemented a free movement of labour programme in 2011. To make this workable, skills are to be certified through the Caribbean Vocational Qualification (CVQ). CVQ is a competency based qualification. Students must demonstrate competence in reaching CARICOM Approved Occupational Standards developed by practitioners and employers (i.e. the industry experts). In the early stages of the education and training transformation in the region, Carriacou and Petite Martinique through TAMCC is well placed to develop a niche for itself in special skills associated with the green economy.

International Educational Exchange

There are opportunities for research in very relevant topics related to sustainable development, climate change, natural resources and green economy. These topics are of great importance to SIDS and are currently capturing the attention of international research organizations. Already, there is interest for the development of possible partnerships with students from Northeastern University and University of California at Berkeley (at Associate's, Bachelor's, Masters and Ph. D. levels). Opportunities might include sabbaticals for professors doing research both for North-South and South-South technology transfer. Students may be interested in summer programmes, Spring break short courses or field trips, student exchange programmes for one or two semesters such as the "Dialogue of Civilizations" programme, etc. Education and post-study opportunities can be developed for internships, development of small local businesses, food and agriculture, construction, water system management, waste management, services sector, hospitality sector, transportation sector, vendors of local products and souvenirs. Also, opportunities should be developed for local students and professors to be trained in specialized international schools. There is a great opportunity to utilize the highly-educated group of senior professionals who now live in the islands in new applied university programmes.

Camp Carriacou

Camp Carriacou was previously a marine biology research centre converted into a hotel in the 1970s. Located on a beautiful hillside overlooking the ocean, it is now just clusters of deteriorated buildings that can be rebuilt for research purposes. If this site could be rebuilt into a marine biology research centre, it would be a great resource for educational tourism. If sufficient interest and funding were found, this site could become a "Centre of Excellence" for research on green economy, renewable technologies, climate change, and blue economy (oceans).

5.4 Jobs in Carriacou and Petite Martinique

Grenada has a population of approximately 100,000 people, with an economy that is based on tourism, construction and agriculture. After Hurricane Ivan struck in 2004 and Hurricane Emily struck Grenada, in quick succession thousands were left homeless and many nonresidential areas were damaged. Although most hotels and restaurants reopened by 2007 because of the intense period of recovery that followed these hurricanes, the global economic crisis of 2008 resulted in harsh negative consequences for Grenada. In 2004 the rate of unemployment in Grenada was roughly 24% (US Department of State, 2012). Around this time the population began moving from rural to urban areas because there were more job opportunities in tourism and construction since the damage caused by the hurricanes was yet to be fixed. This shift, however, caused agriculture and the rural economy as a whole to suffer. Today, most jobs are found in tourism and construction of houses.

5.4.1 The Potential for Green Jobs in Carriacou and Petite Martinique

There is ample room for development within the field of agriculture, land management, water conservation, public health and tourism in Carriacou and Petite Martinique. These sectors are all connected so that improvements in one sector can create new spaces for jobs and growth in another (Worldwatch Institute, 2008). Therefore, the proposed plans to build new desalination plants can result in many temporary as well as permanent jobs in construction and operation.

According to the 2011 budget statement, the Government of Grenada has committed to creating a greater focus on agricultural production, with a goal of minimizing food imports to the country (Burke, 2011). The sustainable production of root crops and the development of an agro-processing industry could attract more farmers, material suppliers, retailers and distributors. Sustainable agricultural practices can be incorporated into this development thrust and provide numerous jobs. For instance water management in the form of training farmers about the irrigation techniques provides a new realm of education and job creation. Similarly, the Government’s attempt to construct a fisheries plant will result in multiple temporary jobs in construction, as well as a number of permanent jobs in transportation and maintenance.

The country’s goal for an indigenous clean energy system will not only provide greater energy independence and reduce greenhouse gas (GHG) emissions, but it can also act as a driver for significant, positive economic growth (Worldwatch Institute, 2008). A model was used to explore the potential for renewable energy to create a complementary job market in Petite Martinique and Carriacou, and for Grenada as a whole. The relationship between electricity production and job growth based on 2010 GRENLEC data was modeled, as well as various scenarios based on renewable energy proposals according to the National Energy Policy (NEP) of the Government of Grenada (Government of Grenada, 2011). This is an example of the type of analysis that can be done for other sectors of development to gauge the potential scale of jobs benefits from various investments.

5.4.2 Grenada’s Utility and Labor Force

Currently utility companies provide ample job opportunities to people living in Grenada, and they have the potential to provide even more related jobs in the field of renewable energy.

GRENLEC and NAWASA are the two major utility companies. GRENLEC employs 230 people and NAWASA employs 200.

Recent trends in the expansion of construction and maintenance job markets as well as training programmes established by utility service providers bodes well for the emphasis being placed on renewable energy in Grenada. Further work is needed to explore the structure of the energy sector and its employment chain. Tertiary education programmes are also crucial elements in the development of a workforce that can support a shifting energy paradigm. Understanding how graduates from these programmes approach the job market is an important future step.

5.4.3 Green Jobs Model

A green jobs model was used in this study to forecast potential green jobs in the energy sector. The model was designed by the Renewable and Appropriate Laboratory (RAEL) at the University of California, Berkeley. The modeling methodology is adapted from the original work of Max Wei, Shana Patadia and Daniel Kammen at the RAEL. The model is based on direct construction, installation and maintenance jobs and indirect (non-energy sector) job multipliers (per GWh) for different energy resources based on literature and project review (Wei, et al., 2012). It relies on synthesized data from a number of job studies done in the U.S. and Europe as well as data from renewable energy projects within the Caribbean region. The normalization approach of taking average employment per unit energy produced over plant lifetime is used. The Green Job multipliers are static over time (based on aggregation). This allows for easy comparison across technologies with different life spans and capacity factors but assumes a linearity that is not realistic. In the future it can be expanded on to include cost qualifiers in the model for ease of use.

Green Job Multipliers

Direct employment includes those jobs created in the design, manufacturing, delivery, construction/installation, project management and operation and maintenance of the different components of the technology, or power plant, under consideration. Indirect employment refers to the “supplier effect” of jobs created for upstream and downstream suppliers. The number of green jobs created per megawatt of renewable energy deployed is estimated using a series of job multipliers that vary by location and type of technology. These multipliers estimate the direct and indirect jobs created by the development, financing, construction, operation, and maintenance of renewable energy projects.

However, for solar and wind resources a group of Caribbean-based job multipliers was developed based on data from project developers in Jamaica, the Netherland Antilles, Barbados and Grenada. The job multiplier values obtained from data on Caribbean projects for wind energy projects are well within the range of those projects deployed in the US. However, given the small number of installations being deployed relative to its staffing, the job multiplier for Grensol, Solar PV Company in Grenada is disproportionately high and has been excluded in the model runs.

Data were not provided for indirect job effects such as jobs from storage improvements or grid upgrades and grid management. Therefore, a general indirect multiplier of 1.9 job-years/GWh was applied, taken from the California Clean Energy Future. As the GRENLEC system evolves to handle more sources, this may be an area of potential job growth.

BAU and Model Scenario Assumptions

Historic energy sales from 2005 to 2010 were obtained from annual GRENLEC reports. During this period sales grew approximately 4% per annum, due to the level of reconstruction taking place. CARILEC projects a 6% load growth overall by 2015 (CARILEC, 2010). From this a growth rate is assumed that declines from 4%, levels to roughly 1% per annum by 2015 and remains at 1% out to 2020. For the business as usual case, it is assumed that oil-fired generators meet all increase in demand without any further increase in efficiency of generation or supply.

Many of the assumptions made for the expansion of renewable energy over the next decade are taken from the themes of the Grenada NEP (see Table 5.1). Assuming that by 2020 approximately 40% of total annual energy demand in Grenada will be met by renewable energy generation, 8 MW of geothermal energy would meet 30% of this demand while 6 MW of solar PV and 4 MW of wind generation could contribute 5% each. This represents an annual energy use of roughly 84,000 MWh supplied by renewable energy resources.

	2011					2020				
SOURCE	**Installed Capacity (MW)**	**Capacity Factor**	**Annual Energy Use (MWh)**	**Percentage of Total Energy Use**	**Percentage of Total Generation**	**Installed Capacity (MW)**	**Capacity Factor**	**Annual Energy Use (MWh)**	**Percentage of Total Energy Use**	**Percentage of Total Generation**
Fossil Fuels	50	0.42	185,790	100%	100%	50	0.42	127,136	60%	60%
Solar PV	0	0	0	0%	0%	6	0.2	10,512	5%	5%
Wind	0	0	0	0%	0%	4	0.35	10,731	5%	5%
Geothermal	0	0	0	0%	0%	8	0.9	63,072	30%	30%
		RE Total	0	0%	0%		RE Total	84,315	40%	40%
		TOTAL	185,790				TOTAL	211,894		

Table 5.1: Model assumptions

5.5 Further Potential for Green Jobs

The results show that a modest number of jobs can be created by renewable energy generation by 2020. Over 50 permanent direct jobs could be created by 2020. Including indirect jobs related to up and down stream material suppliers or subcontractors would bring this to over 165 jobs. This is likely an underestimate given the small economies present in island regions. Induced employment accounts for the expenditure induced effects in the general economy due to the economic activity and spending of direct and indirect employees. If an induced job multiplier from the California Clean Energy Future of 2.5 job-years/GWh is used, a total of 320 permanent jobs are created.

Importantly, the cumulative number of job-years created is approximately over 1,600 by 2020 based on the projects outlined (see Figure 5.1). These job-years can be divided into a number of different job types or lengths depending on the needs of the sector. For instance, a heavier emphasis could be placed on temporary jobs with 6 month or year-long contracts during the earlier years of development to spread income benefits as Grenada revives from the economic recession. The distribution of wages would potentially impact the assumptions regarding induced economic and job impacts.

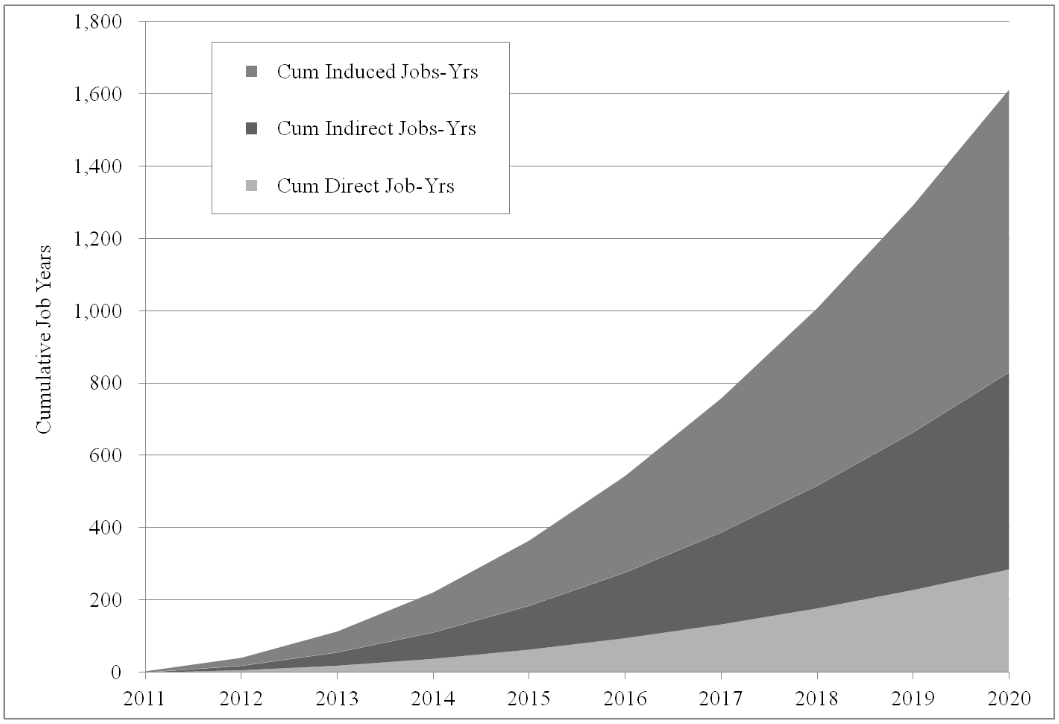

Figure 5.1: Cumulative job-years created by 40% renewable energy scenario

Geothermal energy dominates job creation (Geothermal Energy Association, 2010). Direct jobs are those associated with the construction, operation and maintenance of geothermal power plants. It is important to note that often a significant number of these jobs will be accounted for by contractors and subcontractors, particularly at the construction and manufacturing stage and thus reported numbers for developing direct job multipliers may be underestimates. The range of indirect jobs throughout all aspects of resource development is extensive, and would include government regulators, lawyers, architects, equipment service personnel, geologists, business management personnel, security guards, and more.

There are a number of alternative scenarios that could be modeled to observe impacts on job creation. For instance, the number of jobs created would increase if energy efficiency measures such as solar water heating are incentivized as well, so as to reduce total energy demand. Energy efficiency measures require long term construction, operation and maintenance positions. If a further 10% of energy demand was reduced by solar water heating, a total of 375 jobs and 1,900 job-years could be created. Again, it is important to note that the indirect impact of renewable on a small economy is likely to be much larger than projected here.

As another alternative, if the model is run using the Grensol solar multiplier it quickly dominates the expansion of jobs and increases the total number of renewable energy related jobs to almost

1200 and the total number of job-years to 6,000 by 2020. Furthermore, according to the NEP, nearly 100% of electricity generation could be produced by renewable energy by 2030. Assuming that the larger part of this generation supply comes from investments in geothermal energy, a total number of over 700 permanent jobs would be created by 2030.

5.6 Conclusions

Education and job opportunities are closely linked. A more appropriately educated work force will be able to maximize as well as create new job opportunities, which will ultimately help improve the economic situation. The challenges for education and training for a green economy can be overcome by a comprehensive forward-looking programme. It is clear that green technologies will not flourish without a well-trained technical and supporting labor force. Therefore, there is a need in Carriacou and Petite Martinique to improve the competitive skills of its human resources base in order to support the green economic development that is envisaged. Major changes to the current education structure are necessary to support a greener economy. Concerted efforts are required to develop the capacity and better align skills training to the rapidly-changing employment, social and economic realities.

Expanding on the current education system of Carriacou and Petite Martinique will be essential to securing a transformation towards a greener economy with jobs and research in priority areas. A more focused education programme with an active international knowledge exchange component would be beneficial for locals as well as international students and professors. There are opportunities to "green" existing training programmes for traditional occupations by incorporating energy efficiency skills and knowledge into curricula, rather than promoting stand-alone, green training programs. If such programmes are kick-started early in Carriacou and Petite Martinique, then graduates from such programmes can be early entrants into the special job market which would give them an added advantage.

Transforming the education system to meet future needs requires substantial resources. Recently, Canada announced the Skills for Employment initiative that will help the Caribbean region build a skilled workforce necessary for economic growth. This consists of an investment of approximately $40 million in projects. Projects like these can help provide the transformation in Carriacou and Petite Martinique.

Once a well-educated work force has been created it is possible to multiply jobs, manifold. According to the model presented in section 5.5, in eight years as many as 300 permanent jobs can be created by shifting away from fossil fuel electricity generation. Given the lack of data available within the region, there are a number of limitations in the methodology, largely centered on the model's conservative nature in estimating the indirect impacts of increased deployment of renewable energy and energy efficiency projects. In spite of such a limitation, it is possible to identify the potential for renewable energy to have economic co-benefits for Grenada along-side reducing demand for imported fuels. The economic linkages that exist within and surrounding the energy sector will continue to be explored to quantify such costs and benefits more accurately as the potential for indigenous energy sources to support economic development should not be understated.

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6. Transport

6.1 Background

The framework for the development of Carriacou (Peters, et al., 2007), which was adopted by the local government after the 2008 general elections, points to strategies that are consistent with the concept of a green economy. Such strategies need an integrated approach that links social, economic and environmental priorities into actions that promote sustainable development and poverty eradication.

In the development framework for Carriacou and Petite Martinique, transportation is highlighted as being strategic in the new economy. This new economy will depend on an efficient transport system to deliver smoothly a flow of goods and personnel to where they are needed. The aim of green transport is to provide a land and sea transport system that is developed with the islanders firmly in mind, planned for their needs and environmentally sustainable. This means making investment and planning decisions which can shape a transport that is sustainable for the long-term. This goal can, however, be faced by a number of challenges, including:

- Reversing the recent trend in greater reliance on fossil fuel-powered cars and buses as the main form of transport, particularly given the multifaceted nature of the problem and solution.
- Meeting the needs of the changing demographics to better address the needs of the growing senior population, people with special mobility needs and wheelchair users.
- Developing a sustainable financing framework for this sustainable transport system.

The lack of information on transport systems in Carriacou and Petite Martinique represents another major challenge. It is necessary to obtain time-series and basic data on transport and to evaluate the land and sea transport systems in Carriacou and Petite Martinique with particular emphasis on quantifying its efficiency.

6.2 Transport Systems in Small Islands

Small Island Developing States (SIDS) can have acute transport challenges (Enoch, et al., 2004) which include lack of investment in public transport, lack of basic transport infrastructure and a shortage of efficient vehicle stocks. These problems are further compounded by national development challenges which relate to geographic features of size and remoteness or isolation. The small size feature that characterizes SIDS can cause economic vulnerability and limitations in the development of environmentally sound transport systems. Transport services are often costly to establish and maintain.

Transport System in Carriacou and Petite Martinique

Carriacou has a relatively good network of roads with sufficient access to road transport during daylight hours. The components of the transport system in Carriacou and Petite Martinique are shown in the Table 6.1.

Type	**Means**
Land transport Carriacou (automobiles)	• Private vehicles • Private minibuses • Trucks
Inter-island transport between Carriacou and Petite Martinique	• Passenger ferries • Private speed boats
Inter-island transport between Carriacou and Grenada	• Air transport • Cargo • Passenger ferry

Table 6.1: Components of transport system in Carriacou and Petite Martinique

Road Transport

In recent times there has been a greater dependence on the automobile. This has been a result of the growth in automobile ownership which is fueled by the availability of foreign used vehicles, an inflow of retirees from North America and Europe who are able to import vehicles free of import taxes, and the improvement in household disposable income fuelled by an underground economy, a successful fishing industry and remittances.

There is no public transport system in Carriacou and Petite Martinique; however, there are private operators of minibuses and taxis that provide fee-paying transport. In addition, private car owners regularly provide transport free of charge. The privately operated transport system suffers from similar problems encountered by the publicly operated system. Low ridership makes the service financially unsustainable, particularly during weekends and school holiday periods.

As there are no limitations on ownership of minibuses, except access to finance, there appears to be many minibuses competing for the limited passenger base. This can lead to inefficient use of the system. Table 6.2 presents data on the number of vehicles in Carriacou and Petite Martinique in 2011. Table 6.3 lists the cost of airport taxi and public transport (short drop) in small islands of the Caribbean. Carriacou has the most expensive fares in both categories in all the listed islands.

VEHICLE TYPE	NUMBER
Cars	123
Trucks	67
Pickup Trucks	78
Buses including super carry	79
SUV/ARV	760
Vans	35
Moto Cycle/Scooter	65
Club Cart	5
Bac Hoe	7
Dumpers	6
Tractor/Bobcat/Loader	6
Stone Roller	1
Total	**1,232**

Table 6.2: Number of vehicles in Carriacou and Petite Martinique

Location	Airport taxi Cost/mile (US$)	Public transport Short drop
Carriacou	7.50	1.31
Grenada	3.00	0.94
St. Lucia	1.30	0.75
St. Vincent	6.25	0.75
Barbados	1.25	0.75
Tobago	1.62	0.32

Table 6.3: Cost of airport taxi and public transport (short drop) in small islands of the Caribbean

Inter-Island Transport

1. *Ferry*

The services for inter-land transport are based on ferries that operate on a daily basis at a cost to the public. Although the system seems very reliable, the cost is considered too high for many islanders who need to travel from one island to the other. Table 6.4 presents the cost of the ferry travelling from St. George's to different islands of Grenada.

Location	Cost/mile (US$)
Petite Martinique	43.00
Carriacou	31.00
Gouyave	--
Grenville	3.00
St. Davids	--
Sauters	3.00

Table 6.4: Cost of ferry (water transport) travelling from St. Georges to different parts of Grenada (public transport)

2. Air

Carriacou has a small airport with flights offered to the public on a daily basis. The service represents an important and fast alternative for commuting between the islands. It complements the public water transport serviced by the ferry.

Data Requirements

A comprehensive analysis of the current transport system in Carriacou and Petite Martinique and an assessment for a future low-carbon and efficient transport system require data on a number of important issues. Part of the information needs can come from data from the Department of Inland Revenue. A survey of operations of private and public vehicles can be undertaken. Daily records of vehicle entrance and exit from Hillsborough can be observed from the main points into the town. This can be supplemented by personal questionnaires to vehicle owners and reports from sales from service stations. Other valuable information may be obtained from data on the operation and finances of minibuses and ferry services.

6.3 Alternate Fuels for Vehicle Fleets

Many Caribbean countries have begun to explore producing alternative fuels, most commonly ethanol produced from sugar crops and biodiesel from the African palm and jatropha trees. The resulting biofuels are often exported, but in some cases they are utilized locally along with traditional fossil fuels. For example, the "Biodiesel Haiti" project aims to establish jatropha (a Central American tree whose seeds can produce up to 40% oil) in deforested areas throughout the impoverished country (Environmental News Network, 2007).

The embodied energy (and associated emissions) in biofuels increases according to the shipping methods and distances involved. Alternative fuels such as ethanol and biodiesel are commonly referred to as carbon-neutral, as the CO_2 that is released from their combustion came directly from the plants that were used to create them, and therefore directly from the air. Biodiesel can potentially be used in standard diesel generator sets with only minor infrastructure changes. In theory, any diesel engine could operate on up to 100% biodiesel. In order to protect the diesel generator system, filtration and quality control are paramount when using any blend of biodiesel. Grenada has a very strong history of agriculture with fertile land. The potential of harvesting land and growing crops on the islands for alternative fuels is an area that warrants further investigation.

6.4 Potential for Electric or Hybrid Options

6.4.1 Electric Vehicles

Electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) could have a large impact on transitioning Carriacou and Petite Martinique to a green economy. EVs completely eliminate reliance on gasoline but typically lack the flexibility to drive long distances. Plug-in hybrids have a longer range due to their internal combustion engine but still rely on using gasoline and emit CO_2, albeit with better economy than conventional vehicles. Most PHEV designs incorporate larger batteries than a typical hybrid (5-10kWh vs. 1-2 kWh) to allow for electricity-only driving. These larger batteries can be charged by plugging the car into a standard outlet or through regenerative braking while driving. With a limited range, adoption by commuters in the US has been slow. However, on a small island like Carriacou or Petite Martinique, this limited range presents far less of an issue. In addition, electric vehicles could be well-suited for Grenada's tourism industry. A recent study in Maui found that 15-20% of vehicles on the island's roads are driven by tourists (PV News, 2011). These tourists make for great EV users because they are more likely to be wooed by their novelty and green aspects than buyers concerned with day-to-day commuting.

Electric vehicles store power taken from the grid for use later on the road. As such, transitioning a sizeable portion of the vehicles on Carriacou and Petite Martinique to EV would increase the demand for electricity from the grid.

6.4.2 Transport Ferries

Grenada has a ferry service with daily trips between the main island, Carriacou and Petite Martinique. In general, contributions from ferry travel to climate change have received less scrutiny than land and air transport and vary considerably according to factors like speed and the number of passengers carried. Although ferries are effective and widely used in island countries, they have relatively high greenhouse gas (GHG) emissions and low fuel efficiency when compared to various forms of land transportation as shown in Table 6.5. In addition to alternative fuels, ferries can also benefit from renewable energy technologies such as solar and wind.

MODE	Pass-mi/Gal**			Btu/pass-mi			CO2 g/pass-mi		
	low	AVG	high	low	AVG	high	low	AVG	high
Motor Coach	160.0	**184.4**	201.5	685	**749**	862	51	**56**	64
Van Pool	28.2	**101.9**	194.6	709	**1,354**	4,891	53	**101**	364
Heavy Rail	47.0	**155.3**	200.6	688	**889**	2,939	121	**156**	517
Commuter Rail	58.2	**85.8**	249.1	1,127	**1,608**	2,372	108	**177**	286
Intercity Rail	52.4	**66.0**	175.7	785	**2,091**	2,635	138	**179**	196
Car Pool - 2 person	41.2	**55.4**	111.4	1,239	**2,492**	3,353	92	**185**	250
Light Rail	14.4	**120.5**	214.9	642	**1,146**	9,596	113	**202**	1,689
Trolley Bus	53.4	**104.4**	122.1	1,130	**1,321**	2,582	199	**233**	454
Car - Avg Trip	32.5	**43.8**	88.0	1,569	**3,154**	4,244	117	**235**	316
Domestic Air Travel		**42.3**			**3,260**			**243**	
Transit Bus	3.9	**32.5**	126.8	1,088	**4,245**	35,123	81	**299**	2,615
Car - 1 Person	20.6	**27.7**	55.7	2,478	**4,983**	6,706	184	**371**	499
Ferry Boat	2.0	**12.6**	31.0	4,447	**10,987**	68,632	331	**818**	5,109

Table 6.5: Average passenger miles per diesel-equivalent gallon for various forms of transportation

Companies like Australia's SolarSailor are investigating the use of photovoltaic (PV) panels mounted on the exterior surfaces of ferries to offset a portion of the fuel use (SolarSailor, 2012). For example, Figure 6.1 shows SolarSailor's hybrid-powered 100 passenger "Solar Golf" ferry. Three of these ferries are currently being demonstrated in Hong Kong, with a reported 8% of the ships' energy use being offset by roof-mounted solar panels.

Many sailboats are also being equipped with small wind turbines. These turbines typically have a capacity of a few hundred Watts and provide DC voltage for recharging the boat's battery. In 2008, Alcatraz Cruises in San Francisco, California added the "Hornblower Hybrid" (Figure 6.2) to its fleet of ferries. The 150-passenger boat has a hybrid power system with two ten-foot tall 1.2 kW vertical-axis Savonius-type wind turbines in addition to 1.2kW of roof-mounted solar PV (Alcatraz Cruises, 2008). In addition to solar panels and wind turbines, the "Hornblower Hybrid" also has Tier 2 marine diesel engines. These cleaner, fuel-efficient engines reduce the amount of diesel fuel used, emissions and overall carbon footprint. The customized drive system allows the captain to monitor the energy needs of the vessel and select the most efficient power sources. For example, when the boat is idle at the dock, the engines will shut off, and the motors will run on energy stored in the battery banks.

As the ferries which presently serve Carriacou and Petite Martinique reach the end of their useful life, transitioning to hybrid-powered boats (such as those below) would notably reduce the fleet's fuel use and GHG emissions.

Figure 6.1: SolarSailor's "Solar Golf" hybrid powered ferry (8% of energy from On-Board PV)

Figure 6.2: Hornblower Hybrid wind, solar and diesel ferry

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7. Agriculture, Fisheries and Food Security

7.1 Introduction

Over the past four years, the global economic crises in developed countries in combination with food scarcity and high food prices have highlighted both the urgent need and the potential for developing sustainable agricultural systems. This need is greatest in the case of small island states like Grenada and its dependencies of Carriacou and Petite Martinique that face formidable challenges to sustain an adequate food security through their domestic sources of food supply.

These challenges of food security are further exacerbated due to the small and isolated island economy where a stable supply of food is often interrupted by natural disasters such as hurricanes, droughts and other unexpected environmental changes. Quite often, for many small islands, domestic food supply is the last resort for survival when natural disasters occur. The importance of these challenges has been recently highlighted by the Food and Agriculture Organization (FAO) in its theme for 2011 World Food Day Celebration *"Food Prices- From Crisis to Stability"* (FAO, 2011). In small island developing states (SIDS), increasing food imports at the expense of domestic food supply has been a major issue from food security and nutritional standpoints.

After declining for about 30 years, domestic food supply in Carriacou and Petite Martinique has shown slight improvements in the past three years as a result of greater support by the government for the agricultural sector, particularly to small subsistence farmers. Subsistence agriculture, which has provided basic food necessities to the islanders in the past, remains an important sector in terms of its potential to influence sustainable development through employment creation, food security and poverty eradication. It also supports a green economy through its impact on climate change and biodiversity. However, the threats of increased natural disasters, poor agriculture sector planning, the aging of the farming population and the relatively easy access to cheaper imported foods create vulnerability in the islands' food security. This vulnerability is further exacerbated by an increasing population pressure on extremely limited land, thereby forcing islanders to cultivate smaller plots and marginal land for food production which has contributed to declining agricultural productivity. The situation, therefore, requires new thinking that highlights agriculture's potential as a positive driver of food security, environmental sustainability and economic opportunity in small islands.

Agriculture in Carriacou and Petite Martinique historically has been practiced on a plantation type system in which production was focused mainly on traditional export crops like sugar cane, limes, coconuts and cotton. As the markets for these crops weakened over time and productivity declined, the commercial production of these crops virtually disappeared. Sugar cane was phased out with the abolition of slavery and with the decline of the world price of sugar. The production of limes began to decline in the 1920s when yields on mainland Grenada were found to be superior to those in Carriacou. However, up to 1981 the lime factory on the Craigston Estate was operational. Coconuts were planted in the 1870's but were depleted in the late 1970's (Government of Grenada, 1988). The cultivation of cotton, which was a primary product of colonial Carriacou, ended in the 1970s when the quantities produced were too small to make the local ginnery profitable. The last significant export of limes and cotton took place in the 1970s.

The decline in export driven agriculture also resulted in a change in land distribution with the plantations being partitioned into smaller plots which facilitated the development of a class of small subsistence farmers. The transformation of agriculture from plantation to small farmed plots led to an intensive type of production in which the farmer, in trying to be self-sufficient, integrated livestock production with crop production and concentrated on the production of ruminants, corn, beans and small quantities of vegetables. As lands passed from one generation to the next, it was further sub-divided, resulting in some plots becoming economically non-viable.

This resulted in poor and inadequate land use and agricultural practices, notably the emergence of a *"leggo beast season."* This practice, which originally involved the freeing of livestock to fend for themselves during the dry season, ultimately developed into a perennial practice. This *"leggo beast season"* and the lack of enforcement of the anti-stray livestock legislation contributed significantly to the poor performance of subsistence crop production during the 1990s and 2000s. Some of the current poor practices and the potential threats of climate change require a new thinking of the way agriculture is promoted in Carriacou and Petite Martinique. Already, the Ministry of Carriacou and Petite Martinique Affairs (MOCPMA) through its Department of Agriculture is embracing the concept of green agriculture for the islands.

The MOCPMA has recognized the importance to further reinforce the need to approach agriculture and food security through a sustainable mechanism by taking into account prevailing influential factors in order to achieve synergistic development and outcomes. It hopes to make use of the low-carbon, labour intensive and community-based practices, which have existed for decades as central elements to the greening of the agriculture sector.

Small islands like Carriacou and Petite Martinique are especially poised to take advantage of the benefits of sustainable agriculture and to link it with the emerging tourism industry. Organic and other green agricultural practices, which are low in inputs, are widely practiced in the islands, although to date the practices are not certified by the MOCPMA. The potential of this green agriculture to tourism is due to the robust and growing international preference for both raw and processed organic and other green agriculture by the tourists from the islands' traditional tourist markets in Europe and North America. This preference by tourists provides an excellent opportunity to improve income and living conditions in the islands through appropriate linkages between agriculture and tourism.

While agriculture has experienced decline, fisheries have grown over the past 25 years due to the introduction of long-line fishing. As is typical of many small islands, marine and coastal resources are critical to the economy of Carriacou and Petite Martinique, their food security and their cultures. The sustainable use of the marine resources is one of the primary tools to eradicate poverty in the islands and as such the management of ocean resources for economic development is an integral component to the islands' efforts in developing a green economy.

7.2 Land Use and Management

7.2.1 Land Tenure

The value of land in the islands has increased as it is recognized that land is a finite and dwindling resource. The price of land has moved from $200 per acre in the 1960s to $2500 per acre in the 1970s to a current high of $800,000 per acre. During the period of slavery, Carriacou was divided into 46 estates ranging in size from the modest four hectares of Monsieur Belmar, to 283 hectares of Dumfries (Slade, 1984). In Petite Martinique there were two estates. Since the demise of the plantation economy, these estates have been continuously divided into small plots. In 1793 there were 23 estates (Grenada Action Forum, 2011). Today, there are more than 7,354 individual plots of land (Carriacou Inland Revenue Department, 2012). In many cases plots have become too small to be economically viable for use in crop production or livestock rearing. The common law system of land ownership and land tenure in the islands has not changed for over two hundred years. Hence it is not uncommon for family-owned undivided lands to be vested in the name of an ancestral family member who had died in the 1850s. The current situation relating to land property rights has negatively affected the optimal use of lands on the islands. For example, family land disputes often result in lands being left abandoned. In other cases, users of the lands are not highly motivated to utilize the land in a sustainable manner due to uncertainty in ownership. The complexity of land property rights and the extensive subdivision of land are restricting the full realization of the potential productivity of the land. This situation has been observed in other small islands (Asian Development Bank, 1998).

The second element of land tenure relates to state owned lands. In Petite Martinique all lands are owned by private individuals and the church. In Carriacou the government owns three agricultural stations which are located at Limliar, Belair and Dumfries with acreages of 40, 15 and 57 hectares, respectively. In addition, government owns 90 hectares of forest reserves in various locations on Carriacou and has declared similar acreage of privately owned lands for the same purpose. The Carriacou Land Settlement and Development Board is a body charged with the responsibility for the management and distribution of government lands, but no such policy and authority are established for private land development.

7.2.2 Land Use

Carriacou has very fertile soils of volcanic origin which are distributed widely and are the basis for a strong green agriculture sector. There is no existing official land use policy governing sustainable use and development of land. Nonetheless, the MOCPMA follows the recommendation of the Carriacou and Petite Martinique Integrated Physical Development and Environmental Management Plan (Anon, 1998) in the absence of any formal policy. Discussions are currently being held on developing a land policy that would facilitate sustainable land use and a green economy. Land use in Carriacou has changed significantly over the past 200 years. The current land use is shown in the land use map (Figure 7.1).

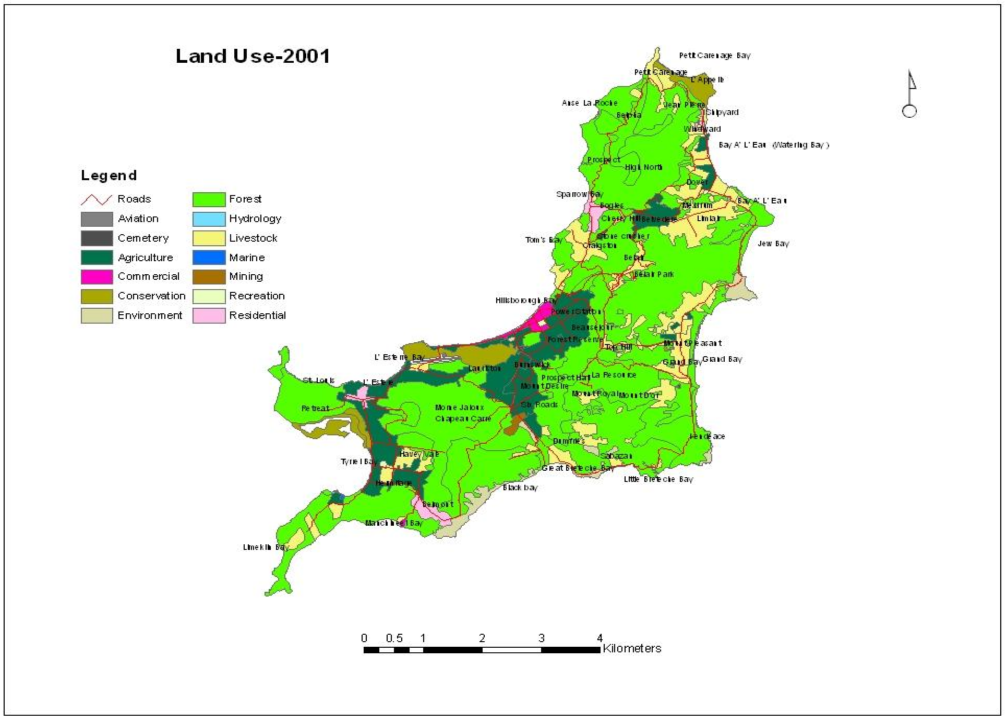

Figure 7.1: Land use mapping of Carriacou in 2001

Approximately 17% of all lands is registered for agricultural purposes in Carriacou and is used for crop and livestock production (Carriacou Inland Revenue Department, 2012). During the past 20 years there has been a steady decline in available agriculture lands. This decline was largely due to a growing construction industry fuelled by an increasing number of citizens returning from overseas who are building retirement homes but are also raising land property rights issues. The repossession of lands by returning citizens further constrains the utilization of some unused lands as there is uncertainty in the status of the land while the owners remain abroad. This impact on the use of land resources is very complex and sensitive to address as the construction sector accounts for a significant portion of employment in Carriacou and Petite Martinique.

Figure 7.2: Severe soil erosion at Belvue

Other concerns in land use relate to prolonged land degradation from runoff water and poor agricultural practices over decades, as is seen in the Belvue area (Figure 7.2), overgrazing, and coastal erosion from rising sea levels. Land degradation from overgrazing (Figure 7.3) is due to overstocking as a result of the large number of stray animals. Based on the 1995 agricultural census, Peters (2003) estimated the livestock population in Carriacou to be approximately 7,200, an equivalent of 2,444 Tropical Cattle Units (TCU) based on Pagot’s methodology (Pagot, 1992). Assuming all the current agricultural lands were used by livestock, the stocking rate of 0.3 ha/TUC indicates overgrazing. These concerns, however, can be addressed by adequate land use policy and education in proper land practices. Such land use policies must be grounded in an integrated approach to solving the problems.

Figure 7.3: Erosion on a sheep farm due to overstocking

7.3 Agriculture Water

Water, which is necessary for agriculture and food security, also determines and influences any form of sustainable development in a country. The earliest form of irrigation in Carriacou was the use of channels which were established in the late 1700's to direct rainwater from the hills for agriculture (Howard, 1950). Today, while agriculture is primarily rain-fed, water from rainwater harvesting ponds and tanks and from shallow dug wells supplement rainfall in some cases.

During the dry season these water sources are heavily relied upon for the sustenance of agriculture and food security. These sources are further burdened by the demand for water during this period for domestic and construction purposes. This is a serious challenge as all the sectors are important, and hence there is a need for a logical and sustainable use adoption strategy to utilize water especially during the dry season. Agriculture and food security are also affected by limitations in accessing and distributing water from these sources.

Irrigated agriculture is largely undeveloped in Carriacou and Petite Martinique. The irrigation potential has not been quantified due to the lack of readily available data. Less than one hectare of agriculture is under organized irrigation systems. As water for irrigation is generally scarce, particularly during the dry season, micro-irrigation and drip irrigation holds some potential. Overhead sprinkler irrigation is not attractive as water wastage can be high. Crops grown under irrigation are mainly vegetables. On mainland Grenada, the costs for sprinkler and micro-irrigation systems are 6,200

Figure 7.4: Small scale irrigation using RWH

US$/ha and 8,700 US$/ha, respectively (FAO, 2000). The costs of these systems in Carriacou could be 15% to 20% higher.

The current irrigation practice by most producers involves the pumping of water from rainwater ponds and cisterns or the trucking of water to the farm (Figure 7.4). Due to the small scale of operation, the practice is expensive. There is an urgent need to properly assess the potential of irrigation and to develop management strategies for its adequate application towards sustainable agriculture and food security.

Droughts significantly impact crop and livestock production in the islands. In Carriacou and Petite Martinique livestock production experienced 20% and 40% losses, respectively, due to the droughts associated with El Nino in 1983 and 1992 (UNFCCC, 2000). The impact of the 2009/10 drought on livestock production was not quantified. During droughts, farmers are forced to obtain local fodder, purchase concentrates, or free their animals to forage in the villages and forests. Other impacts of the drought were a drop in poultry productivity, premature lambing in the case of small stocks and increased incidents of dog attacks on small ruminants. The greatest livestock losses were in cattle which often got stuck at dried out ponds and water holes (Figure 7.5).

Figure 7.5: Cattle at Belair pond unable to reach drinking water (2009)

7.4 Crop Production

Crop production is mainly at the subsistence level. There is a diverse variety of crops cultivated yearly to meet subsistence and commercial demands. The main crops are corn, pigeon peas, watermelon, pumpkin, cantaloupe, ground provisions, bananas, plantains, bluggoe and vegetable (tomatoes, lettuce, cabbage, seasonings, celery and peppers). Cultivation, which is seasonal, is generally rain-fed and is practiced throughout the island and in almost every home. More than 50% of crops produced is consumed locally, while some are sold to mainland Grenada and to the Grenadine Islands. While routine data on production are not collected, there is anecdotal evidence that a wider variety of crops is being cultivated for the last 10 years, especially increased banana production. The potential for increasing the volume of staple crops like corn, peas and beans depends on adequate land policy, improving the availability of water for agriculture, recruiting more youths into the sector and improving access to financing.

7.5 Livestock Production

The livestock industry in Carriacou grew during the 1960s and 1970s. This coincided with mass migration of a significant portion of the working population and the decline in the production of limes and cotton due to low prices. Consequently crop lands that became abandoned were converted to be used for livestock production. Many of the new livestock farmers, however, were landless. Based on the 1995 agricultural census, 11%, 13% and 12% of cattle, sheep and goats, respectively, are owned by landless farmers while 35%, 48% and 46% of cattle, sheep and goats, respectively, are reared by persons having less than half an acre of land (Peters, 2002).

Livestock rearing was mainly carried out by the children in the household with each child having responsibility for five to ten sheep and or goats. There was a good market for live animals in Trinidad and Tobago and Martinique from the 1960s to 1980s. New breeds were introduced during this period and Carriacou ultimately developed a reputation of producing some of the best quality livestock (black belly sheep and red pole cattle) in the region. Currently, the government is using this advantage of having good breeds of livestock in developing Carriacou as a centre of excellence in livestock production and is introducing better breeds and focusing on small ruminants. Poultry production is done on a very small scale with households rearing up to a few dozen heads of chicken. These small operations result in high cost of production, making the local product uncompetitive in comparison to cheaper imports.

The livestock industry is vulnerable to natural disasters such as droughts and hurricanes but, being small, is able to recover quickly from the impacts of natural disasters. During droughts up to 40% of animals could be lost, while hurricanes could completely wipe out the livestock infrastructure. The industry also suffers losses through predial larceny and dog predation.

Despite the recent progress made in expanding the livestock industry, greater emphasis on aligning the industry on a green path (through improved marketing, capacity building, easier access to investment funding and improved infrastructure such as the development of abattoir and cold storage facilities) can have positive effects on food security. These activities, which can provide the necessary enabling environment, must be supported by adequate government policies.

7.6 Fisheries

The fishing industry has grown through the 1990s with the adoption of new ideas and techniques. Notwithstanding the negative impacts from climatic conditions in the past 20 years, the industry has shown great resilience and can be considered to be stable. Nonetheless, there are signs of declining levels of fish stocks and depletion of other forms of marine life such as coral reefs. There are various types of fishing methods being practiced, like the traditional bottom line, fish pots, scene fishing, nets, spare fishing and most recently long fishing. The main investments and modernization of this sector are concentrated in Petite Martinique, while some Carriacou fishermen are still practicing the traditional type of fishing. Within the past 10 years Petite Martinique has moved from about two long line fishing vessels to approximately 40 vessels, with indication that the number is expected to increase in 2012. Most of the long lines fishing vessels are based on mainland Grenada. The main export is yellow fin tuna which is shipped to the

Unites States. Fresh fish is shipped from Carriacou to French Martinique almost every week. This important market, which started in 1979, is supported by artesian fishers and is an essential contributor to the local economy and livelihoods for various communities. Figure 7.6 shows the production of artesian fisheries over the past six years.

The Fisheries Division of the MOCPMA has implemented a number of laws and regulations to ensure proper use of the resources and sustainable development of the sector. There are closed seasons for various species of fish and for some time the harvesting of in sea urchins was prohibited due to earlier over-exploitation of the species. The Fisheries Division recently commissioned its first Marine Protected Area (MPA) in Carriacou, called the Sandy Island Oyster Bed MPA, (SIOBMPA). The division has also continued to focus heavily on training fishermen and other stakeholders, developing and improving local fish markets to meet the requirements of the European Union, which is the islands' main fish export market for artesian fisheries. The main challenge for artesian fishermen relates to adequately responding to gluts due to above average catches or limited external markets. Little fish processing is carried out and hence there is an opportunity for increased fish processing using energy efficient technology.

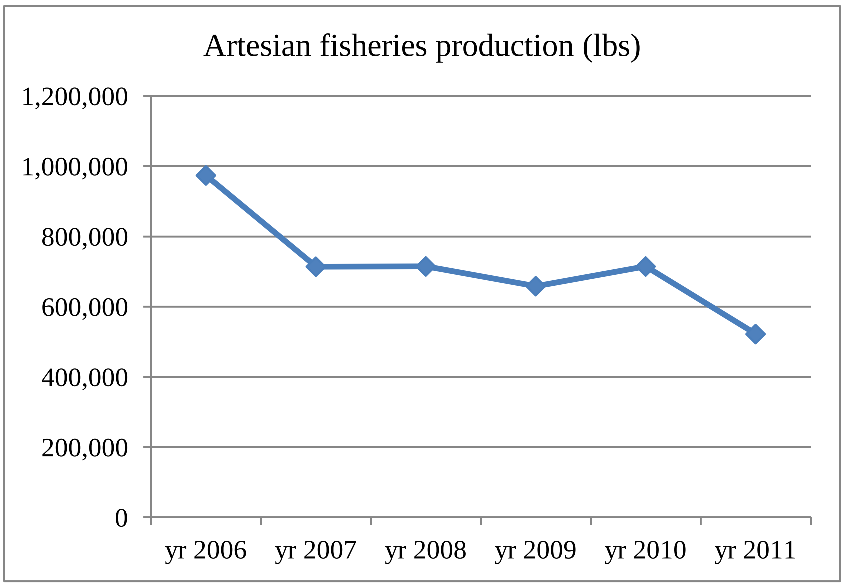

Figure 7.6: Production of artesian fisheries

7.7 Agricultural Policy

National development objectives, plans and procedures and successful outcomes are significantly influenced by adequate and effective policy guidelines. After the devastation of the agriculture sector in 2004 and 2005 by hurricanes Ivan and Emily, respectively, the Government undertook the initiative to develop an agriculture policy to guide the reconstruction and recovery process. The 2007 policy has not been implemented in Carriacou and Petite Martinique. A review of the document shows that Carriacou and Petite Martinique were not adequately considered, hence the main issues specifically for Carriacou and Petite Martinique are not addressed. The document does not address water for agriculture, land management or the livestock production advantage that exists in Carriacou. There is, therefore, the need to develop an agriculture policy for

Carriacou and Petite Martinique that recognizes the arid-type conditions on the islands. This policy should have an underpinning philosophy of sustainable agriculture and a green economy. Specifically, the Belair Agricultural Station can be expanded to support farmers by producing planting material for distributing to farmers in order to sustain a reliable crop production sub-sector. In addition, there is an avenue for the development of other subsectors like agro-forestry and agro-processing. Although the forestry sector is small, if properly integrated, it can contribute to a green economy by supplying indigenous timber for boat-building and furniture. This green economy would provide an opportunity to incorporate solar energy units on future agriculture structures, such as milking parlors, sheep and goat units, abattoir and improvements to existing facilities like our fish market centres.

7.8 Conclusions and Recommendations

Substantial gains in agricultural productivity can be realized through investment, innovation, and effective policy. However, realizing these gains will require an exceptional level of collaboration among stakeholders in the agricultural value chain, including the Government, companies, entrepreneurs and civil-society organizations, farmers and consumers. The development of a green agriculture in Carriacou and Petite Martinique requires adequate agriculture and land policies that promote the use of efficient and alternative energy sources. Ideally, this requires a holistic and integrated approach to development where backward and forward linkages can be established between sub-sectors of the islands' economy.

Table 7.1: SWOT Analysis

Strengths	**Weaknesses**
• Practices some aspects of green economy approaches • An ideal platform and attributes for any sustainable development initiative • Good agricultural resource base in small ruminant livestock production	• Reduced planning and development for agriculture by the Ministry • Some poor practices are deeply rooted and may be difficult to remove • Lack of appropriate funding avenues • Inadequate water availability, accessibility and distribution for agriculture production
Opportunities	**Threats**
• Agro-processing and value added products as diversified alternatives • Absorbing, adapting and diffusing green technologies into agriculture • Integration of agriculture and ecotourism sectors for sustainable resource use and development • Integrate solar use in fishing and agricultural sectors such as pumping units for irrigation systems	• High and increasing cost of production as a result of labour and input supplies • Aging farming population • Pest and diseases (pink mealy bug, fruit fly, mango seed weevil) • Stray livestock; "leggo season" • Land degradation due to drought, erosion, accelerated sea level rise and climate change occurrences • Dog predation

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8. Ecotourism

8.1 Introduction

Small island developing states (SIDS) in the Caribbean are prime tourism destinations, with much intrinsic natural beauty and diverse activities. While the uniqueness of the islands is attractive to tourists, SIDS are very vulnerable to anthropogenic influences putting pressure on natural resources. Some SIDS in the Caribbean have developed their tourism industry to ensure top quality infrastructure and services for their visitors without taking into consideration sufficient societal an environmental values and sustainability standards. Tourist activities and the physical development that caters to the tourism industry can negatively impact the environment by putting strain on the limited natural resources of the islands. Tourism management is essential to preventing environmental degradation while pursuing economic growth and developmental goals.

Expansion of the tourism industry should be part of a wider sustainable development strategy, compatible with effective environmental conservation, and should ensure that the local community acquires an equitable share in the benefits. Tourism should be environmentally sustainable, economically viable and socially equitable (WTO, 1999). These three aims are specifically upheld by ecotourism, which is defined by the International Ecotourism Society as "responsible travel to natural areas that conserves the environment and sustains the well-being of local people" (TIES, 1990). Ecotourism is a non-consumptive use of nature and part of an appropriate development strategy to conserve the environment while improving the welfare of local people (Koens, Dieperink, & Miranda, 2009). Tourism demand for resources, such as land, water, energy, and food, may compete with the needs of local people, leading to social inequality and injustice (UNCSD, 1999). Community-based ecotourism therefore focuses on the involvement of the local community in its development to ensure that benefits remain within the community (WWF, 2001). Community-based tourism is a development strategy by which environmental, social and economic needs of local communities are met by means of opportunities relayed by the industry (Goodwin & Santilli, 2009).

In SIDS, a comprehensive and integrated approach to community-based ecotourism can be a crucial component for sustainable development and poverty eradication. If appropriately developed, tourism can raise awareness of the value of environmental assets, contribute to the creation of protected areas through financial contributions and improve environmental infrastructure with appropriate green practices, all in support of the creation of a green economy.

SIDS in the Caribbean with limited funds may prioritize management in a way more favorable for businesses but less favorable for the environment. These islands, with their fragile ecosystems, are better suited to small scale ecotourism which would be less taxing on the environment. With the increasing popularity of eco-heritage and nature tourism, Grenada has looked to this form of specialty tourism as a way of diversifying its tourism product. This is recognized in the islands' Tourism master plan (Government of Grenada, 2000).

8.2 Current Tourism Situation

The Tourism Strategic Plan of Grenada recognizes the potential for ecotourism to diversify the tourism industry (Government of Grenada, 2011). The evolving structure of the Grenadian economy has moved from high dependency on agriculture to high dependency on services. Recently the government has emphasized economic transformation including an economic strategy based on sustainable economic growth, improved disaster preparedness, human resource development and improved environmental management. The five main sectors of the strategy of economic transformation are health and education, tourism and hospitality services, agro-business, energy development and information communication technology (Government of Grenada, 2011).

The services sector in Carriacou and Petite Martinique is dominated by tourism and supporting services. Tourism revenue is mainly derived from visitors from other regional islands, and the main attractions are the four festive seasons: carnival in February, string band and maroon festival in May, regattas in August and the Parang festival in December (MOCPMA, 2011).

The current tourism industry on the islands is relatively untapped, leaving much room for expansion with sustainable development techniques. As part of the Grenadines, the tropical marine climate of Carriacou and Petite Martinique attracts tourists year-round, except for hurricane season. The islands are very vulnerable to natural and anthropogenic influences and have fragile ecosystems that are better suited for small-scale ecotourism that would be less detrimental. Through analysis and deliberation, it has been found that Carriacou and Petite Martinique need to introduce environmental regulations to protect sea resources before expanding their tourism industry, while improving the existing attractions and infrastructure. Five priority areas identified for the tourism industry expansion are customer service quality, marketing promotion, product development, regulatory environment, and air transport (Government of Grenada, 2011). Development of the ecotourism industry in Carriacou and Petite Martinique needs to integrate environmental conservation and community support as essential parts of tourism management.

In 2011 the total number of rooms registered with the local Tourist Board was 186, with maximum accommodation of 283 beds. There are other small and occasional operators who use private homes and generally market themselves through word of mouth. Many of the tourist accommodations use solar water heating and are designed for natural ventilation in order to avoid excessive use of air conditioning.

8.3 Plans for Future Development

Carriacou and Petite Martinique have been facing increased emigration due to limited job opportunities, and thus population has declined. Developing ecotourism will create employment opportunities and simultaneously facilitate local education, making the islands more attractive to the local youth. Small local businesses can ensure that the diaspora has the possibility to actively provide inputs and contribute to the development. Further economic opportunities are in food and agriculture, construction, water system management, waste management, services sector, hospitality sector, activities sector, transportation sector, and vending of local products and souvenirs.

8.4 Limitations

8.4.1 Energy and Water Limitations

Integrated energy and water systems are necessary for tourism facilities that will be separate from and not infringe upon local necessities through appropriate management and maintenance. Water and energy system viability, wastewater treatment and disposal of waste while minimizing external costs on the environment are indispensible in areas of physical tourism facility development. There is a need to use ecological materials and installation of renewable sources of energy systems in all new buildings and new tourism construction as well as installation of solar and wind power in public work projects of communities where tourism will be introduced (UNCSD, 1999).

Energy and water infrastructures have to be built in an integrated manner with the promotion of the use of alternative sources of energy. Renewable energy resources can provide essential support to fulfilling the islands' current and increased water demand that comes along with developing ecotourism. Pumping water powered by solar and wind-generated electricity can replace expensive and ineffective water transportation. The combination of photovoltaic and wind turbines can enhance security of supply of electricity and water. There is a need for reliable sources and reserves of water and energy in case of disaster situations, such as droughts or tropical storms, and renewable energy can provide essential services for locals and ensure appropriate services for visitors, such as lighting, pumping water, heating and cooling, refrigerating, and communication facilities.

Water system quality is an essential part of tourism development. While SIDS in the Caribbean are faced with less frequent but more extreme storms during hurricane season, they also experience extended dry periods and extreme drought conditions during the dry season. To facilitate the growth of tourism industry sustainably, it is necessary to improve the water supplies to meet the needs of the tourists while not infringing on the clean water supplies of the local community and denying their needs.

Carriacou and Petite Martinique are almost completely reliant on rainwater harvesting with most residences depending on their own rainwater harvesting systems. Communal cisterns have also been installed in public buildings, school hospitals, medical clinics and churches. However, the islands experience low rainfall, only about 100 cm annually, and over 80% of the year goes without rain (MOCPMA, 2011), making it difficult to ensure a sufficient amount of clean water supply for not only locals but also for visitors. Rainwater harvesting development is well advanced in Carriacou and Petite Martinique but will be insufficient to meet demand for water when the tourism industry expands. An integrated water system, using water desalination through alternative energy, can complement rainwater catchment to meet the projected rising demand for clean water.

8.4.2 Waste Treatment Limitations

The tourism industry cannot be developed without an appropriate and efficient wastewater treatment system. Inappropriate waste and wastewater management will be potentially destructive to the islands' ecosystems and the environment. In the long run it can limit land productivity and fertility for agriculture, lower air quality, harm flora and fauna, and contaminate water systems.

Management must ensure the prevention of wastewater disposal into uncontaminated land and water. In Carriacou, small hotels and guesthouses now use septic tank systems for their wastewater disposal (MOCPMA, 2011). Alternative methods of wastewater disposal such as packaged treatment plants could reduce threats posed by inadequate wastewater treatment.

8.5 Opportunities

8.5.1 Marine-Based Ecotourism

Marine-based tourism is a major strength of SIDS in the Caribbean, so it is important to develop tourist attractions while providing the management and technical skills for the local population to control that sector. Carriacou offers diverse diving opportunities; the mangrove habitats, seagrass beds and coral reef systems provide opportunities for marine-based tourism including scuba diving and snorkeling. Sea kayaking between beaches also can be developed as a tourist attraction.

The promotion of Carriacou and Petite Martinique as a yachting centre is seen as a priority, considering that one of the main tourist attractions is the Regatta sailing festival (Government of Grenada, 2011), and this can be done by improving facilities and services such as water, sewage disposal and power at berthing points.

Two critically endangered sea turtle species, the Leatherback and Hawksbill, regularly nest on many of the beaches of Carriacou from March to August (MOCPMA, 2011). Turtle watching during these months is underdeveloped as a tourist attraction yet should be appropriately managed. Although whales are no longer plentiful around Carriacou, there is some opportunity for whale watching. Dolphins are more plentiful and are seen regularly from February to August between Carriacou and Grenada.

Marine Protected Area

Carriacou and Petite Martinique have recognized the value of protecting their natural resources and therefore have put in place some environmental policies that are more specific and advanced than other SIDS. What is now the Marine Protected Area (MPA) had been considered a potential site for a new port prior to investigating the possible negative implications on the environment. The MPA of Sandy Island and the Oyster Bed now has legislation for conservation of the marine environment, Sandy Island, the oyster bed and surrounding mangroves (Figure 8.1).

Development in the MPA and around the island for ecotourism could be very beneficial, such as a beach walk.

Figure 8.1: Oyster beds in Carriacou

Reefs close to shore provide a natural barrier that keeps waves calm during stormy periods and protects the land. In the mid-1950s, a manmade sea wall was constructed much further out from what is now the shoreline for coastal protection purposes. Beach erosion in the area was primarily caused by unmonitored sand mining. Hurricanes Lenny in 2001, Ivan in 2004 and Emily in 2005 raised sea levels, damaging main roads all along the coast (MOCPMA, 2011). Taking temporal changes, weather conditions and extreme storms into consideration, while ecotourism development along the coasts could be very beneficial, precaution must be taken in order to ensure the sustainability of the projects, regardless of natural influences and environmental hazards.

Beaches

On the islands there are a lot of pristine beaches that must be preserved for recreation. To develop those in a sustainable way, lavatory facilities, food pick-up facilities like restaurants and cafés and an easy access to these beaches, such as roads or well marked paths, should be constructed. Beach cleaning and maintenance service programmes should be developed.

Regattas

Regattas are an important part of traditional marine tourism activities. The Regatta Committee of Carriacou hosts the annual Regatta cultural and sporting event for competitors from the Eastern Caribbean and North America (MOCPMA, 2011). The Committee has focused on the local boat-building skills by promoting Regattas. Boats for competition are used for other purposes such as fishing. Carriacou can promote training and the eventual development of the Grenadines School of Seamanship. The possibility of taking part in regattas or simply watching races can be included in tourism activities offered by Carriacou and Petite Martinique. For the last 35 years, the Regatta Committee of Carriacou has hosted the annual Regatta cultural and sporting event for competitors who come from across the Eastern Caribbean and North America.

Navigation and Seamanship

A sailing school to facilitate sailing as a tourist attraction and a navigational school to provide skills and opportunities for youths, in a way to reduce emigration, should be developed. Furthermore Carriacou can be promoted as a source of workers for the shipping and cruise ship industries.

Boat Building and Berthing Facilities

Boat building is a potential industry for the island that can be encouraged and supported by providing training skills for the locals and by promoting the development of a pleasure boat building industry. Moreover, it is necessary to provide support for all levels of fishing, in a way that creates a completely environmentally sound fisheries industry. This would include developing a program that lifts the status of fishermen. Small and medium size fishermen could benefit from locker type facilities for storage of gear and small inexpensive berthing facilities. Promoting the development of a local fleet can be achieved by providing the corresponding enabling environment. A scheme of procuring larger vessels that could be managed locally can be discussed with international partners.

8.5.2 Land Based Ecotourism

Figure 8.2: Belair colonial house

There are many project areas for land-based ecotourism on the islands. The Belair Park, a colonial heritage village now in ruins, was once a beautiful building used for educational and ministerial purposes (Figure 8.2). Through restoration of the magnificent colonial central building, Belair Park can become a tourist attraction and a local community centre and museum. The surrounding park provides the preferred location for the local cultural string band festival, the “Maroon fete”, and with tourism interest it could be developed to host other indigenous music festivals, strengthening local community involvement.

Camp Carriacou

Camp Carriacou, previously a marine biology research centre, was converted into a hotel in the 1970s. Now, the beautiful hillside overlooking the ocean is just a cluster of deteriorated building foundations. If this site could be rebuilt into a marine biology research centre, it would be a great resource for educational tourism. If it could be restored as a high quality hotel, it would attract a lot of luxury/relaxation tourism.

Development of Botanical Garden and Parks

Botanical gardens are ideal sites for educational tourism promoting knowledge of indigenous botany. The development of botanical gardens for educational tourism of indigenous botany is an ideal project worth undertaking. On Carriacou there is a currently unmaintained empty park (Green Area) that used to be a botanical garden created during the British colonialization. The Green Area is located next to a secondary school with 500 students. The Government and the school can collaborate to clean this area in order to create a park including a pond for scientific and educational purposes for the secondary school and recreational fishing. A new plan foresees this Green Area as an eco-activity park incorporating a stage, a playground, tables, benches and activities for families. The government is currently in the process of relocating the Carriacou botanical garden to Belair. In 2011, a spice garden was established. This botanical garden would complement the Belair Park which is used for local festivals like the Maroon and String Band festival. The relic estate house at Belair Park can be refurbished to become a home for the local museum.

A potential botanical garden location is on the Madame Pierre site (50 acres) on Petite Martinique. The Madame Pierre site, which is now suffering from hillside erosion, has the potential to attract tourists as a botanical garden and its rehabilitation into a lush, fertile park can support indigenous plants and trees, preserve biodiversity and foster the conservation of native species.

8.6 Infrastructure Development

Infrastructure and services fulfill tourism needs for sanitation, food provision, lodging, information, transport and safety. The key is to provide services that meet tourism needs while minimizing negative impacts, allowing access to opportunities for understanding, appreciation and enjoyment of the environment (Eagles, McCool, & Haynes, 2002). As tourism grows, additional opportunities are created for investment and development. Tourism induces improvements in public utilities for the local community, such as clean water systems, wastewater systems, land management and improvements in transport infrastructure with upgraded roads, nature trails, airports and public transportation (Kreag, 2001). Slower development provides time for local communities to reassess tourism growth and make beneficial changes while rapid development can depreciate a community's infrastructure, lead to resident dissatisfaction, and increase negative environmental impacts (Kreag, 2001).

There must be appropriate policy implementation prior to tourism industry expansion in order to avoid detrimental effects of construction. Also, in supporting the local community, policies should be put in place to avoid the construction of large internationally renowned chain hotels which contribute a lot of funds for rights to land, yet have their own standards and might not adhere to flexible local policies for water and land protection. Road infrastructure improvements and continuous maintenance are necessary for connections to tourism areas. Beach management and facilities on SIDS in the Caribbean are of vital importance to the attractiveness of the tourism destination, as are the quality of hotels while ensuring the sustainability of the housing with appropriate construction techniques and infrastructure management. Tourists need safety and security in accessibility and reliability of health care services as well as protection from crime. Green standards for buildings must be implemented in policy changes. Tourism facilities need to be built using appropriate construction materials and techniques that are not detrimental to the environment. Standards for urbanization must ensure environmental protection with appropriate land mapping and management by implementing zoning that will recognize the special conditions of Carriacou and Petite Martinique and foster the implementation of the Integrated Physical Development Plan (MOCPMA, 2011).

8.6.1 Transportation

An appropriate action plan for an expanding tourism industry will be to focus on transportation sector improvements. Currently, the Lauriston airport on Carriacou services tourism and there is an Inter-island communication (IIC) ferry service system. To foster IIC and transportation, tax relief incentives need to be set for ferry service providers. Furthermore, adequate infrastructure, a berthing terminal for the inter-island ferry, berthing for tourist and local boats and energy supply need to be provided. Establishing a working group of public boat owners and traders is recommended in order to reduce cargo costs of goods to Carriacou and Petite Martinique.

The Ministry wishes to expand Lauriston Airport capacity to transport more tourists to the islands, exploring the use of seaplanes in providing a more environment friendly solution for increased aircraft traffic. A study to determine the optimal use of the airport needs to be commissioned as airport extension and development are necessary to transport tourists to the islands.

Public bus systems and private taxi systems for visitors to Carriacou and Petite Martinique can be developed which are safe and reliable, running on renewable fuels or electricity. A renewable energy-powered bus or cab system along with improved roads can provide sustainable internal island transportation. All sustainable tourism attractions need roads, rest stops, and environmentally friendly transport with local drivers and tour guides to support the local community.

8.6.2 Standards for Urbanization to Ensure Environmental Protection

Urbanism standards and policies must be implemented to ensure environmental protection. Appropriate land mapping and management can be promoted by implementing zoning. Zoning recognizes the special conditions given on Carriacou and Petite Martinique and fosters the implementation of the Integrated Physical Development Plan. A tribunal led by a judge with experience in land ownership issues is recommended to solve tenure problems. The approach used in valuing Carriacou and Petite Martinique lands needs to be revisited as the current model encourages owners to convert agricultural lands to residential lands.

Appropriate and reliable infrastructure is the groundwork for successful tourism experiences supported by the high quality of the industry. The use of appropriate technologies, construction materials and techniques are essential in ensuring sustainable architecture. Policies should be in place to mandate green standards for buildings, using appropriate construction materials and techniques of construction that are non-detrimental to the ecosystems where tourism facilities will be built. Such construction projects should take into consideration the surrounding air, soil, water systems, plants and animals to minimize possible disruption. Infrastructure development should incorporate such things as resilience to natural hazards and weather-proof facilities that will meet tourism needs with reliable roads and transportation, secure hotels and rest areas, accessible health care facilities, continuity of activities, clean drinking water and food provision. Construction standards might follow the example of the “Caribbean Quality Standards” set for buildings.

8.7 Economic Opportunities

Carriacou and Petite Martinique have been facing increased emigration and thus population decline as educational and job opportunities on the islands are limited. The significant diaspora has impacted the economic development of the islands, and as of 2000 about 50% of the population had migrated (MOCPMA, 2011). Developing ecotourism will create employment opportunities and simultaneously facilitate local education making the island more attractive to the local youth. Small local businesses will ensure that the younger generation has the possibility to actively provide inputs and contribute to the development.

The marine economic opportunities can be expanded upon. Boat building can be a potential industry for the island that must be encouraged and supported by providing training skills for boat building for the locals and by promoting the development of a pleasure boat building industry. It is also necessary to provide support for all levels of fishing in order to create an environmentally sound fisheries industry. Promoting the development of a local fleet can be achieved by providing the corresponding enabling environment. Navigation and seamanship should be supported with the development of a sailing school to facilitate sailing as a tourism attraction and a navigational school to provide skills and opportunities for youths, providing more opportunities to avoid further emigration issues. If the shipping and cruise line industries are going to expand with the growth of tourism, legislation must be in place to restrict the number and limit the detrimental environmental impacts of ships, while supporting job opportunities for local seamen.

8.8 Conclusions

A comprehensive integrated approach to community-based ecotourism is necessary for Carriacou and Petite Martinique. Expanding the previously un-tapped tourism sector will foster economic diversification, employment opportunities, poverty eradication, and provide patterns of sustainable ecotourism development. The islands will experience job creation, greater educational opportunities, economic growth and development, and economic diversification since all sectors of the economy will expand with more tourism, including agriculture and fishing industries, service sectors, construction, transportation, hospitality and hotel management, and small local businesses. The diaspora of the young population leaving Carriacou and Petite Martinique can be reversed and the new generation can start contributing to the development of the local economy.

Expansion of the tourism industry and economic development can take place without environmental degradation only when land management policies are revised and implemented. Environmental policy will need to be reformed to avoid degradation of ecosystems that will be subject to more pressure by tourism. Mismanagement of the tourism industry and inappropriate facility maintenance can lead to possible environmental degradation, pollution, and ecosystem disruption. A fraction of tourism related profits can be used to finance environmental protection and conservation, specifically designating the most vulnerable and fragile ecosystems as protected areas.

Currently there are limited natural water and energy resources. The rainwater harvesting system is advanced in Carriacou and Petite Martinique but will be insufficient to meet demands of extended tourist infrastructures; therefore, a more adequate system must be developed to cater to visitors. Current patterns of energy supply are expensive and unsustainable on Carriacou and Petite Martinique as the islands have to import fossil fuels. Utilization of renewable energy resources, most notably photovoltaic and wind-energy, would provide a more cost effective, more secure and environmentally friendly supply that will satisfy the local and tourism related energy demand. The absence of sufficient water and sanitation polices should be reviewed and facilities at public recreational locations should be constructed without harming the environment and with appropriate wastewater management.

The implementation of local skills and knowledge in all sectors of the economy, in collaboration with international bodies of knowledge and welcoming appropriate technology transfer, will lead to the successful development of a sustainable, community-based ecotourism industry. Adopting a comprehensive and integrated approach that takes all elements of the economy, society and environment into consideration will be the framework for ecotourism success within the context of poverty eradication and sustainable development.

Table 8.1: SWOT Analysis

Strengths	**Weaknesses**
• Pristine beaches • Many areas still undeveloped	• Limited natural water and energy resources • Lack of land management policy: Environmental policy might need to be reformed to avoid degradation of ecosystems. • Absence of water and sanitation policies, toilet facilities at public recreational places • Population leaving Carriacou and Petite Martinique instead of contributing to the development of the local economy
Opportunities	**Threats**
• Expansion of tourism industry and economic development without environmental degradation • Fraction of tourism related profits used to finance environmental protection and conservation • All sectors of the economy will expand with more tourism • Implementation of local skills and knowledge for development	• Mismanagement of tourism industry and inappropriate facility maintenance • Possible environmental degradation, pollution, and ecosystem disruption if tourism industry is not managed correctly • Possible increase in tourism related crime

8.9 Possible Projects

<u>Project 1:</u> BelAir Park (Colonial House / Fete Site)
Aim: *To restore the park as a cultural events centre*
Target: Local businesses, activities, shows
Description: The BelAir park is a cultural heritage site where activities can be held which will attract local and international tourists

<u>Project 2:</u> Green Area
Aim: *To restore the botanical garden in Carriacou as a recreational and educational playground and family park*
Target: Secondary school, family and students
Description: The botanical garden in Carriacou can be restored to be an eco-activity park

<u>Project 3:</u> Botanical Garden
Aim: *To restore Madame Pierre (affected by hillside erosion)*
Target: Botanists, indigenous plant species
Description: The Madame Pierre site can become a botanical garden which will attract tourists interested in botany and locals interested in preserving their local plant species

<u>Project 4:</u> Beaches
Aim: *To construct beach tourism facilities*
Target: Beach activities, local businesses
Description: Lavatory facilities and stores along the beach will attract business from tourists

<u>Project 5:</u> Hotels
Aim: *To build sustainable housing for visitors*
Target: Local construction industry, services
Description: In the form of small hotels, hostels, cabins / huts, small-scale tourism housing can meet demand while not having drastic negative effects on the surrounding environment, while managed and maintained appropriately

<u>Project 6:</u> Adventure Tourism – Land and Water Activities
Aim: *To provide services and activities for tourists*
Target: Local businesses in water sports, sailing, hiking / touring the land, etc.
Description: Local entrepreneurs can start businesses in managing activities for tourists

<u>Project 7:</u> Educational Tourism
Aim: *To provide activities to educate visitors*
Target: Local and international students, professors, local experts
Description: Give visitors an opportunity for local knowledge exchange

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9. Environmental Sustainability

9.1 Introduction

Climate change impacts, including sea level rise, are some of the most pressing concerns for the governments of Small Island Developing States (SIDS). Among the issues that must be addressed is the interconnection between coastal areas, particularly beaches, and economic development.

Experts from Grenada have identified a number of priority areas for adaptation to the potential impacts from climate change. Critical areas selected for assessment include: hillside erosion, beach erosion, water management and the need to green the economy with integrated systems and renewable energy technologies.

9.2 Background

Coastal areas and beaches are central to the economic and social development of most SIDS in the Caribbean. For example, in Grenada's tourism driven economy, the activities associated with the tourism industry are mainly concentrated in the southwest region, where the country's idyllic beaches are located. In Carriacou and Petite Martinique, where the tourism products are less developed, beaches are also central to development and growth. The high vulnerability of the tourism sector, for which most activities are located on the coastline, is well documented (Government of Grenada, 2000). In the late 2000s, a workshop was held entitled "Wise Coastal Practices for Beach Management in Carriacou and Petite Martinique" that highlighted many issues related to the management of beaches on these islands. Since that time there have been some positive outcomes such as the improved cleanliness of the beaches, a reduction in sand mining, installation of toilet facilities on one beach, and the establishment of a marine protected area which includes some of the important beaches on the island. Nonetheless, there is need for continuing efforts to optimize the use of all the beaches on the islands.

Since the early 1980s, the impacts of natural processes and human influences on coastal areas and beaches in the Eastern Caribbean have become more severe and costly. During the 1990s, the "UN Agenda 21" in 1992 and the follow-up "Declaration of Barbados and the Programme of Action for the Sustainable Development of Small Island Developing States (SIDS)" in 1994 highlighted the challenges of SIDS and the environmental deterioration of the coastal areas. Since then, there has been sustained interest in the equitable and sustainable management of coastal resources of small islands. This has resulted in these resources being explored and promoted through a series of events and ongoing field project activities.

Against a background of mounting shoreline erosion, increased hurricane frequency, rising sea levels and economic dependency on coastal tourism, the small islands of the Caribbean face a major dilemma of how to maintain and expand their coastal tourism industries while simultaneously conserving their beaches for both island residents and tourists (Cambers, 2003). This would require continuous analysis of data on historic and current coastal and beach changes. While extensive historic data is not available, several interventions through projects like "Coast and Beach Stability in the Eastern Caribbean (COSALC) Project" have been undertaken to highlight the current challenges in managing coastal areas and to educate the wider population on best practices. More specifically, these projects were aimed at developing an in-country capability so that island states can assess and manage their beach resources within a framework of integrated coastal management (Cambers, 2003).

Past experiences suggest that it is usually difficult to gain the support of national politicians and senior administrators in giving high priority to environmental concerns or in becoming committed to coastal development and management issues. The current administration in Carriacou has adopted all the key elements of the "The Integrated Physical Development and Environmental Management Plan for Carriacou and Petite Martinique" (Anon, 1998) into its "Integrated Development Framework for Carriacou and Petite Martinique" (Peters, Prime, & Davidson, 2007). In Carriacou and Petite Martinique, a window of opportunity presently exists as senior government personnel are showing a genuine interest in engaging in sustainable development activities. The window of opportunity should not be missed.

Beaches are continuously changing – from day to day, month to month and year to year. Over long periods beaches may accrete or erode. Beach monitoring must be driven by the need to provide appropriate data for coastal and beach management. There are several stages in a monitoring process:

- Understanding the past: short term fluctuations and long term trends in beach evolution need to be identified to understand the present and predict the future.
- Identifying potential problems: monitoring allows significant changes to be identified in advance so that a reasoned response can be developed and implemented. For example, beach erosion may lead to damage to important tourism facilities.
- Projecting the future: past and recent developments along the shoreline are a guide to the future evolution.
- Monitoring management operations: feedback on beach response to interventions will guide future management, possibly suggesting refinements or alternatives.

Given the importance of some of the coastal erosion problems in Carriacou and Petite Martinique, a beach monitoring system that would incorporate the strengthening of the local capacity in managing its beach resources is necessary. This monitoring programme may include the following activities:

(1) Designing a time-series data collection programme for the main areas of beach erosion in Carriacou and Petite Martinique;
(2) Proposing an implementation plan with participation of civil society and students from local schools for a period of five years or more; and
(3) Identifying basic equipment and monitoring systems for measuring all relevant parameters.

9.3 Review of Coastal Erosion in Carriacou and Petite Martinique

9.3.1 Beaches in Carriacou and Petite Martinique

Sandy beaches are widespread along the coast of Grenada and its dependencies. Carriacou has many beautiful beaches, which are key natural resources for the development of tourism. Besides their importance for tourism, the beaches are highly valued by island residents for relaxation, sports and simple enjoyment. They represent an important part of islanders' natural heritage. The beaches also provide areas for fish landing sites and fulfill the role of flexible barriers protecting valuable land and infrastructure during storms and hurricanes (Cambers, 2003).

Typically these beaches are located in small pockets within bays and have active profile widths varying from 14 m to 45 m. In some cases, sand deposits extend up to 150 m landward from the high watermark. Most beaches have profiles of an exponential form with declining offshore gradient (Dean, 1991). The beaches tend to be flat (mean slope of 7.5 degrees in Carriacou) with no well-defined dune system. Dune heights are generally less than 1.5 m, which is typical for the Caribbean where dunes range from very low formations of 0.3-0.6 m to large hills of sand up to 6 m. Where dune systems existed, developments on some beaches have destroyed them. Sand texture and colour vary from fine to coarse and black-grey to golden-white, respectively.

Many of the beaches on Carriacou are located on the Caribbean Sea side of the island. The main beaches are at Harvey Vale, Paradise, Lauriston, Anse la Roche, Petite Carenage-Lillitte, Windward, Mt. Pleasant, Grand Bay, Sabazan, Black Bay and Manchineel Bay. Harvey Vale Beach, which is found within the Tyrrel Bay, has white-gold fine-grain textured sand. The beach is well protected by the Southwest and Jack Iron point peninsulas. Similarly, Paradise and Lauriston beaches are sheltered by head rocks at Point Cistern and Lauriston Point, respectively. These two beaches are flat. Eroded material from these two beaches drifts towards Sandy Island which is about 1 km from the shore. Hillsborough Beach is less well protected than the beaches at Harvey Vale, Paradise or Lauriston and is particularly vulnerable to the Northern Atlantic winter induced storm surges (winter surges). Bogles Beach is unprotected and consists of very coarse beach materials. At Bogles, the beach is steeper than the other beaches and is less vulnerable to tropical storms and winter surges. Petite Carenage-Lillette is the only beach on the northern side of the island. This beach has been relatively undisturbed by human activity, partly because of inaccessibility. Material for this beach is supplied from dead corals from the Eastern Coast reefs. The beaches at Windward and along Watering Bay which lie along the rougher Atlantic Coast are comprised of predominantly fine black sands with occasional pockets of coarser white sand and are well protected by coral reefs.

Estimates of the lengths of the man-made structures within the beach berm obtained from a comparison of aerial photographs of 1992 and field observations in 2000 show that up to 80% of some beaches have developments that restrict the natural coastal processes (Peters, 2001). Along the most popular beaches, tourism and coastal protective infrastructure influence the natural beach processes. A few beaches have not been developed and provide an opportunity for planned development that can ensure sustainability. An example is the Anse la Roche Beach (Figure 9.1), which due to its remoteness, difficult access and good natural protection has changed little over the years.

Sandy Island (Figure 9.2) is important for tourism in Carriacou and has become a favored site for yachters, shore parties from cruise ships and scuba divers. However, there are growing concerns relating to large losses of the islands' beaches due to erosion during severe storms, and about the degradation of the island and the surrounding reefs, which is believed to be associated with the intensified tourism traffic.

Figure 9.1: Anse La Roche Beach – undeveloped due to remoteness

9.3.2 Beach Erosion

Being small islands, Carriacou and Petite Martinique are naturally subjected to coastal erosion, including beach erosion. Such erosion is a global problem and a complex phenomenon, which is influenced by natural, physical and morphological processes. The natural forces that are pertinent to Carriacou and Petite Martinique include hurricanes and tropical storms, high waves and sea-level rise. Hurricanes and tropical storms, occurring between June and November, cause dramatic beach changes usually resulting in serious beach erosion. High waves between November and April, resulting from the winter storms in the North Atlantic Ocean, are known as swell waves or locally as "ground seas". Sea-level rise, which is a long-term factor taking place very slowly over decades, causes shorelines to retreat inland.

Figure 9.2: Sandy Island, Carriacou – a 1995 photo (before major erosion)

Already the potential impact from the intensification of hurricanes and the associated storm surges is being observed. Moreover, within the past 15 years storm surges have been responsible for irreparable damage to some beaches in Carriacou and Petite Martinique. The impact of high waves (ground seas) that occurred during the North Atlantic winter was seen during Hurricane Lenny in 1999 (winter storm surges) when the highest recorded waves were experienced on the Hillsborough Beach (Figure 9.3). Typically, the damages from high waves are far reaching as the sea defense walls and roads are washed away. Examples of such extreme damages were seen at Harvey Vale after Hurricane Lenny where the beach lost about 6 m of its width and the adjacent roadway collapsed. Sandy Island lost over 50% of its area during Hurricane Ivan (Government of

Grenada, 2000). In many cases, the beaches recover after many years if there are no additional major storm events during that period. However, these beaches often do not recover to the pre-damage conditions.

Figure 9.3: The effects of storm surges on Hillsborough beach 1999

The high costs of infrastructure reconstruction are indicative of the extent of the damage. In the case of storm surges during Hurricane Lenny (Figure 9.4), coastal damages in Grenada were estimated at US$93.4 million or about 27% of its GDP (USAID/J-CAR, 2000). The erosion due to these natural processes can be exacerbated by human activities such as sand mining, removal of shoreline trees and other vegetation, pollution and destruction of coral reefs, or the establishment of inappropriate developments along the coast, particularly on beaches. Such situations have been observed in both Carriacou and Petite Martinique. At Tibeau, Petite Carenage, Mt. Pleasant, Grand Bay, Sabazan and Lauriston, where sand mining was practiced, the environmental impacts have been noticeable. At Tibeau, the site of the oldest cemetery, graves have been disappearing at an alarming rate (see Figure 9.5). At Grand Bay and Sabazan, Fitzpatrick *et. al* (2006) reported that both sites are eroding at an average rate of approximately 1 m per year along the lengths of their coastal profiles. This is particularly worrying as these sites represent the largest and archaeologically richest sites on the island and in the region (Fitzpatrick, et al., 2006). The indications are that the loss of historical artifacts due to natural and human causes is catastrophic and that these sites are likely to be completely destroyed within the next two decades if erosion continues at its present rate.

Figure 9.4: Beach erosion at Harvey Vale due to storm surges generated by Hurricane Lenny in 1999 leading to the collapse of a main roadway

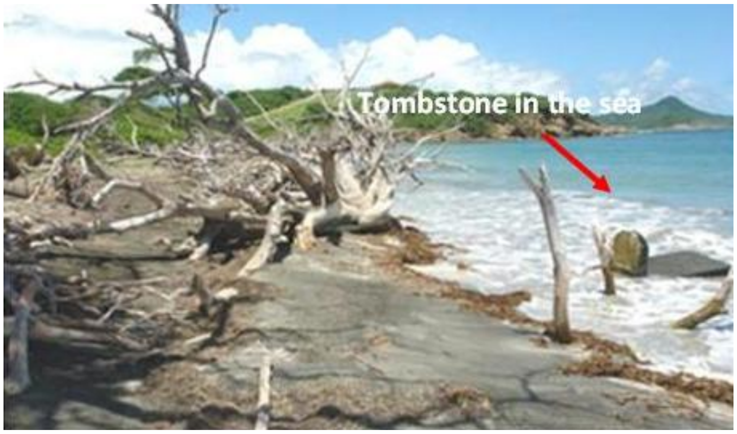

Figure 9.5: Severe beach erosion at Tibeau, where sand mining was practiced (a 2010 photo)

Recently, the Carriacou and Petite Martinique communities have become aware of the long-term environmental consequences of coastal erosion and are calling for action. For example, in 2007 a delegation from severely eroded coastal areas made representation to the Minister of Carriacou and Petite Martinique Affairs for corrective action in the case of sand mining (The Grenada Today News Paper, 2007).

Today, climate change and sea level rise pose an additional threat to the stability of coastal areas. Depending on the geomorphic setting there are two distinct effects of sea level rise on beach erosion (Stive, et al., 1990). Where there are no inlets or barriers to the sandy beaches, rising water upsets the equilibrium of the beach volume and profile, and erosion provides a profile adjustment, which is the “Brunn rule”. On coasts interrupted by inlets and bays, sea level rise causes additional erosion of the shoreline as the inlets and bays act as an additional sink for eroded sands. This is the indirect effect of sea level rise according to Stive *et al.* (1990). There have been some efforts to address the coastal erosion problem. In 2006, a project funded by the Global Environment Facility (GEF) implemented small grants in Carriacou to promote soil conservation practices, to slow or prevent erosion and protect existing coastal habitats (particularly mangroves and sea turtle nesting beaches) by establishing terrestrial and coastal vegetation within critical areas (UNDP, 2006).

There are two main beaches on the western side of Petite Martinique at Sanchez and Mang. Since the 1960s, the beach at Sanchez, which is the location of all major public facilities, has been subjected to continuous natural and man-induced erosion. The extent of this erosion over the past 50 years can be estimated by superimposing the approximate shoreline in the 1960s based on older photographs and islanders’ recollections. When this is done, Figure 9.6 illustrates the erosion history at Sanchez. All the area between the current shoreline and the superimposed shoreline was sufficient to accommodate a thriving boat building industry which recorded some of the largest schooners built in the southern Caribbean. At the point close to the current public jetty, at least 40 m of coastline has been lost in the last 50 years. The erosion at the Sanchez site was exacerbated by the removal of trees along the coastline. Recently, the erosion has become a major concern for the residents on the island.

Figure 9.6: Erosion at Sanchez, showing the reconstructed 1960s’ shoreline (in black)

The coastal erosion in Petite Martinique is now reaching critical proportions as the only community playing field on the island has almost disappeared. Furthermore, more than 30% of the playing field has disappeared since Hurricane Lenny in 1999 (Figure 9.7). Remedial and restorative work in the area of the playing field using groins has been estimated to cost approximately US$1.0 million. The only road linking the main activities centre at Sanchez and Madame Pierre is threatened with collapsing which would create a virtual division between the two villages. Based on anecdotal evidence, along this coastal road about 10 meters of the coast has been lost since the 1980s. In the absence of mitigation the road could collapse in a few years.

Figure 9.7: The only playing field in Petite Martinique which has undergone rapid coastal erosion is further threatened by climate change and sea level rise

9.3.3 Mitigation of Beach and Coastal Erosion in Carriacou and Petite Martinique

Mitigating beach and coastal erosion in the islands has been approached by two methods. Hard engineering methods (Figure 9.8) are performed by the Government and are expensive. In some cases rehabilitation work is effective for only a few years, and the rehabilitation process has to be repeated. Figure 9.9 shows a site at Windward, where new rehabilitation was required after 10 years. The inability of the Government to respond to some erosion problems on a timely basis results in increasing levels of erosion at sites ultimately resulting in rehabilitation work that is often beyond the financial capability of the Government. To overcome this inability, informal short-term solutions are often applied which do not involve engineering designs of defense structures in the form of sea walls but where any available material that can offer some immediate protection is used. These materials may include old vehicles or rubble from construction waste.

Figure 9.8: Protective sea wall and stone works mitigate the impact of erosion at Lauriston, Carriacou

Figure 9.9: Protective sea wall and stone works threatened by coastal erosion at Windward, Carriacou

9.3.4 Previous Beach Erosion Studies in Carriacou and Petite Martinique

Grenada now has a substantial beach change database covering the period 1985 to 2001, with one two-year gap, between 1991 and 1993. There are, however, less data for Carriacou and Petite Martinique. The earliest data collection was carried out on Grenada in 1985 by the National Science and Technology Council, together with the Fisheries Division, Lands and Surveys Division, and the Land and Water Resource Unit through the Grenada Coastal Monitoring Programme. This research work was in response to severe coastal erosion problems identified on the Grand Anse Beach and other beaches around the island. Estimates of beach erosion based on beach profiles and a comparison of aerial photographs from 1950 to 1986 show losses of 5,000-10,000 ft^2 of beach per year (Cambers, 1984).

In Carriacou, the first beach monitoring began in 1997 when the Hillsborough Secondary School and the Fisheries Division measured the erosion of some of Carriacou's beaches. They measured the beach slope and width every three months at numerous sites around the island. Both accretion and erosion were observed during the monitoring of some beaches on Carriacou from 1997 to 1999 as shown in Figure 9.10.

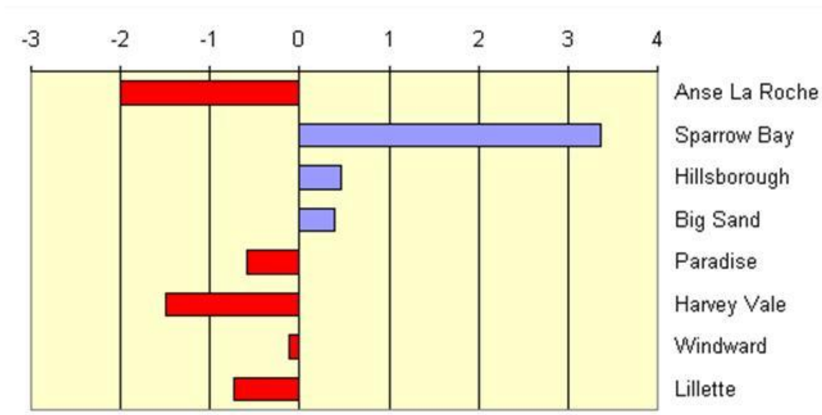

Figure 9.10: Beach changes (m/year) on the main beaches in Carriacou from 1997 to 1999 (Source: Chambers, 2000)

Peters (2001) estimated the level of beach erosion in Carriacou based on information from a combination of sources, namely, beach surveys over a three-day period in July 2000, aerial surveys (1958, 1966, 1982 and 1992) and expert judgment (experts include fishermen, boat builders, beach property owners and some local environmental activists). Utilizing expert judgment-based knowledge of the lands, loss of foot-paths and roads, coastline and beach recession along some parts of Harvey Vale Paradise, and Hillsborough (west coast), the estimated maximum beach erosion was 10 m over 45 to 50 years.

At Harvey Vale, aerial photographs indicated that there was significant beach erosion since Hurricane Janet in 1955. The location of the Harvey Vale-Hermitage junction in a 1958 aerial photograph showed that in 2000 the beach had eroded to such an extent, that it occupied the area where the 1958 road existed (Peters, 2001). During the period there was some recovery such that by 1966 there were well-established manchineel and seagrape trees, yet in the vicinity of the Jetty there are signs of continued erosion. In 1958, there was a 12 m vegetative strip between the road and the Harvey Vale Beach. By 2000, the 12 m vegetative strip had disappeared and is now occupied by the beach (Peters, 2001).

At Hillsborough, beach erosion has had a significant impact. Information from the 1966, 1982 and 1992 aerial photographs and field visits in 2000 show that the original Esplanade on a 10 m vegetative strip prior to 1966 had disappeared by 2000. Most of the erosion occurred during severe events, particularly winter storm surges (Peters, 2001). Along the Lauriston Road, shoreline protection became necessary during the 1980s as the link road to the airport was being threatened. Today, flooding of this strip of road is a common occurrence during the winter storm surges. Using aerial photographs and anecdotal data, the 1950 shoreline for the Lauriston beach was reconstructed and is shown by the black line in Figure 9.11. The beach has eroded more than 33 m in some places over the past 60 years.

Figure 9.11: A reconstructed 1950's shoreline of Lauriston Beach and the remains of recent tree loss due to coastal erosion

On the beaches at Bogles (East Coast) and Black Bay (East Coast), erosion is more difficult to quantify; however, best estimates are about 6 m to 8 m in the past 40 years (15 - 20 cm per year). The material on the beach at Bogles is made up of coarse coral remains and stones. There is evidence of small collapsing caves that were undermined by wave action. However, the evidence of erosion is not so obvious on aerial photographs. At Dumfries, there is evidence of coastal erosion more likely caused by onshore weathering activities than by the action of waves (Peters, 2001). In the case of Lillette-Petite Carenage, during field visits in 2000 a 2 m strip of dead sea grape along 50% of the beach was observed. It is not clear whether the sea grape die-back is a result of erosion alone or a combination of erosion and saltwater intrusion. It is evident that the width of the die-back has been almost constant over at least the past 30 years and that the die-back recedes at about 1.2 m in 15 years (8 cm per year). The relatively low rate of erosion at Lillette-Petite Carenage is seen in aerial photographs taken in 1966, 1982 and 1992 in which little change in the position of the beach line is evident (Peters, 2001). This low erosion rate may be explained by the sheltered nature of the beach and the absence of human development on the beach.

Windward on Watering Bay is protected by offshore reefs; therefore, while beach erosion is evident, it has been low. Some parts of the beach have been damaged by the illegal dumping of waste and the presence of three large shipwrecks in the Bay. The Windward coastal road, which during the 1950s was 4 - 5 m away from the high-water mark, had to be protected during the 1990s as the high-water mark is now against the protected walls (Peters, 2001). During the hurricane season this coastal road is frequently flooded. The once popular beach to the north of the Windward jetty has been reduced to mud banks. The coastline in this area has receded about 10 m over the past 50 years. This is supported by the comparison of aerial photographs from 1966, 1982 and 1992.

9.4 The Challenges of Coastal Erosion Monitoring

Improved and more sustainable management and protection of the coastline in general and beaches in particular is possible through proper knowledge of the impact of past and present erosion, which can be achieved inter alia by means of careful monitoring. Information on beach changes can help to predict future changes and to prepare and develop adaptation policies for climate change effects. One of the biggest problems faced in studying the impact of climate change and sea level rise in developing countries is a lack of data for the necessary analysis, including information about coastal characteristics. Although many techniques are available, they are usually outside the financial reach of SIDS.

While there is no major technical difficulty in monitoring beach erosion, the management of the resulting data has been a problem in some islands. Typically, a number of government agencies and Non Government Organisations (NGOs) collect information. However, the usefulness of the information is diminished due to the lack of a good framework for managing these disparate sets of information. In the case of Grenada, five agencies were involved in data collection, raising questions regarding location of the database and responsibility for updating the database (Cambers, 2003). Overall, there is a lack of formal mechanisms for reporting the results of environmental monitoring to a central agency. This is not unexpected as there are inherent difficulties in SIDS associated with integrated approaches and the nature of management – whether top-down or bottom-up. Such difficulties must be addressed in developing future beach monitoring programmes.

A second challenge in the monitoring of coastal erosion is how to make it sustainable. The difficulties of capacity building in SIDS are well known (UNEP, 1998) and, despite all the efforts made to enhance capacity and improve co-ordination, there are still many problems and constraints. For example, at the end of a project, a number of persons may be trained. However, the enhanced capacity is often reduced due to migration, change of jobs or loss of interest in the project. This is particularly so where the training was carried out through volunteerism. In reporting on a CDB-UNESCO project, Cambers (2003) envisaged vibrant beach monitoring programmes with the data analysis and interpretation being conducted in the country and expected that these programmes would have become self-sufficient in the future and continue without external support. This has not been the case in Grenada. A visit to the National Science Council revealed that monitoring ended with the formal completion of the project and current staff is unaware of the project or the location of the results. In Carriacou, none of the 12 students who were involved in the beach monitoring programme are currently on the island.

9.5 Project 1: Beach Monitoring Project for Carriacou and Petite Martinique

The beach monitoring project is driven by the need to provide appropriate data for coastline management and would focus on one specific aspect of management, namely the monitoring of physical changes in beaches.

The aim of this project is to promote beach management and erosion control practices among Carriacou and Petite Martinique communities by understanding the past changes in beach evolution in order to better understand the present conditions of the beach and predict the future.

The main objective of this project is to establish a beach-monitoring programme that is sustainable for Carriacou and Petite Martinique through capacity building and institutional strengthening by:

- Identifying potential problems of beach erosion so that reasonable responses can be developed and implemented;
- Providing public education on beach management issues;
- Supplying the necessary tools and installation of specially prepared software; and
- Providing the necessary training to use the software to analyse and interpret the data.

Other associated objectives that may be undertaken by the Ministry of Carriacou and Petite Martinique Affairs (MOCPMA) resulting from the Beach Monitoring Project are:

- Predicting the future of beach erosion and impacts on developments; and
- Monitoring management operations and making appropriate refinements or alternatives.

The main outcomes of the proposed project are as follows:

- The formation of a community group that focuses on environmental issues, particularly beach erosion;
- Public education on the importance of beaches and beach monitoring to local development;
- Enhanced interest in beach monitoring among students such that this can become the focus of academic research for students;
- A cadre of trainers on beach monitoring (four teachers, one fisheries officer, and one person from Works Department);
- Data on the state of beach erosion (five years of monthly data for eight beaches); and
- A system or institutional arrangement for beach monitoring and beach management.

The project would focus on the major beaches in Carriacou and Petite Martinique. All measurements would be land based and should not be too onerous on the students and volunteers. While it would be useful to obtain bathymetric data of the beaches, bathymetric surveys would not be included in the monitoring project (SIOBMPA). Furthermore, water quality measurements are outside the initial scope of this beach monitoring project. However, consideration should be given to including this at some later date as water quality data are important for beaches like Hillsborough, Harvey Vale and Paradise that are frequently utilized by tourists and residents.

9.5.1 Methodology (Utilization of the Sandwatch Model)

Beach monitoring should include a subset of the baseline measurements and may include surveys at a range of different frequencies (e.g. hourly water levels, monthly walkover observations, seasonal profiling, annual aerial photography, five-yearly bathymetric surveys). Measurements of coastal erosion can be made by direct or indirect methods. Direct measurements are based on change analysis and are carried out on site, in the field. This procedure involves the measurement of displacement, or positional change over time, of specific features such as shorelines, beaches and cliffs relative to a known or fixed point. This may involve the use of a common measuring tape or more sophisticated equipment such as a Total Station or a high precision GPS in conjunction with survey monuments, corners of buildings or erosion pins. A measurement is made representing the distance of the feature of interest to the known position.

The monitoring programme must be appropriate to the site, cost effective, flexible and must provide the amount and quality of data required for decision-making. The degree of precision of the data required would determine the methodology. In the case of Carriacou and Petite Martinique very precise measurements of sub-centimeter scale would be useful for the management of a coastal area or a beach. However, less precise measurements may be sufficient.

The methodology proposed for implementing this beach monitoring project would be the Sandwatch Model approach. Sandwatch is a global programme which provides a framework for children, youths and adults, along with teachers and local communities, to work together to critically evaluate the problems facing the beach environments and to develop sustainable approaches to address these issues (UNESCO, 2010). This programme is being targeted as a flagship project for the "UN Decade of Education for Sustainable Development (2005-2014)"

9.5.2 Participants/Target Groups

To improve the sustainability of the monitoring programme, it is important to broaden the capacity by involving as many persons and groups as possible in the fieldwork. In this regard, the following groups of persons are proposed to be involved.

1. School students from the two secondary schools on the island

It is clear that education plays a central role in the response at all levels to the projected changes in the world's climate. In Carriacou and Petite Martinique, it is therefore important to improve the understanding of young people of the nature and causes of climate change by involving them in the observation and measurements of these changes and in the actions taken to mitigate the impacts of these changes. This approach was explored during the Beach Monitoring Project of 1997-1999 when the Hillsborough Secondary School participated in monitoring exercises. The other secondary school on the island was not involved and this may have limited the scope for strengthening the capacity of the project. Future beach monitoring exercises should involve both secondary schools. In this regard, the administrations of the two secondary schools in Carriacou have expressed a desire to be involved in future beach monitoring programmes. Given its importance, beach monitoring should be incorporated into the curriculum of the fourth and fifth forms as part of the School Based Assessment (SBA) for the Caribbean Examination Council (CXC).

2. The staff of Sandy Island/Oyster Bed Marine Protected Area (SIOBMPA)

The Sandy Island/Oyster Bed Marine Protected Area was established on 31st July 2010 with an objective to strike a balance between socio-economic development and environmental sustainability. Three important beaches (Paradise, Sandy Island and Harvey Vale) are located within the protected area and the management of these beaches is essential. The sustainability of the protected area is somewhat dependent on the beaches within the site as most land-based activities related to the operation of the protected area takes place on the beaches. There is, therefore, a shared interest in obtaining data on erosion or accretion of these beaches. There are two other strong reasons for involving the staff of the SIOBMPA in future beach monitoring. First, the staff is under the control of the MOCPMA, and second, it has the prerequisite capacity to successfully undergo training and undertake beach monitoring exercises. Ideally, the monitoring of the beaches within the protected area should be incorporated as a routine activity of SIOBMPA's operations.

3. The Works Department –Environmental Wardens

In 2010, the MOCPMA hired six Environmental Wardens with the responsibility to patrol the beaches and monitoring sand mining, which is a threat to coastal erosion. The current staff, like their counterparts in the SIOBMPA, is quite suited for involvement in future beach monitoring. Involvement in such exercises can be integrated into their current scope of work.

4. Participating NGOs/community groups

In Carriacou and Petite Martinique, there are not many NGOs and community groups that are interested in environmental issues. It would, however, be useful to promote the establishment of such groups among the participants from the wider community, particularly the youths and returning retired nationals. There are many highly skilled and trained persons among the retired nationals on the islands who spend much of their leisure time on the beaches and are keen to contribute to the development of the islands. It is possible to encourage these persons to come together in a beach monitoring project. Exploratory enquiries with some of these persons suggest that this would be a viable source for community beach monitors.

9.5.3 Frequency and Timing of Measurements

Beaches evolve continually in response to waves, water levels, winds, human activities and biological processes. Rates of change in beaches vary from the micro-scale of wave periods, through tidal cycles, up to seasons and long term evolution over decades. Micro-scales are of little practical significance. Beach changes that would be obviously useful to monitor will be a result of storms (one or two days), seasonal changes or changes due to long-term evolution over decades. It is important that beach monitoring officials recognize these different scales. Baseline measurements must establish the existing situation, including the potential short-term variability of that situation.

Establishing the baseline for the upper beach may require observations every month for a year. Subsequent monitoring of the beach and dune face could be less frequent and reduced to twice yearly. Continuous beach monitoring, over an extended period, would reveal changes from storm surges and allow predictions of the impacts of extreme events. As the intention of the project is to establish long-term trends, measurements should be undertaken when sea conditions are likely to be impacted by the same phenomenon over a long time. For example, the beach profiles to be completed within two days of the peak spring tides of every second month would allow seasonal variations to be established and year-on-year trends to be identified with minimal observer bias.

9.5.4 Monitoring Sites

Normally, a reconnaissance survey should be made to identify obvious signs of erosion. Earlier work has shown that most of the key beaches on Carriacou and Petite Martinique are undergoing some form of erosion and therefore the project should include as many of these beaches as possible. Beaches on which there are major current developments (Harvey Vale, Paradise, Hillsborough, Sandy Island and Sanchez) and beaches that have been identified or have the potential for major future developments (Anse la Roche, Dumfries –Sabazan, Lillette and Tibeau) should be monitored. The points on these beaches where the actual measurements should be taken would be identified during the implementation of the project. Figure 9.12 shows the location of the beaches that should be monitored.

Figure 9.12: Location of proposed beach monitoring sites on Carriacou and Petite Martinique

9.5.5 Mobilizing the Beach Monitors

It would not be necessary to mobilize monitors from the MOCPMA as they would be assigned the monitoring tasks. However, it would be important to orient them on the beach monitoring programme, its objectives and benefits to the islands. In the case of the students, a Memorandum of Understanding (MOU) between the schools and the MOCPMA should be established detailing the responsibilities, expectations and benefits relating to both institutions. The project officials would need to consult with the Ministry of Education to formulate a system to allow for the monitoring work by the students to be credited in their academic certification.

In case of the community group, the Youth Division of the MOCPMA should identify which among its current youth groups may be interested in the beach monitoring project. Young people, particularly the unemployed, may be more motivated when they can link future opportunities with current volunteer work. In this regard, by undertaking the monitoring activities the young people are also developing research and analytical skills. A certificate of participation in the beach monitoring project can be awarded to participants. This certificate can be recognized in assessing the qualification for jobs in some of the Ministries that are involved in environmental issues.

In the case of the returning retired nationals, participation in the monitoring programme can be linked to their investment in the improvement of the beaches that they use. In this regard, the MOCPMA can develop projects for beach enhancement that incorporates the participation of the returned retired nationals through their involvement in the monitoring project.

9.5.6 Training

An individual with the relevant skills in beach monitoring can educate the trainers. The two regional institutions that can be considered for providing this training are:

- The Department of Civil Engineering (Coastal Group) UWI; and
- University of Puerto Rico.

Training of the trainers should include:

- Indoor training session on the theory of beach processes and beach monitoring;
- In situ briefing on beach monitoring techniques;
- Field training;
- Software training; and
- Training in data recording and analysis.

In order to get local support for the project, a series of public education sessions should be undertaken with communities on the importance of beaches and beach monitoring to national development, coordinated by the Community Development Unit at MOCPMA.

9.5.7 Project Management

The MOCPMA, or the Department of Local Government when it becomes operational, would be responsible for implementing the project. The assigned agency would be responsible for mobilizing the monitors, procuring equipment, securing and distributing equipment and for collating, analyzing and storing all data. It should be the policy of the MOCPMA or the Department of Local Government to acquire, review, maintain and make high-quality beach data available to national planning agencies and the general public for the purpose of beach erosion management. An implementation schedule for the beach monitoring project is shown in Figure 9.13.

Activities	Year 1				Year 2				Year 3				Year 4				Year 5				Responsibility
Mobilizing Community	■																				MOCPMA
Public awareness workshops	■				■								■								MOE – local expert
Training of trainers	■	■							■												Expert consultant
Training of monitors			■							■											Trainers
Field monitoring				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Monitors
Procurement of equipment		■	■																		Government/ funding agency
Installation of software			■																		Expert/consultant
Analysis of data				■				■								■				■	MOCPMA
Review of project									■						■					■	MOCPMA
Design of programme for beach enhancement									■						■						MOCPMA

Figure 9.13: Implementation schedule for beach monitoring project

9.6 Project 2: Petite Martinique Hillside Erosion

9.6.1 Hillside Erosion in Petite Martinique

Petite Martinique receives an annual rainfall of less than 40 inches. This rainfall was sufficient for sugarcane and cotton during the period of slavery and for some subsistence agriculture thereafter. As lands are limited, households utilized the lands intensively for crops like corn, pigeon peas, beans and some vegetables during the rainy season and for livestock during the dry season. In modern times Petite Martinique has experienced accelerated levels of hillside erosion as the scrubby and improvised remaining forests do not provide a protected soil cover in upland watersheds. During heavy downpours of rain, runoff is almost total, resulting in sheeting erosion. Using Google and aerial maps the level of erosion was estimated for Petite Martinique. The results show that more than 30% of the eastern side of the island is severely eroded and another 10% to 15% is moderately eroded (see Figure 9.14).

Figure 9.14: Severe hillside erosion on the north-eastern side of Petite Martinique

Soil erosion in Petite Martinique has been of major concern for decades but there is little information on the economic impacts or the economic value of soil. The losses of soil in terms of the irreplaceable inputs are the primary factors determining the productivity and economic costs of erosion. The problem at Madame Pierre, on the eastern side of Petite Martinique, is that about 40 acres of land are severely degraded and now lie bare through soil erosion from years of deforestation, poor land use and inappropriate land management practices. These man-made influences of soil erosion add to the susceptibility to erosion of the island's volcanic soils, steep slopes (15% to 25%) and short land run. These lands now suffer from fertility and/or micronutrient deficiencies, and continuing exposure results in further soil leaching and erosion. Comprehensive quantitative data on soil erosion rate and the extent of land degradation are not available; however, cursory observation and interviews with the elder islanders suggest that soil erosion has been severe and is worsening. This assessment is supported by the evident state of abandonment and desertification. To date there is no systematic and planned approach to investigating and documenting alternative sustainable land use and land management systems in Petite Martinique.

9.6.2 Factors Influencing Hillside Erosion in Petite Martinique

The causes and consequences of soil erosion in Petite Martinique are far from being settled. However, there are five factors, past and present, that can explain most of the severe soil erosion.

1) Traditionally, in order to maximize crop production, islanders hand-ploughed the lands at the commencement of the rainy season every year. This practice induced high levels of soil erosion. Such soil erosion was particularly severe during the 1950s and 1960s when peanuts were cultivated on the eastern side of the island. For this crop the soil was ploughed at least twice per year; first at planting time at the commencement of the rainy season and then at harvest time.

2) Small ruminants such as sheep and goats are well suited to marginal land, abandoned crop land, eroding land and land not usable for other crops. Therefore, the Madame Pierre area has traditionally been used for small ruminant production. However, over time there was overstocking and as there was no reseeding and improving of the pastures there was an increased potential for erosion. During the dry season the small livestock forage the fields for what little vegetation is available and it is common to see these livestock rake the ground with their feet to get at the dry roots of grass. At the onset of the rainy season, the loose soil is readily washed away.

3) During the first part of the 20th century, boat building required good timber. The majority of the local cedar trees were harvested for planking. As a result the upper reaches of the hillsides became more bare and susceptible to soil erosion.

4) In Petite Martinique all lands are privately owned so that there are no crown lands. Over the years, lands are passed from one generation to the next and are divided in the process. In many cases the legal owner of a plot is someone who has died 60 or more years ago. As the number of interests in any given plot increases, so too does the complexity of proper management.

5) Policy issues are other factors influencing hillside erosion. Thomas (2000) identified causes for the high levels of land degradation in Grenada, Carriacou and Petite Martinique as follows: lack of a land use policy and agricultural policy; lack of coordination of land management institutions; inadequate capacity of land management institutions; lack of enforcement of regulations; and lack of public awareness.

9.6.3 Responding to the Erosion Problem in Petite Martinique

On a small island like Petite Martinique with its limited land space, unused lands represent an important resource that can be a useful component in the sustainable development of the island. A project can be sited on the north-eastern side of the island (Figure 9.15). When implemented, this project can be utilized for improving food security on the island albeit at small levels or to create appropriate facilities in support of the tourism industry. For example, it can also provide the opportunity for the development of a botanical garden, since there currently are none on the island. A botanical garden can be a tourist attraction for visitors to the island and could target visitors at the nearby all inclusive resort on Petite St. Vincent.

The methods of soil conservation have been well studied and practiced globally. In Grenada, grass barriers are consistently promoted and implemented on approximately 15-20% of all vegetable and food crop farms to minimize soil loss and associated degradation and conserve limited water resources, particularly in hilly areas (FAO, 2012). Some grass barriers were used in both Carriacou and Petite Martinique during the 1950s and 1960s with some success.

Figure 9.15: Northern half of Petite Martinique showing the proposed project site

However, lack of maintenance subsequently resulted in the loss of these barriers. Furthermore, in highly degraded areas, vegetative barriers are more difficult to establish and maintain. Hence, where stones are readily available, stone barriers can be built, resulting in the immediate restoration of the land. Once these stone barriers are established, then grass barriers can be used to reinforce the soil trapping mechanism. To make the use of stone and grass barriers sustainable, the community must see the need for and potential benefits from soil conservation. In this way their active participation through the provision of labour and the local natural resources reduces the costs of the project.

9.6.4 Project Aims and Objectives

The main thrust of the project follows a method used on a land rehabilitation project in Carriacou that utilized local knowhow and resources. In this Carriacou project, a D4 caterpillar bulldozer was used to create stone barriers along the contours as shown in the Figure 9.16.

This first aim is to foster the generation and spread of soil conservation using stone barriers reinforced by grass barriers.

The associated objectives are: (1) reduce water and wind-induced soil erosion; (2) reduce the transport of sediment and other water-borne contaminants to the small mangrove patch; (3) increase infiltration and available soil moisture; and (4) improve the arability of the existing lands.

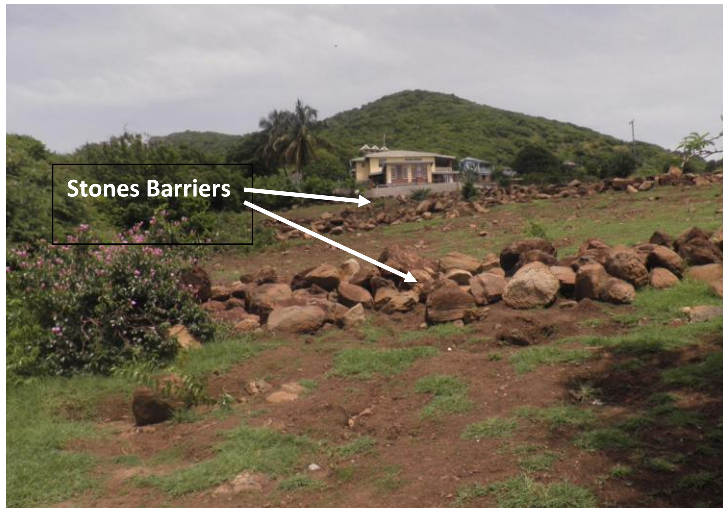

Figure 9.16: Stone barriers successfully established to reverse hillside erosion in Carriacou

The second aim is to provide an alternative tourism site by developing a dry land botanical garden. The specific objective in this case would be to establish a viable botanical garden of dry land plants (including native plants of Carriacou and Petite Martinique).

A project of this nature would have many direct and indirect impacts. The main direct impact and outcomes of this project would be:

Environmental impacts

- Conservation of biodiversity through land conservation, and reforestation;
- Conservation of coastal resources (coral reefs) through reduced pollution; and
- Reduction in soil and water pollution.

Community impacts

- Increased availability of arable land;
- Better educated and informed farmers and communities;
- Communities educated on sustainable livelihood practices and techniques;
- Demonstration plot providing the opportunity to broaden activities; and
- Improved tourism product.

9.6.5 Project Design

For the project, stone barriers would be constructed following a similar method used in Carriacou. On the site at Madame Pierre a bulldozer would be used to push the stones along the contour line. The smaller stones would be packed as tightly as possible by hand. Guinea grass would be planted upstream of the stones. When established, the grass would trap soil and also provide roof material that could be used on the nearby resort. In the year following the creation of the stone barriers, fast-growing dry land trees can be planted on the contours above the barriers.

The Botanical Gardens

The botanical gardens in Petite Martinique would provide an opportunity to preserve local flora biodiversity. While there are previous works on identifying the different indigenous plants (Hawthorne, et al., 2004), there has been no known undertaking of this sort attempted before. The collection and establishment of these plants would be a progressive effort and would require the active involvement of locals. For example, many fishermen camp on the keys during some special periods for fishing. Planting material can be collected from these small rocky islands to be included at one location in the gardens.

For the development of the gardens, four types of plants are proposed in the early stages:

- Native plants of Grenada that can flourish despite low rainfall and marine exposure such as the Bougainvillea;
- Cacti, succulents and other trees and plants suited to the microclimate at Madame Pierre;
- Plants alien to the region but found in private collections; and
- Fast-growing trees suited to dryland (dry land palms, Plumeria cultivars and others).

Selective planting and water conservation techniques can be used to transform the current landscape into a garden where plants suitable to these drylands can thrive and flourish. For example there are a number of native and alien cacti present in Carriacou and Grenada and material from these species can be collected and planted.

9.6.6 Project Support / Financing

The islands' size and isolation seriously limits their options, and with their vulnerability to storms and economic shock, environmental problems such as soil erosion are particularly challenging and often call for solutions requiring resources that are not available locally. In other cases, what is required is some kind of seed funding that can motivate the community to take sustainable action. With these considerations, it would be recommended that this project be implemented through a cooperative effort between the local government for Carriacou and Petite Martinique and the UN.

9.7 Conclusions

Environmental issues are of utmost importance for SIDS and represent a major concern for Carriacou and Petite Martinique. The impacts of climate change already affecting many SIDS demand decisive action. This study on greening the economy of Carriacou and Petite Martinique represents a window of opportunity for engaging in sustainable development activities. Erosion of the coastal areas and hillsides of Carriacou and Petite Martinique is a major concern of residents and the Government. Caused by a number of factors, hillside erosion has reduced the fertility of the land resulting in reduced agriculture and livestock production. Considering that the problem in many parts of the islands has reached serious proportions, doing nothing is not an option, if food security and environmental sustainability are to be given credence. New interventions using lessons learnt from earlier efforts at soil erosion and available technology can go a long way as a way in which the islanders can adapt to the impacts of climate change on degradation of coastal and upland areas of the islands. The costs of protection and rehabilitation of coastal areas and beaches are already high and are generally outside the financial capacity of the country. Data collection on the current rate of coastal and beach erosion can facilitate planning of future work so that priority can be given to protecting critical locations.

The growth of green economies in the adaptation to climate change can be boosted if there are genuine success stories of interventions, albeit on small scales. The proposal of this chapter provides an opportunity to implement pilot projects that are easy to manage, as they are based on simple technology, can engender wide community involvement and provides an output that is useful for the growth of the key economic sectors – agriculture and tourism. The assumption of community participation in this project is realistic as there is a history of wide community involvement in community-type projects. Community involvement would minimize the initial capital required for the project. The success of the projects can propel other communities to undertake similar activities using their own resources or using available external resources for sustainable development or for adaptation to climate change. If all efforts are made to see these projects through, the benefits that may accrue will far exceed the initial investment.

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10. Conclusions

This study represents a first attempt to define the major changes needed to induce the transformation of the economy of Carriacou and Petite Martinique towards a greener economy that would facilitate sustainable development and enhance the well-being of the population. This comprehensive and integrated assessment, performed by national, regional and international experts, demonstrates that opportunities exist to initiate a major coordinated transformation of the economy of Carriacou and Petite Martinique and that such a transformation may indeed provide important knowledge and information for the implementation of green economy strategies for these islands, for the whole country of Grenada and for other Small Island Developing States (SIDS). Furthermore, the limited assessments, based on expert analysis and available data, reveal that ample benefits can be derived from a concerted effort to promote green technologies and integrated systems that support sustainable development.

The development of a "Road Map" for the design and implementation of a green economy not only needs to take into consideration major factors affecting sectors and subsectors of the economy as well as very important aspects within the social, economic and environmental dimensions of sustainable development, but it also needs to include all these factors and aspects in an integrated and holistic approach. This integrated framework creates the necessary value added in the design of green strategies. In addition, it is necessary that the overall transformation be based on local and national sustainable development criteria and priorities defined by decision makers and national stakeholders. The optimal combination of strategies, technologies and systems needs to be designed based on endogenous capacities and a full consideration of cultural, social and traditional aspects of the communities involved. The transformation plan has to be based on a "bottom-up" approach that incorporates community needs, national priorities and traditional strengths supported by international cooperation and technological innovation.

Energy represents a critical factor in this endeavor, and the optimal development of green energy technologies can be supported by the existence of ample renewable energy resources in Carriacou and Petite Martinique. The development of integrated systems based on renewable energy is not only feasible but may create synergies with other important development issues such as water and waste water management and agriculture and food security. Utilization of renewable energy resources, most notably photovoltaic, geothermal and wind energy would provide a more secure, more environmentally friendly and more cost effective way to satisfy the local and tourism energy demand.

The implementation of an Integrated Water Resource Management programme is an indispensable task for the authorities of Carriacou and Petite Martinique. Water availability, which has already been altered in many communities by climate change, can be improved by the enhancement of the infrastructure supporting storage and distribution of rainwater. The restoration, expansion and effective transformation of this unique infrastructure of Carriacou and Petite Martinique promises to reduce the water shortages observed during the dry seasons and could also represent a very important approach that can be followed by other countries experiencing major water problems. Nevertheless, it is clear that economic expansion and, in particular, the development of ecotourism facilities will demand additional water resources that can be obtained through the implementation of advanced seawater desalination technologies including reverse osmosis. The link between renewable energy and water is a synergetic opportunity that can be exploited on Carriacou and Petite Martinique.

A movement towards sustainability requires changes in the educational opportunities made available locally and globally. In evaluating the training opportunities in Carriacou and Petite Martinique, it is clear that this represents a tremendous opportunity. The establishment of vocational careers and degrees in the priority areas of the country are of critical importance and seem indispensable for supporting a major transformation of the economy of these islands. The availability of educational programmes in areas of interest such as ecotourism, environmental management, sustainable development, climate change, green economies and natural resource management should help in the development of green jobs and in the reduction of the exodus of the younger generations. Education and job opportunities are closely linked. A more appropriately educated work force will be able to maximize as well as create new job opportunities, which will ultimately help Grenada achieve sustainable development. The challenges for education and training for a green economy can be overcome by a comprehensive forward-looking programme. It is clear that green technologies will not flourish without a well-trained technical and supporting labor force.

The revival of the agricultural sector by using innovative mechanisms cannot be overemphasized. Renewable energy technologies for irrigation and water distribution should facilitate this task. Substantial gains in agricultural productivity can be realized through investment, innovation, and effective policy that include and incorporate adaptation and mitigation measures towards climate change. However, realizing these gains will require an exceptional level of collaboration among stakeholders in the agricultural value chain, including governments, companies, entrepreneurs and civil-society organizations, farmers and consumers. Sustainable agricultural development in Carriacou and Petite Martinique requires adequate agriculture and land policies that promote the use of alternative energy sources.

Transport efficiency and an increase in transport options (by sea, air and land) are priorities for inducing sustainable development. In particular, the efficient development of public transport will translate into real benefits for the communities. This development framework for Carriacou and Petite Martinique suggests that transportation will be a key component in the new economy. This new economy will depend on an efficient transport system to smoothly deliver goods and personnel to where they are needed. The aim of green transport is to provide a land and sea transport system that is developed with the needs of the islanders in mind and is environmentally sustainable.

Sustainable community-based ecotourism represents one of the most promising areas for economic development. The extensive natural environments and pristine, undeveloped beaches are important assets for Carriacou and Petite Martinique that could be protected while allowing innovative approaches for their utilization for tourism purposes. There is the potential to expand the previously untapped tourism sector to foster economic diversification, employment opportunities, poverty eradication and to provide patterns of sustainable ecotourism development. Rainwater harvesting is advanced in Carriacou and Petite Martinique but will be insufficient to meet the increased demand coming from extended tourist infrastructures. Current patterns of energy supply are expensive and unsustainable on Carriacou and Petite Martinique as the islands have to import fossil fuels. Utilization of renewable energy technologies would provide an effective way to satisfy tourism energy demand.

In the area of environment, it is clear that climate change impacts are already a fact of life. Rising sea levels, beach erosion, less precipitation and more intense dry seasons are some of the effects already being felt in Carriacou and Petite Martinique. Environmental adaptation is critical and related programmes should be implemented with a sense of urgency. Climate change, sea level rise and their impact on SIDS are some of the most pressing concerns for the governments of these states. Among the issues that must be addressed is the interconnection between coastal areas, particularly beaches, and the economic development of many SIDS. Experts from Grenada have identified a number of priority areas for adaptation to potential impacts from climate change. Critical areas selected for assessment include: hillside erosion, beach erosion, water management and the need for integrated systems and renewable energy technologies.

Lessons Learned

The study on Carriacou and Petite Martinique proved to be a challenging but very valuable task. Extensive discussions with national, regional and international experts were necessary to accomplish the assessment and to reach conclusions on specific proposals to move forward with a green strategy that supports sustainable development within a holistic framework. Even though the analysis and study provide definitive answers about the approach to follow to green the economy, there is the need for more in-depth assessment. Time and additional financial and technical support are necessary to expand the analysis and to formulate the most desirable path to sustainable development. One major conclusion for this exercise is the urgent need to establish new and expanded data and statistical programmes. The programmes are particularly necessary for the priority areas of Carriacou and Petite Martinique which include: natural resources, beach erosion, precipitation patterns, renewable energy potential and water availability. The lack of consistent time series data and statistics limits the capability for performing more quantitative research that may support the transformation toward a green economy.

Next Steps

The study conducted in the last two years represents a starting point for a more thorough assessment of the overall current and future situation of Carriacou and Petite Martinique. One of the next steps is to continue the work that has been started with a follow-up, more in-depth assessment of specific aspects, factors and problems. The momentum that may be realized from the publication of the findings of this first exercise should provide the basis for the continuation of this challenge. The definition of one or two major sustainable community-based ecotourism projects could become the lead projects that would trigger the implementation of the Road Map outlined in this publication. These ecotourism projects will force decision makers and financial supporters to develop and build the necessary green infrastructure, human capacity and technological integrated systems that will support the transformation towards a green economy. Another indispensable step is to secure the full support of the decision makers and the elaboration of the corresponding policies that would support this transformation. Consensus at the highest governmental level would be necessary to move in the right direction and to get the domestic and international support for immediate action.

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