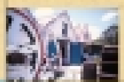


Barbados'

First National Communications

To the United Nations
Framework Convention
on Climate Change (UNFCCC)

October 2001

Barbados'

First National Communications

To the United Nations
Framework Convention
on Climate Change (UNFCCC)

Government of Barbados

October 2001

BARBADOS'
FIRST NATIONAL COMMUNICATIONS

Under
The United Nations
Framework Convention
On Climate Change (UNFCCC)

PUBLISHED BY
Ministry of Physical Development Environment
4th Floor, Frank Walcott Building
Culloden Road, St. Michael
Barbados, W.I.

EDITED BY
Christine Wellington and Rawleston Moore

DESIGNED AND PRODUCED BY
G&A Design & Advertising Inc., Barbados

CD DEVELOPMENT BY
Envision Visual Communications Inc., Barbados

PRINTED BY
Dynamic Colour Imaging, Barbados

CONTACTS
Christine Wellington
Ministry of Physical Development Environment
4th Floor, Frank Walcott Building
Culloden Road, St. Michael
Barbados, W.I.
Tel: (246) 431-7680/5
Fax: (246) 437-8859
Email: meenr@sunbeach.net, technical@meenr.gov.bb

Rawleston Moore
Caribbean Planning for Adaptation to Global Climate Change (CPACC)
Regional Project Implementatin Unit
Lazaretto Complex, Black Rock,
St, Michael
Barbados, W.I.
Tel: (246) 417-4580
Fax: (246) 417-0461
Email: moorecpacc@sunbeach.net

Acknowledgments

The Ministry of Physical Development and Environment wishes to thank the following for their assistance in preparing this initial national communication:

The Ministry of Finance and Economic Affairs
The Energy Division
The Soil Conservation Unit
Barbados Meteorological Services
The Ministry of Agriculture and Rural Development
The Environmental Engineering Division
The Sewerage and Solid Waste Management Project
The Ministry of Health
The Barbados Water Authority
The National Council for Science and Technology
National Petroleum Corporation
Central Emergency Relief Organization
Barbados Association of Professional Engineers
The Caribbean Planning for Adaptation to Climate Change Project
The University of West Indies, Cave Hill Campus
Alleyne Planning and Associates
Global Climate Strategies Inc
Barbados Light & Power Company Limited

and all those who have contributed to the completion of this document.

Further the Ministry of Physical Development and Environment wishes to thank the United Nations Development Programme and the National Communications Support Programme for their assistance.

Minister's Foreword

On behalf of the Government of Barbados, I have the honour to present Barbados' First National Communication to the United Nations Framework Convention on Climate Change.

As a vulnerable small island developing state, the threats associated with globally and regionally projected changes in climate are of great and immediate significance. While there are still areas of uncertainty in the scientific literature, the work of the Intergovernmental Panel on Climate Change makes it clear that the threats are real, and require a coordinated response at the global, regional and local scales. This First National Communication indicates, inter alia, that the consequences of climate change including elevated air and sea-surface temperatures, sea-level rise, possible changes in extreme events and reduction in freshwater resources, could negatively impact the economic and social development of our island.

This document identifies and highlights the many challenges which will confront the island, as it seeks to design and implement an appropriate adaptation strategy. In this context, I take pride in underscoring the fact that although Barbados is a small developing country with limited resources, Government has already begun to make considerable strides in meeting the challenges of adaptation by implementing sound coastal and water resources management strategies, as well as initiating a successful renewable energy programme. However, like other small island states, we remain concerned that while we have begun to allocate our scarce resources to the process of adaptation to climate change, there is no concomitant global commitment to the reduction of greenhouse gases, which is the real source of the problem we now face.

I therefore urge the international community to swiftly ratify and implement the provisions of the Kyoto Protocol, and thereby reduce the vulnerability of countries such as my own. This, our First National Communication, is an expression of the commitment of the Government of Barbados to the United Nations Framework Convention on Climate Change, and its willingness to continue to work with our global partners to respond effectively to the threat that lies ahead.

Just as recent events have caused great international collaboration and resource mobilisation, we now need to unite in the critical fight to save our earth. Let us tangibly demonstrate that we are equal to this challenge.

H. Elizabeth Thompson, M.P.
Minister of Physical Development and Environment

Contents

Contents cont'd pg

Contents cont'd pg

Contents cont'd

Executive Summary Of Barbados First National Communications To The UNFCCC

CHAPTER 1: Barbados' National Circumstances

Climate & Geography

Barbados, the most easterly of the islands of the Lesser Antilles, is a small island developing state of area 431 km^2, located in the Caribbean at 13° 4' North latitude and 59° 37' longitude.
The island is non-volcanic, consisting of underlying sedimentary deposits, all capped by a layer of coral up to 300 feet (90m) thick. In the more elevated north-eastern part of the island, erosion has removed the coral cover across an area comprising about 15% of the island's total surface. This unique section of the island is known as the Scotland District, and has within it the island's highest promontory, Mount Hillaby, which stands only 340m above sea level. The topography of Barbados is also marked by giant cracks in the limestone cap of the island, which form a complex series of gullies running mainly from this higher, eastern portion of the island to the west coast. These gullies, act as a major conduit of recharge of rainfall to the limestone aquifer, transporting water via underground streams to discharge into the sea at the west coast.

Barbados enjoys a tropical, oceanic climate with an average temperature of 26.8°C, with no drastic changes in either seasonal or daily temperatures. Weather seasons can be classified as either wet or dry, with the wet season coinciding with the Atlantic hurricane season, which runs from June to November. Monthly average rainfall ranges from a peak of approximately of 168.4mm (6.63in) during the wet season, to a low of approximately 39mm (1.53in), during the dry season.

The island is affected by a number of weather systems during the year. During the wet months, most of the rainfall is derived from tropical waves moving across the Atlantic Ocean, along with the Inter-Tropical Convergence Zone (I.T.C.Z.), which shifts northwards on occasions, especially during the passage of tropical waves. Although during the dry season, upper level troughs and lows and, to a much lesser extent, the tail end of cold fronts which survive after moving off the eastern seaboard of the United States of America, can contribute to the rainfall totals.

Social characteristics

The island's population is approximately 267,000, and is mainly of African descent. There is a slight female majority, the females making up 52% of the population.
The majority of the population lives within three coastal parishes, and 25% live within 2km of the coast, in a so-called 'urban corridor,' which runs along the entire length of the west and south coasts.

A former British colony, the constitution of 1966 established a governmental structure based on the British parliamentary system. The British monarch is the head of state and is locally represented by a governor-general. A prime minister, a cabinet, an elected House of Assembly, and a nominated Senate are the main governmental institutions.

There is no one living in absolute poverty on the island, and literacy has hovered around the 98% mark for the last two decades or so, which is largely attributable to the long-standing, comprehensive, mainly government-funded school system.

Economy

The Barbados economy historically was a sugar-based one; however, like many other microstates, Barbados has found it necessary to diversify its economy in the post- independence period, to develop a wide enough range of traded sectors, so vital for the generation of foreign exchange. The Tourism, Sugar, Manufacturing, and Finance and Business Services sectors generate foreign exchange, especially vital, since Barbados imports nearly all of its food stuffs, fuels, construction materials and other goods.

In looking at the vulnerability of its economy to Climate Change, the Sugar and Tourism sectors stand out as the most vulnerable. Sugar contributes about 2% of GDP, while Tourism contributes about 15%.

CHAPTER 2: Vulnerability And Adaptation

Of the numerous impacts of Climate Change expected, increases in atmospheric temperature, sea level rise (and its attendant impacts of erosion, inundation and saline intrusion), and changes in weather patterns (notably changes in the amount, and seasonality of rainfall, and changes in storm intensity), are expected to pose significant problems to Barbados.

Coastal Vulnerability

Sea level-rise has several induced impacts, namely, erosion, coastal inundation and saline intrusion of coastal fresh water aquifers. Eroding coastlines place critical infrastructure in Barbados at risk of inundation, with serious implications for the tourism industry, utilities and other sectors in Barbados. The Intergovernmental Panel On Climate Change (IPCC) in their third assessment report also suggest that the intensity of the most severe hurricanes is likely to be greater, thus compounding the possible effects sea level rise.

Through the Caribbean Planning for Adaptation to Climate Change project an initial coastal vulnerability assessment for Barbados has been carried out, with an analysis of the effect of sea level rise (three scenarios 0.2m, 0.5m and 1m) primarily on the southern and western coasts of Barbados, with specific emphasis on erosion and inundation impacts, and calculations of beach loss at specific pilot sites.

Several of the island's beaches are narrow, averaging between 12-15m in width, such that land loss will result in diminishment of beach capacities to protect against flooding and inundation, increasing vulnerability to storm surges, and in some cases, total loss of beaches, since modelled beach losses, were sometimes as great as 30m inland.

Furthermore, a rise in relative mean sea level also reduces the freeboard of coastal defences. The combination of higher breaking waves and reduced freeboard will result in larger overtopping rates and more extensive flooding of coastal property.

In modelling water elevation levels during a 1:100 storm year event under the various scenarios of sea level rise, there are indications that flood zones can range anywhere from 150m to 1km inland.

Vulnerability of Water Resources

Fresh water resources are likely to be threatened in two main ways by climate change: (i) by sea level rise, which is likely to increase salt-water intrusion within freshwater aquifers; and (ii) by increased frequency and severity of droughts, as has been experienced in recent decades, and which may intensify in the future in the Caribbean region, as many climate models suggest. Barbados is almost entirely dependant on groundwater supplies.

With available per capita natural water resources estimated at 350 m^3 per person per year, Barbados is classified as a water scarce country (Reid, 1994). The total annual water resources of Barbados are estimated at 59.0 million m^3 per year in an average year and approximately 45 m3 million per year in a 1:15 year drought. This is based on an annual average rainfall of 1450 mm per year (Klohn Crippen, 1997). Up until February 2000 fresh groundwater accounted for 96.8% of Barbados' potable water supply; while fresh water springs accounted for 3.2% of the water supply. Two desalination plants have been recently built in Barbados, the larger of which is capable of supplying up to 10 % of the island's drinking water needs. Together these plants are capable of relieving approximately 12% of the stress on the nations water reserves.

Barbados' groundwater aquifers are unconfined, and hydraulically connected to the sea. 86.4% of the island's drinking water comes from three coastal catchments, namely the St. Michael catchment (52.8% of total), the St. Philip catchment (20.2%) and the West Coast catchment (13.4%).

The wells of the West Coast catchment are, on average, 992.80 m away from the sea, with water levels about 0.3m above sea level on average. Therefore these are seen as the most at risk to suffer from saline intrusion. Impacts of salinisation of this catchment are great, since some 51,000 persons along the West Coast, and northern parishes of Barbados, are serviced by this catchment, as is the island's luxury tourism sector, the shopping areas of two of the island's towns, the island's largest sugar factory and its lone cement plant. Therefore it is crucial that Barbados begin investigations into water supply augmentation, since any loss of output from the West Coast catchment will have serious implications for the island.

Climate Related Disasters

The IPCC's Third Assessment Report 2001 indicates that more intense periods of precipitation over many areas such as the Caribbean is very likely, as is the intensification of floods. While the IPCC notes that there is no consensus regarding the predicted behavior of tropical cyclones in a warmer world, individual studies have reported the likelihood of a possible increase of approximately 10-20% in intensity of tropical cyclones under enhanced carbon dioxide conditions (IPCC 2001).

In Barbados fifty-eight (58) severe rainfall (flood) and wind events of a significant nature have been documented from 1955-2000. Hurricanes and tropical storms in 1955, 1970, 1980, 1980, 1994, 1995(2), 1997 and tropical waves in 1998 caused flooding, damaged houses and buildings, and displacement of people. Hurricane Janet in 1955 was the last hurricane to directly hit Barbados. At that time, thirty-five (35) persons were known to have died, and eight thousand, one hundred, (8,100) small dwelling houses were damaged, leaving twenty thousand (20,000) people displaced.

Barbados has also sustained significant losses from passing systems, and flooding from rainfall events. Hurricane Allen in 1980 passed to the north of Barbados causing over BDS $7 million dollars in damage; whilst a tropical wave in combination with an upper level trough in August 1995, produced up to 225mm of rain in certain areas of the island, causing severe flooding and over BDS $ 4 million dollars in damage. (US $1.00 = BDS $2.00)

Agricultural Vulnerability

The IPCC third assessment report notes that for the Caribbean, there are indications that by the years 2050 and 2080, annual mean temperatures could increase by 2.03 °C, and 3.06 °C respectively, while annual mean precipitation could decrease by 5.2% by 2050 and 6.8% by 2080. A change in seasonality has also been indicated, such that precipitation will likely increase in what would normally be regarded as the drier months (December to February), and decrease in the traditionally wetter months (during the third quarter of the year).

These predictions, if they materialize, are likely to undermine Barbados' food security. Unless preventative measures are taken, and in the very near future, a temperature increase of 2°C-3°C over the next 50-80 years could see several local plant and animal species gradually vanishing from the Barbadian landscape.

Impacts on Crops

The IPCC third assessment report notes that under certain conditions, a doubling of carbon dioxide concentration in the atmosphere could see a 20 -40 % decrease in sugar yield; which could have devastating implications for sugar production in Barbados, which acts as Barbados' second most important foreign exchange earner, contributing some 4% to GDP.

Higher atmospheric temperatures are influencing soil temperatures, and consequently, several local commercial crops are being affected at different growth and development stages. Microbial activity can also become accelerated, hastening the break down of soil organic matter, such that most of the nutrients released are more prone to leaching or run off with the first rains. This acts to reduce the soil's ability to retain moisture, also impacting negatively on soil erodability and fertility. Additionally, since some temperature sensitive soil microbes often exist in symbiosis with flowering plants (spermatophytes), diminished performance of the microbes could lead either to increased mortality or reduction of biomass building in plants, and consequently a reduction in food production.

In Barbados, certain insect pests breed during the dry season. Higher temperatures and lengthened periods of drought therefore, are expected to increase the number of generations of insect pests each year, increasing their destructive potential, as well as the pest: predator ratio. In addition, research has already shown some defoliators, such as Lepidopteran insects (moths), become even more destructive as atmospheric CO_2 increases.

High temperatures together with low rainfall increase the frequency of fires, one of the greatest threats to the local sugar crop. Weeds are also expected to thrive with increased temperatures, such that increased use of pesticides will likely increase the farmer's overall production cost.

Stray livestock, starved of moisture and sufficient fodder, have been identified as serious pests for farmers; although, in recent times, monkeys and birds have been equally as destructive, as natural plant systems also suffer diminished biological activity and production of biomass under increasingly lengthy drought periods.

Impacts on Livestock

At present, poultry birds have shown the greatest vulnerability to increasing temperatures, as tens of thousands of these animals die each year as a result of heat related illnesses. Consequently, both egg and meat production is expected to decline under the IPCC scenario of rising temperatures. Larger animals (cows, sheep, pigs, etc) tend to be a more resistant to heat stresses; yet in recent times, high daily temperatures have been responsible for the death of several mature pigs and young piglets. Both meat and milk production in ruminants, are expected to decrease as daily temperatures increase.

Reduced availability of local meat and meat-products will impact negatively on food quality, quantity, and ultimately, on human nutrition. There will also be associated economic problems, threatening the very existence of the small farmer, since they will have to provide adequate shade and shelter for animals, in order to obtain maximum production from their farm animals, increasing overall production costs. In addition, meat and other livestock products would have to be imported to supplement expected shortfalls, impacting negatively on foreign reserves.

The quality and quantity of grasses, including those that are regularly consumed by large ruminants (cows, sheep, goats, etc.) would be significantly reduced if precipitation predictions for the future become a reality, since plant production, including that of grasslands, will be diminished. Farmers may either have to increase the sizes of their grasslands or consider other food supplements, both of which add operational costs, and threaten the livelihood of the farmer.

Implications for Agricultural Water Resources and Patterns of Use

The 15% to 20% reduction in rainfall predicted for 2050 and beyond could have a devastating impact on local agriculture, particularly on those crops that require a constant supply of water to induce and sustain fruit and foliage production. Currently, less than 5% of Barbados' cropped lands are under irrigation, a figure that will certainly need to increase under the current climate scenarios. Demands on water for agricultural use are already high, and in order to meet future water demands, it is likely that storage facilities for agricultural water (dams, wells, etc.) will have to be increased, adding once again to the farmer's overall production cost.

Saline waters resulting from overdrawn wells, and changes in the seasonality of annual rainfall are expected, such that there will likely be a need to alter planting seasons, as well as to carry out crop breeding research, to find cultivars suitable for the altered conditions of growth.

Future requirements to sustain Agricultural Activity

Barbados needs to start developing new food security strategies since global warming is expected to place a variety of agricultural crops including rice and wheat, at risk. There is also a need for scientific research for more resistant crops, as well as an examination at the necessary changes in irrigation and fertilizer regimes.

Vulnerability of Coral Reefs and Fisheries

Barbados has an estimated 4.9km^2 of bank reefs and an estimated 1.4km^2 of fringing reefs located on the west, south west, south east, east and the north of the island. At the west coast, fringing reefs extend 300m out from the beach, to a depth of 10m. Extending from these reefs are patch reefs, which terminate at about 30m depth. Bank reefs on the west coast are found between 700m-1km from the shore. The south west coast has relic fringing reefs in depths of 6-15m, while 1km from the shore, the bank reef runs parallel to the shore and is continuous with west coast bank reef.

The north west coast supports some of the most extensive and diverse hard corals in Barbados. The southeast and east coasts are fully exposed to the Atlantic Ocean, and thus there are no fringing reefs in these areas. There is however a bank reef on the south east coast, which is around 400km from the shore.

In Barbados the coral reefs play a vital role in sand creation, beach stabilization, and the prevention of erosion by dissipating wave energy. In addition reefs are an important income generator, as many tourists are attracted to the coral reefs and their associated flora and fauna, for recreational dives. In terms of fisheries the coral reefs support a vibrant and diverse flora and fauna, many of which are commercially viable.

Coral reefs around the island exist in varying degrees of health. Although anthropogenic activity is blamed largely for deterioration of reefs about the island, increased ocean temperatures have caused an increase in coral bleaching events, lending credence to the IPCC third assessment prediction of increased incidence of coral bleaching episodes in the Caribbean. In 1998 coral reef bleaching in Barbados occurred, and monitoring based on in situ identification of coral species affected, showed that over 95% of all brain corals ***Diploria*** Sp had been white bleached, over 60% of all boulder star corals ***Monstastrea annularis***, and approximately 25% of all massive starlet corals ***Siderastrea siderea*** were bleached. Subsequent monitoring has shown that algal coverage increased significantly at every area observed, and the recovering corals experienced high mortality.

The fisheries industry is extremely important in Barbados. 2200 fishers are employed in the industry of which 80% are full time. Target fisheries are largely pelagic and demersal, as nearshore coastal reef fishery landings have declined significantly over the last two decades. Freshwater fisheries are virtually non-existent.

Reef fish kills have been observed from time to time in Barbados waters. During the period August to November 1999 there was a major fish kill, which was attributed to the influx of flow from the Orinoco River of South America, with above- normal temperatures and chlorophyll concentrations, and low nocturnal oxygen levels. This fish kill was devastating to the local fishing community, and is an example of the type of problems, which could occur in Barbados under a changing climate.

Adaptation Measures and Options

Coastal adaptations options mainly include the implementation of set backs and zones for coastal buildings, a building code for coastal buildings, beach nourishment in order to enhance resilience of a particular beach, or the construction of groynes, revetments and breakwaters.

There are many categories of water resource adaptation options that might be considered, namely: (i) reworking of distribution and management policy; (ii) improved water resources assessments; (iii) demand management; (iv) improved public education; (v) revision of metering and pricing policy; (vi) employment of water conservation practices and devices; (vii) leakage detection and control; (viii) use of physical options to combat changes in the level of the salt water interface; and the (ix) use of technological options to augment water supply.

The majority of adaptation options with regards to agriculture will focus on doing the suitable research on climatic conditions in the future and the selection of appropriate varieties of crops for cultivation in the changing climatic conditions. There is also a need for capacity building in the area agricultural research as it pertains to climate change, as well as a source of funding for such activity.

Through Component Four (Formulation of Adaptation Policy for Climate Change) of the CPACC project several national consultations on the issue of adaptation to climate change have been held, to aid in the drafting of an initial adaptation policy for Barbados. A number of adaptation/ management options have been identified as possible solutions to assist in coping with the impacts of climate change across sectors, however, it is clear that there is a need for further capacity building, sectoral analysis and research, in order to better assess vulnerabilities and implement specific adaptation options and policies.

CHAPTER 3: Barbados' First National Greenhouse Gas Inventory

Barbados has, for the first time, calculated anthropogenic GHG emissions and removals by sink for the years 1990, 1994 and 1997 based on the Intergovernmental Panel on Climate Change (IPCC) Revised 1996 Guidelines for National Greenhouse Gas Inventories. For all sectors, the Tier I or simplest methodologies for estimation of emissions and removals were used.

Barbados is heavily dependent on the importation of fossil fuels for energy and transportation requirements, and as such, fuel combustion is the main source of greenhouse gas emissions. Analysis of the national GHG inventory for the years 1990, 1994 and 1997, produced the following main points:

- CO_2 emissions make up 94% of total GHG emissions in 1990, 96% in 1994 and 96% in 1997. A comparison of the three years investigated shows a progressive increase in total CO_2 emissions from 1990 to 1997. CO_2 emissions in the years 1990, 1994 and 1997 were calculated at 1,564.23 Gg, 1,913.81 Gg and 2,198.40 Gg respectively.

- The greatest source of CO_2 emissions is from the combustion of fuel used for the genera tion of electricity, an average of 74% for the three years investigated. This is followed by CO_2 emissions from combustion of fuel for road transportation, which on average accounts for 14% of emissions of this GHG. CO_2 emissions from fuel combustion in the manufacturing/industrial, commercial/institutional, residential and agricultural sectors in Barbados are relatively small, together making up an average of 9% of total CO_2 emissions.

- Consideration of total emissions of non-CO_2 GHGs reveals that the gas of greatest con cern is methane (CH_4). Methane emissions show a progressive increase from 1990 (78.66 Gg) to 1994 (85.07 Gg) to 1997 (86.36 Gg), however, the percentage of total emissions remained constant for the three years at 4%.

- Emissions of the other non-CO_2 GHGs, carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO_2), oxides of nitrogen (NO_x) and hydrofluorcarbons (HFCs) are considerably lower than emissions of CH_4 for all of the years, together accounting for an average of 0.55% of total emissions.

- Land Use changes and forestry, which is characterised by the regrowth of natural biomass on abandoned agricultural lands, removed some 11 Gg of CO_2 annually for all years investi gated.

As expected, the energy sector is responsible for the majority of the emissions of CO_2, followed by emissions from the industrial processes sector, where the island's lone cement plant is the primary source of CO_2 emissions.

The major anthropogenic cause of removal of atmospheric CO_2 is the regrowth of abandoned agricultural lands to a natural state. However regrowth of biomass will not likely be a major GHG sink on the island in the future, due to the current pressure on agricultural lands for conversion to residential or commercial development.

Land filling of solid waste and the handling of wastewater were found to be significant sources of CH_4, indicating the need for greater investigation into the implementation of flaring or gas recovery schemes.

On a global scale, GHG emissions from Barbados are small; and it should be kept in mind that a significant amount of energy is consumed in catering to the near quarter million visitors present on the island at any given time, alongside the resident population of about 267,000.

CHAPTER 4: Strategy For The Atement Of Greenhouse Gas Emissions

The United Nations Framework Convention on Climate Change (UNFCCC) sets an "ultimate objective" of stabilizing "greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." The UNFCCC is also acknowledges that "dangerous" level of greenhouse gases is, in this context, a socio-political rather than a scientific question.

Barbados has undertaken the development of a Greenhouse (GHG) Abatement Strategy, based on the outcome of its first Greenhouse Gas Inventory for the years 1990, 1994 and 1997. The purpose of the GHG Abatement Strategy for Barbados was to identify abatement options, which can be implemented to reduce or eliminate the GHG emissions of Barbados, especially where such abatement options can bring economic and environmental benefits.

Specific objectives of the abatement strategy were:

a) To review the GHG emissions of Barbados as presented in the national GHG Inventory
b) To identify the major sources of GHG emissions in order to determine where abatement efforts should be targeted in the first instance
c) To review initiatives or strategies that are currently being undertaken or investigated in Barbados aimed at reducing or eliminating GHG emissions
d) To recommend further strategies and/or methods that could be implemented to reduce GHG emissions.

Based on the findings of the GHG Inventory, abatement efforts and resources for Barbados should be focused on controlling/reducing:

- CO_2 emissions from fuel combustion for electricity generation.
- CO_2 emissions from road transportation.
- CO_2 emissions from cement production
- CH_4 emissions from waste management activities.
- CH_4 emissions from agricultural activities.

The abatement strategy for Barbados is presented as broad abatement options, which are geared towards the reduction or elimination of GHG emissions in those sectors and subsectors (as defined in the 1996 Revised IPCC Guidelines for National Greenhouse Gas Inventories) determined to be making the greatest contribution to the total emissions of Barbados.

Reducing Fuel Consumption for Electricity Generation

The main source of CO_2 emissions in Barbados is the combustion of fuel for electricity generation. The Barbados Light & Power Company Ltd. (BLPC) is the sole generator of electricity for public use in Barbados, and so the operations of this company must be targeted for action. Therefore any attempts to reduce GHG emissions from fuel combustion must target the operations of the BLPC. At the present time, the BLPC depends on three fuel types: residual fuel oil (no.6), distillate (diesel and AvJet) and natural gas.

Based on the BLPC estimations of fuel use (at 5% growth) to satisfy system demand in 2008, the IPCC methodology was also used to calculate CO^2 emissions. Comparing the 2008 estimate of total CO^2 emissions (over 890 Gg CO^2) from fuel combustion for electricity generation with the 1997 estimate (496.68 Gg CO^2), it can be seen that there is an expected 80% increase in emissions from this source in just over 10 years.

The BLPC has already undertaken investigations into fuel reduction options, which would also serve to abate the level of GHG emissions. One of these is the development of a 9MW wind farm, which would likely be implemented within the next 10 years. It is estimated that the wind farm would produce 3% of the total energy demand and reduce fuel consumption for electricity generation by about 4%, with a corresponding estimated 5% reduction in CO^2 emissions from this source (using 1997 emissions level). Other abatement options being considered are methane recovery at the island's landfill, use of liquefied natural gas, bagasse cogeneration, and solar generation of electricity (photovoltaics).

Emphasis on Energy Efficiency Measures in the Industrial, Commercial and Residential Sectors

Reducing the demand for electricity in the industrial, commercial, and residential sectors through the adoption of energy efficient measures and technologies has also been identified as an abatement option.

In the industrial sector, measures could include the upgrading of technology and equipment to achieve greater energy efficiency, the undertaking of energy audits, and the development of energy use reduction and efficiency plans for individual companies. In the commercial and residential sectors, giving emphasis to the use of energy efficient equipment in lighting, refrigerating and air-conditioning is priority. The development of linkages between the Ministry of Physical Development and Environment and various components of the private construction industry to encourage the design, construction, use and management of energy-efficient commercial and residential buildings will also have long term impacts on GHG emissions from these sectors.

Reduction of CO_2 Emissions from the Cement Industry

About 5% of global CO2 emissions originates from cement production. About half of this is from calcinations and half from combustion processes. Barbados' GHG Inventory indicated that local cement production accounts for an average contribution of 7% of total CO_2 emissions from calcining the limestone in the raw mix. The contribution to emissions from fuel combustion was not determined separately; but fuel use by this sector was included in the figure for fuel combustion by the manufacturing, industries and construction sector.

The Arawak Cement Company Ltd. is the only cement production plant in Barbados. In general, emissions of CO_2 from the cement manufacturing process can be reduced by: (i) Improvement of the energy efficiency of the process through equipment changes; (ii) shifting to more energy efficient processes of cement production (eg. from (semi) wet to (semi) dry processes); (iii) increased substitution of CO_2 -generating clinker with industrial by-products such as coal fly ash and blast furnace slag, to produce blended cements; (iv) removal of CO_2 from flue gases.

Introduction of Electric Vehicles and Hybrids

The combustion of fuel by road vehicles makes the second largest contribution to the total CO_2 emissions of Barbados. The introduction of electric vehicles (EVs) has the potential to significantly reduce emissions of GHGs from this source. Investigations have been undertaken into the feasibility of making the transition in Barbados from internal combustion engine vehicles to (EVs) and hybrids. Having considered the effective range of these vehicles, Barbados' flat terrain, and the average weekly distance traveled by the Barbadian driver, EVs have been found to be more than adequate for usage by most commuters and tourists in Barbados. Hybrids, vehicles that use a small amount of petroleum, also offer a good distance range and low emissions. EVs and hybrids could also pave the way for fuel cell vehicles (once these become commercially available). Options for introducing EVs and hybrids to Barbados, include: (i) replacing current government vehicles; (ii) Offering rental agencies VAT incentives to add some of these vehicles to their fleets for use by tourists; and (iii) Offering car dealerships VAT incentives to sell electric scooters.

Reducing the Disposal of Organic Materials in Landfills

The primary sources of CH_4 emissions are from waste management (landfilling and sewage handling), indicating a need for improvement of waste management practices, particularly the reduction of landfilling of organic waste. Organic materials currently account for about 47% of the Municipal Solid Waste (MSW) stream in Barbados.

In 1993, the GOB embarked on an Integrated Solid Waste Management Programme (ISWMP), of which composting is an important element, aimed at reducing the quantity of organic waste going to the landfill. There are two categories of the National Composting Programme: (i) commercial composting which will take place on a large scale, receiving yard waste from a variety of sources and producing high quality compost for sale to agriculture and other sectors; and (ii) home composting which involves encouraging householders to compost their kitchen scraps and yard waste.

Educating the general public and the commercial sector to adopt composting practices as well as other general waste reduction and recycling techniques is also key to the success of this abatement option.

Recovery of Methane Gas from the Mangrove Pond Landfill

The recovery of CH_4 from Barbados' landfill is a possible option for the elimination of emission of this gas from this source. Developed countries have for some time been successfully employing technologies for the recovery and use of landfill gas (LFG). The CH_4 content of LFG typically ranges from 45% to 55% in municipal solid waste landfills that are in the final stages of decomposition; and a study undertaken in 1998 by the Barbados Light & Power Company Ltd. revealed that the mean concentration of methane at each of seven (7) sites tested at the island's Mangrove landfill ranged from 34.5% to 52.3%. It was deduced that this suggested that, at some of the sites tested, the landfill is in final stages of decomposition. It is also possible. There were also indications that fissures in the clay cap were acting as an escape route for methane, leading to lower recorded levels of methane at some sites.

Local, on-site use of LFG to generate electricity will likely be the most economically feasible option for Barbados. Good candidates for end uses of landfill gas-to-energy include use in facility buildings or leachate evaporators, and nearby municipal and private buildings, such as recreational facilities, and schools in the area.

Increased Support for Research and Development

Ongoing research and development in all sectors is a necessary aspect of ensuring the success of national efforts to minimize emissions of GHGs. Financial and political support for organizations, both in the government and non-government sector, and for programmes or technologies which show real potential for contributing to the reduction of GHG emissions, is crucial.

Potential Obstacles to the Adoption of Abatement Options

A number of factors, which may hinder the adoption of the recommended abatement options, have been identified. These factors, outlined below, will likely be remedied, at least in part, by the introduction of appropriate policy measures and public education programmes:

- Lack of information and/or understanding of the need for GHG abatement and hence for the adoption of abatement measures
- Shortage of capital and lack of access to acceptable financing
- Aversion to the risk involved in adopting new technologies
- Higher cost of abatement technologies
- Lack of public and political support for the implementation of abatement measures
- Inadequate institutional arrangements

It should be recognized, however, that GHG abatement measures must be pursued in conjunction with climate change adaptation measures, since the phenomena of climate change and its potential adverse impacts are the collective result of the activities of all nations.

CHAPTER 5: Policies And Actions

The Government of Barbados has recognized that environmental management is a crucial component of sustainable development. Protection of the environment has, however, become even more crucial in recognition of the vulnerability of Barbados to climate change. As such, a number of coastal projects, works and policies have been developed within the last decade, as a general proactive step to combating the threat of climate change.

Apart from taking adaptive steps to the climate change problem, the Government of Barbados, has on its own initiative, embarked on an overhaul of its energy sector to increase the use of renewable energy sources and employ sensible energy conservation techniques. These projects are aimed at enabling Barbados to become more independent and self reliant in catering for its energy needs, as well as to bring it closer to being a true model for sustainable development.

Legal Issues and Climate Change

There are approximately 37 main pieces of legislation in Barbados, which deal with environmental, land use and building issues. Of these 37 statutes, 62% may be classified as environmental, 27% as related to land use and 1% as related to building. In Barbados only 10 out of the 37 existing statutes dealing with environmental, land use and building issues have been enacted after 1992, the year of the United Conference on Environment and Development (UNCED), a watershed in respect of the global environment movement. Of the post-1992 legislation, 6 are environmental, and the remaining 4 address land use matters. At the same time, the majority of the pre-1992 environmental, land use and building laws were enacted in the early 1970s. The majority of existing environmental laws in Barbados, therefore, are not modern.

In order to deal with climate change impacts such as coastal erosion, flooding and salinization, it will be necessary to amend current legislation by: (i) strengthening the content of legislation and the promoting effective enforcement measures; (ii) increasing penalties so that legislation is in fact a deterrent to non-sustainable behaviour; and (iii) providing for the selective relocation of critical services.

In other instances new legislation will be necessary. Proposed are : (i) a Climate Change Act; (ii) an Environmental Management Act; (iii) a Disaster Management Act; (iv) a Building Code, with the establishment of a Building Authority; (iv) Environmental Impact Assessment legislation; and (v) a general inclusion of the Precautionary Principle in local legislation.

Coastal Zone Management Issues

As a small island state, coastal zone management is crucial to Barbados surviving climate change impacts. In 1983 the Government of Barbados established the coastal conservation project unit, which has evolved into the current Coastal Zone Management Unit. The purpose of the coastal conservation project unit was to conduct diagnostic studies of the islands coasts, and subsequently, this project unit focused on the west and south coasts of Barbados, designing various engineering and non-engineering measures for beach protection, stabilization and enhancement. Responsibilities of the CZMU at present include reviewing planning applications for developments in the coastal zone, conducting monitoring and research, enforcing the Coastal Zone Management Act and any subsidiary regulations, and acting as the advisor and lead focal point for coastal zone management for the Government of Barbados (GoB).

Intergrated Coastal Zone Management in Barbados is supported by two pieces of legislation: the Coastal Zone Management Act and the Marine Pollution Control Act. The Town and Country Planning Act, which establishes the framework for national planning and development, supports these two acts.

The Marine Pollution Control Act establishes the framework for pollution control in the marine environment, authorizing legislation for environmental protection, and applies to most sources of marine-based and land-based pollution.

The Coastal Zone Management Act of 1998 establishes the legal framework for coastal zone management in Barbados. The Coastal Zone Management Act requires the development of a Coastal Zone Management Plan (CZMP) (currently awaiting final approval), which presents general and specific guidance for: (i) Global and regional coastal change; (ii) Conservation management; (iii) Maintenance and construction of coastal structures; (iv) Beach management recreation and safety; (v) Fisheries; (vi) Coastal habitat restoration; (vii) Community tourism; (viii) Resource exploration and extraction; (ix) Water quality; (x) Zoning; (xi) Set Back, access and views to the sea; and (xii) Environmental Impact Assessment.

The Draft Plan is to begin the statutorily mandated process of public consultation and parliamentary approval by the end of 2001. Despite this, the GoB has been adhering to its recommendations, and the CZMU has been putting into practice the recommendation of the plan, particularly with respect to: (i) the evaluation of all coastal-related development proposals which require building permits; (ii) EIAs for all coastal developments; (iii) enforcement of building set-backs and zoning of ecologically sensitive areas, both along the coast and in the marine zone; and (iv) enforcement of design requirements related to coastal engineering practice.

The CZMU has overseen demonstration projects for beach protection and enhancement, which were constructed and implemented with financial assistance from international donor agencies. As a result of the success of the demonstration projects, this unit is now in the process of finalizing engineering designs, with financial assistance from international funding agencies, for another six (6) coastal adaptation projects.

Renewable Energy in Barbados

As late as the 1950's, when there were 22 sugar cane factories in operation, 50% of Barbados' primary energy was from renewable energy sources. Today the main renewable energy sources are sugar cane bagasse and solar water heaters, which contribute 15% of the island's primary energy.

The Government of Barbados today seeks to return to greater dependence on renewables, and has supported work into solar, bagasse cogeneration, wind energy and ocean thermal energy conversion technologies.

Solar Technologies

On a clear day during the dry season, a 430 square kilometre island like Barbados receives 3 billion kWh on such a day. This is 1.08×10^{16} joules or the energy equivalent of about 1.87 million barrels of oil, which is similar to a year's petroleum imports for the island (Headley, 2001). Recognising this, the Government of Barbados has been a great supporter of solar technology and research.

(i) Solar water heating in Barbados

Solar water heating represents an example of sustained application of renewable energy technology in the region as a whole. In Barbados, it was especially successful, such that today, Barbados is the leader in the Caribbean in the use of this technology.

The Government of Barbados supported this initiative with the following policies:

- Taxes on raw materials to the water heater manufacturers were waived.
- Taxes on non-solar water heaters were kept high (60%) or increased.
- Householders who purchased solar water heaters were allowed a 100% rebate on the cost of the heaters on their income taxes.
- Hotels that borrowed from the government-run Development Bank, were compelled to carry out energy audits. These audits usually suggested the use of solar water heaters.

Barbados accounts for over 60% of the solar water heaters used in the region and is responsible for the manufacture of 80% of them.

The private sector also played a large role in promoting the use of solar water heaters. Included in their activities were:-

- The production of reliable and abundant supplies of the solar water heaters;
- The implementation of major consumer awareness programs as part of marketing process;
- The securing of lease purchase agreements for water heaters in order to overcome the high initial costs; and
- The recruitment of a large number of solar water heater retailers.

Over 32,000 solar water heaters have been installed, with a total electricity saving of 128 million kWh, and an estimated financial savings to the consumers of $19.2 million US/year. This in turn is the heating equivalent of 227,000 barrels of oil, and a foreign exchange saving to the island was about $US 6.8 million.

In addition to the fiscal benefits, a substantial quantity of emissions, such as carbon dioxide, sulphur dioxide and the oxides of nitrogen (CO_2, SO_2 and NO_x) are not emitted with the use of solar water heating, and the Barbados Light and Power Company (BLPC) also benefits by not having to produce the equivalent of what is about 19% of its 1998 production total of 658 million kWh.

(ii) Photovoltaic power

Photovoltaic (PV) systems have been used in the Caribbean for many years for telecommunications, where they powered microwave repeater stations, and navigational aids in remote areas.

PV systems have module efficiencies of 10 to 15%; and because of the intrinsically low efficiency of the system, a kWh of electricity from PV is about ten times the price of that from conventional fossil fueled generators or modern wind turbines. PV power, however, is increasing at about 20% per year; and the European Photovoltaic Association maintains that a five-fold growth in yearly production, then the economies of scale will result in a 50% reduction in the cost of PV cells (Headley 2001).

Having witnessed the success of the solar water heater programme, the Barbados Government is now placing a major emphasis on photovoltaics. There are a number of projects already on stream.

Barbados has about 37 kilowatts peak (kWp) of PV installed at various sites, making it one of the leading Caribbean countries in the utilisation of this technology. The largest of these systems are:

- 1100Wp at the University of the West Indies (UWI) for solar cooling.
- 17,300Wp at Harrison's Cave for running the cave's lighting system.

- 3,000Wp at Combermere School for operating a computer laboratory.
- 2,000Wp grid-tied PV system installed at BLPC's Seawell Generating Station, at Grantley Adams airport.
- 2,000Wp at Government Headquarters to operate lights and provide emergency power.
- 11,100Wp at the Skeete's Bay fishing complex on the island's East Coast powering a one-tonne-per-day solar ice maker for the fisherfolk
- A 300Wp portable PV system is used to demonstrate the flexibility and versatility of the technology to members of the public.

With the exception of the Barbados Light and Power Company system, these PV systems have been financed by the Government of Barbados, since it is hoped that Barbados will gain the same image in solar photovoltaic power as it has in solar water heating. Additional to these demonstration projects, the Government has held training workshop, both for technicians and secondary school students, to ensure that the capacity is developed to sustain a new, expanding solar photovoltaic industry. "Hands on" training in designing and assembling a photovoltaic system, was included in the workshops; and schools were provided with a photovoltaic panel at the end of the workshop, to be used at the school for development of projects.

(iii) Solar Crop Dryers and Solar Stills

Barbados has also been involved in promoting solar drying for agricultural crops, and solar distillation.

Solar drying techniques have been used in Barbados since 1969. In 1973, the University of the West Indies began to build solar crop dryers; and in 1976 the first large-scale dryer was produced, with a 1600-kg capacity for drying sugar cane. Since 1990 solar drying facilities have been used to dry many different crops, including sweet potatoes, eddoes, yams and other vegetables. The University of the West Indies, Cave Hill Campus, established a solar drying project in 1995, and has recently developed the Artisanal Dryer, which has been exported in the Caribbean region.

The Government of Barbados is currently working with the Centre for Resource Management and Environmental Studies (CERMES) of the University of West Indies to construct solar stills in every secondary school in the country, to provide distilled water for use in science laboratories and other purposes. Already, 12 of the 21 secondary schools have been equipped with these stills, providing an average of 8 litres per day, with some schools selling the excess distilled water produced. Similar to the workshops held under the schools' photovoltaics programme, there was a workshop held in 1999 in the operation of solar stills. This initiative has been extremely successful, making the use of electric stills a thing of the past.

Wind Energy

The Government of Barbados has been investigating the possibility of wind generation for over a decade.

In 1998 the Government of Barbados carried out a feasibility study for a wind farm at the north of the island. Winds were almost exclusively easterly, with a mean wind speed calculated at 7.34m at a height of 40m.It was concluded from this data that the conditions are favourable for the construction of a wind farm, which would have a 10 month setting up phase and a 9 month construction phase, and generate about 16MW of energy. The local power utility wishes to invest in a wind farm; however the major impediment to this becoming a reality is the current difficulty in acquiring/leasing suitable sites for the wind farm.

More recently, there has been interest expressed in three sites in the north and south east of the island, for a wind farm with a proposed capacity of 11.25 MW and an expected cost of BDS$28m.

The 11.25 MW wind farm would result in about 26GWh of electricity or about 3 to 4% of the year 2000's net electricity generation, and would be just over 2% of the projected net generation for the year 2010.

A larger wind farm would generate more electricity. One major barrier to this however, is the island's dense population, which restricts the size of good wind sites, as well as their distance from residential areas.

Bagasse Cogeneration

With the imminent removal of preferential rates paid for sugar to the former colonies of the European Union, the sugar industry in Barbados faces an uncertain future. In addition, Barbados' costs of production are much higher than the world market price of sugar, such that there is now a need to maximize the value derived from sugar cane.

Sugar production is one of the few agricultural processes where the energy output is greater than the input. It was therefore recognized that the excess energy might be harnessed, most of which is contained in the bagasse (the waste plant material after the cane has been ground), to produce electricity for sale to the national grid. In the year 2000, Barbados produced 537,000 tonnes of cane and 58,333 tonnes of sugar.

In a traditional sugar factory, there is little attempt to optimise the process, however, the efficient process engineering developed by the French firm SIDEC separated the generation of electricity and process steam from the other activities of the sugar factory and made them into a separate entity: a co-generation plant.

Since bagasse is only available during the crop season for about four months per year, the co-generation plant has to use another fuel for the other eight months. More than 35 of these plants are operating in France, (including some at mills that process sugar beet), as well as in the overseas departments of Réunion, Mauritius and Guadeloupe. To date almost all co-generation plants use coal as their alternate fuel, a low sulphur variety being used in the Guadeloupean installation, along with stringent processes of operation, to minimize emissions.

The French plants have proven to be quite successful, such that in the year 2000, 20% of electricity (132 MW) generated in Mauritius was derived from bagasse. In Guadeloupe sugar production is of a similar scale to that of Barbados, and in 2000, Bagasse/coal generating capacity was 64MW, which is more than half of Barbados' year 2000 peak electricity demand. The Government of Barbados has sent representatives to visit the cogeneration plant in Guadeloupe, and the Barbados sugar industry is now considering setting up one new factory and phasing out the three existing old factories. In addition, the Barbados Light and Power Company (BLPC) is exploring cogeneration as a way to meet increased electricity demand.

The Government and BLPC are considering the prospect of jointly setting up a 60 MW co-generation plant next door to the proposed new factory. The Government is exploring, however, a cost-effective alternative to the use of coal as the alternate fuel of the proposed plant.

Projected Renewable Energy Systems

Renewable energy projects currently under consideration for the island are:

- 16MW in wind turbine farms at good wind sites in northern Barbados.
- A 3 MW ocean thermal energy conversion (OTEC) plant.
- A 10 MW waste combustion plant.
- A 2 MW wave power plant 2 MW of solar PV distributed around the island.
- Setting up manufacturing facilities to produce high purity silicon for the computer chip and solar PV industries. (The possibility of a joint venture with Trinidad and Guyana is being explored.)
- Producing hydrogen from renewable energy to power fuel cell vehicles, e.g. cars and buses.

Other Government Initiatives

Renewable Energy Centre

Recognising the untapped potential in the area of renewable energy, and recognizing the economic implications of fossil fuel dependence, the Government has committed to the establishment of a Renewable Energy Centre to offer international scientists and technologists the opportunity to do research into renewable energy, as well as address institutional and policy issues which have played a major part in preventing the implementation of renewable energy projects. The centre will engage in training, research, development and demonstration in the area of Renewable Energy, as well as Energy Conservation; and will also include working exhibits of renewable energy technologies to educate the general public. It is expected that this institution will play a role in developing capacity in the region and eventually become a node in the international renewable energy network.

Government is willing to provide some initial financing to set up the centre, but there is a need of further funding.

Energy Conservation Programmes in Barbados

The Government of Barbados has been addressing the issue of energy conservation in a number of ways. At present, the Demand Side Management Feasibility Study, in conjunction with Barbados Light and Power Co Ltd, has been completed.

The Study report contained a number of recommendations for the utilities, government and energy industry. A number of recommendations have been offered to reduce the conditioning and refrigeration loads, which represent the largest use of energy in the commercial and industrial sectors. The leading suggestions in the report are calls for improved maintenance, and the use of electronic controls and occupancy sensors, to better control the shutting off of air conditioners in vacant hotel rooms.

The second most critical area for improved cost effectiveness was lighting. In many cases the use of T8 fluorescent lamps to replace existing T12 fixtures could save up to 20% of the lighting load. The use of compact fluorescent lights to replace incandescent lighting applications was also seen as a major potential energy saver.

The Government of Barbados will have a role to play to making the energy conservation equipment affordable locally, by removing import duties for such technologies. Investigations have begun into the possibility of the implementation of energy efficient standards to provide a basis of energy efficiency legislation.

The Government of Barbados has also recognized that the long-term success of the energy conservation process is contingent on a general attitudinal and behaviourial change of the Barbadian population as a whole to energy consumption. As such the Energy Division has begun an active energy conservation programme focusing on the schools as well as the general public.

The Barbados Natural Gas Sector

The Government of Barbados firmly supports natural gas as a cleaner fossil fuel.
The National Petroleum Corporation (NPC) is a public corporation established as successor to the Natural Gas Corporation by the National Petroleum Corporation Act Cap 280, which came into effect on April 1, 1981. Its primary function is the sale of natural gas for domestic, commercial and industrial use through its pipeline network. The purpose of the enterprise is to provide and maintain an adequate, reliable, competitive, safe and efficient gas service to existing and potential customers at a reasonable cost.

At the end of March 2001, the Corporation had 13,069 active customers; 12,511 domestic, 556 commercial and 2, classified as "special customers", the latter who receive reduced rates of purchase, because of the national benefits of their operations. These two customers are the Queen Elizabeth Hospital and the Barbados Light and Power Company Limited.

Gas is transported to customers via some 401.22km (249.32miles) of pipe distribution system.

The reserves estimates for April 2001, were 4.0 billion cubic feet (Bcf). This represents a total supply of 6 years given the current annual average usage of 645 million cubic feet (MMcf).

NPC is faced with a number of factors which are hindering expansion of its service, including the following:-

- High capital cost associated with the expansion of its distribution network.
- High cost of tools and materials to provide a safe and efficient gas supply. All materials and tools are imported.
- Competition from other petroleum products, for example industrial diesel, kerosene, fuel/ gas oil and L.P.G.
- High cost of natural gas equipment compared to electrical and other petroleum products' equipment.

Despite these limitations, the NPC is still exploring potential markets for natural gas such as:-

- Air conditioning for the commercial offices and hotel industry
- Cogeneration projects in the hotel industry
- Electricity generation in the manufacturing sector as this sector seeks to improve its efficiency
- Compressed natural gas (CNG)/ Liquefied natural gas (LNG) vehicles
- Industrial cooling projects.

Barriers to the Implementation of Renewable Technologies in Barbados

Barriers identified were : (i) financial and economic; (ii) lack of awareness of newer technologies; (iii) higher local operational costs of newer technologies; (iv) barriers related to policy; (v) lack of the addition of environmental cost on the use of fossil fuels; and (vi) lack of training and regional expertise in newer technologies.

The Governments of the Caribbean have recognized the existence of these barriers, and the Caribbean Energy Information System was set up in order to enhance the linkages between energy entities in the region. In 1998, the organisation developed a project with UNDP and GEF, aimed at removing barriers to renewable energy development. It is expected that this project will strengthen the energy institutional frameworks and prepare Caribbean countries to better explore and implement renewable energy technologies.

Technological Needs and Requirements

While Barbados has made major advances in the area of renewable energy, Barbados sees the assessment of vulnerabilities and adaptation options as priority. The Caribbean Planning for Adaptation to Climate Change (CPACC) project has provided initial capacity building in the area of vulnerability and adaptation. The Government of Barbados views the work of the CPACC as extremely important in allowing Barbados to examine adaptation options.

The continuation of work started by the CPACC project is therefore of extreme importance. The Government of Barbados views the establishment of a Regional Climate Change Centre as extremely important in achieving this goal, and in guiding the very development of Barbados and the region as a whole.

Critically, there is a need for the downscaling of the global climate change models or the development of regional models, which will allow a more insular and comprehensive understanding of how the changing climate will impact small island states in the region. It is hoped that the establishment of the regional climate change centre will aid in furthering much of the initial work of CPACC, to better ensure that climate change activities become integrated into the development activities of countries in the region. It is hoped that the international community will provide the relevant resources to allow the establishment of the regional climate change centre, which is a necessity for all countries in the region.

There is a need for major capacity building in Barbados in coastal zone issues and water issues, but particularly in the area of agriculture and climate change. The initial national communications of Barbados has not addressed the area of climate change and health, and the socio-economic impacts of climate change, as there is a dearth of research in these areas. This indicates the urgent need for capacity building and funding to allow in depth studies of these components in addressing climate change issues.

There will also be a requirement for significant financial resources to finance the evaluation and implementation of adaptation options identified under Component 4 (Formulation of Adaptation Policy) of the CPACCProject.

A number of proposed renewable energy options have been identified in this document. Abatement options have also been identified. Hence there are a number of potential projects identified for inclusion in the Clean Development Mechanism of the UNFCCC. One area, which may be very attractive in terms of the Clean Development Mechanism, is the vital tourism sector, since the low-seasonality of the industry results in an annual presence of an additional 400,000-500,000 persons in the form of visitors. Considerable amounts of energy are expended, directly, and indirectly on this tourist population, who for the most part, are from industrialized countries, and arrive with their first-world energy consumption practices. Thus a reduction of GHG emissions from this source will result in a considerable reduction in the overall emissions of Barbados.

Funding from developed countries is also required to aid in the establishment of the proposed Renewable Energy Centre, benefits from which should set Barbados well on the path to cutting its dependence on fossil fuels, at the same cutting its foreign exchange expenditure, to better stabilize its economy.

There is also a need for a sustained, effective public education programme for the populace on global climate change and the social, economic and cultural impacts which might be sustained by the island and its people.

List of Figures

CHAPTER 5: POLICIES AND ACTIONS

List of Tables

CHAPTER 1: BARBADOS' NATIONAL CIRCUMSTANCES

CHAPTER 2: VULNERABILITY AND ADAPTATION

CHAPTER 3: BARBADOS' FIRST NATIONAL GREENHOUSE GAS INVENTORY

CHAPTER 4: STRATEGY FOR THE ABATEMENT OF GREENHOUSE GAS EMISSIONS

CHAPTER 5: POLICIES AND ACTIONS

Abbreviations Used

LIST OF ABBREVIATIONS USED

BDS	Barbados
BLPC	Barbados Light and Power Company Limited
BNOCL	Barbados National Oil Company Limited
CERMES	Centre for Resource Management and Environmental Studies
CNG	Compressed Natural Gas
CPACC	Caribbean Planning for Adaptation to Global Climate Change
CZMA	Coastal Zone Management Act
CZMP	Coastal Zone Management Plan
CZMU	Coastal Zone Management Unit
DOC	Degradable Organic Carbon
EED	Environmental Engineering Division
EV	Electric Vehicles
FAO	Food and Agricultural Organisation of the United Nations
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GoB	Government of Barbados
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-tropical Convergence Zone
LFG	Landfill Gas
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
MAR	Ministry of Agriculture and Rural Development
MEA	Multilateral Environmental Agreement
MPE	Ministry of Physical Development and Environment
MSW	Municipal Solid Waste
NGHGIB	National Greenhouse Gas Inventory of Barbados
NPC	National Petroleum Corporation
OTEC	Ocean Thermal Conversion Energy
PV	Photovoltaic
SSA	Sanitation Service Authority
UNCED	United Conference on Environment and Development
UNFCCC	United Nations Framework Convention on Climate Change
UWI	University of the West Indies
VAT	Value Added Tax

ABBREVIATIONS FOR CHEMICAL COMPOUNDS AND OTHER SCIENTIFIC ABBREVIATIONS USED

CH_4	Methane
N_2O	Nitrous Oxide
CO_2	Carbon Dioxide
NO_x	Nitrogen Oxides
NMVOC	Non-Methane Volatile Organic Compound
NH_3	Ammonia
CFCs	Chlorofluorocarbons
Cl	Chloride
HFCs	Hydrofluorocarbons
PFCs	Perfluorocarbons
SO_2	Sulphur Dioxide
SOx	Sulphur Oxides
Bcf	Billions cubic feet
Gj	Gigajoules
GWh	Gigawatt hours
in	inch
KWh	kilowatt hour
KWp	Kilowatt peak
MGD	Millions gallons per day
MMcf	millions cubic feet
MW	megawatt
m	metre
mm	millimeter
NCV	Net Caloric Value
^oC	degrees Celcius
ppm	parts per million
psi	pounds per square inch

PREFIXES AND MULTIPLICATION FACTORS USED

Multiplication Factor	Abbreviation	Prefix	Symbol
1 000 000 000 000	10^{12}	Tera	T
1 000 000 000	10^9	giga	G
1 000 000	10^6	mega	M
1 000	10^3	Kilo	K
100	10^2	hecto	H

STANDARD EQUIVALENTS

1 tonne	1 000 kilogrammes
1 kilogramme	2.2046 lbs
1 hectare	10^4 m^2
1 calorie	4.1868 Joules

Chapter 1

Barbados' National Circumstances

1.1 INTRODUCTION

Barbados recognises the Framework Convention on Climate Change as one of the major outcomes of the UN Conference on Environment and Development held in June 1992 in Rio de Janeiro. As such, Barbados signed the United Nations Framework on Climate Change (UNFCCC) on June 12, 1992 and ratified it at the Rio "Earth Summit" on March 23, 1994, recognising the instrument as the best path to curtailing global greenhouse gas emissions, and addressing the Climate Change phenomenon. Barbados ratified the Kyoto Protocol, on August 7, 2000.

The Government of Barbados has recognised that in facing the impacts associated with the Climate Change phenomenon, such as sea-level rise (and its associated phenomena such as coastal erosion, inundation, and saline intrusion of fresh water aquifers), and increased/ variability in climate (inclusive of rainfall and storm frequency), low-lying Small Island States like itself face real social and economic upheaval

The preparation of this initial national communication is one of the many steps Barbados is taking in order to fulfil the obligations as a party to the Convention

1.2 COUNTRY INFORMATION

1.2.1 HISTORY

The first known indigenous people to the island of Barbados were Arawak Amerindians, who appear to have been present from about 2,000 years ago. The first Europeans arrived in the island during the 16th century, using it as a water source during their early explorations of the region; and it is at this point that the island is said to have gained the name "Los Barbadoes" (bearded-ones), apparently so named for the island's bearded fig trees.

The first English ship arrived at the island in 1625 under the command of Captain John Powell, who claimed the island on behalf of King James I. On February 17th 1627, Captain Henry Powell landed with a party of 80 settlers and 10 slaves to occupy and settle the island. The colonists established a House of Assembly in 1639, making it the third-ever Parliamentary Democracy in the world.

The island's forests were cleared slowly at first, as early settlers planted such crops as tobacco and cotton. However, sugar was introduced as early as the 1630 s, cultivation of this crop expanded rapidly, such that by the 1700s, Barbados was almost wholly deforested.

The production of sugar, tobacco and cotton was initially heavily reliant on the indentured of servants, who were usually of Scottish, Welsh and Irish origin, working in the British colonies for a set period of time, with the promise of some small parcel of land, rather than languishing in His Majesty's Prisons for what was often a minor theft charge in the Mother Country. However, with the expansion of the sugar industry, a potential market formed for slaves and sugar-making technology, which was provided largely by the Dutch, who were to supply Barbados with their requirements of forced labour from West Africa. The majority of the slaves arriving at the island came from Sierra Leone, Guinea, Ghana, the Ivory Coast, Nigeria and Cameroon. And with the labour of the slaves, Barbados quickly dominated the sugar industry in the region, and held this position until the late 18th century, when Jamaica and the Leeward islands established a booming sugar trade of their own.

After the abolition of slavery in 1834, Barbados was unique in that much of its freed population managed to obtain an education in the post-Emancipation period of the late 1800s and early 1900s, such that today Barbados boasts a literacy rate of over 95%.

Barbados gained full independence on Nov. 30, 1966, with a Westminster style constitution, although it maintains ties to the British monarchy, represented locally by the Governor General. At the time of independence, the economy was expanding and diversifying, mainly as a result of the policies pursued by the governments formed after the planter-merchant elite lost power. This early move to diversify has held Barbados in good economic stead, even with the fall of agricultural trade across the region.

Barbados is an independent sovereign state within the Commonwealth and continues to play a leading role in the establishment of regional cooperation. In 1968 Errol Barrow, the prime minister in 1966-76 and 1986-87, helped form the Caribbean Free Trade Area, which became the Caribbean Community, or Caricom, in 1973. Barbados has one of the most stable political systems in the English-speaking Caribbean, with its well-established parliamentary democracy, and history of peaceful election and transition of political power.

1.2.2 GEOGRAPHY

Barbados, the most easterly of the islands of the Lesser Antilles, is a small island developing state of area 431 km^2, located in the Caribbean at 13° 4' north latitude and 59° 37' west longitude. It is bordered by the Caribbean Sea on the west coast and the Atlantic Ocean on the east, with a coastline of 97 km, and an exclusive economic zone of about 167, 000 km^2.

Figure 1.1: Map of the Caribbean Region

Barbados has been likened to a 'ham bone' in shape, with a broader mass at the south that tapers towards the north. The island is divided into 11 parishes. Of the Lesser Antilles, Barbados is the only entirely, non-volcanic, sedimentary rock island. The rocks underlying Barbados consist of sedimentary deposits, including thick shales, clays, sands, and conglomerates, laid down approximately 70 million years ago. Above these rocks are chalky deposits, which were capped with coral before the island rose to the surface. The topography of Barbados is marked by a complex series of gullies running mainly from the higher, eastern portion of the island to the west coast. These gullies are giant cracks in the limestone cap of the island, which act as a major conduit of recharge of rainfall to the limestone aquifer, and act to transport water via underground streams to discharge into the sea at the west coast.

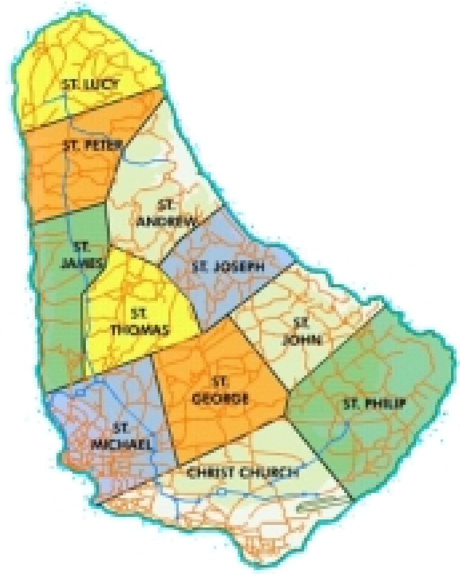


Figure 1.2: The Island of Barbados.

A layer of coral up to 300 feet (90 metres) thick covers the island, except in the more elevated north-eastern part of the island, where erosion has removed the coral cover across an area comprising about 15% of the island's total surface. This unique section of the island is known as the Scotland District, and has within it the island's highest promontory, Mount Hillaby, which stands only 340m above sea level. The rest of the island is low-lying, and much of the population resides within the so-called 'urban corridor', a narrow zone along the west and southwest coasts within 2 km of the shore, which is below the 25m contour line.

1.2.2.1 Soils and drainage

Barbados has mainly residual soils, including clays, which are rich in lime and phosphates. Soil type varies with altitude; thin black soils occur on the coastal plains, and more-fertile yellow-brown or red soils being found predominately in the highest parts of the island, where the limestone cap of coral limestone has cracked to reveal the mixed sediments below.
There are no major rivers or lakes and only a few streams, springs, and ponds, the very existence of which is often contingent upon of level of annual seasonal rainfall. Rainwater percolates

quickly through the underlying coral limestone cap, draining into underground streams that discharge off the leeward (west) coast. These ground water streams are the main source of the domestic water supply.

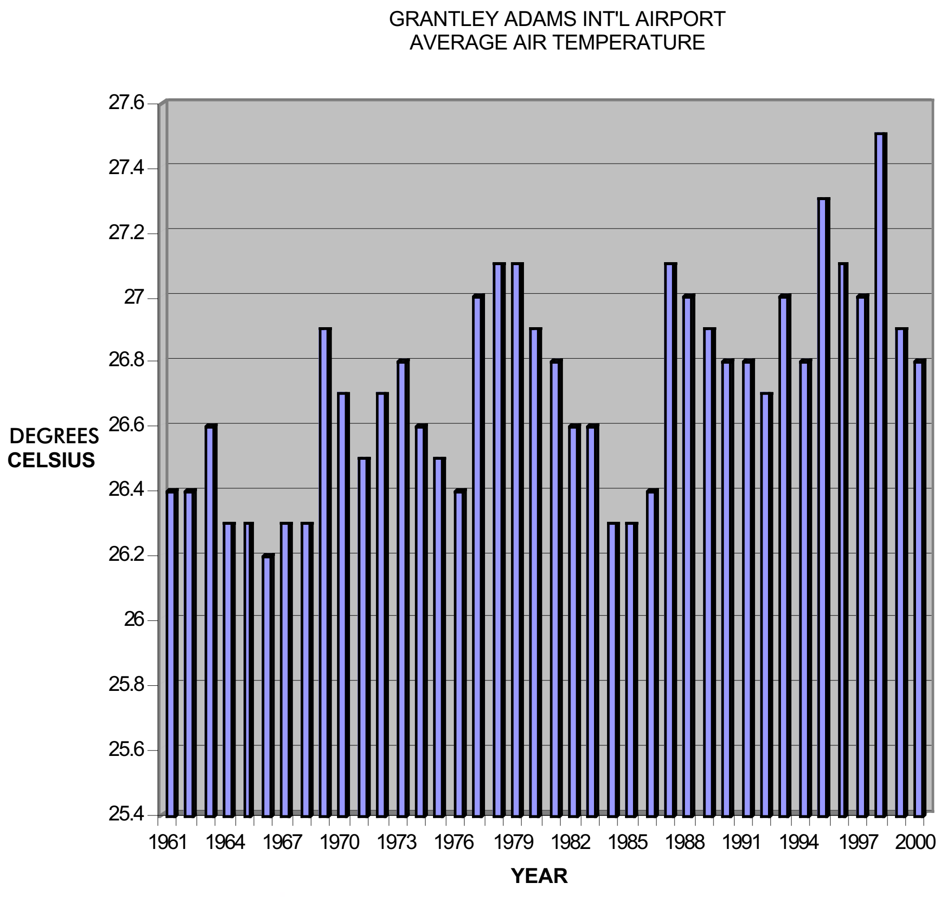
1.2.3. CLIMATE

Barbados enjoys a tropical, oceanic climate with an average temperature of 26.8°C. Despite the fact that there are no drastic changes in either seasonal or daily temperatures, it is noteworthy that there appears to have been a general increase in the recorded air temperature over the last forty years or so (See Figure 1.3), by perhaps 0.5-1.00 °C.

Weather seasons can be classified as either wet or dry. The wet season coincides with the Atlantic hurricane season and runs from June to November, with the wettest month being October with an average rainfall of approximately of 168.4mm (6.63in). The dry season lasts from December to May, the driest month being March, with an average rainfall of approximately 39mm (1.53in).

The island is affected by a number of weather systems during the year. During the wet months, most of the rainfall is derived from tropical waves moving across the Atlantic Ocean, along with the Inter-Tropical Convergence Zone (I.T.C.Z.), which shifts northwards on occasions, especially during the passage of tropical waves.

Figure 1.3: Average daily air temperature (°C), Grantley Adams International Airport.



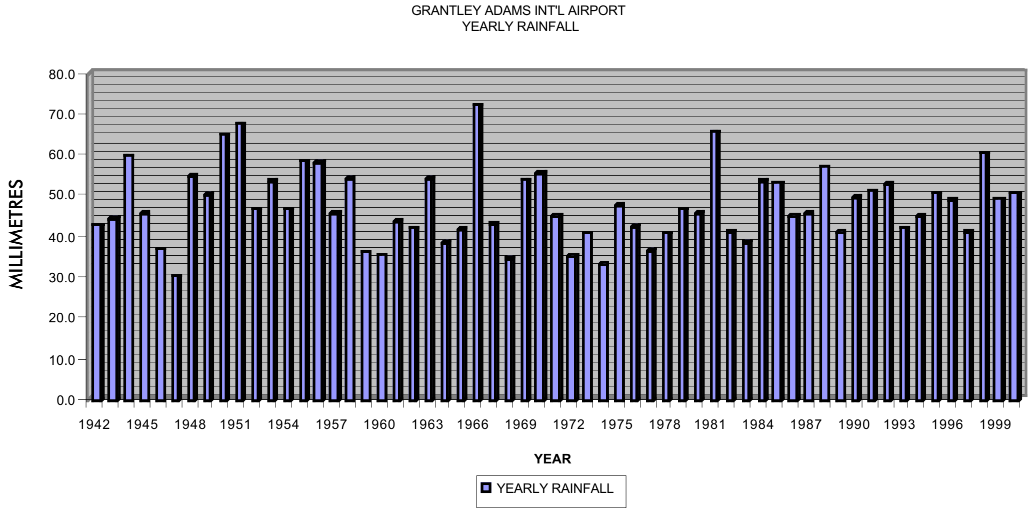


Figure 1.4: Annual rainfall (mm) for Barbados (1942-2000)

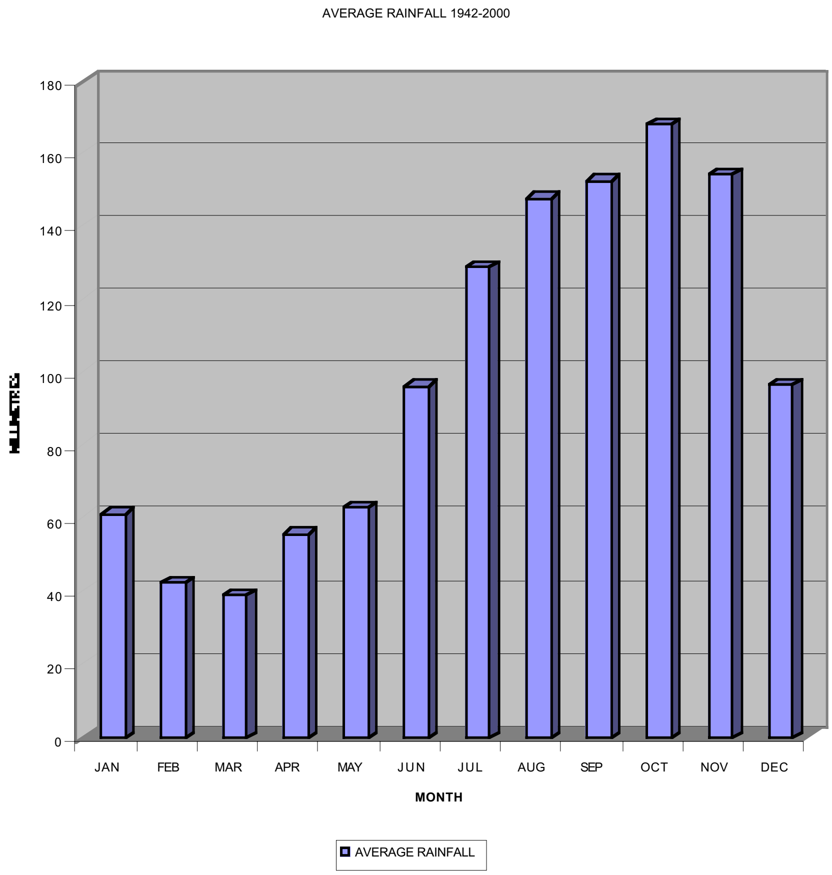


Figure 1.5: Average monthly rainfall (mm) (1942-2000) in Barbados.

During the dryer months, upper level troughs and lows and, to a much lesser extent, the tail end of cold fronts which survive after moving off the eastern seaboard of the United States of America, can contribute to the rainfall totals. In addition to the above, heavy showers and thunderstorms sometimes develop, mostly over central and western areas, when strong daytime heating, along with light winds and an abundance of moisture, are present. This type of weather is more prevalent during the summer months, and leads to flash flood conditions over low-lying areas along with minor infrastructural damage. Associated with this flash flooding is damage to roads and the erosion of soil from agricultural land.

On occasion, the strong downdrafts from thunderstorm activity can lead to minor structural damage. This damage is normally in the form of a few downed trees and electricity poles along with damage to rooftops.

The major source of beachfront erosion is caused by the passage of deep surface lows as they cross the Atlantic Ocean. These can occur at any time of the year and are a major threat to the low-lying areas on the west coasts, the locale for most of the tourism infrastructure.

The last hurricane to hit Barbados directly was Hurricane Janet in 1955. This means that most of the population has no first hand knowledge of hurricanes and their impact on life or property. This, however, is not say that the island has not sustained damage from passing tropical disturbances.

Despite the island's good fortune in having not experienced any major direct hits by storm systems, having examined the 1999 report from the US National Oceanographic and Atmospheric Administration, it is strongly believed that the region as a whole is seeing an intensification of hurricanes and storms (Headley, 2000). During the period 1995-1999, the Atlantic/Caribbean region has had 41 hurricanes, 20 of which have been Category 3 or greater on the Saffir-Simpson scale with a minimum wind speed of 111 mph (179kph). The 1999 season had five Category 4 hurricanes with a minimum wind speed of 131 mph (211 kph). This weather pattern is unprecedented since regular records began in 1886; and as a result several islands, of the northeastern Caribbean in particular, have experienced great difficulty getting affordable, or indeed any, insurance coverage, as underwriters and reinsurers have grown reluctant to offer their services to cover hurricane/storm in the region.

1.3. POPULATION

1.3.1 THE PEOPLE

The majority of the population, more than 80 percent of the population, is of African Descent; the remainder consisting of those of European descent (4%), and persons of mixed African and European, or East Indian descent (16%). English is the official language, and although the local Bajan dialect, a form of 'Africanized' English is the everyday language spoken.

The majority of the population is Christian (largely Anglican), although there are several Christian denominations present (Roman Catholic, Baptist, Pentecostal, Seventh Day Adventist, Latter Day

Saints for example). There is also a significant Muslim population, and a mosque in the capital city of Bridgetown, which largely comprises those of East Indian descent in its congregation.

1.3.2 DEMOGRAPHIC TRENDS

1.3.2.1. Population Growth

In 1997 the population of Barbados was recorded as 266,990, making it one of the ten most densely populated countries in the world. Over the last decade, the population has grown at an average rate of 0.3%

Since the 1950s the rate of population growth has been slowed by a successful family-planning program and by emigration, mostly to the U.K., especially during the 50's and 60's, as well as to other parts of the Caribbean and to North America. In the same period the death and infant mortality rates declined sharply, and life expectancy rose above 70 years.

Birth rates, death rates and infant mortality, and hence rates of natural increase and population growth, have held steady since the 1970s (Figures for the last decade shown below)

POPULATION, RATES OF BIRTH, DEATH AND INFANT MORTALITY

YEAR	RESIDENT POPULATION AT DEC. 31	BIRTH RATE	DEATH RATE	RATE OF NATURAL INCREASE	INFANT MORTALITY	POPULATION GROWTH	RATE OF UNEMPLOY-MENT RATES
	('000 persons)	(Per 1000 pop.)	(Per 1000 pop.)	(Per 1000 pop.)	(Per 1000 births)	(%)	(%)
1990	260.8	16.5	8.2	8	15.5	0.5	15
1991	262.5	16.2	8.7	7.5	15.3	0.4	17.3
1992	263.1	15.6	9	6.8	13.8	0.2	23
1993	263.9	14.3	9.1	5.2	9.8	0.3	24.3
1994	264.3	13.4	8.9	4.5	8.5	0.2	21.9
1995	264.4	13.1	9.4	3.7	13.2	0.4	19.7
1996	264.6	13.3	9.1	4.2	14.2	0.1	15.6
1997	266.1	14.3	8.7	5.6	13.2	0.6	14.5
1998	266.8	13.6	9.3	4.3	7.8	0.4	12.3
1999	267.4	14.5	9	5.5	10	0.2	10.4
2000(P)	267.9	14.1	9.1	5	16.7	0.2	9.2

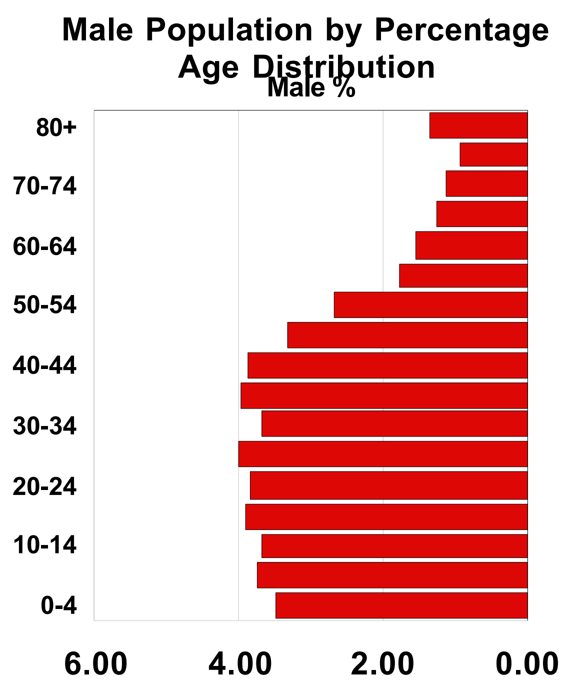
Table 1.1 : Population growth statistics for Barbados.

1.3.2.2. Population Structure

The age distribution, by sex, of the Barbados population in the year 2000, is given below.

Age Categories	Male %	Female %	Total Population	Male	Female
5-9	3.72	3.64	19,757	9,981	9,776
10-14	3.67	3.61	19,529	9,841	9,688
15-19	3.91	3.89	20,938	10,484	10,454
20-24	3.84	3.75	20,374	10,302	10,072
25-29	4.00	4.02	21,527	10,745	10,782
30-34	3.67	3.79	20,026	9,846	10,180
35-39	3.96	4.3	22,175	10,634	11,541
40-44	3.85	4.26	21,766	10,333	11,433
45-49	3.31	3.61	18,552	8,876	9,676
50-54	2.68	2.84	14,808	7,185	7,623
55-59	1.79	2.12	10,481	4,802	5,679
60-64	1.53	1.91	9,245	4,118	5,127
65-69	1.24	1.65	7,752	3,328	4,424
70-74	1.12	1.62	7,341	3,003	4,338
75-79	0.92	1.37	6,143	2,471	3,672
80+	1.34	2.22	9,567	3,600	5,967
			249,981	119,549	130,432
Percent contribution to total population, by sex				48	52

Table 1.2: Barbados' population demographic data (2000).



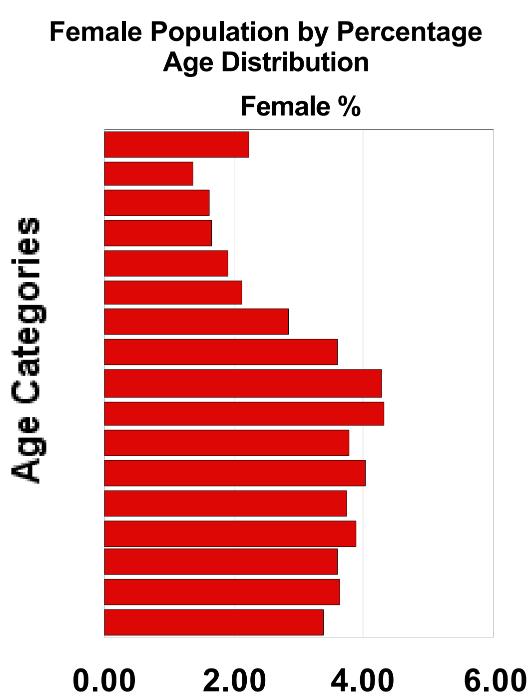


Figure 1.6: Barbados' population pyramid (2000 data).

The age and gender structure of the population reflect a slight female majority, the females making up about 52% of the population versus 48% for the males.

The population pyramid for the population reflects the decreased birth rate, and slowed rate of natural increase, since the younger age groups reflect an increasingly smaller proportion of the total population, such that the age categories comprising the 20 to 45 year olds, which correspond to the income-generating group, are actually the largest proportion of the population (39%). The pyramid's shrinking base also suggests that in the future, as is occurring in developed countries, the population of Barbados will go into decline, with a negative rate of increase. This is likely due to the decreased birth rate as Barbadian females delay the onset of child bearing, and limit the size of their families. An aging population might also be expected, with a relatively small income-generating group to support the retired and elderly, which will likely translate to increased strain on the National Insurance and Pension scheme.

As will be discussed later in this chapter, it should be noted that because Barbados has a low seasonality, 'high-end' type of tourist industry, annually there are about 400,000 to 500,000 additional persons on the island in the form of visitors. Because of the 'developed country' consumption patterns of the average visitor, and the fact that the industry caters to this type of visitor, it means that there is a significant disparity between the consumption pattern of the average native Barbadian, and the tourist, and an overall drain on the island's water and energy, in catering directly and indirectly to the tourism industry.

1.3.3. LOCATION OF POPULATION CENTRES

With the exception of Warrens and Six Roads developments, located towards the central and eastern inland portions of the island, respectively, all of the principal urban settlement (including that of the capital, Bridgetown) is located within the coastal urban corridor. Over 60% of the island's total population is located in the three coastal parishes of St. James, St. Michael, and Christ Church. Approximately 25% of the island's population lives within 2 km of the coast, concentrated within a continuous linear coastal urban corridor, extending for the entire length of the west and south coasts. Since the 1990s there has been increasing pressure for residential housing development, and the coastal urban corridor has expanded significantly along the south coast, with a change of land use from agricultural lands to subdivisions for residential purposes.

Traditionally many Barbadians have lived in villages and 'tenantries'. Tenantries often comprise of wooden houses - locally known as chattel houses - located traditionally on the borders of the large estates. Although these houses were owned by their occupants, they stood on rented ground. The majority of Barbadians now aspire to owning their "house spots", since they could be put off of their rented spots in the past. However, they have gained much assistance by the passing of relevant legislation to encourage land ownership in Barbados.

The construction of the traditional, wooden "chattel house" has been on the decline, going from being 72.5% of all houses built in 1970, to 39.98% in 1990. Barbadians have over the years seen to the conversion of their homes from wood to concrete. In 1990, 35.47% of all homes were concrete, and 21.3% of houses were a mix of concrete and wood. However, despite these apparent improvements, there are several fundamental issues of housing quality and design as pertains to resistance to natural hazards, which have yet to be addressed nationally. About 45% of all houses were built over 20 years ago. Nearly all homes have both electricity and running water.

The distribution of residential housing mirrors that of the population distribution, along the west and south coast coastal urban corridor. Apart from a few enclaves, coastal property tends to be high income, high value real estate. The majority of homes in Barbados as a whole are owner occupied, although coastal properties have a lower incidence of owner occupation.

Also of note is the existence of settlements in flood plains and coastal water courses. Around the capital of Bridgetown, for example, there exists much low income, 'slum' housing, which sits on what is in essence low gradient coastal land, which forms part of the Constitution River catchment.

1.4 GOVERNMENT

The constitution of 1966 established a governmental structure based on the British parliamentary system. The British monarch is the head of state and is locally represented by a governor-general. A prime minister, a cabinet, an elected House of Assembly, and a nominated Senate are the main governmental institutions. The Democratic Labour Party (founded in 1955) and the Barbados Labour Party (founded in 1938) are the main political parties. The legal voting age is 18. The Supreme Court of Judicature consists of the High Court and Court of Appeal. Magistrates' courts have civil and criminal jurisdiction.

1.5 INFRASTRUCTURE

There are several water supply wells and mains along the south and west coasts, although the Barbados Water Authority has longed ceased to pump form coastal wells, in recognition of their vulnerability to saline intrusion. In addition the Barbados Light & Power Company Limited (BLPC), the sole electric utility on the island, has two of its main facilities on two sites, both of which are located near to the shoreline, on either side of Bridgetown, apart from three other generating stations located about the island.

Local telecommunications is provided by Cable & Wireless BARTEL Limited; and telephone and increasingly, internet access, is widely available on the island.

1.5.1 TRANSPORTATION

The island has a large network of roads. The two coastal highways that run out of Bridgetown, northward along the west coast, and towards the southeast, are the connective vein within the coastal urban corridor. These highways are both barely above sea level, running essentially along the back beach routings.

Bridgetown has a deepwater harbour, which accommodates the larger cruise liners and other vessels; and the island possesses an international airport at its southern end, the Grantley Adams International Airport, which acts as a major regional hub for several international airlines.

1.6 EDUCATION

The first Education Act was passed in 1850. It provided for the establishment of an Education Committee, with a part time Inspector as its Executive Officer. Since then there have been newer Education Acts. In 1981 a modern Education Act was passed which still governs the education system. The Act spells out the particular functions of the Minister, the Chief Education Officer and the various Special Committees. It mentions the stages of education - primary, secondary and tertiary - and the kind of management structure in place at each level. The Act makes provision for private education, compulsory attendance from five-plus to sixteen-plus, the inspection of educational institutions and the method of granting scholarships/bursaries. Accompanying the Act is a set of regulations, which deals specifically with the day to day working of the system. From time to time, changes are made to the Act as dictated to by special circumstances. The Minister of Education is responsible for all matters relating to education.

There are three levels of education - primary, secondary and tertiary. The primary stage (3+ to 11+) is subdivided into early education (3+ to 7+) and a junior section (7+ to 11+). The secondary stage caters to students 11+ to 16+ but will undergo some changes with curricular reform.

There are 81 public primary schools excluding annexes; 23 public secondary schools and 9 Government sponsored secondary private schools; and three Government tertiary institutions. In 2000-2001 there were 23,986 students in public primary and 3,618 in private nursery and primary schools; 20,156 in Government secondary schools and an additional 1,293 in private secondary schools; and 7,417 in the three Government tertiary institutions.

The UNDP (1992) has published a figure of literacy for the island as 98.8%, which is largely attributable to the long-standing, comprehensive, mainly government-funded school system. The government places high priority on education; it allocates more than 20 percent of its budget to education, and all education in public institutions is free. Facilities for secondary, technical, and vocational education have expanded rapidly since the 1960s; a polytechnic, a community college, and several new secondary schools have been established. Most training at the university level is done at the University of the West Indies, which maintains a campus at Cave Hill in Barbados.

1.7 HEALTH AND WELFARE

Social conditions have been upgraded by political changes since World War II and by improvement in the economy. Today there is no one living in absolute poverty on the island, and starvation is unknown to the population. Indeed, obesity, and obesity related diseases such as diabetes, and high blood pressure are the island's greatest health problems.

Sustained efforts by government agencies in sanitation, public health, and housing have significantly improved health conditions. The diseases associated with poverty and underdevelopment have been eliminated or controlled. Health care is provided by both public and private agencies. Other areas of social welfare, notably child care, family life, pension plans for the elderly and disabled, public aid, and the status of women, have benefited from government attention. Community centres and playing fields have been established in most parts of the island.

1.8 ECONOMIC TRENDS

1.8.1 HISTORICAL BACKGROUND

At the end of World War II, the British Government embarked on a period of 'Colonial Development', which saw the transition to representative government and political independence, which was finally achieved November 30, 1966. Attendant to this period, Barbados saw a transition from a small, dependent, sugar economy, to the service economy that exists today. In the post-independence period, the economy diversified first into Tourism and light manufacturing during the 1970s and 80s; although the late 1980s and 1990s have been marked by a shift towards offshore banking services, computer services and data processing, and expansion of the light manufacturing sector. These transitions have been largely dependent on the state's encouragement of foreign capital, particularly in the manufacturing and tourism sectors, as well as the provision of a wide range of public goods and services for the Barbadian people, significantly raising the standard of living on the island. (Howard, 1989).

The development of the Barbados economy has been largely constrained by its limited natural resource base. The island is small in size (only 432 km^2 in size), with a relatively dense population (270, 000 persons approximately), with only small to moderate deposits of oil and natural gas, which are used to supplement local consumption and energy production. With its thin relatively undifferentiated, non-volcanic calciferous soils, Barbados was little suited to any crops other than sugar; although there have been strong signs of soil exhaustion and drops in fertility associated with this latter cash crop across the last 20 years or so. Barbados' people are considered its greatest resource, and the expansion of the services sectors reflect this.

1.8.2. THE BARBADOS ECONOMY TODAY

With these limitations, there has been great effort towards the diversification of the economy, with moderate success, such that the year 2000 saw the eighth consecutive year of economic growth on the island, real economic activity growing by an estimated 3.5% over the first nine months of that year. Table 1.3 shows Real Gross Domestic Product (GDP), while Table 1.4 shows GDP (at Current Prices) by Sector of Origin. Year 2000 figures are not available at the time of writing of this report.

Despite the Barbados economy's near decade of growth (see Figure 1.7), Barbados, like the other microstates of the Caribbean exhibits two (2) fundamental characteristics, which make its economy very vulnerable: (1) the inadequate pace of the promulgation of public policy initiatives to promote rapid restructuring of the economy in the face of the global open-market; and (2) excessive 'openness' to trade and foreign dependency. These tendencies can be seen as endemic to small island economies, a legacy of colonial monoculture and small size (CCA report, 1991).

Whereas in the continental situation, one finds a larger, more self-sufficient and diversified economy, the small island economies tend towards insular, highly specialised production lines. To achieve the rising standard of living associated with economies of scale, Barbados, like other islands in the region found it necessary to penetrate large foreign markets, the foreign exchange from the sale of these narrowly specialised exports (ie. sugar) or specialised services (eg. Tourism) enabling islanders to satisfy their diverse consumption requirements and overcome limited resource endowments. This intensive specialization, however, engenders instability since minor changes in foreign demand or costs can produce widespread local positive (booms) and negative (recessions) impacts. This results in an "export-propelled" economy, with sales to the foreign market representing the primary engines of economic growth because they fuel the secondary re-spending that filters through the smaller local markets. (CCA report, 1991).

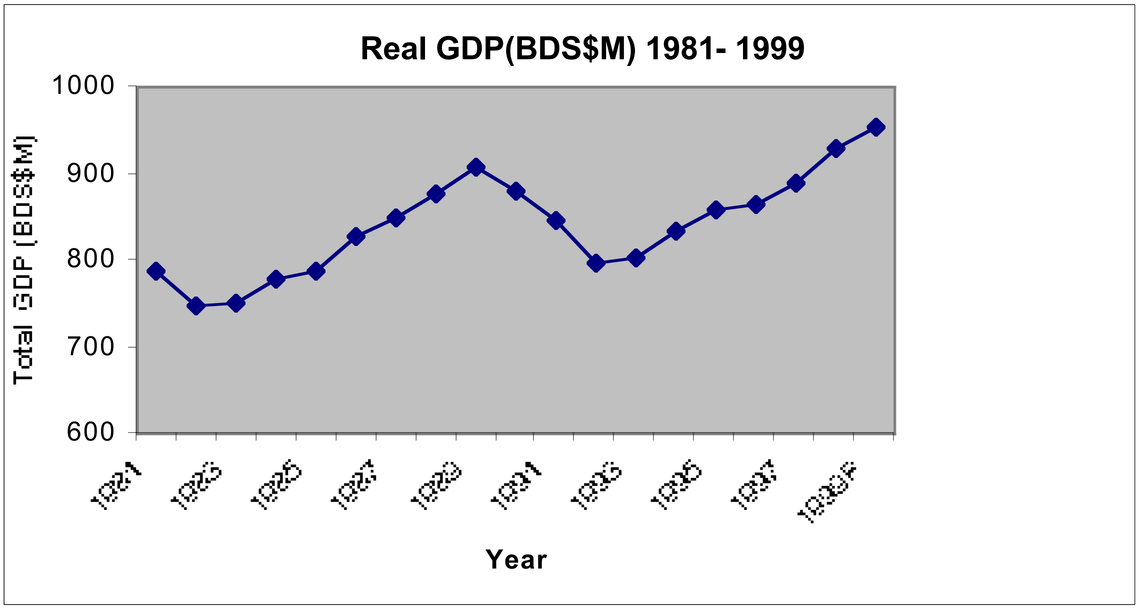


Figure 1.7: Barbados' Real GDP (BDS$M) 1981-1999.

Although Barbados has done much to diversify its economy in the post- independence period, it has proven very difficult for the island, like most other Small Island Developing States (SIDS), to develop a wide enough range of traded sectors, so vital for the generation of foreign exchange. Barbados imports nearly all of its food stuffs, fuels, construction materials and other goods.

However, it has only its Tourism, Sugar, Manufacturing, and Finance and Business Services sectors to generate foreign exchange. With the recent developments of the WTO and the removal of special concessions for sugar with the EU, the increased competition between tourism destinations, and the relatively strong Barbados dollar which tends to add expense to the Barbados product, Barbados has been finding it increasingly difficult to balance its traded and non-traded sector output, making it difficult to see a growth in net international reserves (NIR).

Estimates of Real Gross Domestic Product
1981-1998
(1974 Prices)

Year	Sugar	Non Sugar Agriculture	Mining and Quarrying	Manu- facturing	Electricity Gas and Water	Construc- tion	Wholesale and Retail Trade	Tourism	Transport Storage & Communi- cations	Buisiness & General Services	Government Services	TOTAL
1981	41.6	26.9	3.9	91.4	16.5	58.7	158.2	103.5	51.9	130.3	104	786.9
1982	38	28.7	4	86.5	16.8	51.7	145.5	89	53.5	133.5	100.8	748
1983	36.3	33	4.9	88.7	19.5	51.2	141.2	87.3	54.3	134.1	101.3	751.8
1984	42.5	33.3	6.8	90.4	20.4	50.7	90.6	93.4	57	135.4	101.8	778.5
1985	42.4	33	7.3	81.8	21.4	49.9	154.1	90.6	58.7	140.8	106.9	787
1986	47.1	31.7	7.7	86	22.8	53.5	163.3	96.7	61.4	145	111.8	827
1987	35.4	34.6	7.2	80.3	23.7	56.8	172.3	111.4	64.5	145.7	116.2	848.2
1988	34.1	31.8	6.7	85.7	25.3	61.9	176.6	123.1	64.8	150.1	117.4	877.5
1989	28.2	31.8	6.2	90.3	26.1	66.9	181	135.5	68.9	155.5	118.6	909.1
1990	29.5	35.6	6.5	87.9	26.4	60.1	172	127.2	62.9	151.4	120.4	879.1
1991	28	34.1	6.3	83	27.2	55.6	161.2	115.8	67.6	147.7	117.4	844.8
1992	23	33.4	5.7	76	27.6.	51.1	148.4	113.5	65.2	139.9	112	796.2
1993	20.9	32.9	6.3	73.8	27.5	53.7	152	117.7	66	141.1	112	802.7
1994	22.2	31.1	6.9	78.8	28.6	53.9	159.7	129	67.9	144.5	112	834.5
1995	16.6	36.8	7.4	84.7	30.4	57.4	164.9	130.3	70.1	147.2	113.1	858.6
1996	25.3	37.2	7.4	85.1	31	60.3	174.1	132.5	72.5	154.5	114	864.9
1997	27.6	34.4	7.4	88.8	31.9	64.5	182	135.1	75	155.9	114.8	889.7
1998R	20.5	33.3	9.7	91.6	34.7	73.8	193.7	143.6	78.2	162	116	928.5
1999P	22.7	34.5	13.5	90.6	36.4	78.6	201.7	143.5	81.2	167.8	117.1	954

Table 1.3 : Barbados' Real GDP ($BDS) (Source: Barbados' Statistical Service).

Gross Domestic Product by Sector of Origin
1981-1999
(Current Prices)

Year	Sugar	Non-Sugar Agriculture	Mining & Quarrying	Manufacturing	Electricity, Gas & Water	Construction	Wholesale & Retail Trade	Tourism	Transport Storage & Communi-cations	Finance & Business	General Services	Government	GDP at Factor Cost	Add Net Indirect Taxes	GDP at Market Prices	Per Capita GDP at Factor Cost ($ '000)
1981	69.8	59.1	13.1	189.7	38.6	138.3	368.8	206.5	113	210.2	69.4	229.7	1706.2	198.4	1904.6	6.8
1982	56.2	65.8	16.1	205.5	44.7	122.1	398	181.1	134.8	250.1	76.7	233	1784.2	205.8	1990	7.1
1983	57	78.6	16.3	238.7	52.9	132.5	378.5	186.5	154.1	258.9	80.9	264.3	1898.9	213.7	2112.6	7.5
1984	59	80.2	31.1	264.1	68	130	412.3	206.8	171	270.9	85.7	295.5	2074.6	228.2	2302.8	8.2
1985	58.7	79.3	27.9	231.7	72.7	117.9	451.1	225	185	297.8	89.6	344	2180.7	229.3	2409.9	8.6
1986	61.8	84.6	16.9	229.3	72.2	131.4	485.7	233.9	197.5	311	94.1	379	2297.3	348.7	2646	9.1
1987	68.7	102.9	18.4	223.6	80.7	144.3	529.9	270	225.4	313	97.3	424.8	2498.9	414.8	2913.7	9.8
1988	67.1	105.8	17.1	240.2	84.8	170.3	547.8	315.1	226.6	358.5	99.2	435.1	2667.7	431.6	3099.2	10.4
1989	49.7	100.5	17.5	233.3	91.6	196.7	596.2	361.9	227.8	424.9	106.2	503.4	2909.6	517.5	3431.7	11.3
1990	58.5	101	19.5	237.6	91.7	193.9	589.1	338.5	244.5	432.9	109.3	548.7	2965.3	474.9	3440.2	11.5
1991	54.6	107.2	18.6	230.8	100.1	161.9	575.5	315.4	254.2	435.5	109.7	530.1	2893.7	500	3392.5	11.1
1992	51.1	107.3	17	203.2	105.2	112.6	498.9	317.3	248.6	453.1	107.7	486.7	2709	474.1	3182.8	10.3
1993	46.8	114.7	15.2	206.6	106.7	120.9	506.8	361.9	261.4	437.1	110.6	509.2	2797.9	509.9	3301.1	10.5
1994	49.6	100	16.9	208	102.4	133.5	515	408.9	279.5	471.5	122	522.8	2930.1	553.2	3473.9	11.1
1995	50.6	147.6	18	211.7	110.2	151.8	542.8	419.7	307.1	505.9	131.8	550.1	3147.5	591.8	3739.3	11.9
1996	64.1	160.9	20.7	206.4	117.1	163.3	584.8	442	320.9	563.6	146.1	587.5	3377.4	610.8	3988.2	12.8
1997	69	122	21.2	224.7	117	213	625.7	450.8	340.6	632	157.8	636.6	3610.4	799.1	4407.7	13.6
1998R	56.5	96.3	23.1	243.5	128.2	238.8	702.2	482.2	376.2	702.4	179.8	674.5	3903.7	852.1	4755.8	14.7
1999P	56	146.3	27.8	240.4	134.5	258.2	737	464.5	415.3	754.5	189.9	687.5	4137.9	842.2	4980.1	15.4

Source: Barbados Statistical Service

Table 1.4: Barbados' GDP (at Current Prices) by Sector (Source: 1999 Economic Report, Ministry of Finance and Economic Affairs)

The first three quarters of the year 2000 saw a 5.3% rise in traded sector activity, with a corresponding 2.7% increase in the non-traded sector, and a sizeable increase in NIR. It should be noted however, that this influx in foreign exchange was due mainly to the government's borrowing of BDS$200 million on the international capital market, private capital inflows, and lower retained imports, apart from the increased earnings from tourism.

1.9 CLIMATE CHANGE AND THE BARBADOS ECONOMY

With respect to the traded sectors' vulnerability to Climate Change and its associated impacts, the sugar and tourism sectors are at greatest risk. If one considers the potential coastal inundation impacts which might accompany sea-level rise, the finance and business services sector, and manufacturing sector might also be at risk, given the fact that a fair amount of the island's industrial parks and business houses are located on the coast within 2km of the shore, beneath the 25m contour. However, compared to the sugar and tourism sectors, these sectors are more able to adapt and relocate in the face of these impacts. In addition, the potential Climate Change impacts of increased temperature and altered variability and/or diminishment of rainfall, are of greatest impact for the latter sectors. These sectors will therefore be treated separately in the next sections.

1.9.1 SUGAR SECTOR

As aforementioned, sugar was the largest contributor to GDP and the traded sector in the pre-independence period. However, with the subsequent economic diversification, sugar production and contribution to GDP fell dramatically, although several factors contributed to the fall of sugar. The Central Bank of Barbados has seen the contribution of sugar to GDP fall from 9.2% in 1971, to only 1.9% in 1995; and sugar's contribution to GDP has hovered around the 2% mark for subsequent years.

The last two decades have seen a dramatic decline in soil fertility and an increase in the frequency of agricultural drought, such that the resultant fall in sugar yields have made it increasingly difficult to make the export quota for the European Union. Compounding this is the fact that the majority of the land formerly under sugar cultivation was taken out of cultivation during the period of economic diversification and the significant growth of residential areas and other infrastructure for an increasingly wealthy population. At present there are approximately 8, 500 hectares of land under sugar cultivation.

In addition to this, the price per tonne for sugar, formerly guaranteed from the European market to its former colonies, has fallen steadily over the years as the price of production has risen, with minor fluctuations, for the last 20 years (see Table 1.5). There has been the recent removal of protection for agricultural products of former colonies, so that with the European Union moving towards world market prices, Barbados can only predict the size of the sugar market, but not the price it will receive for its product. In addition, Barbados is paid in non-US currency which fluctuates against the US dollar, to which Barbados' currency is itself tied, impacting on Barbados' NIR.

The situation has now become so dire, that despite the fact that the Government of Barbados is infusing the Sugar Industry with local dollars, producing sugar at a loss, limited sugar production continues because of the precious foreign exchange generated by the sale of brown sugar to overseas markets. The paucity of traded sectors makes this necessary at this time, although the Barbados Government recognises its non-sustainability. All local sugar is currently exported, local

Estimates of Real Gross Domestic Product
1981-1999
(1974 Prices)

Year	Production						Sugar Exports					
	Canes Reaped per hectare ('000 ha)	(tonnes)	Canes Milled ('000 t)	Sugar Produced ('000 t)*	Tonnes Cane/ Sugar	Tonnes Sugar per ha	Sugar Value ($M)*	Tonnes (%GDP)	('000)*	Export Export Price/t	Earnings ($M)	Production Cost/t
1980	16.1	74.9	1204	136.6	8.8	8.5	131.8	7.9	119.6	914.8	115.5	756
1981	15.8	60.7	962	97.5	8.9	6.2	88.1	4.1	63	965.9	63.4	1050
1982	15.8	51	766	85.5	9.4	5.4	71.5	3.1	89	776.3	71	1220
1983	14.1	50.1	705	82.8	8.5	5.9	69.4	3	73.5	717.8	53.6	1223
1984	14.1	57.8	812.8	100.4	8.1	7.1	76.9	2.8	85.9	747.9	64.2	1197
1985	13.9	57.3	793.5	100.2	7.9	7.2	79.5	3.2	83.4	755	62.9	1251
1986	13.9	65.5	908.2	111.1	8.2	8	73.1	2.7	98.6	628.2	62	1112.4
1987	12.8	54	689	83.4	8.6	6.5	78.2	2.7	70.2	1040.1	71.2	1327.8
1988	11.5	60.6	698.8	80.3	8.7	7	77.2	2.9	67.9	1085.5	67.2	1360.6
1989	11.1	50.4	560	66.3	8.5	6	60.8	2.1	51.8	1004	52	1548.9
1990	10.5	57.8	606	69.3	8.7	6.6	71.9	2.5	56.5	1183.2	66.9	1561.8
1991	10.3	57.2	587	65.7	8.9	6.4	69	1.9	52.6	1181.1	62.2	1637
1992	9.2	57.2	528	54	9.8	5.9	65.6	1.9	52.3	1276.2	66.7	n.a.
1993	7.9	55.9	441	48.5	9.1	6.1	57.5	1.7	48.4	1249	56.8	n.a.
1994	7.8	56.3	439	51.9	8.5	6.7	60.3	1.7	50.3	1181.8	59.5	1345
1995	7.5	47.6	357	38.5	9.3	5.2	52.8	1.6	38.6	1362	52.5	1806
1996	8.4	63.3	534.9	59.1	9.2	7	73.4	1.9	55.7	1312.2	73.1	1333
1997	8.9	63.8	570.9	64.6	9	7.2	76.6	1.9	57.8	1248.9	73	1397.2
1998R	8.4	53.4	448.7	48	9.4	5.7	61	1.4	46.7	1211	56.6	1545.3
1999P	8.5	61.2	521.9	53.2	9.8	6.3	57.5	1.4	50.5	1132	57.2	1526.4
Source: Barbados Statistical Service												

Table 1.5: Barbados' Sugar Statistics (1980-1999) (Source: 1999 Economic Report, Ministry of Finance and Economic Affairs)

consumption being satisfied by import from the cheaper Latin American countries such as Guatemala. In addition the high of output of non-traded sectors such as the Construction, and the Transport, Storage and Communications sectors, across the last three decades, have made it necessary for the Government to keep every foreign exchange generator operating at all costs to feed these sectors. Adding value to the sugar product (eg. by doing local refining of sugar) or diversification of the use of sugar cane (eg. exploring the feasibility of the use of cane bagasse in a cogeneration plant to produce electricity) has been explored; but costs associated with further refinement of the sugar, and limitations of quantities of sugar cane available have prevented such ventures from being profitable or competitive.

The last decade or so has seen fluctuations in sugar exports due to both difficulties in the production of sugar, as well as the fluctuation of currency and other global market factors. In the year 2000, sugar production rose by 9.7% to 58, 400 tonnes, up from 50, 500 tonnes in 1999 and 46, 700 tonnes in 1998 (there was a drought in the latter year). Despite these increases in yields, the export earnings from sugar have not climbed correspondingly, due to declining price per tonne and the decline in the euro against the US dollar. However, contributions of foreign exchange have made it necessary to continue sugar cultivation until another traded sector can supplement sugar's contribution to NIR.

1.9.1.1. Potential impacts of Climate Change on Sugar

There has been a change in the frequency of rainfall, with dry spells becoming increasingly common, although annual rainfall averages can appear constant in some data sets. The increase in frequency and length of dry spells severely impacts penetration of rainfall into Barbados' limestone aquifer, and affects the sugar cane crop, as sucrose content is extremely sensitive to quantity and timing of rainfall during the plant's life cycle. This in turn affects quantity and quality of sugar.

In addition, increases in salt content of soils due to the increased evapotranspiration of plants brought on by conditions of water scarcity, are resulting in the concentration of certain soil salts, exacerbating soil fertility problems, therefore negatively impacting on sugar yields. This compounded by decreasing acreage of land under sugar cultivation has led to a general trend of diminished sugar output across the last two decades.

Thus, this important traded sector is under direct threat of Climate Change impacts.

1.9.2. TOURISM SECTOR

Barbados has been engaged in significant tourism marketing since about 1955, when the Development Plans paved the way for the development of financial, tax, institutional and legislative support to the tourism sector (eg. the Hotel Aids Act of 1956 allowed significant fiscal concessions for the construction and operation of tourist accommodation, and the establishment of the Barbados Tourist Board in 1958). Long stay arrivals have trebled since 1970, and tourism is considered somewhat of a 'success' story. Tourism's contribution to real GDP has increased from 8.9% in 1971 to 15.2% in 1985 (Whitehall, 1997); and contribution to real GDP has held around the 13% to 15 % mark throughout the 1990s (See Table 1.3). Across the first three quarters of the year 2000, Barbados was still able to see an 8.6% increase in the sector, with long-stay visitors arrivals rising some 6 percentage points higher than the corresponding period in 1999. There was also a 22% rise in cruise ship visitors for the first three quarters of 2000, reversing the decline of 19.6% seen in 1999.

Barbados is considered a mature tourist destination, this sector experiencing a prolonged period of unbroken acceleration from 1956 to 1967, followed by a fairly lengthy period of decelerating growth from 1967 to 1974. Then between 1976 to1989, Barbados saw an irregular rejuvenation of the sector, followed by another stagnation phase between 1988 and 1993 approximately. However since 1994, there have been significant increases in tourist arrivals, such that there was recorded in 1999 a 76.46% increase in tourist arrivals over the 1993 recorded arrivals (See Table 1.6)

Despite this, the past decade or so has seen the sector experience significant periods of uneven growth of arrivals; and there have been worrying signs such as a recent decline in the number of rooms offered to tourists, the inability to attract significant investment by foreign hotel chains and a possible erosion of customer service (See Table 1.7).

The increase in tourist arrivals has been achieved, in large part, through aggressive advertising, and the targeting of masses of 'high end' tourists. Much emphasis has been placed on marketing the island's beaches and coastal resources (eg. coral reefs). As such, over 90% of all hotels are within or proximal to the beach, with 70% of the island's hotels located within 250 metres of the high water mark. This translates to the island's hotels sitting almost exclusively within the 1 in 500 and 1 in 100 inundation zones, placing them at risk of major structural damage.

Being a 'mature' destination, Barbados has followed the trend towards high density, mass market, short-staying, low seasonality tourism, common to such destinations. However, this type of tourism has created significant socio-cultural and environmental stress since it has developed in the absence of adequate regulatory controls, particularly for the preservation of coastal resources. Further, it means that, as aforementioned, annually there are an additional 400,000 to 500,000 persons present on the island (apart from the native populace), who tend to represent an extra 'drain' on the island's resources and services. The quantity of water and energy spent on each tourist is significantly larger than the per capita consumption for the ordinary native Barbadian, since the majority of the island's tourists are from developed countries, and as such, the Tourism industry seeks to provide the visitor with "first world" amenities. Thus for example, where the average Barbadian lives in a naturally ventilated house, washes dishes by hand, and dries their laundry on a clothesline, the tourist will reside in air-conditioned quarters, and will have his laundry and any dishes used cleaned and dried with an electric appliance. These differences in consumption patterns impact greatly on the island's resources.

Destruction of coastal vegetation, beach erosion, decline in water quality and availability, destruction of reefs and mangroves, increase in sewerage and solid waste, rise in vehicular traffic and noise, and general shoreline deterioration have been the bane of many of the tourist destinations of the Eastern Caribbean. Barbados receives about double its population in visitors annually, placing much strain on utilities, infrastructure and natural resources.

With such amenity losses, governments are therefore forced to move away from the natural attractions traditionally associated with the tropical destination, and towards high-volume, man-made attractions such as duty-free shopping, and increasingly, as in Barbados, the development of heritage and sports tourism. (CCA report, 1991).

In addition, Barbados saw a marked decline in price-competitiveness, particularly between 1970 to

1988; although its relative competitiveness has not appeared to have declined significantly since that time, except with respect to Jamaica, where that country experienced a massive devaluation of its currency.

To face the challenges presented by maturity of the tourism product, Barbados has set about the task of improving the tourism product via several avenues. These include:

- quality enhancement of the island's natural resources through environmental policy and prod uct diversification;
- productivity gains through improved labour relations, and the encouragement of improved customer service, including the friendliness of the general population;

Tourist Arrivals by Country of Residence

(stay overs)

1980-1999

Year	USA	Canada	United Kingdom	Germany	Other Europe	Trinidad& Tobago	Other CARICOM	Other	Total
1980	85971	84934	56226	11380	16195	45114	40294	19135	369915
1981	74472	69897	72090	11381	15619	43838	43051	19587	352555
1982	75511	59619	51147	9144	12444	45046	36912	13955	303778
1983	113983	53198	47662	7241	10093	47662	36279	12201	328325
1984	140202	67307	46274	6709	10111	43023	41424	12834	367652
1985	148093	70573	38822	6101	10565	32526	39240	13215	359135
1986	166250	60285	47590	6872	12210	21866	40367	14330	369770
1987	175093	64349	79152	9681	13338	25303	39053	15890	421859
1988	170773	65667	101231	11684	22051	22372	41927	15822	451485
1989	154269	65564	118122	10119	32416	18660	44180	17929	461259
1990	143295	57841	94890	12680	40234	18350	43948	20854	432092
1991	119069	46287	88166	20274	37326	16681	41307	25112	394222
1992	110685	49999	88759	19337	42941	15946	36885	20918	385472
1993	112733	49190	100071	28920	31958	21597	36460	21597	395979
1994	109092	52286	123455	31524	35602	22138	35799	22138	425630
1995	111983	53373	126621	28372	40977	22146	40990	22146	442107
1996	111731	54928	139588	25867	35505	15786	40966	22712	447083
1997	108095	58824	155986	18900	44797	18314	45267	22107	472290
1998R	106300	59946	186690	12109	52936	19785	50573	24058	512397
1999P	107737	58193	202959	10418	30877	24892	60797	21997	517870

Table 1.6 : Barbados' Tourism arrivals by country. (1980-1999) (Source: 1999 Economic Report, Ministry of Finance and Economic Affairs).

Selected Indicators in the Tourism Industry 1980-1999

Year	Share in GDP	Total Expenditure ($M)	Average Length of stay (nights)	Hotel Bed Occupancy Rate	No of Beds	HotelRoom Occupancy Rate%	Arrivals Stayover Visitors	Cruise Passengers
1980	11.7	473.7	9.8	65.3	13400	68.6	369915	156462
1981	12.1	523.7	9.6	54	14100	57.5	352555	135782
1982	10.2	502.2	8.3	45.5	14400	48.8	303778	110743
1983	9.8	503.2	7.7	46.7	14300	51.8	328325	102519
1984	10	560.7	7.1	45.1	14300	57	367625	99168
1985	10.3	618.1	6.3	35.9	14000	40.9	359135	112222
1986	10.2	647.3	6.5	47	13900	48.3	369770	145335
1987	10.8	757.2	6.5	55.4	13800	57.5	421859	228778
1988	11.8	918.5	6.7	60	13700	63.9	451485	291053
1989	11.9	1055.6	7.1	62.7	13726	64.3	461259	337100
1990	9.8	987	6.8	56.3	13767	57.5	432092	362611
1991	5.8	919.5	6.9	48.2	11674	50.5	394222	372140
1992	11.8	925	6.9	49.1	11803	46.3	385472	399702
1993	13	1055.9	7	51.3	11554	52.9	395979	428611
1994	14	1196	7.1	56.4	11495	57.4	425630	459503
1995	14.5	1223.6	7.6	56.7	10229	59.2	442107	484670
1996	13.9	1288.6	6.9	59.5	11432	60.6	447083	509975
1997	13.8	1314.4	6.6	62.4	10483	63.2	472290	517888
1998R	12.3	1405.7	5.9	52.7	na	52.5	512397	506610
1999P	11.2	1354.3	na	na	na	na	517870	432854

Table 1.7 : Selected Indicators in the BarbadosTourism Industry (1980-1999) (Source: 1999 Economic Report, Ministry of Finance and Economic Affairs).

- increased market visibility through promotion and the encouragement of the repeat visitor phenomenon; and, as aforementioned,
- the move towards sports tourism, particularly 'high end' golf course tourism.

1.9.2.1. Potential impacts of Climate Change on Tourism in Barbados

In the Caribbean region, expected impacts of Climate Change are: coastal inundation due to sea level rise, with an attendant increase in tidal and storm surge levels; increases in temperature; changes in rainfall patterns; and more frequent and severe weather events such as a droughts, tropical storms.

Barbados' tourism sector is under great threat due to the high risk of damage of its coastal infrastructure with any increases in sea level. In addition, water scarcity is likely to be exacerbated with the irregularity of rainfall expected under the Climate Change scenario, which in turn impacts on sanitation and health. The Barbados Government has been focusing on encouraging golf course tourism, and extensive construction of top class courses has begun on the island.

However, these developments are extremely water intensive, and the Barbados will have to make considerable effort to augment already scarce water supply to satisfy the requirements of these high investment developments.

Increased storm activity in the region too will place coastal infrastructure at risk, but will also act to destabilise the investment climate, since it is likely that insurance premiums for the region will further increase insurance premiums. At present, the regions premiums have increased due to increases in flooding and storm events in North America. An overall increase of social costs and cost of living would also be expected, serving to lessen cost competitiveness of the island as a tourist destination.

Increases in temperature globally can be greatly detrimental to tropical tourist destinations, since the influx of winter tourists is vital to the sector. Milder winters will lessen the incentive for northerners to trek to the tropics to escape the cold weather. Conversely, increased and altered seasonal temperatures in the tropics thus far have resulted in unusually warm waters, which have resulted in heat stress of coral reefs, so vital to the tropical tourist destination package. Incidents of widespread coral bleaching have been documented in the literature, also acting to decrease the efficacy of the coral reef as a natural protector of the shoreline, and source of beach sand. Warmer waters have also acted to spur bacterial blooms, resulting in large fish kills about the island's reefs, littering the beaches and driving away bathers.

National Circumstances

Criteria	1990	1991	1992	1993	1994	1995	1996	1997	1998
Population ('000)	260.8	262.5	263.1	263.9	264.3	264.4	264.6	266.1	266.8
GDP (US $)	1482.7	1446.3	1354.4	1395.6	1460.4	1573.8	1688.7	1804.3	1962.4
GDP per capita ('000 US $)	5.8	5.6	5.2	5.3	5.6	6	6.4	6.8	7.4
Share of industry in GDP (percentage)	8.7	8.6	8.1	7.9	7.7	7.3	6.7	6.8	6.7
Share of services in GDP (percentage)	85.9	85.8	86	86.3	87.2	86.4	86.6	87.9	89.3
Share of agriculture in GDP (percentage)	5.4	5.6	5.6	5.8	5.1	6.3	6.7	5.2	4
Urban population as percentage of total population	45	45	46	46	47	47		48	48
Forest area (square Kilometres, define as appropriate)	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
Population in absolute poverty	NA	NA	NA	NA	NA	NA	NA	NA	NA
Life expectancy at birth (years)	75.1		75.6	75.7	75.9	76		76.4	
Adult Literacy rate (percentage)	98.8		97	97.1	97.3	97.4		97.6	
NA not applicable									

Table 1.8: Summary of Barbados' National Circumstances

Chapter 2
Vulnerability and Adaptation

2.1 INTRODUCTION

Small island states such as Barbados are the most vulnerable to the changing climate. In this chapter the key sectors of water, agriculture and coastal zone issues are examined in terms of vulnerability to a changing climate and the potential impacts this could have. Some of the analysis in this chapter has resulted as a consequence of work from component 6, Coastal Vulnerability and Risk Assessment, of the Caribbean Planning for Adaptation to Climate Change Project. Possible adaptation options are suggested.

2.2 VULNERABILITY ISSUES

2.2.1 Sea Level Rise and Coastal Zone Issues

One of the most serious challenges facing Barbados as a result of global warming and a changing climate is sea level rise and the consequences of increased coastal erosion and inundation and salt-water intrusion into coastal aquifers. Eroding coastlines will place critical infrastructure in Barbados at risk to flooding. This will have serious implications for the tourism industry and other sectors in Barbados. The IPCC in the third assessment report also suggest that the intensity of the most severe hurricanes is likely to be greater, thus compounding the possible effects sea level rise.

Through the Caribbean Planning for Adaptation to Climate Change project an initial coastal vulnerability assessment for Barbados has been carried out. In this assessment, there was an analysis of the effect of sea level rise (three scenarios 0.2m, 0.5m and 1m) primarily on the southern and western coasts of Barbados, with specific emphasis on erosion and inundation impacts, and calculations of beach loss at specific pilot sites (Graeme Hall, Holetown, Sandy Lane, Carlisle Bay, Casuarina, Cattlewash, Speightstown, Dover and Brighton). Figure 2.1 below shows the location of the pilot sites.

Figure 2.1: Location of the Pilot sites for the Initial Coastal Vulnerability Assessment of Barbados.

The northwest, west and southwest coasts are characteristically low lying, sandy, and hence erodable in nature. As a consequence these coasts are susceptible to the effects of sea level rise. The east and southeast coasts are generally cliffed with a few pocket beaches and are therefore potentially more resilient to the effects of sea level rise. The south and west coast of Barbados have the most critical infrastructure and is quite heavily populated.

The principle impacts expected in Barbados at the pilot sites as a result of sea level rise are coastal erosion, inundation and salt-water intrusion into coastal aquifers.

2.2.1.1. Erosion In Barbados

Erosion can be described as the wearing away of land by the action of natural forces. On a beach, it is the carrying away of beach material by wave action, tidal currents, littoral currents, or by deflation (removal of loose material from a beach or other land surface by wind action).

Significant shoreline/beach loss is expected due to sea level rise as many of our beaches are narrow (averaging 12-15m wide) and of gentle gradients (generally <10 degrees). Greater wave energy associated with higher sea level will cause increased rates of beach erosion and coastal land loss. Rates of retreat will be influenced locally by a range of factors including nearshore bathymetry, incident wave energy, amplitude spectra, wave approach direction, physio-chemical, geologic and morphologic properties of shoreline materials, sediment transport pathways, sediment production rates as well as sources. Profile steepening (where underwater portions of the beach erode more quickly than the visible portion) is also believed to become a major concerning factor. This is particularly significant, as it implies that beaches will erode more quickly during a storm than when profiles are flatter, as might be expected under calm conditions; and thus they will no longer provide as much protection from storms as in the historic past. Figures 2.2, 2.3 and 2.4 below show examples of beach erosion in Barbados.

Figure 2.2: Erosion at Holetown, St. James.

Figure 2.3: Erosion at Coral Reef Club St. James

Figure 2.4: Erosion at Crane Beach, St. Philip.

The Bruun rule was used to calculate land loss at the pilot sites utilizing three scenarios of sea level rise: 0.2m, by 2020, 0.5m by 2050 and 1m by 2100. Table 2.1 below, shows the land loss which will occur under the various scenarios.

Table 2.1: Land Loss scenarios under various scenarios of sea level rise.

Location	Land Loss (m) : 0.2 (m) Sea Level Rise	Land Loss (m) : 0.5 (m) Sea Level Rise	Land Loss (m) : 1(m) Sea Level Rise
Holetown	1.55	3.43	5.79
Sandy Lane	1.44	5.06	10.42
Carlisle Bay	3.03	7.51	18.44
Casuarina	2.02	7.63	31.54
Cattlewash	3.3	8.0	15.10
Speightstown	1.13	2.70	6.50
Brighton	1.60	3.75	7.40
Graeme Hall	2.52	6.05	28.60
Dover	2.82	7.70	12.12

2.2.1.2. Inundation in Barbados

It has already been noted that many of the beaches in Barbados are narrow and average between 12-15m in width. Thus any land loss is extremely significant. The land loss will result in a reduction in the natural capacity of the beach to protect against flooding and inundation. It also makes the surrounding area more vulnerable to storm surges. The loss of land at these pilot areas is critical; and may see the collapse of the beaches in these areas. All of these sites are frequently utilized by tourists, and thus the tourism industry and the economy would be permanently damaged if land loss, as suggested in the previous table, occurs.

Inundation is defined as flooding, by the rise and spread of water, over a land surface that is not normally submerged. A rise in the mean sea level is important at the coast, since the wave heights there are limited by available water depth. Furthermore, a rise in relative mean sea level also reduces the freeboard of coastal defences. The combination of higher breaking waves and reduced freeboard will result in larger overtopping rates and more extensive flooding of coastal property. Figures 2.5 and 2.6 show examples of inundation in Barbados.

Figure 2.5: Inundation at Mullins, St Peter

Figure 2.6: Inundation at Holetown, St. James.

In Barbados most of the coastal structures are designed to withstand various extreme weather conditions presently existing along the shoreline. Many of the coastal structures would be damaged in a 1:100 year storm event such as a hurricane. Sea level rise would compound the damage caused by a 1:100 year storm event, resulting in increased flooding and inundation. The predicted elevations of water levels during a 1:100 year storm event were calculated for the sea level rise scenarios of 0.2m by 2020, 0.5m by 2050 and 1m by 2100, for the south and west coasts of Barbados.

As a result of the study there are some key areas of concern. On most of the south coast, extensive flooding is predicted up to and inland of the main highway, such that flooding is predicted to be in excess of 1km inland. A zone of flooding approximately 150m wide is predicted to occur through the capital Bridgetown. On the west coast the flood zone will be up to 300m in some area. A preliminary list of critical infrastructure which will be affected is given in the table below.

Table 2.2 : Critical Infrastructure which lies in the Coastal Inundation Zone.

Examples of Coastal Infrastructure Affected
Barbados Light & Power Company Ltd.
Barbados Port Authority
Fort Willoughby (Coast guard station)
Holetown Police station
Weston Fire station
Oistins Govt Complex
Government Headquarters (Ministry of Finance)
Coastal Zone Management Unit
Bayview Hospital

Geriatric hospital
Oistins fish complex, Bridgetown fish complex, Secondary and Primary landing sites
Port St. Charles Marina
Desalination plant at Spring Garden
Shell, Esso & Texaco fuel storage & processing facility at Spring Garden
Flour Mill
Major coastal highways (Highway 1 & 7)

The list shows that critical infrastructure such as the island's sole electrical utility company, hospitals and fuel storage facilities, could become flooded and experience extensive damaged. A vast number of hotels will be flooded as well.

The coastal zones of Barbados are thus extremely vulnerable to sea level rise. These preliminary studies show that vital infrastructure could be lost under a variety of sea level rise scenarios. Land loss will occur, bringing serious economic loss, as well as changing the physical nature of the Barbados coastline.

2.2.2. WATER RESOURCES

Fresh water resources are likely to be threatened in two main ways by climate change. Firstly, by sea level rise, which is likely to increase salt-water intrusion within freshwater aquifers. Secondly, by increased frequency and severity of droughts, as has been experienced in recent decades; and many climate models suggest this may intensify in the future in the Caribbean region. Barbados is almost entirely dependant on groundwater supplies.

With available per capita natural water resources estimated at 350 m^3 per person per year, Barbados is classified as a water scarce country (Reid, 1994). The total annual water resources of Barbados are estimated at 59.0 million m^3 per year in an average year and approximately 45 m^3 million per year in a 1:15 year drought. This is based on an annual average rainfall of 1450 mm per year (Klohn Crippen, 1997). Up until February 2000 fresh groundwater accounted for 96.8% of Barbados' potable water supply; while fresh water springs accounted for 3.2% of the water supply. Two desalination plants have been recently built in Barbados. One plant is capable of supplying up to 10 % of the island's drinking water needs. An additional small plant has been built by a local hotel to produce irrigation water. Together these plants are capable of relieving approximately 12% of the stress on the nations water reserves. Therefore Barbados is still 88% dependent on rain-feed groundwater resources.

Under present conditions the Barbados Water Authority utilizes 34 millions of gallons per day (MGD) of the national water resources for drinking water. The desalination plant produces 10.8%, the St. Michael catchment 52.8%, the St.Philip catchment 20.2%, the Westcoast catchment 13.4%, and the Springs produce 2.8% of the national drinking water supply. Figure 2.7 shows the groundwater catchments in Barbados.

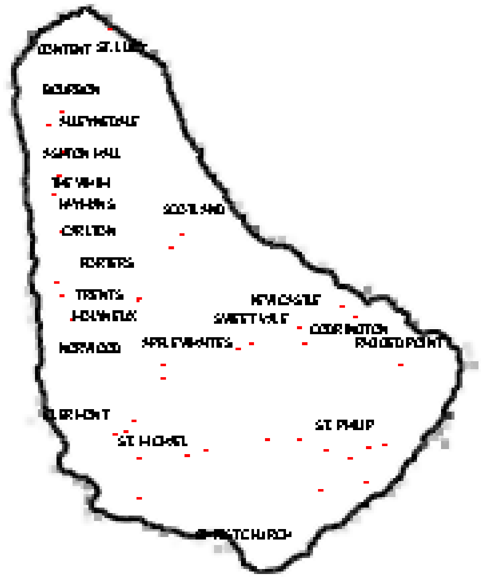


Figure 2.7: Distribution of groundwater catchments and wells in Barbados.

The major aquifers are found in the coralline areas; and Barbados' aquifers are unconfined aquifers, hydraulically connected to the sea. Thus sea level rise, and the resultant saline intrusion, could have a significant impact on the water supply in Barbados.

2.2.2.1. Saline Intrusion in Barbados

Saline intrusion has both a horizontal and a vertical component, with the salt water moving horizontally into the aquifer and vertically upward due to the influence of pumping on the dual density relationship between fresh water and salt water. Through component 6 of the CPACC project an analysis of the effect of sea level rise on the freshwater supplies of Barbados was performed.

Water levels in the St.Michael catchment have been measured at 0.45 to 0.60m above sea level with fluctuations of up to 1.35m. The water wells in the St.Michael catchment area are also located a good distance inland. The water levels in the St. Philip catchment have been measured at 0.3 to 0.6m above sea level with fluctuations up to 1.2m. Many of the wells in the St.Philp catchment are also located inland. At the West Coast, the water levels are on average 0.3m above sea level. Traditionally many West Coast Wells were a few hundred metres inland. However, due to saline intrusion in the 1940s, pumping of these wells was stopped. At present, wells in use are further inland, on the first land terrace inland from the coast.

Table 2.3 below shows mean distance of the wells in the catchment from the coast.

Table 2.3: Mean distance of catchments from the sea (m).

Catchment	Mean Distance from Sea
St. Michael	4539.18 m
St.Philip	4750.50 m
Westcoast	992.80 m

The wells in the west coast catchment are those more likely to suffer from saline intrusion. Barbados Water Authority (BWA) pumping data for June 2000 shows that the West coast catchments provide 13.4% or 4.93 MGD of the national potable water budget. According to the BWA statistics, however (WRMWLS, 1997), this figure provides water for approximately 51,000 persons along the western coast and the northern parishes of Barbados. Additionally these catchments are licensed to provide an additional 6.93 MGD to private users. This includes significant parts of St. James, and all of St. Peter and St. Lucy.

The area serviced includes the island's luxury tourism sector, the shopping areas of Speightstown and Holetown, and the island's largest sugar factory. The parish of St. Lucy has one garment manufacturing factory, which employs about seventy (70) persons, and a cement plant, which employs about one hundred persons. Therefore the West coast wells are extremely important for much of the island's population and economic activity.

An analysis of the effect of a 0.2m, 0.5m and a 0.9m rise in the sea level, on the west coast catchment was performed. The west coast catchment already suffers from saline problems as a result of overpumping, which causes the chloride value in the water to be above the WHO limit of 250 ppm of Chloride (Cl). Analysis of water quality and rainfall data collected by the BWA shows that there is a seasonal element to the present chloride problems in this catchment. The highest probability of exceedence of 250 ppm chloride occurs in July and December, which corresponds to the end and beginning of the dry season respectively.

The effect of this seasonality is that during the dry season, under a scenario of sea level rise and reduced rainfall the catchment will be significantly more vulnerable to saline intrusion. This is due to the fact that the general elevation of the saline interface will be raised and with less recharge the freshwater lens will be significantly thinner and more subject to upconing.

Equations used by Mahesha (1995) were used to track the movement of the toe of the freshwater saltwater interface. Analysis showed that under the sea level rise scenarios suggested, the wells in the west coast catchment could not be used for drinking water purposes.

It has already been noted that these wells provide water to the 51,000 people and much of the hotel industry on the luxurious west coast. Thus it is clear that under certain conditions Barbados will have to look to augment its water supply for certain areas of the country as potable water will be lost as a result of sea level rise.

Changes in precipitation and temperature for the Caribbean region as outlined by the IPCC in the third assessment report, will also have a devastating effect on Barbados's freshwater supply. The amount of freshwater available will decrease dramatically under these conditions, and Barbados will have to examine alternatives (eg. expansion of the desalination sector) in order to provide enough freshwater for local use.

2.3 CLIMATE RELATED DISASTERS

The IPCC's Third Assessment Report 2001 indicates that, in addition to rising sea levels, other phenomena that can contribute to natural disaster losses (human and economic) may change in a greenhouse-enhanced climate. The IPCC Report indicates that more intense precipitation over many areas such as the Caribbean is very likely. It is likely that there could be intensified floods and/or droughts. While the IPCC notes that there is no consensus regarding the conclusions related to the behavior of tropical cyclones in a warmer world, individual studies have reported the likelihood of a possible increase of approximately 10-20% in intensity of tropical cyclones under enhanced carbon dioxide conditions (IPCC 2001).

In Barbados fifty-eight (58) severe rainfall (flood) and wind events of a significant nature have been documented from 1955-2000. Table 2.4 below gives a summary of the dates of the events. Hurricanes and tropical storms in 1955, 1970, 1980, 1980, 1994, 1995(2), 1997 and tropical waves in 1998 caused flooding, damaged houses and buildings, and displacement of people. Hurricane Janet in 1955 was the last hurricane to directly hit Barbados. Thirty-five (35) persons were known to have died. Eight thousand, one hundred, (8,100) small dwelling houses were damaged leaving twenty thousand (20,000) people displaced.

Barbados does not have to have a "direct hit" from a hurricane in order severe damage to occur. Hurricane Allen in 1980 passed to the north of Barbados causing over BDS $7 million dollars in damage. Flooding from rainfall events is a major concern. A tropical wave in combination with an upper level trough in August 1995 produced up to 225mm of rain in certain areas of the island, causing severe flooding and over BDS $ 4 million dollars in damage.

With increases in intensity of rainfall, increases in flood events are likely to occur. This will result in increases in the amount of financial resources that will have to be allocated to flood prevention activities. It is clear that there will be a need to strengthen meteorological warning capabilities, and it may be necessary to relocate and remove buildings, which may be in flood prone areas. There will be the need to strengthen and improve general preparedness and response measures in future years given the likelihood that there be increase flooding from intense rainfall events.

Table 2.4: Significant weather events for Barbados, 1955 to 1999

Event Number	Year	Month	Date	Event Description
1.	1955	September	13	Severe Weather
2.			22	Hurricane Janet
3.	1956	April	13	Severe Weather
4.		August	7	Flooding
5		September	26	Severe Weather
6	1957	October	30-31	Flooding
7.		November	18	Severe Weather
8.	1958	June	29	Severe Weather
9.	1959	September	25	Severe Weather
10		October	11	Severe Weather
11.	1960	December	5	Severe Weather
12.	1961	July	19-23	Severe Weather
13.	1963	September	24	Severe Weather
14.	1964	December	7	Severe Weather
15.	1965	December	25-26	Flooding
16.	1966	May	24-26	Flooding
17.		December	8-9	Severe Weather
18.	1967	November	20	Flooding
19.	1970	October	2	Flooding
20.	1977	October	30	Flooding
21.	1980	August	3	Hurricane Allen
22.	1981	October	9-10	Flooding
23.	1983	September	28	Flooding
24.	1984	October/November	31-04	Flooding
25.	1985	October	19	Flooding
26.		November	11	Flooding
27.	1986	September	7	Tropical Storm Daniel
28.	1987	July	5	High Winds
29.		September	21	Tropical Storm Emily
30.		November	21	Flooding
31.	1988	September	9	Flooding
32.			14	Flooding
33.		October	18	Flooding
34.	1989	September	4	Flooding
35.			11	Flooding
36.			27	Flooding
37.		November	10	Flooding
38.	1990	May	1	Flooding
39.		October	3-4	Flooding
40.	1991	November	22	Flooding
41.	1992	November	20-21	Flooding
42.	1994	September	9	Tropical Storm Debbie

Event Number	Year	Month	Date	Event Description
43.	1995	August	3	Tropical Wave
44.			25	Tropical Storm Iris
45.		September	13-14	Hurricane Marilyn
46.	1996	October	12	Flooding
47.	1997	August	4	Tropical Wave
48.			25	Flooding
49.		September	4	Tropical Storm Erika
50.	1998	August	23	Tropical Wave
51.		September	1-2	Tropical Wave
52.			8	Tropical Wave
53.		October	20	Flooding
54.		December	27	Flooding
55.	1999	August	26	Micro Burst
56.		November	1	Flooding
57.			17-20	High Sea Swells
58.		December	8	Flooding

2.4 AGRICULTURE

In 1999 agriculture contributed approximately 4% to the GDP, with sugar being the most important contributor. Sugar is Barbados' second most important foreign exchange earner. The IPCC third assessment report notes that studies have indicated that under certain conditions sugar cane yield could decrease by 20 -40 % under a doubling of carbon dioxide concentration in the atmosphere. This could have devastating implications for sugar production in Barbados and for Barbados's ability to earn foreign exchange.

The IPCC third assessment report notes that for the Caribbean, there are indications that by the years 2050 and 2080, annual mean temperatures could increase by 2.03 °C, and 3.06 °C respectively. Conversely, annual mean precipitation could decrease by 5.2% by 2050 and 6.8% by 2080. These predictions, if they materialize, are likely to have a very negative impact on both global and local agriculture, such that, apart from the sugar sector suffering, Barbados' food security may very well be under severe threat. Unless preventative measures are taken, and in the very near future, a temperature increase of 2°C-3°C over the next 50-80 years could see several local plant and animal species gradually vanishing from the Barbadian landscape.

Also, a change in seasonality had been indicated, such that precipitation will likely increase in what would normally be regarded as the drier months (December to February), and decrease in the traditionally wetter months (during the third quarter of the year).

2.4.1. Impact on Crops

In Barbados, already, higher atmospheric temperatures are influencing soil temperatures, and consequently, several local commercial crops are being affected at different growth and development stages. With respect to some vegetables, germination within the last five years had been very poor, and this has been attributed primarily to increasing soil temperatures. For cash crops such as lettuce, tomatoes, cabbage, etc, high soil temperatures are renowned for root hair damage and the scorching of hypocotyls, which more often than not result in early seedling death or the retardation of plant growth.

2.4.2. Impact on Soil and Nutrient Cycling

High soil temperatures increase the rate of microbial activity, which accelerates the break down of soil organic matter, which in turn can affect the plant in one or more ways. Rapid break down of organic matter means that nutrient recycling would no longer be gradual and sustainable, as most of the nutrients released would be lost to both run-off and leaching following the first rains. Also, the rapid conversion of organic matter into nutrients would reduce the soil's ability to retain moisture hence creating drought conditions, and ultimately barren lands, which are often very susceptible to soil erosion.

Additionally, beneficial soil microbes such as mycorrhizae and rhizobium species are most effective in a given temperature range, and as a result, increasing soil temperatures could negatively affect their biological performance. Further, as a result of the symbiotic relationship that often exists between these microbes and several flowering plants (spermatophytes), diminished performance of the microbes could lead either to the dying off or reduction of biomass building in plants, and consequently a reduction in food production.

2.4.3. Implications for Pests

In Barbados, certain insect pests breed during the dry season. Higher temperatures and increased periods of drought therefore, are expected to increase the number of generations of insect pests each year, increasing their destructive potential; and this is especially true for those insects that already have more than one generation annually. In addition, research has already shown that defoliators, such as Lepidopteran insects (moths), become even more destructive as atmospheric CO_2 increases.

What is ever more significant, is that the ratio of destructive pest species to their natural enemies is expected to change in favour of the pest under the climate change scenarios for Barbados, thus increasing both the reproductive and destructive capabilities of the pest.

High temperatures together with low rainfall usually provide an environment conducive to destructive fires; and indeed, fires are some of the greatest threats to the local sugar crop, which is currently Barbados' second most important foreign exchange earner. Weed competition is already a major threat to agricultural crops, and temperature predictions for 2050 and beyond tend to favour the growth and development of some very destructive weeds, which would mean that additional funds must be designated for weed control, which in turn will affect the farmer's overall production cost.

An indirect pest-related impact might also be considered. Stray livestock, starved of moisture and sufficient fodder, have been identified as serious pests for farmers, although, in recent times however, monkeys and birds have been equally as destructive, as natural plant systems also suffer diminished biological activity and production of biomass. Previously, both monkeys and birds were confined to wooded habitats where wild fruits and other sources of food were in abundance. The lack of sustained rains over time has reduced food production in many of these wooded areas, especially at a time when populations of these animals have increased. And so, like livestock, monkeys and birds are being forced to look for alternate sources of food and water; and unfortunately agricultural lands happen to be prime targets.

2.4.4. Impacts on Livestock

Temperature predictions for the mid and latter part of this century are expected to affect the local livestock industry even more severe. At present, poultry birds have shown the greatest vulnerability to increasing temperatures, as tens of thousands of these animals die each year as a result of heat related illnesses. Consequently, both egg and meat production is expected to decline; negatively impacting on food and nutrition in Barbados. Larger animals (cows, sheep, pigs, etc) tend to be a more resistant to heat stresses; yet in recent times, high daily temperatures have been responsible for the death of several mature pigs and young piglets.

Heat stresses also reduces both meat and milk production in ruminants, and the fact that most of these animals, cows in particular, graze in the sun for much of the day, local meat and milk production are expected to decrease as daily temperatures increase. Reduced availability of local meat and meat-products will impact negatively on food quality, quantity, and ultimately, on human nutrition. There will also be associated economic problems, since local meat producers would have to either alter existing farm buildings, or construct new ones to provide adequate shelter for animals, in order to obtain maximum production from their farm animals. This obviously increases the overall production cost and could possibly wipe out traditional small farmers, and entire farming communities. In addition, meat and other livestock products would have to be imported to supplement expected shortfalls, impacting negatively on foreign reserves.

The low rainfall impacts negatively on biomass building in most, if not all, plants and that includes grasslands. Certainly, the quality and quantity of grasses, including those that are regularly consumed by large ruminants (cows, sheep, goats, etc.) would be significantly reduced if precipitation predictions for the future become a reality. To ensure that farm animals receive an adequate amount of food and nutrition, farmers may either have to increase the sizes of their grasslands or consider other food supplements, both of which will require additional funds. There are already problems with respect to very high operational costs, which is certainly expected to increase in the very near future and could see several livestock farmers going out of production either temporary or permanently.

2.4.5. Implications for Agricultural Water Resources and Patterns of Use

Soil moisture is very critical to the growth and development of most terrestrial plant species. Long droughts or low annual rainfall are known to place additional stress on trees and other agricultural crops making them much more vulnerable to attacks from pests and diseases. The

15% to 20% reduction in rainfall predicted for 2050 and beyond could have a devastating impact on local agriculture, particularly on those crops that require a constant supply of water to induce and sustain fruit and foliage production. It is estimated that less than 5% of Barbados' cropped lands are currently under irrigation, and should rainfall predictions become a reality, this would mean that more agricultural crops would have to be grown under irrigation, placing additional stress on a resource that is already scarce. Demands on water are multi-sectoral and water for agricultural use is already in competition with potable water, water for industrial use (including golf courses) and water for recreational and environmental purposes. In order to meet future water demands, it is likely that storage facilities for agricultural water (dams, wells, etc.) will have to be increased, adding once again to the farmer's overall production cost.

During the dry season ground water levels normally fall, and as a result, water being extracted from wells during this period usually impacts negatively on crop yields due to its high salinity. Also, as aforementioned, there is an expected change in the seasonality of annual rainfall. This would certainly mean that planting seasons would have to be changed, i.e. crops that are normally grown between June and August will have to be grown either earlier or later, so that the young plant germinates when water is plentiful.

Considering this, the need for research is becoming increasingly imperative, as changes in precipitation will no doubt force changes on the types of cultivars and strains being planted, which in turn would affect both irrigation and fertilizer regimes. Precipitation changes could also favour the proliferation of many destructive crop pests and weeds, hence, yields in some of the more vulnerable crop species are likely to decline.

2.4.6. Future requirements to sustain Agricultural Activity

A reduction in local foods and food products could very well have a spiraling effect, as imports would have to be increased, with obvious financial implications, since additional strain will be placed on Barbados' scarce foreign reserves. It is crucial then, that Barbados start developing new food security strategies since global warming is expected to affect several geographical regions, placing at risk a variety of agricultural crops including rice and wheat, both of which are consumed in extremely large quantities by the local population. Based on Barbados' experiences thus far, unless funding for scientific research for more resistant crops is provided, most of our agricultural crops, ephemerals (short crops) in particular, might not be able to cope with the 2°C increase being predicted for the year 2050 and beyond. Therefore within the next 50-80 years, higher soil temperatures, decreased precipitation and changes in precipitation, will likely have a very negative impact on local crop yields, and ultimately on Barbados' overall nutritional balance.

2.5 CORAL REEFS AND FISHERIES

2.5.1 Coral Reefs and possible Impacts

As with most island states the coral reefs in Barbados represent one of the islands most important resources. In Barbados the coral reefs play a vital role in island. The majority of sand found on the

West and South coasts of Barbados is typically white, and of coralline algal nature, derived directly from coral reefs and its associated ecosystems. Robust reefs also aid in beach stabilization, and prevent the erosion of these beaches by causing powerful waves to break away from the shore and dissipating wave energy.

Tourism is a key industry in Barbados and many tourists are attracted to the coral reefs and their associated flora and fauna, for recreational dives. The coral reefs also generate sand for the beaches. Thus the coral reefs are extremely important economically for Barbados. In terms of fisheries the coral reefs support a vibrant and diverse flora and fauna, many of which are commercially viable.

Coral reefs possess some of the highest levels of biodiversity and are located, in varying degrees of health, around the entire island of Barbados. The potential on Barbadian reefs for the discovery of drugs with medicinal value is great. At present, drugs have been discovered from the marine environment to deal with hypertension and leukemia, as well as for use in contraceptives. A variety of pharmaceutical medicines have also been obtained from the aquatic flora.

Barbados has an estimated 4.9km^2 of bank reefs and an estimated 1.4km^2 of fringing reefs located on the west, south west, south east, east and the north of the island (see figure 2.8 below). The west coast is quite calm and is characterized by a sloping shelf where fringing reefs extend 300m out from the beach, to a depth of 10m. Extending from these reefs are patch reefs, which terminate at about 30m depth. Bank reefs on the west coast are found between 700m-1km from the shore. The south west coast has relic fringing reefs in depths of 6-15m, while 1km from the shore the bank reef runs parallel to the shore and is continuous with west coast bank reef.

Figure 2.8: Coral reef distribution around Barbados.

The north west coast supports some of the most extensive and diverse hard corals in Barbados. The southeast and east coasts are fully exposed to the Atlantic Ocean and thus there are no fringing reefs in these areas. There is however a bank reef on the south east coast, which is around 400km from the shore.

Studies conducted have revealed that the west coast fringing reefs are generally in poor condition, while the patch reefs on the south west coast have significantly deteriorated during the survey period. Some improvement in the condition of the fringing reefs has however been observed in the last survey episode carried out in 1998. The bank reefs are in relatively good condition, although some deterioration and signs of disease have been observed. From the initial surveys carried out on the Atlantic coast, it appears that the reefs are for the generally healthy and support a rich and diverse community of marine fauna in particular. On both the west and south coast reefs, results from the study indicated that there was an increase in abundance of hard corals as well as number of species between 1987 and 1997. On the west, there was an increase in macroalgae and turf algae, while on the south; there was a general decrease in macroalgae. On the bank reefs, total hard coral abundance decreased on both the west and south coast reefs, primarily it is thought as a result of turf algae. Macroalgae also increased on the reefs.

The deterioration of the reefs on the west coast is primarily due to anthropogenic activity. The majority of the population, hotels and infrastructure of Barbados are located in the south, southwest and west of Barbados. Thus the problems of sewage, fertilizers and pesticides are thought to be the primary cause of coral reef degradation. The Government of Barbados has begun to address this issue through the passing of the Marine Pollution and Control Act in 1998 and through sewage treatment projects for the south and the west coast.

While rising sea level may not affect coral reefs, increased temperature due to climate change could cause an increase in coral bleaching events. The IPCC third assessment report notes that the incidence of coral bleaching will rise rapidly with the rate of increase highest in the Caribbean. In 1998 coral reef bleaching in Barbados occurred, and monitoring based on in situ identification of coral species affected, showed that over 95% of all brain corals ***Diploria Sp*** had been white bleached, over 60% of all boulder star corals ***Monstastrea annularis***, and approximately 25% of all massive starlet corals ***Siderastrea siderea*** were bleached. While there was a high degree of bleaching there were no signs of mortality observed during the initial monitoring. Further monitoring has shown that algal coverage increased significantly at every area observed. In addition areas, which had recovered from mass bleaching, were now experiencing a high degree of mortality. Thus climate change will have significant negative impacts on the coral reefs in Barbados if increased temperatures cause frequent bleaching events. Damage to coral reefs will affect fisheries, tourism and ultimately the livelihood of the country.

2.5.2. Impacts on Fisheries

The fisheries industry is extremely important in Barbados. In 1995 it was estimated that the fishing industry contributed 1% of the GDP (Sedley, Gabor & Ruthen 1997). 2200 fishers are employed in the industry of which 80% are full time. Target fisheries are largely pelagic and demersal, as nearshore coastal reef fishery landings have declined significantly over the last two decades. There are twenty-six coastal landing sites (see figure 2.9) and three fish processing plants located in the country. Freshwater fisheries are virtually non-existent.

Reef fish kills have been observed from time to time in Barbados waters. During the period August to November 1999 there was a major fish kill. This fish kill was attributed to the influx of water with higher than normal temperatures and chlorophyll concentrations and low nocturnal oxygen levels. This appeared to be associated with an unusual trajectory in the sea, of waters from the Orinoco River. This fish kill was devastating to the local fishing community, and is an example of the type of problems, which could occur in Barbados under a changing climate.

Figure 2.9: Distribution of Fisheries Landing Sites.

Source: Fisheries Division Ministry of Agriculture and Rural Development

ENVIRONMENTAL MANAGEMENT AND LAND USE PLANNING FOR SUSTAINABLE DEVELOPMENT

The bleaching of coral reefs will obviously have a negative affect on fisheries stocks, as the coral reefs are a nursery for many fish species. Further research is needed in order to understand the change, which could occur with regards to fish species under a changing climate.

2.6 ADAPTATION MEASURES AND OPTIONS

Given the vulnerability of Barbados to climate change, adaptation and the implementation of adaptations policies and options are extremely urgent given the little progress, which is being made with regards to reducing greenhouse gas emissions.

2.6.1 Coastal Zone Adaptation Measures and Options

With regards to the coast, the general impacts include erosion, beach and land loss, and flooding and inundation. In Barbados the Coastal Zone Management Unit of the Ministry of Environment Energy and Natural Resources is responsible for reviewing planning applications for developments in the coastal zone, conducting monitoring and research, enforcing the Coastal Zone Management Act and any subsidiary regulations, and acting as the advisor and lead focal point for coastal zone management for the Government of Barbados.

Coastal adaptations options mainly include the implementation of set backs and zones for coastal buildings, a building code for coastal buildings, beach nourishment in order to enhance resilience of a particular beach, or the construction of groynes, revetments and breakwaters.

The Coastal Zone Management Unit is involved in a number of projects, which are designed to protect the coastal regions of Barbados. These projects are further discussed in Chapter 5 Policies and Actions.

2.6.2 Water Adaptation Measures and Options

The generally expected impact of sea level rise on the water resources of Barbados is the increased salinization of most of the westcoast wells. Increased salinity of the water means an effective loss of water resources, as it is no longer of a quality fit for human consumption. This probability becomes more significant, when other factors such as a reduction in recharge due either to reduced rainfall, increased run-off, increased evapo-transpiration or sewering of the west coast are taken into account. The adaptive strategies outlined here will deal with the increased salinization of the aquifers and the potential reduction in available water resources

2.6.2.1 Policy Options

The WHO drinking water standard for chlorides is 250 ppm. This is regarded as an aesthetic value related to taste but it does have minor health implications. Since these are only guideline values, government could set standards to reflect higher values, provided there are no serious health effects. This would significantly reduce the risk of these wells exceeding the new guideline values for chlorides. In Barbados this should be taken with caution as a rise in chlorides goes together with a rise in sodium. Given the high incidence of hypertension in Barbados this option might put the population at risk

2.6.2.2 Improved Water Resources Assessment

One major gap usually identified in monitoring the effects of climate change and in particular water resources trends is the lack of data. To detect any changes in water resources either due to usage or climate change, there must be a sustained effort to capture good quality data, with well-trained staff to analyse the data. Such data gives national authorities the ability to see how the aquifer is performing under current and past stresses.

A case in point is the salinity borehole programme that was to be managed and monitored by the BWA and the Ministry of Agriculture. The objective of this programme was to provide long term monitoring of the saline: freshwater interface in the aquifers. The programme was discontinued and the data lost, due to a lack of adequate resources (human and technical), to see the programme to its conclusion.

Such a programme is in the process of being re-started. This will provide vital data on the movement of the saline: freshwater interface. This should be done in conjunction with regular measurement of water level and quality. This is currently being done by the BWA and the water quality database goes back to 1992 for all public supply wells.

2.6.2.3 Demand Management and Leakage Control

If demand is reduced the abstraction from the aquifers is reduced, as are the probability of the negative effects of saline intrusion. Demand management, the key to this problem, is a multi-faceted exercise. It entails public education, pricing policy, metering, water conserving devices and leak detection

2.6.2.4 Public Education

Sustainable water use, with or without sea level rise, means convincing the public that fresh water resources are scarce and valuable resources and need to be protected. Public education is the key in re-directing cultural attitudes to water use and to direct them to purchase and use low water use fixtures.

Presently, through its Public Relations Department, the BWA uses Public Service Announcements, Advertising campaigns, tours and lectures to educate the public and to raise awareness on water issues.

2.6.2.5 Metering and Pricing Policy

Effective metering of consumers is the only way a water utility can accurately verify usage by its customers. Such data provided by the meters is essential in planning water demand reduction strategies. Once a substantial proportion of the customer base has been metered, a "rising-block tariff" can be imposed. This system targets the high water usage, while allowing customers the average amount of water necessary for daily use at a reasonable rate. Presently over 85% of the customer base in Barbados is metered. The next step should be the introduction of the tariff. Presently the BWA uses a two tiered system where non-commercial users are charged at a base rate of BD$1.50 per cubic metre. If use exceeds 34 m^3 in a thirty day period the excess is charged at the commercial rate of BD$2.12 per cubic metre.

2.6.2.6 Water Conservation and Water Conservation Devices

Many household plumbing fixtures can be a significant source of unnecessary water usage of which the toilet is a prime example. The conventional toilet uses significantly more water than the low use toilet. Low water use toilets sometime come with a double flush system with smaller amounts of water for urination than for defecation.

One major hindrance to the use of these and other water conservation devices, such as showers and taps, is the price. Government should give incentives for the purchase of low water use fittings and impose an environmental tariff on the high use fittings. A Tariff-Incentive policy could have a significant impact on the west coast as many hotels, not generally known for their water conservation practices, are located on this coast and will be affected.

Since 1997 the Government of Barbados has made it a planning requirement that all houses with over 1500 square feet floor space, must have a system of collecting rain water to supplement its non-potable water use requirement, for things such as the wetting of gardens. Such a policy reduces the stress on the aquifer by eliminating these water-demanding operations from the extraction demands. Furthermore such policies increase the awareness of the customer as to practical ways that the customer can be involved in water conservation.

2.6.2.7 Leakage detection and Control

Piped water supply systems often have substantial leaks and active leak detection and repairs are a required and ongoing part of water supply system management. The Water Resources Management and Water Loss Studies (1997, Task 6) reported unaccounted for water (UFW) at an average of 60%. A targeted leak detection and repair programme aiming to reduce this figure to 40% would significantly reduce the stress on the aquifer or make approximately 3 MGD available to the system. It should however be noted that UFW may not be synonymous with leakage as it includes items such as services missed by the authority and underestimated water usages. The Barbados Water Authority estimates leakage between 25% and 40%. It is usually more cost effective and environmentally prudent to control leakage than to develop an alternative source.

2.6.2.8 Physical Options

The sea level rise being predicted in the climate change scenarios are relatively slow and long-term. If one considers sea level rise, not taking any other climate change factors into account, the expected increase in sea level will have a concomitant rise in the water table. Under such a scenario the option would be to adjust the level of pumps, to maintain the same distance between the saltwater interface and the bottom of the pump.

At present the BWA uses the strategy of reducing production or a complete shut down of wells in breach of the WHO chloride standard. Such a policy would continue to be helpful once alternative water resources could be found to supplement those taken out of supply.

Sea level rise will not however be the only effect of climate change. Reduced rainfall and increased temperature can be negatively impacted leading to reduced recharge to the aquifer. This will in turn lead to the reduction in the thickness of the freshwater lens and increasing the probability of saline intrusion. The option of multiple wells across the aquifer could be used. Here each well would extract less than the single well but from different locations. Such an arrangement would lead to a reduction in the local drawdown and reduce the potential for upconing of the saline interface allowing better exploitation of the source.

2.6.2.9 Technological Options

There are also technological solutions to the water resource problems likely to be generated by sea level rise. Two viable options to help with the situation on the west coast are Wastewater Reuse and Desalination.

(i) Wastewater Reuse

The volume of wastewater generated in domestic situations is generally equal to approximately 90% of water used. In its simplest form, wastewater reuse has the potential to return up to 90% of the water extracted back into the aquifer, if injected directly into the aquifer. The wastewater could be re-injected into the aquifer 300 days upstream of the wells to provide extra recharge or injected downstream to provide a freshwater barrier to saline intrusion.

This wastewater could also be used for the irrigation of the two major golf courses at the West coast (Royal Westmoreland and Sandy Lane), and would result in a significant reduction in abstraction from these catchments. In this scenario the water would be, however, more subject to evapotranspiration, than with direct injection.

The draw back to these options is that firstly they would require significant infrastructure work and a more advanced level of treatment than will be offered at the new West coast water treatment plant. Groundwater modelling carried out by the West Coast Sewerage Study (1998) indicates that this scenario could lead nitrate pollution of the coastal marine environment making nitrate removal a necessary part of the treatment process. Seasonally many west coast areas suffer flooding. The building of infiltration addits along key sections of the watercourses will allow for accelerated recharge of the aquifer while reducing some of the down-stream flooding problems. The effects of this could be two-fold. Firstly it could provide recharge for the wells and secondly it could help to act as a barrier to saline intrusion. Care must be taken with this option and a full investigation would be needed to assess the nutrient and pesticide loading of the water.

(ii) Desalination

Barbados has already used desalination to supplement its national water resources. In February 2000 a 6 MGD brackish water desalination plant. This option can be extended to the west coast. The most cost effective option would be to use the existing wells as source wells. Disposal of the brine would be by way of deep wells at a level of similar salinity. Injection down stream would act as a barrier to seawater therefore reducing the impact of saline intrusion.

2.6.3 Agricultural Adaptation Measures and Options.

The majority of adaptation options with regards to agriculture will focus on doing the suitable research on climatic conditions in the future and the selection of appropriate varieties of crops for cultivation in the changing climatic conditions. There may be a need to change from the traditional crops to new ones, or perhaps there will be a need for the cultivation of drought resistant varieties.
Capacity building in the area of agricultural research as it pertains to climate change, is an urgent requirement in Barbados. There is a need for the funding so that effective research can be carried out.

2.6.4 Formulation of Adaptation Policy through the CPACC Project

Through component four (Formulation of Adaptation Policy) of the CPACC project several national consultations on the issue of adaptation to climate change have been held. These consultations involved identifying the key issues relating to climate change within the country and ranking these issues with the key stakeholders in each sector noting were there was a need to build capacity in order to evaluate the vulnerabilities effectively in order to select the correct adaptation option. The outputs of the workshop are being used to aid in the drafting of an initial adaptation policy for Barbados.

A number of adaptation/management options have been identified as possible solutions to assist in coping with the impacts of climate change. While there has been an initial identification of adaptation strategies (see table 2.5 for some examples), it is clear that there is a need for further capacity building, sectoral analysis and research in order to assess vulnerabilities in more detail, and implement specific adaptation options and policies.

Table 2.5: Examples of Adaptation Options identified during Cross-sectoral Consultations under Component 4 of the CPACC Project in Barbados

Sector	Climate Element	Likely Impact/Issue	Possible Intervention/Management Option
Agriculture	Less Rain/Drought	o Low Crop Yields o Reduction in genetic diversity o Reduced feed for livestock o Concentration of pollutants (fertilizer etc.) o Increases in numbers of generations of pests o Wind-induced soil erosion, with fertility reductions o Increased susceptibility of stressed plants to pest and disease o Increased irrigation costs o Increased risk of fire damage and attendant change in microbial activity in soil. o Altered soil fertility and chemistry	o Research (eg. Breeding programmes; pest and soil studies) o Inventory and monitoring of resources o Shorter rotation of crops to confound multi-generations of pests o Wider applicability of Integrated Pest Management o Exploration of options for wastewater use o Integrated water resource management o Ex situ conservation o Development of Policy on Food Securit

Sector	Climate Element	Likely Impact/Issue	Possible Intervention/Management Option
		o Increased incidence of crop failure in conditions of drought o Reduced crop quality	o Crop Diversification
	Increase in temperature	o Heat stress and losses of poultry, livestock o Reduction in egg and dairy production o Increased water demands from plants and animals o Salinisation of soils resulting from irrigation o Heat stress of workers	o Modification of husbandry methods (eg. Ventilation of coops) o Use of salt tolerant/drought resistant crops o Crop diversification o Selective breeding of livestock o Protective clothing, and flexible working hours for workers
Coastal Marine Resources	Less Rain/Drought	o Reduced influx of nutrients into nearshore	o Enhancement of resilience of natural systems through improved pollution control
	Increased Flooding	o Increased nearshore salinity o Increased sediment load to nearshore (reef stress) o Increased eutrophication o Increased environmental pollutants in nearshore o Decreased salinity in embayed areas	o Enhancement of resilience of natural systems through improved pollution control o Implementation of comprehensive watershed management system o Integrated Pest Management o Improved Coastal resource management planning o Upgrading of drainage systems
	Increase in temperature	o Increased heat-induced mortality, particularly for shallow-water species (eg. Corals) o Sea level rise results in coastal inundation, with loss/increase of some coastal ecosystems.	o Research and monitoring o Natural system replenishment o Coastal defence structures
Water Resources	Less Rain/Drought	o Reduced water availability o Saline intrusion at coast	o Integrated water resource management o Leakage control of mains
	Increase in Temperature	o Increase in evapotranspiration and reduced aquifer recharge o Sea level rise results in salinisation of coastal wells	o Desalination and other augmentation techniques
Human Settlement/ Infrastructure	Less Rain/Drought	o Increase in demand for water o Adverse effect on food supply o Structural damage	o Relocation and redesign of wells o Integrated Water Resource Management o Public awareness o Research and monitoring
	Increased flooding	o Increased insurance costs	o Incorporation of climate change considerations into Building Codes and coastal planning
	Increase in Temperature	o Increased dependence on air conditioning etc. o Sea level rise resulting in erosion, inundation etc.	o Improved building design to promote increased natural ventilation o Enhanced sea defences o Relocation of critical infrastructure where possible o Enforcement of building set backs, and restriction of development in vulnerable areas.

2.7 CONCLUSIONS

Barbados is clearly extremely vulnerable to climatic change. Land loss, erosion, inundation and flooding are all likely to occur. There will be a need augment the water supply as freshwater resources will be affected. Agriculture will also be negatively affected and ecosystems such as the coral reefs are under threat. Local fisheries will also be under severe strain in a changing climate and there is a need for further work to be done in this area.

There is still a need for further research and analysis to be done in the area of vulnerability. For example, there are still no regional climate models to aid in the vulnerability analysis. Global climate models need to be down-scaled in order to be utilised effectively by small island states such as Barbados; and the key to achieving this is the supply of better, more detailed data. Resources should also be made to examine the effect of a changing climate on human health, as well as the socio-economic impacts of climate change.

There is still a need for detailed vulnerability analysis and research in many sectors, as well as for detailed capacity building, before concrete adaptations options can be put in place. While detailed vulnerability analysis has begun in some sectors, such as the water sector and the coastal zone, such that comprehensive adaptation policies and options might be developed and put in place, in many other areas, as in the case of agriculture, there is still a need for capacity building, institutional strengthening, and detailed research.

Chapter 3
Barbados' First National Greenhouse Gas Inventory

3.1 INTRODUCTION

In accordance with Article 4.1 (a) of the United Nations Framework Convention on Climate Change (UNFCCC), all parties to the Convention are required to undertake a complete assessment of their anthropogenic emissions and removals of greenhouse gases (GHGs) and to update and periodically report on this inventory. The ultimate objective of the Convention is the stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

Barbados has calculated anthropogenic GHG emissions and removals by sink for the years 1990, 1994 and 1997 based on the International Panel on Climate Change (IPCC) Revised 1996 Guidelines for National Greenhouse Gas Inventories. These guidelines are intended to assist all Parties to the UNFCCC to undertake comparable inventories.

This is the first inventory of anthropogenic emissions and removals undertaken for Barbados. For all sectors, the Tier I or simplest methodologies for estimation of emissions and removals were used.

The underlying principle of the Tier I methodologies is that levels of energy activity (in the case of the energy sector) or production levels are multiplied by emission factors to calculate emissions of GHGs. Unless otherwise noted, emission factors provided in the IPCC Guidelines have been used for estimation of GHG emissions in all of the sectors.

Consistent with the IPCC Guidelines, estimations of GHG emissions have been made for the following sectors:
- Energy
- Industrial processes
- Agriculture
- Land use changes and forestry
- Waste

It should be noted that since no national data or methodologies exist for the estimation of emissions from the Solvent and Other Product Use sector, it has not been included in the inventory

3.2 SUMMARY OF BARBADOS' NATIONAL INVENTORY

Barbados is heavily dependent on the importation of fossil fuels for energy and transportation requirements. Analysis of the national GHG inventory for the years 1990, 1994 and 1997, produced the following main points:

- CO_2 emissions make up 94% of total GHG emissions in 1990, 96% in 1994 and 96% in 1997. A comparison of the three years investigated shows a progressive increase in total CO2 emissions from 1990 to 1997. CO_2 emissions in the years 1990, 1994 and 1997 were calculated at 1,564.23 Gg, 1,913.81 Gg and 2,198.40 Gg respectively.

- The greatest source of CO_2 emissions is from the combustion of fuel used for the genera tion of electricity, an average of 74% for the three years investigated. This is followed by CO_2 emissions from combustion of fuel for road transportation, which on average ac counts for 14% of emissions of this GHG. CO_2 emissions from fuel combustion in the manufacturing/industrial, commercial/institutional, residential and agricultural sectors in Barbados are relatively small, together making up an average of 9% of total CO_2 emissions.
- Consideration of total emissions of non-CO_2 GHGs reveals that the gas of greatest con cern is methane (CH_4). Methane emissions show a progressive increase from 1990 (78.66 Gg) to 1994 (85.07 Gg) to 1997 (86.36 Gg), however, the percentage of total emissions remained constant for the three years at 4%.
- Emissions of the other non-CO_2 GHGs, carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO_2), oxides of nitrogen (NO_x) and hydrofluorcarbons (HFCs) are considerably lower than emissions of CH_4 for all of the years, together accounting for an average of 0.55% of total emissions.
- Land Use changes and forestry, which is characterised by the regrowth of natural biomass on abandoned agricultural lands, removed some 11 Gg of CO_2 annually for all years investigated.

Table 3.1 shows a summary of the Barbados' first Greenhouse Gas Inventory.

CO_2 Emissions SOURCE	1990	1994	1997
Energy Industries	1032.20	1402.69	1627.51
Manufacturing Industries and Construction	95.50	41.79	39.88
Road Transport	225.12	257.44	251.66
Commercial/Institutional	13.42	150.99	53.43
Residential	15.95	13.47	53.18
Agriculture	5.03	2.00	1.66
Other	0.00	7.00	0.00

NON CO_2 Emissions from Fuel Combustion						
Year	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1990	0.05	0.00	2.38	18.67	3.51	0.00
1994	0.00	0.00	0.09	0.47	0.08	0.00
1997	0.00	0.00	0.05	0.49	0.09	0.00

Total Emissions and Removals	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs
1990	1564.23	11.00	78.66	0.15	2.30	18.67	4.42	0.00	0.00
1994	1913.81	11.00	85.07	0.15	0.09	0.47	0.83	0.18	0.00
1997	2198.40	11.00	86.36	0.15	0.05	0.49	0.87	0.05	0.01

Total Non CO_2 Emissions Total Emissions	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs
1990	78.66	0.15	2.30	18.67	4.42	0.00	0.00
1994	85.07	0.15	0.09	0.47	0.83	0.18	0.00
1997	86.36	0.15	0.05	0.49	0.87	0.05	0.01

Total CH_4 Emissions Source	1990	1994	1997
Fuel Combustion	0.05	0.00	0.00
Industrial Processes	0.00	0.00	0.00
Agriculture	1.13	1.13	1.13
Land Use Change and Forestry	0.00	0.00	0.00
Waste	77.48	83.94	83.94

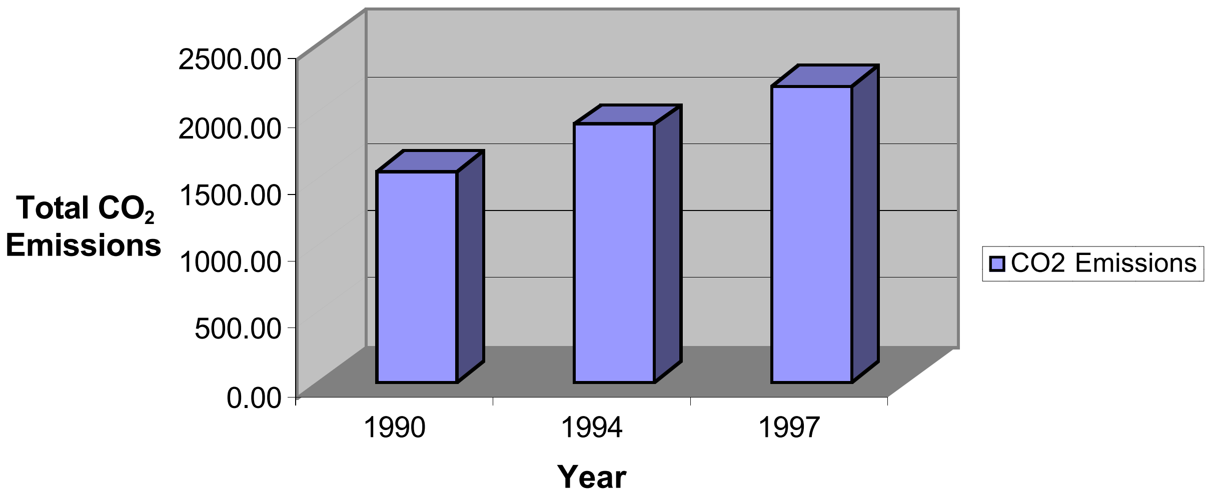
Table 3.1: Barbados' Greenhouse Gas Emissions Summary , for base line years 1990, 1994 and 1997.

3.3 ANALYSIS OF GREENHOUSE GAS EMISSIONS

3.3.1 Carbon Dioxide (CO_2) Emissions

Based on the inventory data, it can be seen that CO_2 emissions make up 94% of total GHG emissions in 1990, 96% in 1994 and 96% in 1997. A comparison of the three years investigated shows a progressive increase in total CO_2 emissions from 1990 to 1997 as shown in Figure 3.1.

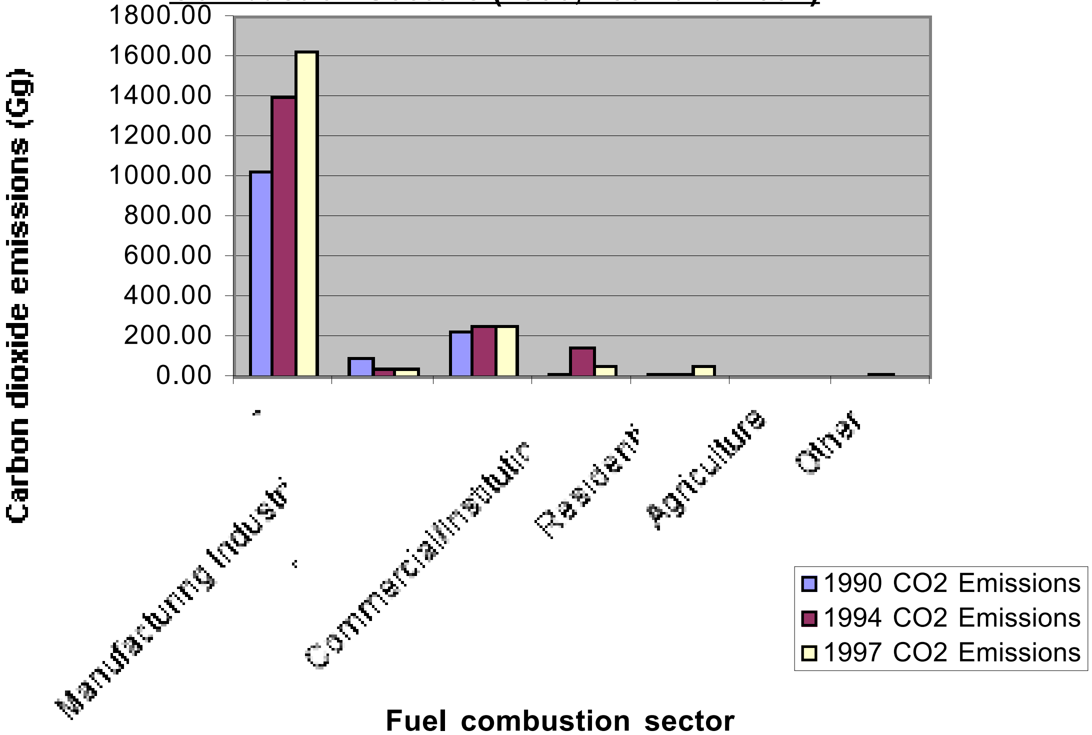
Figure 3.1: Total CO_2 Emissions from all Source Categories (1990, 1994 and 1997)



Assuming a linear growth trend, CO_2 emissions were forecast to increase by 100% in the twenty-five year interval from 1997 to 2022. With the continuation of the rapid economic development that the country is presently experiencing, it is likely that growing energy demands would cause that doubling to occur in less than twenty-five years, should no measures be put in place to limit CO_2 emissions.

Figure 3.2 shows that in each case, the greatest source of CO_2 emissions is from the combustion of fuel used for the generation of electricity, an average of 74% for the three base years investigated. This is followed by CO_2 emissions from combustion of fuel for road transportation, which on average accounts for 14% of emissions of this GHG. CO_2 emissions from fuel combustion in the industrial, commercial/institutional, residential and agricultural sectors in Barbados are relatively small, together making up an average of 9% of total CO_2 emissions. There does not appear to be any constant trend in emissions over the three years, rather there are fluctuations in the levels of the different gases emitted.

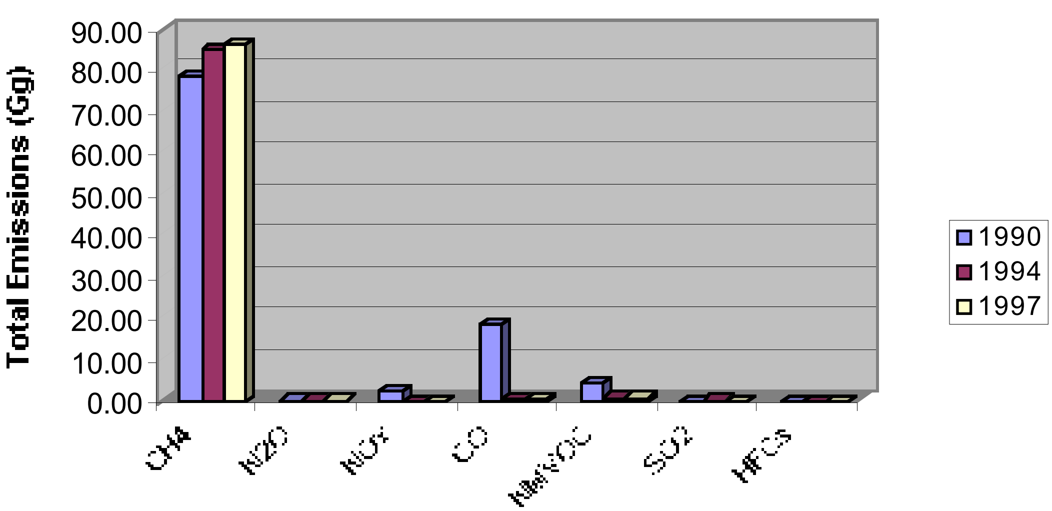
Figure 3.2: Comparison of CO_2 Emissions from Fuel Combustion Sectors (1990, 1994 and 1997)



3.3.2 Non-CO_2 Emissions

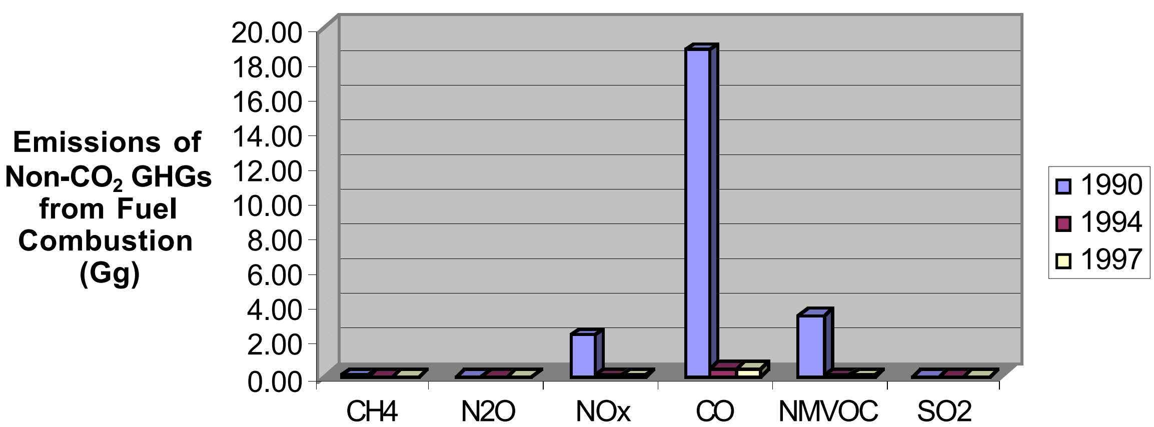
Consideration of total emissions of non-CO_2 GHGs reveals that the gas of greatest concern is methane (CH_4), as illustrated in Figure 3.3 below. Methane emissions show a progressive increase from 1990 to 1994 to 1997, however, the percentage of total emissions remained constant for the three years at 4%. Emissions of the other non-CO_2 GHGs, carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO_2), oxides of nitrogen (NO_x) and hydrofluorcarbons (HFCs) are considerably lower than emissions of CH_4 for all of the years, together accounting for an average of 0.55% of total emissions.

Figure 3.3: Total Non-CO_2 GHG Emissions



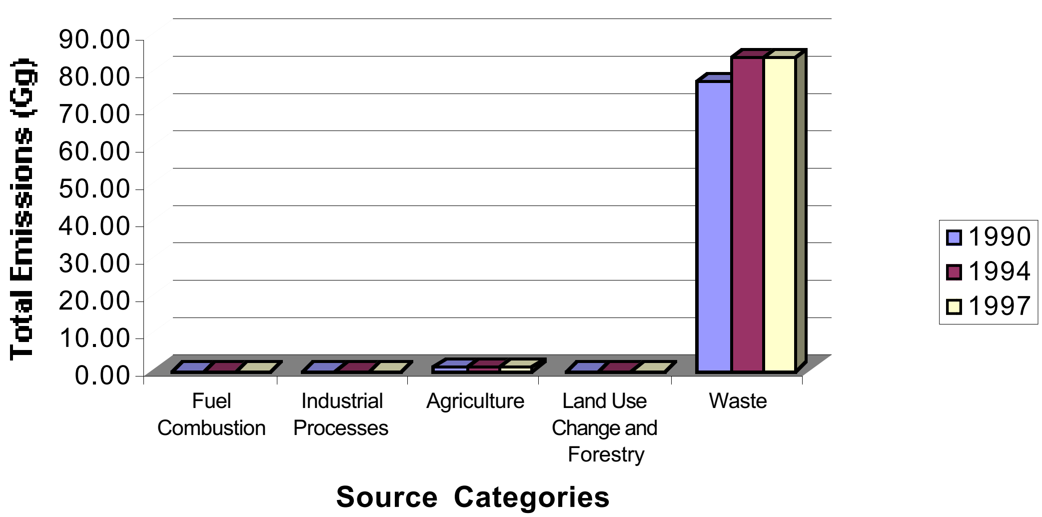
In terms of emissions of non-CO2 GHGs from fuel combustion, the gases of greatest concern appear to be carbon monoxide (CO), oxides of nitrogen (NOx) and non-methane volatile organic compounds (NMVOCs). From the diagram below labeled Figure 3.4, it can be seen that emissions of these GHGs were comparatively higher in 1990 than in the other two inventory years. Review of the GHG emissions data indicates that the greatest source of these GHGs is from the road transportation sub-category of the fuel combustion source category.

Figure 3.4: Comparison of Emissions of Non-CO_2 GHGs from Fuel Combustion (1990, 1994 and 1997)



For the GHG source categories, excluding fuel combustion, the source of the greatest level of CH_4 emissions is the waste management category, which accounts on average for 98% of total emissions of this gas. The next most important source of this GHG is agriculture, making up an average of 1.4% of total CH_4 emissions for the three base years. Figure 3.5 overpage illustrates these points. None of the other categories are significant sources of CH_4 emissions.

Figure 3.5: Total CH_4 Emissions



3.4 ESTIMATION OF GREENHOUSE GAS EMISSIONS AND REMOVALS BY SECTOR

3.4.1 ENERGY SECTOR

The Reference Approach outlined in the IPCC Guidelines was used to estimate emissions of carbon dioxide (CO_2) from the combustion of fuels. In addition estimates were made of emissions of CO_2 and non-CO_2 greenhouse gases (GHGs) by sector: energy industries (electric generation), manufacturing and construction, transport, commercial/institutional, residential and other sectors. The non-CO_2 GHGs include methane (CH_4), nitrous oxide (N_2O), carbon monoxide (CO), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide (SO_2).

However, two approaches were taken in accumulating data, which resulted in considerable disparate estimates of emissions from the Energy Sector. The first was the reference approach, where data used for the inventory was obtained from the Energy Division of the Ministry of Environment, Energy and Natural Resources which systematically records the quantities of fuels imported, exported and consumed for energy purposes. In contrast, the second sectoral approach incorporated data on fuel imports and exports, obtained from the records of the Barbados Statistical Service, which systematically collects data from the Customs Department.

The Energy Division provided an aggregate figure for fuel distributed to marine and aviation bunkers. In reporting these quantities in the inventory, it was assumed that kerosene quantities referred to jet kerosene and was attributed to aviation bunkers. Gasoline and fuel oil quantities were attributed to marine bunkers. Default Net Caloric Values (NCVs) and Carbon Emission Factors were used in the estimation of CO2 emissions based on the Reference Approach.

Estimated emissions were:

	CO_2
1990	766 Gg
1994	620 Gg
1997	1,433 Gg

Emissions of GHGs in Gg using the Sectoral Approach were:

	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1990	1387	0	0	2	19	4	0
1994	1875	0	0	0	0	0	0
1997	2027	0	0	0	0	0	0

For each year, there is a noticeable discrepancy between the estimation of CO_2 emissions using the Reference Approach and using the Sectoral Approach. The estimate of the Sectoral Approach exceeds the estimate of the Reference Approach by a factor of 1.5 to 3 times. The disparate estimates suggest that the data being collected at the Energy Division is less than comprehensive. Compounding this inaccuracy is the fact that several independent businesses in Barbados burn their own fuels to generate on-site electricity. It is highly likely that the fuel combusted by these individuals is not reflected in the Energy Division's records which gathers it's information from the larger, more prominent local companies and sectors.

3.4.1.1. PROFILE OF THE ENERGY SECTOR

As was stated previously, the greatest source of CO_2 emissions is from the combustion of fuel used for the generation of electricity, an average of 74% of the total for the three base years investigated (see Figure 3.2). This is followed by CO_2 emissions from combustion of fuel for road transportation, which on average accounts for 14% of emissions of this GHG.

Figures 3.6 to 3.8 show the relative consumption of fuels in Barbados. The primary fuels produced on the island are crude oil, natural gas and bagasse. All other fuels are imported. Since Barbados no longer has an oil refinery, crude oil that is produced is exported to Trinidad and the refined petroleum products are imported to meet local demand.

FIGURE 3.6: 1990 Fuel Consumption in Barbados

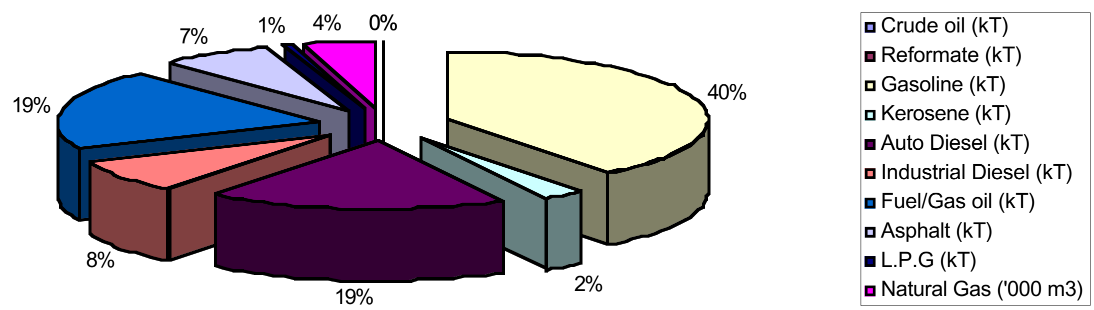


FIGURE 3.7: 1994 Fuel Consumption in Barbados

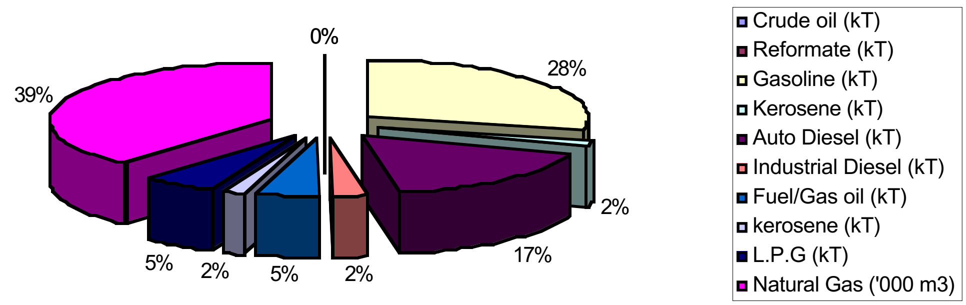
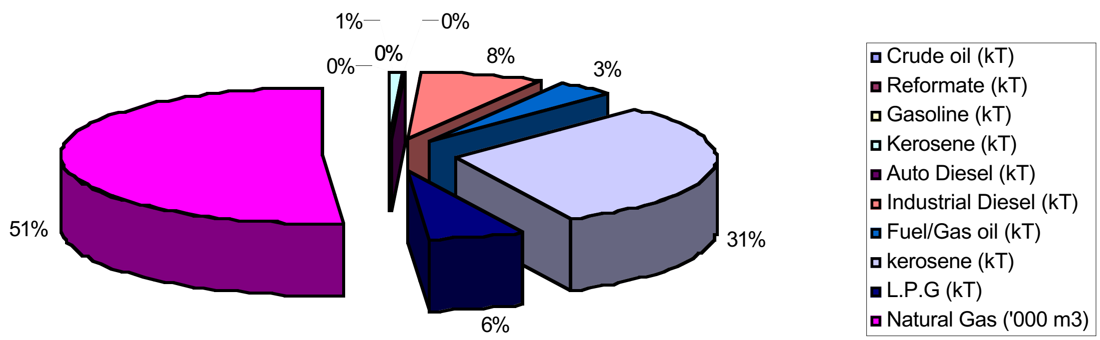


FIGURE 3.8: 1997 Fuel Consumption in Barbados



A study on Demand Side Management has been conducted by the Barbados Light & Power Company, and at present there are plans for the establishment of a Demand Side programme, which would operate through the cooperation of the Barbados Light & Power Company Limited and the Energy Division of the Ministry of Finance , acting to balance the island's supply of fuels with its demand.

The Barbados Light & Power Company

The Barbados Light & Power Company Ltd. (BLPC) is the sole generator of electricity for public use in Barbados, and so deserves special focus. At the present time, the BLPC depends on three fuel types: residual fuel oil (no.6), distillate (diesel and AvJet) and natural gas.

The BLPC has in fact been giving consideration to fuel consumption reduction methods as well as methods for reducing GHG emissions from its operations (Personal Communication, Peter Williams, Senior Planning Engineer, BL&P). In 2000, the BLPC completed a System Expansion Study, which included projections of system demand growth to 2008 and calculation of total CO_2 emissions from fuel combustion in that same year. Based on the BLPC estimations of fuel use (at 5% growth) to satisfy system demand in 2008, the IPCC methodology was also used to calculate CO_2 emissions. The results of this analysis are shown in Table 1 below.

Table 3.2: Projected BLPC Fuel Use and CO_2 Emissions

Fuel type	BLPC projection of fuel use (2008)	BLPC estimate of CO_2 emissions	IPCC estimate of CO_2 emissions
Residual fuel oil	243,059 long tons	773.48 Gg	748.20 Gg
Distillate (diesel&AvJet)	39948 long tons	124.25 Gg	127.56 Gg
Natural gas	7.0 million cu.m	Not estimated	14.72 Gg
Total		897.73 Gg	890.49 Gg

Though the BLPC did not estimate projected emissions of natural gas in 2008, it can be seen that the estimates of total CO_2 emissions using the two methodologies are comparable. Comparing the 2008 estimate of total CO_2 emissions from fuel combustion for electricity generation with the 1997 estimate (496.68 Gg CO_2), it can be seen that without the implementation of abatement options, there is an expected 80% increase in emissions from this source in just over 10 years.

3.4.2 INDUSTRIAL PROCESSES

Industrial processes that chemically transform materials are potential sources for the emission of GHGs. A number of different GHGs may be released from industrial processes, including CO_2, CH_4, H_2O, and HFCs. Information on quantities on production levels of relevant items were obtained primarily from the Barbados Statistical Service, though in some cases, information was provided by the individual production companies.

Total emissions from the industrial processes category were:

	CO_2	NMVOCs	HFCs
1990	177 Gg	1 Gg	0 Gg
1994	38 Gg	1 Gg	0 Gg
1997	171 Gg	1 Gg	0 Gg

Based on the data collected, the CO_2 from this sector contributed anywhere from 2.01% (in 1994) to 11.32% (in 1990) of the island's total CO_2 emissions (average 7.04% of the total).

Estimations made for GHG emissions from the consumption of halocarbons in bulk (refrigeration and airconditioning equipment and fire extinguishers) were based on import data for these items obtained from the Barbados Statistical Service. Since no information was available on the proportion of chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) in these items, the following assumptions were made in order to facilitate the calculations of potential emissions:

- As a result of the increasingly high costs of importing halon containing equipment in the 1990s, it was assumed that all fire extinguishers imported in 1994 were halon containing; half of those imported in 1994 were halon containing; and no fire extinguishers imported in 1997 would have contained halons.
- Due to the phasing out of CFCs in the 1990s, it was assumed that all refrigerators and airconditioning equipment imported in 1990 would have contained these substances (the worst case scenario); half of those imported in 1994 would contain CFCs; and none of the equipment imported in 1997 would contain CFCs.

3.4.2.1 PROFILE OF THE INDUSTRIAL SECTOR

There is little heavy industry on the island of Barbados. The most significant source of GHG emissions in the industrial sector in Barbados is the island's lone cement plant. The significantly lower emissions of CO_2 in 1994 compared to the other two years considered is attributed to the low production of cement in that year, which was about half of that produced in 1990 and 1997. Reasons for the decrease in cement production in 1994 were not ascertained, but the marked decrease in production may have reflected the slump in the traded sector of the Barbados economy, which in turn was caused by a poor performance in the tourist sector in 1993. The resultant shortage in foreign exchange would have slowed activity in the non-traded sectors, such as construction, and could conceivably have impacted cement production.

There is locally significant production of alcoholic beverages (beer and rum) and limited production of foods, which are responsible for generating the small emission of NMVOCs.

Though there is a relatively small chemical manufacturing industry on the island, data on the types and quantities of chemicals produced could not be readily obtained from the production companies. In addition, although there is metal fabrication, there is no metal production on the island.

3.4.3 AGRICULTURE

The agricultural sources of GHGs in Barbados are the rearing of domestic livestock (enteric fermentation and manure management) and agricultural soils. Other potential sources for which methodologies are provided in the IPCC Guidelines, namely rice cultivation and the prescribed burning of savannas are not activities that are relevant to Barbados. Additionally, there is no official burning of agricultural residues and though this activity may take place at the scale of the individual farmer, no documented information was available from which estimates of GHG emissions from this activity could be made.

Due to the diverse nature of the agricultural sector, the various emission processes within this sector were profiled separately, with separate estimations of emissions per emission subsource.

3.4.3.1 Domestic Livestock

A single sub-module was used to estimate emissions of methane and nitrous oxides (NOx) from enteric fermentation and manure management for the following animals: dairy and non-dairy cattle, sheep, goats, horses, pigs, mules, donkeys and poultry.

Barbados' livestock industry is characterized predominantly by small scale operations. Livestock numbers have remained almost constant for over a decade, as can be observed from Table 3.3 below.

LIVESTOCK NUMBERS	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Donkeys	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Mules	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Cattle	28000	30000	30000	30000	28000	28000	28000	24000	23000	23000	23000	23000
Chickens												
(1000)	3710	3300	3300	2900	2900	3100	3400	3700	3500	3500	3600	3600
Goats	4381	4400	4400	4500	4500	4500	4500	4500	4500	4500	4500	4500
Horses	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Pigs	28897	29500	30000	30000	30000	30000	30000	30000	31000	33000	33000	33000
Sheep	39120	40000	40000	41000	41000	41000	41000	41000	41000	41000	41000	41000

Table 3.3: Livestock numbers in Barbados (Source FAO Statistical Database).

GHG emissions from enteric fermentation were calculated as:

	CH_4
1990	1.12 Gg
1994	1.12 Gg
1997	1.12 Gg

Emissions from enteric fermentation contributed to 1.36% of the total CH_4 emissions on average.

For each of the years under consideration, a three (3) year average of livestock numbers was used in the estimations. This average included the numbers for the base year and the years preceding and following this year.

Livestock numbers were obtained from the Ministry of Agriculture and Rural Development (MAR). These numbers were verified and supplemented where necessary by livestock numbers for Barbados recorded in the Statistical Database of the Food and Agricultural Organisation of the United Nations (FAO). The emissions factors selected for estimation of GHG emissions in this sector were those consistent with the Latin American situation.

3.4.3.2 Manure Management

GHG emissions from manure management were:

	N_2O
1990	0.01 Gg
1994	0.01 Gg
1997	0.01 Gg

Manure management is not generally an organized practice by farmers in Barbados. The following assumptions were made in estimating emissions from this subcategory:

- The liquid system was not represented at all,

- Dairy farmers with 20 or more heads of cattle would have practiced anaerobic waste manage ment system,
- For all other animals, the daily spread, solid storage and dry lot and pasture range and paddock systems were assumed to be represented,
- Emissions factors consistent with the Latin American system were used.

3.4.3.3 Agricultural Soils

The primary emission of GHGs from agricultural soils is N_2O as a result of the microbial processes of nitrification and denitrification in the soil. Agricultural soils may also emit or remove CO_2 and/or CH_4. Direct soil emissions may result from the following nitrogen inputs to the soil:

- Synthetic fertilizers
- Nitrogen from animal waste
- Biological nitrogen fixation
- Reutilised nitrogen from crop residues

Estimates of synthetic fertilizer use in Barbados were obtained from the Ministry of Agriculture and Rural Development. These estimates corresponded with figures for synthetic fertilizer consumption in Barbados obtained from the FAO statistical database. As Table 3.4 indicates, fertilizer consumption on the island has been on the decline as a whole across the last decade, reflecting the progressive decline of agriculture, both of sugar and other food crops.

FERTILISER CONSUMPTION (tonnes)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Nitrogenous Fertilisers	1500	1500	1500	1500	1500	2000	2000	2000	2000	NA	NA
Total fertilisers	2700	2700	2700	2700	2700	2000	2000	2000	2000	NA	NA

Table 3.4: Barbados' fertilizer consumption (tonnes) (Source FAO Statistical Database) (NA-data not available)

Production of pulses and of non-nitrogen fixing crops was obtained from the Barbados Economic and Social Report (prepared by the Research and Planning Unit of the Ministry of Finance and Economic Affairs), and from the FAO statistical database. Total production of pulses was 860 tonnes in 1990, and has held at 840 tonnes from 1993 to the present.

Emissions of all GHGs from agricultural soils for the base years 1990, 1994 and 1997 were calculated as:

	N_2O
1990	0.13 Gg
1994	0.13 Gg
1997	0.13 Gg

Emissions from agricultural soils make up 83.27% of the total N_2O emissions; although the emission levels are low due to the small size of the island and the small area of land under cultivation.

3.4.4. LAND USE CHANGE AND FORESTRY

The removal of atmospheric CO_2 as a result of the regrowth of biomass on previously managed lands was estimated as:

	CO_2
1990	11 Gg
1994	11 Gg
1997	11 Gg

This sink is capable of removing only 0.7% of the CO_2 emitted in Barbados.

After the settlement of Barbados by the British in 1627, nearly all of the forest cover in Barbados was removed to facilitate the establishment of sugar cane plantations. Wooded areas in Barbados now account for only two percent (2%) of the total land area (approximately 5,070 hectares). Of this area, approximately 20 hectares is virgin forest found in an area of the island called Turner's Hall Woods. Due to the limited availability of forested areas, there is no harvesting of wood for commercial purposes in Barbados.

In addition, the clearing of wooded areas (by burning) for conversion to permanent cropland and the cutting of trees for fuel are not practiced. Indeed, there are several areas of land that traditionally formed sugar plantations and that have now been invaded by secondary forest growth as the land has been abandoned due to the decline of the sugar industry, thus making Abandonment of Managed Lands the primary category of land use change for the island's inventory. During the 20 years prior to the inventory base year, 1990, estimates from MAR indicate that approximately two to three thousand hectares of land formerly in agricultural production was allowed to revert to a natural state.

For the purposes of this inventory, only forests that are managed for wood products are considered to be either an anthropogenic source or sink of GHGs. Therefore GHG emissions in Barbados from forestry activity were not estimated.

3.4.5 WASTE

Disposal and treatment of industrial and municipal wastes can produce emissions of the most important GHGs. The most important gas produced in this source category is CH_4 from solid waste disposal to land and wastewater treatment. In addition to CH4, solid waste disposal sites may produce substantial amounts of CO_2 and NMVOCs. The process of wastewater treatment can produce NMVOCs, CH_4 and N_2O. No methodologies have been provided in the 1996 Revised IPCC Guidelines for the estimation of emissions of NMVOCs from this source category. Additionally, a methodology has been provided for the estimation of N_2O emissions from human sewage.

In Barbados, the inventory indicated that CH_4 and N_2O were the two gases generated by the operations of waste sector, namely through solid waste disposal and wastewater disposal. The waste sector contributed, on average, 98.61% to the total CH_4 emissions, and 13.5% of the N_2O total.

3.4.5.1 Solid Waste Disposal

Estimated emissions of CH_4 from the island's lone landfill were:

	CH_4
1990	7 Gg
1994	8 Gg
1997	9 Gg

The default methodology provided in the IPCC Guidelines was used to estimate the emission of CH_4 from the island's landfill site. This incorporates a mass balance approach, which uses an estimate of the degradable organic carbon (DOC) content of the solid waste, i.e the organic carbon that is accessible to biochemical decomposition to calculate the amount of CH_4 that can be generated from the waste. The percent DOC by weight of municipal solid waste (MSW) was calculated using the known composition of the solid waste stream in Barbados (Solid Waste Characterization Study, 1994) and the default DOC values of each fraction of waste provided in the IPCC Guidelines.

Mangrove Landfill

There is currently only one active landfill in Barbados, which serves as the only acceptable managed deposition point for municipal solid waste (MSW). This landfill is known as the Mangrove Landfill, and is situated on 32 acres of porous coral limestone in the central parish of St. Thomas. The landfill is divided into two distinct areas known as the Eastern and Western sites. Waste disposal was carried out at the Western site from 1986 to 1992. This site, unlike the Eastern site, is not lined with an impermeable liner and is in excess of 60 feet at its deepest point. Waste disposal at the Eastern site started in 1992 and is still in progress.

Of all the solid waste disposed of at the landfill, approximately 38 percent is collected by the government agency, the Sanitation Service Authority (SSA), as a public service. The SSA achieves 100% coverage of households in Barbados for the collection of solid waste at least once per week. A further breakdown of the SSA's collection service is as follows:

10% of households (in the Bridgetown area)	- daily collection
67% of households	- collection twice per week
6% of households	- three times per week
17% of households	- once per week

The SSA also runs a subsidized commercial (fee-based) collection service, although the quantity of waste collected in this manner is small. The remainder of MSW collection, and virtually all collection of bulky waste, are carried out by private companies.

Data on the quantities of solid waste generated for the inventory years was obtained from the SSA. This data was based on a survey that is done each fiscal year (April to March) over a two-week period. The survey involves weighing the quantity of solid waste collected by SSA vehicles as well as by private haul vehicles. No data was available for the 1990 fiscal year, however, an estimate of the total quantity of waste generated in that year was made using a waste growth rate of 1.0053% per year (Solid Waste Management Programme Design Brief, 1999).

A study was undertaken in 1998 by the Barbados Light & Power Company Ltd. to determine the methane content of landfill gas at the Mangrove Pond landfill. The study revealed that, at the Mangrove Pond landfill, the mean concentration of methane at each of the seven (7) sites tested ranged from 34.5% to 52.3%. It was deduced that this suggested that, at some of the sites tested, the landfill is in final stages of decomposition. It was also felt that fissures in the clay cap may act as an escape route for methane, resulting in lower levels of methane recorded at these sites.

3.4.5.2 Wastewater Disposal

CH_4 and N_2O emissions from the handling of wastewater and from human sewage were calculated as:

	CH_4	N_2O
1990	71 Gg	0.02 Gg
1994	76 Gg	0.02 Gg
1997	76 Gg	0.02 Gg

Based on information collected for the Barbados 1990 Population and Housing Census, disposal of 65% of residential waste water in Barbados is by means of underground suck wells. A further 32% of households use pit latrines. These proportions were assumed to remain the same throughout 1994 and 1997.

Infrastructural development in the tourist industry in the 1970s and early 1980s resulted in a proliferation of hotels, apartments and other businesses along the south and west coasts of the island, which gave rise to increased sewage production. These establishments have sewage treatment plants of varying degrees and sophistication and reliability. Monitoring of effluent from these plants is done on a monthly basis by the Environmental Engineering Division (EED) as a means of minimizing pollution of nearshore coastal waters. In 1997, the GOB completed a wastewater treatment plant and pumping station for the south coast of the island and is in the process of establishing connections. A similar plant is proposed in the near future for the west coast of the island. In addition, there is a sewage treatment plant for the capital, Bridgetown, that handles wastewater from commercial and residential buildings in the city.

3.5 DATA GAPS AND UNCERTAINTIES

In assessing the accuracy of the first National Greenhouse Gas Inventory of Barbados (NGHGIB), it is necessary to evaluate the data collection procedures followed; issues/problems encountered in this process and in applying the IPCC Guidelines for GHG Inventories; as well as data collection and monitoring requirements for future inventories. Such evaluation is crucial because the soundness of the procedures followed in data collection impacts upon the quality of the data, which, in turn, affects the reliability of the inventory estimates of GHG emissions and removals.

The first NGHGIB focused on using readily available data and the simple or Tier I methodologies provided in the Revised 1996 IPCC Guidelines for GHG Inventories. However, it is anticipated that a greater level of detail and accuracy will be required for future inventories, particularly with regard to determining the abatement needs and successes of abatement strategies that have already been implemented. Hence, greater detail and accuracy will also be required in the input data.

The various government agencies have an important role to play in the collection of data and monitoring of data quality. The successful undertaking of future GHG inventories in this manner will therefore require a significant degree of inter-agency cooperation and transparency. The Ministry of Physical Development and Environment (MPE) has a key role to play in this process.

3.5.1. ISSUES ARISING DURING THE DATA ACQUISITION PROCESS

During the data collection process, a number of issues and challenges were encountered which impacted upon the quality of the data that was acquired for use in the inventory. The following sections describe these issues and challenges for each sector of the inventory.

3.5.1.1 Energy Data

The Energy Division provided the bulk of the data for the Energy component of the NGHGIB. Major issues arising were:

- Lack of data on fuels imported, exported, consumed for non-energy purposes
- The Unit of data collection was barrels, which then had to be converted to a weight quantity

using standard conversion factors obtained from the Energy Division. A specific reference for these conversion factors could not be ascertained.

However, fuel data (production, imports, exports, consumption) obtained by the Energy Division is collected on a systematic basis from the Barbados National Oil Company (quarterly collection), the National Petroleum Corporation (quarterly collection), and from the three marketing companies, TexGas, Shell and Hal Petro Gas on a monthly basis. In addition, information on sectoral energy consumption is routinely gathered from individual companies by means of a data sheet provided by the Energy Division.

The major deficiency with the data from the Energy Division is that it omits fuel consumption for non-energy purposes so that emissions from this category could not be estimated.

In addition, the disparate estimates of emissions derived when the reference and sectoral approaches were applied, indicates that the non-energy fuel consumption missed by the Energy Division's data collection is significant. Another possibility is that there is a significant amount of on-site electricity generation by small companies occurring in Barbados, who do not report to the Energy Division.

3.5.1.2 Industrial Processes Data

Difficulties were experienced in acquiring production data from private companies for use in this component of the inventory. Where data requested could not be obtained from the private companies, the primary reasons were:

- No records of production data were kept
- Unwillingness to provide private records for use on the project
- Change of ownership of company over the last decade meant that production records of previous owners were unavailable
- Company was opened subsequent to the years for which data was being requested
- Closure of company subsequent to the years for which data was being requested.

It is estimated that 90% of the data requested from private firms was eventually provided by the Barbados Statistical Service (BSS) which is responsible for the regular collection of production data from private companies. In some instances, comparison of data received from the BSS and private companies revealed discrepancies. It could not be ascertained specifically why this situation should exist, though it is probable that it may be as a result of differences in the methodologies of collection.

The most notable deficiency in data under this component was production information for baked goods that could not be determined from the production companies or from the BSS.

3.5.1.3 Agriculture

Estimates of livestock numbers, crop production and fertilizer consumption used in the inventory were provided by the Ministry of Agriculture and Rural Development (MAR) and were supplemented by data from the FAO statistical database, as well as the BSS.

There is some uncertainty associated with these estimates as the methodology of collection in some instances is unclear. In particular, major issues arising with the MAR data were:

- Lack of yearly records of livestock numbers, estimates were provided
- Unavailability of information on crops or residues that are burnt in the fields
- Lack of assays on yearly production of crops
- Lack of detailed information on the methods of management of animal waste

These deficiencies in data meant that there was a degree of estimation of emissions for the agricultural sector, particularly the manure management source.

3.5.1.4 Land Use Change and Forestry

Since Barbados has no commercial forestry industry, the primary area of concern under this component was the Abandonment of Managed Lands category.

The major difficulty that arose in the estimation of GHG emissions and removals for this category was the lack of specific information on the area of land formerly under agricultural production that was abandoned for this purpose over the 20 year period preceding the inventory. Though an estimate was provided by MAR, it was not possible to determine the proportion of this area which experienced regrowth to a natural state, the proportion of land which continued to degrade, nor the proportion of land that was converted to other uses, such as residential development. For the purpose of the assessment, it was assumed that the entire estimated area reverted to a natural state, i.e wooded area.

In addition, there was no data on species composition of the regrowth (eg. if there were a significant number of nitrogen-fixing plants), which could affect estimates of the capacity of abandoned lands to act as sinks.

3.5.1.5 Waste

Data on solid waste generation was obtained from the SSA. The primary difficulties identified with this data was that:

- Quantity of solid waste generated was derived from a two-week study which is undertaken each year and is not the actual quantity of waste weighed over the specified period since there is currently no scale provided at the landfill site
- No data was available for the year 1990 since no survey was undertaken in that year
- The extrapolation of data from the two-week survey to the entire year does not take into

account the seasonal impact of increased tourist arrivals on waste generated.

Data on sewerage generation is the responsibility of the Environmental Engineering Division, however, the only data currently collected by this agency is data on water quality in the vicinity of municipal and commercial treatment plants. No data on residential or industrial sewage and sludge output could be obtained.

3.5.2. ISSUES ARISING FROM THE USE OF THE IPCC GUIDELINES

In all cases, default emissions factors provided in the IPCC Guidelines were used to estimate GHG emissions for Barbados. This was due to the unavailability of research providing local emissions factors that could be applied to the inventory. In cases where the IPCC Guidelines provided emissions factors for different regions of the world, factors consistent with the Latin American situation were chosen due to proximity, although it is recognized that conditions between Caribbean territories and Latin America can be vastly different. In general, IPCC Factors are ill-suited to the tropical situation.

3.5.2.1 Energy

To convert the tonnage of fuel to its energy equivalent required multiplication by the fuels' Net Caloric Values (NCVs). The IPCC document presented country specific NCVs for a number of countries, not including Barbados. Default NCVs were provided for some refined petroleum products and these were used in the Inventory. Where no default values were provided, particularly in the case of solid fossil fuels, NCVs for the United States were used, since Customs records indicate that this is the primary place of origin of such products imported into Barbados.

3.5.2.2 Industrial Processes

The greatest area of concern with the IPCC methodology in this component was the Tier I method presented for the estimation of potential halocarbon emissions. The methodology requires knowledge of the number of units of halocarbon-containing equipment (air conditioners, various types of refrigerators and fire extinguishers) imported and exported, the weights of each type of unit, and the proportion of the unit's weight that is accounted for by the halocarbon. In most cases, Customs data does not record this level of detail and a more detailed survey of retail outlets to obtain this kind of information would be required.

3.5.2.3 Agriculture

The methodologies provided for this component were relatively easy to apply provided that the relevant data was available. It should be noted that the IPCC Guidelines contain only one level of methodology for this component.

3.5.2.4 Land Use Change and Forestry

The IPCC Guidelines for the estimation of emissions and removals from this category focus primarily on three main types of activities. Two of these: the harvesting of forests for commercial purposes or for fuel wood, and the conversion of forest lands for agricultural production are not relevant to Barbados' current situation. Only the third category, which considers atmospheric carbon dioxide removal from the abandonment of managed lands, is relevant.

3.5.2.5. Waste

Provided that relevant national data is available, the IPCC methodology is easy to apply.

3.6 CONCLUSION

There are no known independent estimates of GHG emissions for Barbados which could be used to verify the results of estimations using the IPCC Guidelines.

In general, record keeping of basic production and import/export data by the relevant Government institutions in Barbados is systematic and up to date. Some improvement can be made in the documentation of methodologies for data collection as this has implications for its reliability for use in the estimation of GHG emissions. With a view towards conducting future inventories to greater levels of detail, much more sophisticated data recording is necessary.

As expected, the energy sector is responsible for the majority of the emissions of CO_2. This is followed by emissions from the industrial processes sector, where the cement plant is the primary source of CO_2 emissions.

The major anthropogenic cause of removal of atmospheric CO_2 is the regrowth of abandoned agricultural lands to a natural state. Due to the fact that the current pressure on agricultural lands in Barbados is for conversion to residential or commercial development, it is not anticipated that regrowth of biomass will continue to be a major GHG sink on the island in the future.

Land filling of solid waste and the handling of wastewater were found to be significant sources of CH_4, indicating the need for greater investigation into the implementation of flaring or gas recovery schemes.

On a global scale, GHG emissions from Barbados are small compared to larger and/or more industrialized countries, and it should be kept in mind that a significant amount of energy is consumed in catering to the near quarter million visitors present on the island at any given time. However, opportunities exist for the abatement of emissions in the interest of minimizing the adverse effects of global climate change. In all source categories, the costs of abatement must be weighed against the potential benefit to the global reduction of GHG emissions, particularly in light of the alternative uses of national finances for social development on the island.

Chapter 4

Strategy for the Abatement of Greenhouse Gas Emissions

4.1 BACKGROUND TO THE ABATEMENT ANALYSIS AND STRATEGY

The release of gases like carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and a number of others into the atmosphere as a result of human activities has been linked to the trapping of solar heat in the atmosphere, similar to the way in which glass traps solar heat in a sunroom or a greenhouse. Hence these gases have been termed greenhouse gases (GHGs). The result of the increase of GHGs in the atmosphere is that, if everything else stayed unchanged, the average atmospheric temperature would increase.

An increasing body of observations gives a collective picture of a warming world and other changes in the climate system. Those observations indicate that the global average surface temperature (the average of near surface air temperature over land, and sea surface temperature) has increased over the 20th century by $0.6 \pm 0.2\ ^0C$. If this trend continues, scientists estimate that the amount of warming will be about 1.40C by the year 2050 (IPCC REPORT: Summary for Policy Makers, 2000). If global warming occurs, though not every day in every place will be warmer, a number of impacts are expected. These include changes in the amount and pattern of rain and snow, in the length of growing seasons, in the frequency and severity of storms, and in sea level. For small island states like Barbados and other islands in the Caribbean region, climate change has potentially devastating impacts on coastal and marine environments, human health, coastal settlements, water supply and the economy, which is in large part dependent upon the success of tourism.

In recognition of the potential adverse impacts of climate change resulting from the greenhouse effect, the United Nations Framework Convention on Climate Change (UNFCCC) sets an "ultimate objective" of stabilizing "greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (human-induced) interference with the climate system." This objective does not specify what these concentrations should be, only that they be at a level that is not dangerous. It also acknowledges that there is currently no scientific certainty about what a dangerous level would be.

As a signatory party to the UNFCCC, Barbados has previously prepared a national inventory of greenhouse gases for the years 1990, 1994 and 1997. Based on the findings of the national inventory, Barbados has undertaken the preparation of this Abatement Analysis and Strategy.

4.2. PURPOSE AND OBJECTIVES OF THE ABATEMENT ANALYSIS AND STRATEGY

"**Abatement**" may be defined as a reduction in the degree or extent of emissions. However, as indicated in section 4.1 above, no standard for reduction of emissions has been identified by the UNFCC. The purpose therefore of the GHG Abatement Strategy for Barbados is to identify abatement options which can be implemented to reduce or eliminate the GHG emissions of Barbados.

The strategy does not aim to specify target levels for reduction since this would depend upon the financial resources available to both the public and private sector to implement programmes and to adopt technologies. In addition, sufficient research has not been carried out on the various abatement options to provide enough information to determine the level of reduction of GHG emissions that would be offered by individual options.

The level of emissions of the main GHGs has been estimated in the first National Greenhouse Gas Inventory for Barbados (NGHGIB) for the years 1990, 1994 and 1997. Based on the results of this inventory, the Abatement Strategy focuses on identifying methods for reducing emissions from those source categories which have been found to release the greatest proportion of GHGs into the atmosphere.

Objectives of the Abatement Analysis and Strategy

Having reviewed the GHG emissions of Barbados as presented in the national GHG Inventory and identified the major sources of GHG emissions, specific objectives of the abatement strategy are as follows:
a) To determine where abatement efforts should be targeted as a priority;
b) To review initiatives or strategies that are currently being undertaken or investigated in Barbados aimed at reducing or eliminating GHG emissions;
c) To identify further strategies and/or methods that could be implemented to reduce or eliminate GHG emissions.

4.3 ABATEMENT OPTIONS

The preceding chapter on the analysis of the Greenhouse Gas Inventory reveals that abatement efforts and resources for Barbados should be focused on controlling/reducing:

- CO_2 emissions from fuel combustion for electricity generation.
- CO_2 emissions from road transportation.
- CH_4 emissions from waste management activities.
- CH_4 emissions from agricultural activities.

Since there is no standard for the level of emissions that would not cause dangerous climatic effects, the aim of the Abatement Strategy is to identify abatement options, including the use of the best available technologies and methodologies to reduce the level of emissions from current levels.

The abatement strategy for Barbados is presented in this section as broad abatement options which are geared towards the reduction or elimination of GHG emissions in those sectors and subsectors (as defined in the 1996 Revised IPCC Guidelines for National Greenhouse Gas Inventories) determined to be making the greatest contribution to the total emissions of Barbados. The rationale behind this approach to the development of an abatement strategy is that priority for allocation of available resources should be where the potential environmental impact is greatest. The development of more detailed recommendations based on these broad options will require consultation with and input from stakeholders in the public and private sector, as well as the development of appropriate policy and legal measures to facilitate implementation of some options.

Under each subheading, which identifies the category of abatement options, some of the initiatives being investigated or already in progress by the public and/or private sector are highlighted. These initiatives either directly or indirectly have the effect of reducing greenhouse gases. Where further abatement options have been identified, these are also described under the appropriate subheading.

Efforts By the Government of Barbados

The Government of Barbados (GOB) has set as one of its objectives the increased use of renewable energy. The aim is to reduce the emissions of greenhouse gases from the combustion of fossil fuels. Currently there is a study on the potential use of photovoltaic technology to produce electricity. It is expected that as this technology becomes less expensive that it would be utilized further and would be able to make a significant contribution to the energy grid of the country. Initial investigation has also been conducted into the feasibility of utilizing wind energy in Barbados to produce electricity. It is expected that by the year 2010, a wind farm capable of supplying 10 percent of the total energy needs of the country would have been established.

There is also a schools solar stills project which is being conducted in conjunction with the Centre for Resource Management and Environmental Studies (CERMES) at the University of the West Indies, Cave Hill Campus in Barbados. This project will allow the 12 secondary schools involved to provide their own distilled water for use in science laboratories. This will be an excellent example to the community of how renewable energy can be used as an environmentally friendly technology to the benefit of society.

In addition draft proposal for the establishment of a Renewable Energy Centre has been prepared and is being reviewed by Government. It is expected that within the next two years this Centre will be operational.

Chapter 5 of the Communications document will detail future plans of the Government of Barbados on the aforementioned projects.

4.3.1 Reducing Fuel Consumption for Electricity Generation

Globally, the greatest contributor to the greenhouse effect has been shown to be the release of CO_2 into the atmosphere as a result of the combustion of coal and other fossil fuels. A key strategy in abating these emissions is to find ways to move away from the dependence on fossil fuels towards an economy based on more efficient use of energy and the promotion of renewable alternatives. As illustrated in the previous chapter, the main source of CO_2 emissions in Barbados is the combustion of fuel for electricity generation. Therefore a key option for the abatement of GHGs is the reduction in fuel consumption for electricity generation and, where possible, a shift towards the use of cleaner energy sources.

The Barbados Light & Power Company

The Barbados Light & Power Company Ltd. (BLPC) is the sole generator of electricity for public use in Barbados. Therefore any attempts to reduce GHG emissions from fuel combustion must target the operations of the BLPC. At the present time, the BLPC depends on three fuel types: residual fuel oil (no.6), distillate (diesel and AvJet) and natural gas.

As has been stated earlier in this document, the BLPC has been giving consideration to fuel consumption reduction methods as well as methods for reducing GHG emissions from its operations (Personal Communication, Peter Williams, Senior Planning Engineer, BLPC, 2000), particularly since it is expected that there will be a growth in fuel consumption to satisfy power demands in 2008. The BLPC System Expansion Study (2000), although it did estimate CO_2 emissions from the combustion of residual fuel oil and distillate (diesel & AVJet), it did not estimate projected emissions of natural gas in 2008 (see Table of results of study in the previous chapter). Despite this, the emission estimates of the BLPC study are comparable to those projected using IPCC methodologies; and comparing the 2008 estimate of total CO_2 emissions from fuel combustion (897.73 Gg CO_2) for electricity generation with the 1997 estimate (496.68 Gg CO_2), it can be seen that there is an expected 80% increase in emissions from this source in just over 10 years. Therefore, it is important that methodologies for abatement be implemented within as short a time frame as possible.

The BLPC has also undertaken investigations into fuel reduction options, which would also serve to abate the level of GHG emissions. One of these is the development of a 9MW wind farm, which would likely be implemented within the next 10 years. It is estimated that the wind farm would produce 3% of the total energy demand and reduce fuel consumption for electricity generation by about 4%. This would result in an estimated 5% reduction in CO_2 emissions from this source. Other abatement options being considered by the BLPC are described in Table 4.1.

Table 4.1 Other BLPC Abatement Options

Option	Comments from BLPC
Recovery of landfill gas	Relatively small source of energy and limited in scope
Use of liquefied natural gas (LNG) imported from Trinidad	Requires a major capital input and would make Barbados dependent on Trinidad for electricity production
Cogeneration (bagasse)	Only feasible during the crop season, therefore not a dependable source
Solar generation of electricity	Not a major energy source

4.3.2 Emphasis on Energy Efficiency Measures in the Industrial, Commercial and Residential Sectors

An additional strategy in the reduction of GHG emissions from the energy sector, particularly electricity generation is to focus on reducing the demand for electricity in the industrial, commercial and residential sectors through the adoption of energy efficient measures and technologies.

In the industrial sector, measures could include the upgrading of technology and equipment to achieve greater energy efficiency, particularly of generic equipment, such as motors and boilers which could be marketed to a wide range of companies. An important aspect of this upgrading process would be the widescale undertaking of energy audits and the development of energy use reduction and efficiency plans for individual companies. The Ministry of Physical Development and Environment (MPE) could play a key role in this process by the provision of technical information to companies in undertaking energy audits.

In the commercial and residential sectors, giving emphasis to the use of energy efficient equipment in lighting, refrigerating and air-conditioning is priority. The hotel sector is already pursuing such initiatives through involvement in programmes to achieve "green hotel" certification. The adoption of energy efficiency measures could be encouraged by the GoB through incentives such as reductions in importation duties for such equipment, which could then be passed on to consumers in the form of reduced prices. The development of linkages between the MPE and various components of the private construction industry to encourage the design, construction, use and management of energy-efficient commercial and residential buildings will also have long term impacts on GHG emissions.

4.3.3 Reduction of CO_2 Emissions from the Cement Industry

Cement is considered to be one of the most important building materials around the world, being mainly used primarily for the production of concrete. Cement production and consumption is therefore closely related to the level of construction activity, and therefore to the general economic activity.

About 5% of global CO_2 emissions originates from cement production. About half of this is from calcinations and half from combustion processes. Based on the information available for Barbados for the years 1990, 1994 and 1997 investigated for the GHG Inventory, cement production accounts for an average contribution of 7% of total CO_2 emissions from calcining the limestone in the raw mix. The contribution to emissions from fuel combustion was not determined separately but fuel use by this sector would have been included in the figure for fuel combustion by the ***manufacturing industries and construction*** sector.

The Arawak Cement Company Ltd. is the only cement production plant in Barbados. Therefore, efforts to abate CO_2 emissions from this source must target the operations of this entity. The Arawak Cement Company Ltd. does not currently measure its CO_2 emissions (personal Communication, Fred Broome-Webster, General Manager, Arawak Cement Company Limited) nor have any specific methodologies been identified for reducing these emissions. The company does measure emissions of sulphur dioxide (SO_2), nitrous oxide (N_2O) measured. Additionally, there is presently monitoring of carbon monoxide emissions because of the potential explosion hazard presented.

At the time of writing of this document, the company had not made any projections of production over the next decade, which would facilitate estimations of CO_2 emissions over that period. However, there are plans in place to seek ISO 14001 certification in the year 2002, so that it is anticipated that by the end of 2001, environmental standards would have been set and additional measurement and monitoring equipment purchased. Thus, the opportunity exists at this juncture for the Government of Barbados to partner with the Arawak Cement Company Ltd. to develop CO_2 and other GHG emission reduction targets and to identify potential methodologies for attaining those targets as part of the company's environmental management programme.

In general, total CO_2 emission during the cement production process depends mainly on:

- Type of production process (efficiency of the process and sub-processes)
- Fuel used (coal, fuel oil, natural gas, petroleum coke, alternative fuels)
- Clinker/cement ratio (percentage of additives)

Emissions of CO_2 from this source can be reduced by:

i. Improvement of the energy efficiency of the process

This may be done by applying more energy efficient process equipment and by replacing old installations by new ones or shifting to complete new types of cement production processes.

ii. Shifting to a more energy efficient process (e.g from (semi) wet to (semi) dry process)

The dry process is generally considered to be much more energy efficient than the wet process and the semi-wet somewhat more energy efficient that the semi-dry process. The processes are exchangeable to a large extent, but the applicability also depends on the raw material available.

iii. Applying lower clinker/cement ratio (increasing the ratio additives/cement: blended cements)

The production of clinker is the most energy-intensive step in the cement manufacturing process and causes large process emissions of CO_2. In blended cement, a portion of the clinker is replaced with industrial by-products such as coal fly ash (a residue from coal burning) or blast furnace slag (a residue from ironmaking), or other pozzolanic materials (e.g volcanic material). These products are blended with the ground clinker to produce a homogenous product, which is blended cement. The future potential for application of blended cements depends on the availability and costs (purchase and transportation) of blending materials, the ease of making changes in the production process, and on standards and legislative requirements. The potential emission reduction by the use of blending materials is an average of 20% of total CO_2 emissions from cement making.

iv. Removal of CO_2 from the flue gases

Typical CO_2 concentrations in the flue gases range from 14 to 33%. In this technique, CO_2 is separated during or after the production process and subsequently stored or disposed of outside the atmosphere. The CO_2 removal process can be split into three separate steps: recovery of the CO_2 (often including drying and compressing), transport of the CO_2 to a location where it is handled further, and utilization, storage or disposal of CO_2.

4.3.4 Introduction of Electric Vehicles and Hybrids

The Barbados Inventory has indicated that combustion of fuel by road vehicles makes the second largest contribution (14%) to the total CO_2 emissions of Barbados. The introduction of electric vehicles (EVs) has the potential to significantly reduce emissions of GHGs from this source. Investigations have been undertaken into the feasibility of making the transition in Barbados from internal combustion engine vehicles to (EVs) and hybrids (Jennings, K, 2000).

According to Jennings (2000), there is an opportunity to introduce EVs as the standard at this time because US-style impediments, such as oil companies wanting to discourage the use of alternative fuels, do not yet exist. EVs have an effective range of at least 167 km per charge, which is considered to be more than adequate for a week's usage by most commuters and tourists in Barbados. Hybrids, vehicles that use a small amount of petroleum, also offer a good range and low emissions. EVs and hybrids will pave the way for the introduction of fuel cell vehicles (once these become commercially available) by starting the shift away from internal combustions engines.

Jennings identifies a number of options for introducing EVs and hybrids to Barbados, including:
a) Replacements for government vehicles,
b) Offering rental agencies VAT incentives to add some of these vehicles to their fleets for use by tourists,
c) Offering car dealerships VAT incentives to sell electric scooters.

The most effective strategy for implementation would be a phased approach, where rentals of cats and scooters to tourists would constitute the first phase, followed by the GoB's commitment to replacing vehicles in its fleet, and thirdly the dale of electric scooters through car dealerships. This strategy provides for tourists and the government to pay the initial cost of introducing these vehicles to Barbadians and offers car dealers an opportunity to exploit a new market without devaluing their current inventory of cars. Once Barbadians have had time to see the effectiveness of EVs and hybrids, they will be more keen to buy them.

4.3.5 Reducing the Disposal of Organic Materials in Landfills

The earlier analysis of GHG emissions indicated that the primary sources of CH_4 emissions are from waste management (landfilling and sewage handling). This suggests the need for improvement of waste management practices, particularly the reduction of landfilling of organic waste. Organic materials currently account for about 47% of the Municipal Solid Waste (MSW) stream in Barbados. This indicates that emissions from the degradation of organics in landfills can be reduced by finding alternative methods to dispose of these materials.

In 1993, the GoB embarked on the undertaking an Integrated Solid Waste Management Programme (ISWMP) which is aimed at developing a "modern, dependable and efficient waste management system, which would be accessible to all citizens, which would protect the environment, improve the standard of public health in Barbados and foster the participation of the private sector in a structured manner." The ISWMP comprises both physical and non-physical components.

Composting is one of the important elements of the ISWMP aimed at reducing the quantity of waste going to the landfill. There are two categories under the National Composting Programme: commercial composting which will take place on a large scale, receiving yard waste from a variety of sources and producing high quality compost for sale to agriculture and other sectors; and home composting which involves encouraging householders to compost their kitchen scraps and yard waste.

With reference to the reduction of the emission of GHGs from the landfill, the most important abatement options is to give continued emphasis to the implementation of the ISWMP, particularly the aspect of educating the general public and the commercial sector to adopt composting practices as well as other general waste reduction and recycling techniques.

The 1995 Draft Feasibility Study for the Barbados Solid Waste Management Programme forecast the quantity of MSW that will be generated in the year 2017. The forecast was made on the assumption that transfer and composting facilities will be designed to accommodate waste arrival and handling over a 5 day week, and use of a 10 hour week. Using the 2017 forecast of 97,820 tonnes of MSW (not including yard waste and bulky waste), an estimated CH_4 emission level of 4.67 Gg was calculated using the IPCC methodology. This is a 48% reduction in emissions from the 1997 level (9.03 Gg) due primarily to the removal of organics from the waste stream, and indicates the importance of emphasizing the composting of organic waste as a strategy for reducing solid waste and for the reduction of CH_4 emissions from landfill sites. In addition, emphasizing the other aspects of the solid waste management strategy, waste reduction and waste recycling, will also serve to delay the time at which a new landfill site will be required, hence reducing the volume of further CH_4 emissions from this source.

4.3.6 Recovery of Methane Gas from the Mangrove Pond Landfill

The recovery of CH_4 from Barbados' landfill is a possible option for the elimination of emission of this gas from this source. Developed countries have for some time been successfully employing technologies for the recovery and use of landfill gas (LFG). The CH_4 content of LFG typically ranges from 45% to 55% in municipal solid waste landfills that are in the final stages of decomposition. In addition to reducing GHG emissions to the atmosphere, LFG recovery schemes have a number of potential benefits to the community, including:

- Turns a landfill into a good neighbour
  - Reduces unpleasant odours
  - Eliminates expansion threats
- Helps the environment
  - Improves local air quality
  - Produces a renewable energy resource
- Offers economic advantages
  - Uses a local energy source that would otherwise be wasted
  - Saves fuel costs
  - Creates employment through project development

As previously stated, the 1998 BLPC study determined the methane content of landfill gas at the Mangrove Pond landfill, indicating that the mean concentration of methane at each of the seven (7) sites tested ranged from 34.5% to 52.3%.

By investigating and selecting from a variety of innovative options for energy recovery and end uses, it is possible to make use of methane emissions from the Mangrove Pond landfill. Since minimizing the cost of transporting LFG energy to users is critical to a project's economic feasibility, local use of LFG is often the most attractive option for small landfills. Good candidates for end uses of landfill gas-to-energy include:

- On-site or nearby use in facility buildings or leachate evaporators, and
- Nearby municipal and private buildings, such as recreational facilities, schools

4.3.7 Increased Support for Research and Development

As can be deduced from the discussion of abatement options in the preceding sections, ongoing research and development in all sectors is a necessary aspect of ensuring the success of national efforts to minimize emissions of GHGs. Financial and political support should be made available to individuals and organizations, both in the government and non-government sector, for programmes or technologies which show real potential for contributing to the reduction of GHG emissions.

4.4 POTENTIAL OBSTACLES TO THE ADOPTION OF ABATEMENT OPTIONS

There are a number of factors which may hinder the adoption of the recommended abatement options. These factors, outlined below, will likely be remedied, at least in part, by the introduction of appropriate policy measures and public education programmes:

- Lack of information and/or understanding of the need for GHG abatement and hence for the adoption of abatement measures
- Shortage of capital and lack of access to acceptable financing
- Aversion to the risk involved in adopting new technologies
- Higher cost of abatement technologies
- Lack of public and political support for the implementation of abatement measures
- Inadequate institutional arrangements

4.5 SUMMARY AND CONCLUSION

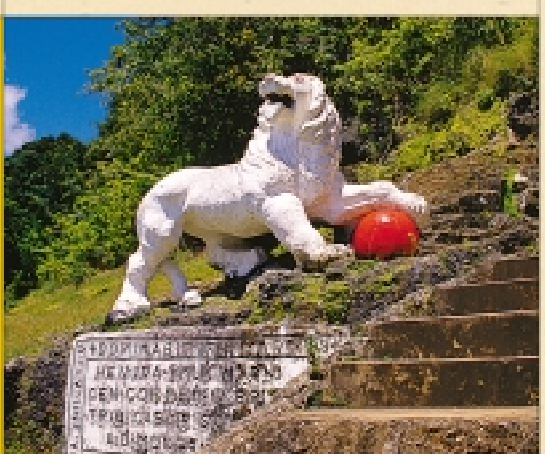
The preceding sections of this document gave an overview of the levels and proportions of GHG emissions of Barbados based on the national inventory of GHGs undertaken for the years 1990, 1994 and 1997. This inventory was undertaken in accordance with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. The overview also indicated the sources of GHGs which were the main contributors to the total emissions of the island, and identified these sources as the main targets for the abatement strategy.

The abatement strategy was presented as a number of broad abatement options. Investigations into the feasibility of all of these options have been undertaken, and some are already in the implementation stage. Further development of those options in still in the early investigation stage, specifically the implementation of electric vehicles and the recovery of landfill gas for energy purposes, will require the development of appropriate policy and legislative measures.

Public education must form a vital part of the strategy to reduce the levels of GHGS emitted by Barbados. The general public must be made aware of the sources of GHGs, including natural processes and human activities, of the potential adverse effects on our national well-being as a result of climate change caused by GHGs, and of the need for individual commitment to participation in abatement efforts. This public education can take place via the commonly used means, such as the mass media, school curricula, public exhibitions and discussions.

It should be recognized, however, that GHG abatement measures must be pursued in conjunction with climate change adaptation measures, since the phenomena of climate change and its potential adverse impacts are the collective result of the activities of all nations.

Chapter 5
Policies and Actions



5.1 BARBADOS' VISION OF SUSTAINABLE DEVELOPMENT

The Barbados Government recognises the importance of environmental management as it seeks its path to sustainable development; particularly since the country relies heavily on tourism as its major foreign exchange earner and provider of jobs. It is vital that the natural beauty of the island be kept intact, its beaches and water quality enhanced, and its variety of animal and plant species preserved. In order for sustainable development to take place it is clear that an effective legal framework should be in place.

Protection of the environment, however, has become even more critical, due to the recognition of Barbados' vulnerability to climate change. The threat of sea level rise, and the other impacts it induces such as coastal erosion, inundation and saline intrusion, as well as the threat of the intensification of storms, have in particular, gained much attention from the Government. As such, a number of coastal projects, works and policies have been developed within the last decade, as a general proactive step to combating the threat of climate change.

Apart from taking adaptive steps to the climate change problem, the Government of Barbados, despite contributing little to global greenhouse gas emissions, has on its own initiative, embarked on an overhaul of its energy sector to increase the use of renewable energy sources and employ sensible energy conservation techniques. These projects are aimed at enabling Barbados to become more independent and self reliant in catering for its energy needs, as well as to bring it closer to being a true model for sustainable development.

5.2 LEGAL ISSUES AND CLIMATE CHANGE

There are approximately 37 main pieces of legislation in Barbados, which deal with environmental, land use and building issues. Of these 37 statutes, 62% may be classified as environmental, 27% as related to land use and 1% as related to building. The most practical criterion for classifying these acts is to determine the predominant purpose and subject matter addressed by the legislation. However, given the linkages between environmental, land use and building issues there is some overlap among the various statutes.

Generally, all 37 pieces of the existing environmental, land use and building legislation, while not exclusive to the coastal zone of Barbados, are applicable, to varying degrees. The coastal zone or coastal area of Barbados derives its definition from the Coastal Zone Management Act (CZMA) where the coastal area is defined as all those areas in which coastal resources are located. Coastal resources mean:

"The land, water and living resources associated with the shoreline marine areas of Barbados, including beaches, shorecliffs, coral reefs, coral rubble, algal beds, seagrass beds, sand dunes, wetlands and other ecosystem found along the shore together with the flora and fauna found in these areas."

This definition suggests a very narrow geographical area limited to the marine/coastal interface.

However under the CZMA coastal zone management area or coastal management area means the area established as such by order made by the Minister. It is apparent therefore that the coastal zone management area comprises a wider geographic area than the coastal area. To date no official coastal zone management area has been designated pursuant to the Act. For the purposes of this report therefore it is assumed that the coastal zone management area coincides with the urban residential corridor as defined by the national Physical Development Plan (PDP) amended 1988.

The 1992 United Conference on Environment and Development (UNCED) represents a watershed in respect of the global environmental movement. Since UNCED several countries have established ministries of environment with supporting environmental legislation. It is apparent that the lack of resources (financial, human, technological) has impeded the efforts of some countries in modernising their environmental laws and strengthening institutional capacity.

In Barbados only 10 out of the 37 existing statutes dealing with environmental, land use and building issues have been enacted after 1992. Of the post-1992 legislation, 6 are environmental in scope, and the remaining 4 address land use matters. At the same time, the majority of the pre-1992 environmental, land use and building laws were enacted in the early 1970s. Considering 1992 as the watershed for the creation of modern environmental laws therefore, then the majority of existing environmental laws in Barbados are not modern.

Climate change will result in coastal erosion, flooding and salinization. In order to deal with these issues effectively there may be a need to amend much of the legislation in the following ways:

a) The strengthening of the content of legislation and the promotion of effective enforce ment measures. The Prevention of Floods Act is one example of legislation in need of content strengthening. The Act is more focused on mitigation than on prevention. There is a need for stronger preventative measures and the express requirement for the preparation of flood management plans as well as provision for flood plain mapping.

b) Enforcement measures in several pieces of legislation are inadequate. For example, the penalties for committing an offence under the Trees (Preservation) Act are a fine of $1000 or imprisonment for a term of 6 months or both. The penalties contained in some pre-1972 legislation must be amended to provide a realistic deterrent in modern day society.

c) Provision for the selective relocation of critical services. The legislation governing the issues of flooding and coastal erosion both lack provisions to facilitate the selective relocation of critical services. This omission could be addressed by an amendment to the individual pieces of legislation or such a provision may be housed in a Disaster Management Act.

While improvements to Barbados' environmental legislation might be accommodated by amending current legislation, in other instances new legislation is necessary. It may be necessary for the following:

(1) Legislation to deal with climate change

This may be dealt with by the enactment of a Climate Change Act, which would focus exclusively on the question of climate change. This approach was adopted by Japan, which is the first country to enact legislation specifically related to climate change in the form of its "Law for the Promotion of Policy and Measures on Climate Change". This Act establishes a strategy for climate change, deals with a mandatory action plan for greening operations at the government level, sets out a voluntary action plan by business enterprises, and identifies centres to facilitate the dissemination of information. Alternatively, provisions dealing with climate change may be contained in a framework Environmental Management Act. Regardless of which method is adopted, the setting up of a Climate Change Unit, to manage the legislation is vital. The unit would also provide a necessary focal point for coordination of action under the Act.

One of the critical functions of the Climate Change Unit should be to increase the involvement of the civil society in the decision-making process. It is recognised that Government alone cannot effectively undertake the required adaptation strategies. The civil society has an important role to play in reducing and preventing the impacts of SLR. The Climate Change Unit therefore should be mandated to encourage the civil society as a partner in the adaptation process.

(2) An Environmental Management Act

In light of the fragmented nature of the legislation, there is a dire need for a framework Environmental Management Act to provide a comprehensive system of environmental management. This legislation should set out the principles to guide policy formulation and decision makers. The Act should provide for

- the implementation of multilateral environmental agreements (MEAs) such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, and the Basel Convention on the Transboundary Movement of Hazardous Wastes and their Disposal, among others.
- the comprehensive management of pollution and incorporation of the 'polluter pays' principle.
- the protection of environmental and natural resources and their sustainable utilization.
- the formulation of a comprehensive environmental management policy.
- the incorporation of the principles of sustainable development and other associated prin ciples such as the precautionary principle, cost benefit analysis and best available technol ogy (BAT) and other best practices
- Environmental Impact Assessment (EIA) guidelines.
- public participation in environmental decision - making and access to information.

(3) Disaster Management Act

Legislation is needed to govern disaster management and to provide for the coordination of disaster management agencies. This legislation could provide for the selective relocation of critical services and a flood management plan. The Caribbean Disaster Response Act provides for the implementation of the Agreement setting up the Caribbean Disaster Response Agency and of certain provisions contained in the Headquarters Agreement of that Agency. The Act is an implementation Act and not an Act dealing with disaster management on a national scale. There is therefore still the need for national legislation.

(4) A Building Code and the establishment of a Building Authority

There is the critical need for the provision of legislation setting up minimum design and construction standards and a national agency to coordinate the implementation of these standards.

(5) Provision of Environmental Impact Assessment (EIA) legislation

The requirement of an EIA is a legal technique used to implement environmental principles and standards. The process requires that an EIA be conducted prior to the undertaking of a proposed activity. It incorporates environmental planning with development planning and seeks to assess the potential damage to environmental resources and minimize that damage. Its genesis is traced to the United States National Environmental Policy Act 1969 and the process has assumed great importance in domestic and international environmental law. Indeed, EIA provisions may be found in numerous international treaties and regional agreements. The EIA process may be incorporated into the legislation of Barbados by way of the inclusion of guidelines in a framework Environmental Management Act, as stated earlier, or by the adoption of stand alone EIA legislation setting out strict, detailed provisions. In either event there must be a clear designation of an authority to act as a centralized focal point for governing the EIA process.

(6) Incorporation of the precautionary principle

This principle originated with the Vorsorgeprinzip principle of German law. It became part of international law as a result of German proposals made to the International North Sea Ministerial Conferences. The principle was adopted in 1992 at the Rio Declaration at the United Nations Conference on Environment and Development (UNCED).

Principle 15 of the Rio Declaration contains a formulation of the principle and states:

"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost effective measures to prevent environmental degradation."

The principle has been described as a principle of customary international law. It is contained in numerous treaties, both regional and international, e.g, the United Nations Convention on Straddling Fish Stocks and Highly Migratory Fish Stocks, the United Nations Framework Convention on Climate Change, the Preamble to the Convention on Biodiversity, the Convention on the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa.

The precautionary principle is especially relevant to the issue of sea level rise and its impacts. The absence of scientific certainty as to the impacts should not be used as an excuse to postpone taking action. The principle should inform the approach to coastal zone management and planning and must of necessity be contained in legislation

5.2.1 Coastal Zone Management Issues

Protection of the environment has become even more critical due to the recognition of Barbados' vulnerability to climate change. The threat of sea level rise, and the other impacts it induces such as coastal erosion, inundation and saline intrusion, as well as the threat of the intensification of storms, have in particular, gained much attention from the Government. As such, a number of coastal projects, works and policies have been developed within the last decade, as a general proactive step to combating the threat of climate change.

The Ministry of Physical Development and Environment (MPE) has primary responsibility for environmental and natural resources management in Barbados. Part of the objective of the MPE is to promote and facilitate the sustainable use of Barbados' resources by encouraging the involvement of all citizens and the integration of environmental considerations into all aspects of natural development, and to work closely with the Energy Division within the Ministry of Finance, to develop all local energy resources in a sustainable manner, seeking to achieve their most efficient and effective use.

The lead organization for coastal zone management in Barbados is the Coastal Zone Management Unit (CZMU) within the MPE. Responsibilities of the CZMU include reviewing planning applications for developments in the coastal zone, conducting monitoring and research, enforcing the Coastal Zone Management Act and any subsidiary regulations, and acting as the advisor and lead focal point for coastal zone management for the Government of Barbados (GoB).

To enable the legal framework for Intergrated Coastal Zone Management, the GoB prepared two pieces of legislation: the Coastal Zone Management Act and the Marine Pollution Control Act (Both Acts were passed by Parliament in December 1998). The Town and Country Planning Act, which establishes the framework for national planning and development, supports these two acts.

The Marine Pollution Control Act establishes the framework for pollution control in the marine environment. This Act is broad, authorizing legislation for environmental protection, and applies to most sources of marine-based and land-based pollution. The Act authorizes the development of subsidiary standards and regulations for land and airborne sources of pollution, seabed activities, and dumping activities.

The Coastal Zone Management Act of 1998 establishes the legal framework for coastal zone management in Barbados. The Coastal Zone Management Act requires the development of a Coastal Zone Management Plan (CZMP) (which is currently awaiting approval by Government). The CZMP presents general and specific guidance for: (i) Global and regional coastal change; (ii) Conservation management; (iii) Maintenance and construction of coastal structures; (iv) Beach management recreation and safety; (v) Fisheries; (vi) Coastal habitat restoration; (vii) Community tourism; (viii) Resource exploration and extraction; (ix) Water quality; (x) Zoning; (xi) Set Back, access and views to the sea; and (xii) Environmental impact assessment.

The Draft CZMP consists of 3 key documents: the Policy Framework; the Integrated Management

Plan for the South and West Coast; and the Integrated Management Plan for the Atlantic Coast. The strategic objective of the CZMP as set forth in the Policy Framework is the sustainable use of the coastal zone by implanting policies, which maintain, and where possible, enhance environmental quality while enabling economic development. To achieve this objective four main policies were established: (i) applying standards and procedures; (ii) seeking compatibility between socio-economic and environmental interest; (iii) conservation heritage, culture and ecology; and (iv) working and living with dynamic coast.

The implementation of the CZMP has been advancing according to the process prescribed in the Coastal Zone Management Act. The Draft Plan must still undergo a statutorily mandated process of public consultation and parliamentary approval. It is expected that this process will begin by the end of 2001. Although the Draft Plan has not been legally adopted pursuant to the Act, on the basis of Cabinet approval, the GoB has been adhering to its recommendations. The CZMU has been putting into practice the recommendation of the plan, particularly with respect to: (i) the evaluation of all coastal-related development proposals which require building permits; (ii) EIAs for all coastal developments; (iii) enforcement of building set-backs and zoning of ecologically sensitive areas, both along the coast and in the marine zone; and (iv) enforcement of design requirements related to coastal engineering practice.

In 1983 the Government of Barbados established the coastal conservation project unit, which has evolved into the current Coastal Zone Management Unit. The purpose of the coastal conservation project unit was to conduct diagnostic studies of the islands coasts. Subsequently the coastal conservation project unit focused on the west and south coasts of Barbados, designing various engineering and non-engineering measures for beach protection, stabilization and enhancement.

Demonstration projects for beach protections and enhancement were constructed and implemented with financial assistance from international donor agencies. Figures 5.1 through 5.6 show examples of the demonstration projects.

Figure 5.1(a): Asta Beach Pre-Construction

Figure 5.1(b): Asta Beach Post Construction

Figure 5.2(a) : Heywoods Pre-Construction

Figure 5.2(b): Heywoods Post Construction

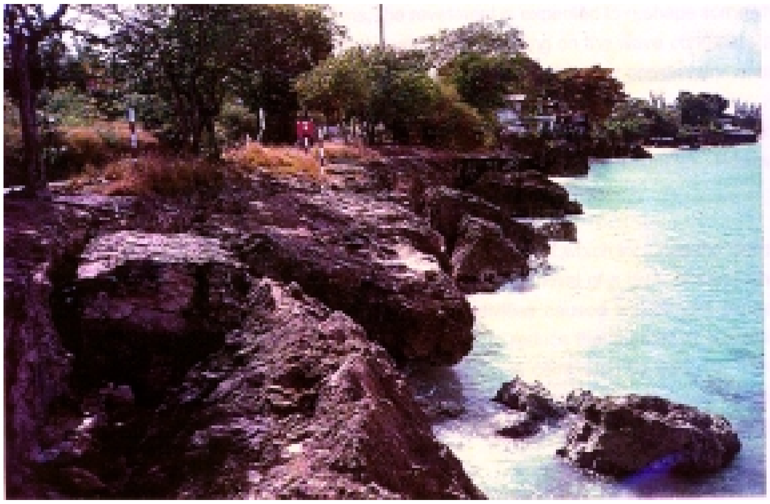


Figure 5.3(a): Paynes Bay Pre-Construction

Figure 5.3 (b): Paynes Bay Post Construction

Figure 5.4(a): Reads Bay Pre- Construction

Figure 5.4(b): Reads Bay Post Construction

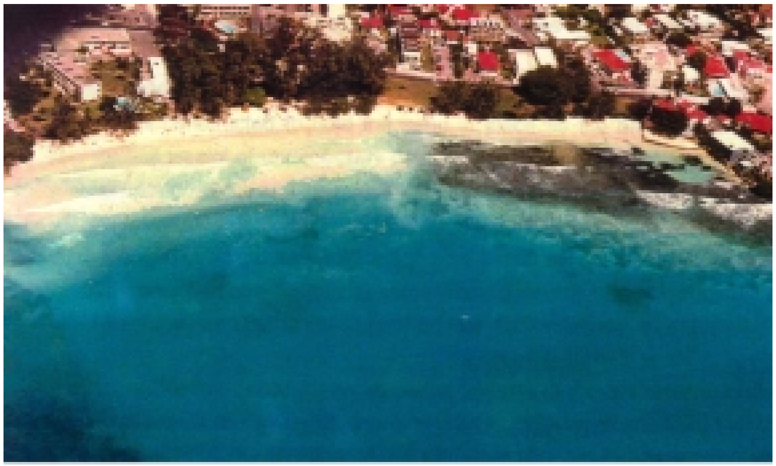


Figure 5.5(a): Rockley Beach Pre- Construction

Figure 5.5(b): Rockley post construction

Figure 5.6(a): Speightstown Beach Pre-Construction

Figure 5.6(b): Speightstown Post construction

As a result of the success of the demonstration projects a detailed coastal zone management plan has been designed and the coastal zone management unit is now in the process of finalizing engineering designs, with financial assistance from international funding agencies, for the following proposed projects:

a) Rockley to the Drill Hall - Waterfront Improvement
b) Woman's Bay (Silver Sands) - Headland Protection
(c) Crane Beach, St. Philip - Restoration and Enhancement
(d) Holetown Beach Improvement
(e) Welches Beach Improvement
(f) Walkers Savannah - Dune Restoration

These projects can be considered adaptation projects.

5.3 RENEWABLE ENERGY IN BARBADOS

Apart from taking adaptive steps to the climate change problem, the Government of Barbados, despite contributing little to global greenhouse gas emissions, has embarked on an overhaul of its energy sector to increase the use of renewable energy sources and employ sensible energy conservation techniques. These projects are aimed at enabling Barbados to become more independent and self reliant in catering for its energy needs, as well as to bring it closer to being a true model for sustainable development.

As such, Barbados, on its own initiative, has developed several adaptation and renewable energy projects, both planned and on-going, which speak directly to the problem of the impacts of climate change and growing greenhouse gas emissions.

History of Renewable Energy in Barbados

Renewable energy has had a long history in Barbados. After sugar was introduced to the island in the middle of the seventeenth century, the windmill soon followed, and at the height of their popularity they were five hundred and fifty five of them at sugar plantations across the island. Sugar cane bagasse was used as the fuel to concentrate the juice and produce sugar. Several hundred multi-bladed windmills, "fanmills", were used to pump water, but most of these have been dismantled. In the 1950's, when there were 22 sugar cane factories in operation, and sugar cane waste or bagasse was their main source of process heat, 50% of the island's primary energy was from renewable sources. (Headley, 2000).

Today, the main renewable energy sources are sugar cane bagasse and solar water heaters, which contribute about 15% of the island's primary energy supply (see Table 5.1). The Government of Barbados, in conjunction with the Centre for Resource Management and Environmental Studies (CERMES) of the University of the West Indies, is working towards having renewable energy contribute 40% of the island's primary energy by 2010.

There has been much work into the development of solar technologies, including solar water heating, solar crop dryers and solar stills, and solar photovoltaic (PV) systems. In addition, there has been considerable exploration into the generation of power through bagasse cogeneration, wind energy farms, and ocean thermal energy conversion (OTEC).

Resource	Barrels of Oil Equivalent (BOE)[a]	Percent Share of Primary Energy Mix
A. Indigenous Energy		
1. Oil	707, 564[b]	
2. Natural Gas	323, 570	10.7
3. Liquified Petroleum Gas (LPG)	23, 129	0.8
4. Hydro	none	none
5. Geothermal	None	none
6. Other Renewable Sources	Not available	
• Fuelwood	none	
• Bagasse	229, 000[c]	7.5
• Charcoal	none	none
• Agricultural Waste	Not available	
• Solar Thermal	227,000[d]	7.5
B. Imported Energy		
1. Petroleum Products	2,085,937	6.7
2. Orimulsion	148, 600	4.9
Total Energy Used	**3,037,236**	100.00

Table 5.1: Barbados' Primary Energy Mix, 1999 (Headley, 2001).

a Source: Energy Division, Ministry of Environment, Energy and Natural Resources.

b Since the closure of the local oil refinery, this oil is exported and is not counted in the local energy mix.

c From a production of 172,540 tonnes bagasse, and a calorific value of 7.7 gigajoues (GJ)/ tone, assuming that oil has a calorific value of 5.8GJ per barrel.

d Assuming 4000kWh per heater per year and 32,000 solar water heaters, with an efficiency of 35% for generation, transmission and distribution of the electricity replaced.

5.3.1. SOLAR WATER HEATING

5.3.1.1. The Growth of Solar Water Heating in Barbados

Solar water heating represents an example of sustained application of renewable energy technology in the region as a whole. In Barbados, it was especially successful, such that today, Barbados is the leader in the Caribbean in the use of this technology.

In the 1970s the Caribbean Conference of Churches was mandated to establish technology transfer training workshops in the region. One area of training was in the manufacture of Solar Water Heaters. From this technology transfer, a group of entrepreneurs set up a company manufacturing solar water heaters. Today, no electric water heaters are imported into Barbados and solar water heaters are a standard feature in the construction of new houses (Hinds, 1999). The Government of Barbados supported this initiative with the following policies:

- Taxes on raw materials to the water heater manufacturers were waived.
- Taxes on non-solar water heaters were kept high (60%) or increased.
- Householders who purchased solar water heaters were allowed a 100% rebate on the cost of the heaters on their income taxes.
- Hotels that borrowed from the government-run Development Bank, were compelled to carry out energy audits. These audits usually suggested the use of solar water heaters.

Although similar initiatives to manufacture solar water heaters were tried in other Caribbean countries, there was no government support by way of tax incentives. Barbados accounts for over 60% of the solar water heaters used in the region and is responsible for the manufacture of 80% of them.

The private sector also played a large role in promoting the use of solar water heaters. Included in their activities were:-

- The production of reliable and abundant supplies of the solar water heaters;
- The implementation of major consumer awareness programs as part of marketing process;
- The securing of lease purchase agreements for water heaters in order to overcome the high initial costs; and
- The recruitment of a large number of solar water heater retailers.

One company formed in the 1970s almost single-handedly introduced the benefits of solar water heaters to Barbados; and continues to be the major water heater manufacturer in Barbados and the region (Hinds, 1999).

5.3.1.2. Benefits of the Use of Solar Water Heating

The solar energy available in the Caribbean is much greater than the energy which we use as imported fossil fuels. Table 5.2 shows the average solar energy received in kWh/m2/day at four Caribbean sites.

Table 5.2: Solar Radiation in kWh/m² at four Caribbean Sites (Headley, 2001).

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Grantley Adams Airport, Barbados	5.1	5.6	6.0	6.2	6.1	5.9	6.0	6.1	5.7	5.3	5.1	4.8
V.C. Bird Airport, Antigua	4.6	4.9	5.6	5.9	5.9	5.8	5.9	5.9	5.3	5.0	4.5	4.2
Belize City, Belize	3.9	4.9	5.5	5.0	4.9	4.8	4.6	5.1	4.8	4.6	4.5	3.9
San Juan, Puerto Rico	4.3	5.1	5.7	5.9	5.8	5.9	6.0	6.1	5.6	5.1	4.5	4.1

Since each square metre of surface area receives about 7 kWh of solar energy on a clear day during the dry season, a 430 square kilometre island like Barbados receives 3 billion kWh on such a day. This is 1.08 x 10^{16} joules or the energy equivalent of about 1.87 million barrels of oil. The Energy Division (2000) reported that the amount of petroleum products imported into Barbados in 1999 was 2,085,937 barrels; so the solar energy received on a hot day is similar to a year's petroleum imports (Headley, 2001).

The industry benefitted from the Fiscal Incentives Act of 1974, which allowed the manufacturers to benefit from import preferences and tax holidays. In addition,
in 1981 the Homeowners Tax Benefit was introduced, which allowed the homeowner to claim the cost of the solar water heater on his income taxes, fuelling growth of solar water heating to such an extent that there was an annual major surge in sales in December as people try to beat the end-of-year deadline in order to qualify for the rebate (Headley, 2001).

Over 32,000 solar water heaters have been installed, each saving 4,000kWh per year, with a total electricity saving of 128 million kWh. At 15¢US/kWh, the financial savings to the consumers is $19.2 million US/year. This in turn is the heating equivalent of 227,000 barrels of oil (see Table 5.1 on Barbados' Primary Energy Mix), and a foreign exchange saving to the island was about $6.8 million US (based on the 2000 average oil price of $30US per barrel)(Headley, 2001). In addition to the fiscal benefits, a substantial quantity of emissions, such as carbon dioxide, sulphur dioxide and the oxides of nitrogen (CO2, SO2 and NOx) are not emitted with the use of solar water heating, and the Barbados Light and Power (BL&P) Company also benefits by not having to produce the equivalent of what is about 19% of its 1998 production total of 658 million kWh. These 32,000 solar water heaters are therefore worth 30 to 35MW of additional electric generating capacity (Headley, 2001).

Barbados over the years has tried to encourage its Caribbean neighbours to follow its lead in embracing solar water heating. Given the necessity of the luxury of hot water to the tourist industry, other Caribbean institutions such as the Caribbean Hotel Association and the Caribbean Tourism Organisation, are now encouraging hotels in the region to use solar water heating and benefit from using this clean technology.

5.3.2. PHOTOVOLTAIC POWER

5.3.2.1. History of Photovoltaics in Barbados and the region

Photovoltaic (PV) systems have been used in the Caribbean for many years. Their first widespread use was for telecommunications, where they powered microwave repeater stations, and navigational aids in remote areas. Photovoltaic (PV) systems are seen as advantageous because they generate electricity with neither the complicated rotating machinery associated with conventional systems, nor the requirements for fuel and highly skilled maintenance technicians which are a problem in remote areas (Headley, 2000).

The solar resource for a typical Caribbean island is about 7kWh/m2 on a clear day in the dry season, with a peak intensity of 1000 W/m2 at noon; and PV systems have module efficiencies of

10 to 15%. Headley (2000) has estimated that one can therefore obtain about 700 to 1000 watt hours of electrical energy per day from each square metre of PV module.

Because of the intrinsically low efficiency of the system, a kWh of electricity from PV is about ten times the price of that from conventional fossil fueled generators or modern wind turbines. PV power, however, is increasing at about 20% per year; and the European Photovoltaic Association maintains that if yearly production can be increased from the 200MW shipped in 2000 to about 1000MW, then the economies of scale will result in a 50% reduction in the cost of PV cells (Headley 2001).

Still, the idea of electric power being generated from sunlight in total silence and without pollution is of great intrigue. For these reasons, even though PV is one of the most expensive of the renewable energy technologies, it enjoys a large following among solar energy professionals and laypersons.

Having witnessed the success of the solar water heater programme, the Barbados Government is now placing a major emphasis on photovoltaics. There are a number of projects already on stream.

5.3.2.2. Photovoltaic Projects Implemented in Barbados

Barbados has about 37 kilowatts peak (kWp) of PV installed at various sites, making it one of the leading Caribbean countries in the utilisation of this technology. The largest of these systems are listed below:

- 1100Wp at the University of the West Indies (UWI) for solar cooling.
- 17,300Wp at Harrison's Cave for running the cave's lighting system.
- 3,000Wp at Combermere School for operating a computer laboratory.
- 2,000Wp grid-tied PV system installed at BLPC's Seawell Generating Station, at Grantley Adams airport.
- 2,000Wp at Government Headquarters to operate lights and provide emergency power.
- 11,100Wp at the Skeete's Bay fishing complex on the island's East Coast powering a one-tonne-per-day solar ice maker for the fisherfolk
- A 300Wp portable PV system is used to demonstrate the flexibility and versatility of the technology to members of the public.

The systems at Grantley Adams airport and at Harrison's Cave are tied to the island's power grid, while the others are stand-alone systems.

The major reason for developing stand-alone systems is that this allows electricity to be available in the event that the grid is down, as may be the case after a hurricane. The Government of Barbados intends to install stand-alone PV systems at emergency shelters and places which provide other emergency services such as hospitals and fire stations so that the island is better equipped to recover from natural disasters.

5.3.2.3 Support of Photovoltaics by the Government of Barbados

With the exception of the 2kWp system set up by BLPC, these PV systems have been financed by the Government of Barbados. The Prime Minister has expressed a desire for the island to have the same image in solar photovoltaic power as it has in solar water heating. In order to place Barbados in a position to take advantage of the rapid growth in the industry, therefore, the Government has installed the various demonstration projects; and to coincide with the installation of these PV systems, two (2) training workshops were held to ensure that the capacity is developed to sustain a solar photovoltaic industry. The project was sponsored jointly by the Energy Division of what was then the Ministry of Environment, Energy & Natural Resources, the Ministry of Education, and the University of the West Indies (CERMES).

One workshop was held for technicians and another for students of secondary schools. The Technician workshop held at UWI (CERMES) sponsored by the T-VET Council took place in one week, and covered the fundamentals of project management, systems design, installation and maintenance. Participants were from the Energy Division, Government Electrical Engineering Department and the Ministry of Agriculture, as well as electricians and technicians involved in solar projects.

The schools workshop was held on one (1) day and was subsequently repeated. Nineteen (19) Secondary schools participated in this workshop. Two students and one teacher from each school were exposed to the use of solar photovoltaics and their operation. Also given was "hands on" training in designing and assembling a system, culminating with each school being provided with a photovoltaic panel at the end of the workshop, to be used at the school for development of projects. Funding is now being sought to expand the Combermere School's photovoltaic project to provide electricity for the entire school.

With these initiatives, therefore, the Government of Barbados has sought to familiarize the technicians of tomorrow as well as those presently involved in the Energy sector, with photovoltaic technology. In this way Barbados will be in a better position to take full advantage of the expected expansion of this technology.

5.3.3. SOLAR CROP DRYERS AND SOLAR STILLS

Barbados has also been involved in promoting solar energy for many other purposes. Other major applications include solar drying for agricultural crops, and solar distillation.

Solar drying techniques have been used in Barbados since 1969, where dryers are used for removing moisture from a variety of agricultural crops. In 1973, the University of the West Indies, under its Solar Energy Project, began to build solar crop dryers; and in 1976 the first large-scale dryer was produced, which had a 1600-kg capacity for drying sugar cane. Since 1990 solar drying facilities have been used to dry many different crops, including sweet potatoes, eddoes, yams and other vegetables. The University of the West Indies, Cave Hill Campus, established a solar drying project in 1995, and has recently developed the Artisanal Dryer, which has been exported in the Caribbean region.

The Government of Barbados is currently working with the Centre for Resource Management and Environmental Studies (CERMES) of the University of West Indies to construct solar stills in every secondary school in the country, to provide distilled water for use in science laboratories and other purposes. Already, 12 of the 21 secondary schools have been equipped with these stills, providing an average of 8 litres per day. Some schools are now selling the excess distilled water produced, and the Government is looking to complete the placement of solar stills at the 9 remaining schools. Similar to the workshops held under the schools' photovoltaics programme, there was a workshop held in 1999 in the operation of solar stills. This initiative has been extremely successful, making the use of electric stills a thing of the past.

5.3.4. WIND ENERGY

Wind Projects in Barbados: Past and future

The Government of Barbados has been investigating the possibility of wind generation for over a decade. Wind energy is a growing technology, now in a position to compete economically with fossil fuels in terms of the price per kilowatt hour.

During the late 1980's a number of studies were undertaken to determine the most lucrative sites. The results of the InterAmerican Development Bank (IADB)/Government of Barbados study in 1988 were used as the basis for the construction of a wind turbine. This turbine was located at Lamberts, St. Lucy, at the north of the island, and the electricity produced was fed directly into the utility grid. Unfortunately the project was abandoned in 1991 due to the unsuitability of the design to local environmental conditions since there was an adverse reaction to the sea blast.

In 1998 the Government of Barbados entered into a contract with a British firm to carry out another feasibility study at Lamberts East. The study, which was completed in December 1999, continuously monitored wind speed and direction for a period of one year. The mean wind speed obtained was calculated at 7.34m at a height of 40m. The wind was almost exclusively from an easterly direction.

It was concluded from this data that the conditions are favourable for the construction of a wind farm, which would have a 10 month setting up phase and a 9 month construction phase, and generate about 16MW of energy. The BLPC wishes to invest in a wind farm; however the major impediment to this becoming a reality is the current difficulty in acquiring/leasing suitable sites for the wind farm (Personal Communication, Peter Williams, Senior Planning Engineer, BLPC).

In addition to the present agreement, there has been interest expressed by other wind developers, one of who has submitted a proposal to Government for the development of a wind farm in Barbados. This company is presently interested in three sites in the north and south east of the island, for a wind farm with a proposed capacity of 11.25 MW and an expected cost of BDS$28m.

The contribution of these wind farms will be a good start to putting the island on the path towards its 2010 target of 40% of energy production from renewable energy sources. The 11.25

MW wind farm would result in about 26GWH of electricity or about 3 to 4% of the year 2000's net electricity generation, and would be just over 2% of the projected net generation for the year 2010 (Personal Communication, Peter Williams, Senior Planning Engineer, BLPC). Therefore a wind farm of significant size would be needed to contribute largely to net electricity generation on the island. One barrier to this however, is the island's dense population, which restricts the size of good wind sites, as well as their distance from residential areas.

5.3.5. BAGASSE COGENERATION

5.3.5.1. Background: Use of Energy in Barbados' Sugar Industry

Given that the year 2007 will likely mark the phase out by the World Trade Organisation of the preferential rates paid for sugar to the former colonies of the European Union, the sugar industry in Barbados faces an uncertain future. In addition, Barbados' costs of production are much higher than the world market price of sugar, such that there is now a need to maximize the value derived from sugar cane.

Sugar production is one of the few agricultural processes where the energy output is greater than the input. It was therefore recognized that it should be possible to use the excess energy, most of which is contained in the bagasse (the waste plant material after the cane has been ground), to produce electricity for sale to the national grid.

In a traditional sugar factory, there is little attempt to optimise the process, so that the energy contained in the bagasse is transformed into a saleable commodity. Traditionally, the sugar factory burned bagasse and its boilers produced steam for generating electricity used by the factory, and processing the sugar cane into sugar. A large fraction of the energy is used to evaporate water from the juice to concentrate it to the point where sugar crystallization occurs. Since this requires low pressure steam, and because the price received for electricity by the sugar factories was not high enough to provide an incentive, no serious attempt has previously been made to generate high pressure steam for efficient electricity generation (Headley, 2001).

In the year 2000, Barbados produced 537,000 tonnes of cane and 58,333 tonnes of sugar.

5.3.5.2. The Development of Cogeneration

In recent years, efficient process engineering developed by the French firm SIDEC separated the generation of electricity and process steam from the other activities of the sugar factory and made them into a separate entity: a co-generation plant. Since bagasse is only available during the crop season for about four months per year, the co-generation plant has to use another fuel for the other eight months. SIDEC was originally setup in the 1980's to improve the utilisation of French coal, hence they use coal as the second fuel in most of their co-generation plants. More than 35 of these projects are operating in France, including some at mills that process sugar beet. This technology is also used in the overseas departments of Réunion, Mauritius and Guadeloupe.

The French plants have proven to be quite successful, such that in the year 2000, 20% of electricity (132 MW) generated in Mauritius was derived from bagasse. After several years of negotiations, in 1991, the French initiated their Bagasse Energy Development Programme. On Réunion, the total installed capacity is 437 MW, of which 126.6 MW is hydro and 118 MW is bagasse/coal. Réunion produces about 2 million tonnes of sugar cane per year, which gives 640,000 tonnes of bagasse/year. With a calorific value of 7700 kilojoules/kg, this is equivalent to about 120,000 tonnes of fuel oil.

Guadeloupe, which in the year 2000 produced 564,000 tonnes of cane, 56,299 tonnes of sugar, and 180,000 tonnes of bagasse, saw Bagasse/coal generating capacity of 64MW, such that 7% of the island's energy was generated from bagasse (Headley, 2001).

The Government of Barbados has sent representatives to visit the cogeneration plant in Guadeloupe. To date, every effort has been made to make the cogeneration plant as noiseless and emission free as possible. Plants are outfitted so as to facilitate maximum combustion of the bagasse. 500,000 tonnes of cane per year yield about 5000 tonnes/year of fly ash, which is sold as a fertilizer since its phosphate content is high, making it excellent for acidic volcanic soils, such as is found in Guadeloupe. During the combustion of coal, a moving grate is employed such that the bottom ash falls to the bottom of the furnace. 160,000 tonnes per year of coal gives about 10,000 tonnes/year of bottom ash, which is used as the sub-grade in road making and in cement block production. About 800 tonnes/year of fly ash are also produced, which is now being investigated as a cement additive.

A low sulphur coal from Columbia is used to keep down emissions of sulphur dioxide; and emission of nitrogen oxides (NOx) is low for both bagasse and coal since this can be controlled by careful choice of combustion conditions.

Local environmental regulations require that records be kept of all their emissions and they normally are well under the required maximum values.

5.3.5.3. Barbados' Investigations into a Local Cogeneration Plant

The Barbados sugar industry is now considering setting up one new factory and phasing out the three existing old factories. The peak electricity demand in Barbados reached 124MW in 2000, and the Barbados Light and Power Company (BLPC) is also looking at their increased electricity demand and ways of meeting it.

The Government and BLPC discussed the prospect of jointly setting up a 60 MW co-generation plant next door to the proposed new factory, rather than set up more diesel generators in 2003 to meet the growing electricity demand. However, given the uncertainty of the future market for Barbados' sugar, the Government has delayed their decision to construct the new factory, such that BLPC is proceeding with plans for the installation of a new low speed diesel station, the first phase of which is a 30MW unit in 2003 (Personal Communication, Peter Williams, Senior Planning Engineer, BLPC).

Should the government and the sugar industry be persuaded that a new sugar factory should be constructed, the cogeneration plant should be built next door to it. And should the electricity demand continue to grow, and enough land be retained to produce about 550,000 tonnes of cane, then a cogeneration plant on the scale of the Guadeloupe installation would be feasible.

One marked difference, however is that since Barbados aims to keep its emissions to a minimum, the Government of Barbados would like to find an alternative to coal as the alternate fuel for any cogeneration plants constructed. At the moment, virtually all of the electricity used in Barbados is made in thermal plants burning fossil fuels such as fuel oil or natural gas, and electricity generation costs are about $55 US/MWh. Therefore, in searching for an alternate fuel, projected costs of generating electricity by co-generation must at least match this present cost. Barbados has looked at the possibility of utilizing natural gas as an alternate, which has to date been unsatisfactory due to high associated costs. Progress on this issue, and the final alternate fuel selected, however, will likely be guided by fuel cost, since the construction of a local cogeneration is seen as crucial both for energy generation and the continued production of sugar.

5.3.6. PROJECTED RENEWABLE ENERGY SYSTEMS

The two fastest growing electricity generation technologies in the period 1990 to 2000 were wind at 25% and solar PV at 20% (Headley, 2001). Renewable projects being considered in the future by the Government of Barbados reflect the global trend, and investigate other forms of renewable energy as well. Currently under consideration are:

- 16MW in wind turbine farms at good wind sites in northern Barbados.
- A 3 MW ocean thermal energy conversion (OTEC) plant.
- A 10 MW waste combustion plant.
- A 2 MW wave power plant (consultations have begun with a UK company who have just installed a 500 kW plant on as island off the west coast of Scotland)
- 2 MW of solar PV distributed around the island.
- Setting up manufacturing facilities to produce high purity silicon for the computer chip and solar PV industries. (The possibility of a joint venture with Trinidad and Guyana is being explored.)
- Producing hydrogen from renewable energy to power fuel cell vehicles, e.g. cars and buses. (These emit only water and are very environmentally friendly, hence they would enhance the island's image as a 'green' tourist destination. Buses and cars using this technology are already operating in Germany and Canada; DaimlerChrysler, Ford and Ballard are leaders in this field.)

Of these technologies, the wind turbine farms are the most advanced in terms of planning. As aforementioned, the major barrier to their implementation is the establishment of a policy to determine how independent power producers supply electricity to the consumer and their access to the grid.

Ocean Thermal Energy Conversion

The University of the West Indies is currently investigating Ocean Thermal Energy Conversion (OTEC). The technology will use the temperature difference between the bottom of the ocean and that at its surface, to provide the energy to power a generator. It is a technology, which has much scope for islands, which are volcanic in their geology although it is still to be demonstrated on a large scale. It has been recently discovered that Barbados, although not volcanic, may have some potential for development in this area. The Ocean depth to the north of the island is particularly large, and therefore has a significant temperature differential. The economic feasibility of this technology for Barbados is currently being investigated.

The OTEC plant has been evaluated by the Scientific and Technical Advisory Panel of the Global Environmental Facility (GEF), and Barbados is now considering ways of financing the pre-feasibility and feasibility studies. The main barrier here is that as this will be the first megawatt sized OTEC plant, and there are several technical characteristics which need to evaluated in a working plant which cannot be simulated, Hence construction of the plant will incur the high cost associated with being low on the learning curve. However these are the unavoidable costs inherent in introducing a new source of base load power, and the technology has the potential to supply terawatts of power at sites between latitudes 30° north and 30° south, most of whose beneficiaries will be in the Third World. Therefore the Government sees continued investigation into OTEC as extremely worthwhile.

5.3.7. OTHER GOVERNMENT PROJECTS

5.3.7.1. Renewable Energy Centre

Barbados has been reasonably successful in the application in the area of renewable energy in the area of solar water heating, and the introduction of this technology has revolutionised the energy sector. The Government of Barbados has however recognized that there is still however a large untapped potential in the exploitation of solar and wind power in particular.

The cost of electricity impacts directly on all sectors of the economy, especially the tourism industry, Barbados' greatest foreign exchange earner, where a significant proportion of the revenue is spent on energy costs. The Government is aware that for the renewable sector to grow, research needs to be undertaken to develop cost-effective technologies, applicable to the small island developing country situation. The cost of photovoltaics, for example, has prevented the solar electricity industry from taking off. Research into more efficient photovoltaic materials could see the industry thriving overnight.

To facilitate further development in these areas, and to overcome barriers to technology implementation, the Government proposes to establish a Centre for Renewable Energy. The Centre will offer international scientists and technologists the opportunity to do research into renewable energy, and will also address institutional and policy issues which have played a major part in preventing the implementation of renewable energy projects.

The University of the West Indies has been in the forefront of research into renewable energy through their CERMES programme; however the proposed centre will continue and expand the work on renewables. The centre will engage in training, research, development and demonstration in the area of Renewable Energy, as well as Energy Conservation.

The centre will also include working exhibits of renewable energy technologies. An officer will also be responsible for organizing tours of the facility and short courses for school children and the general public. It is expected that this institution will also play a role in developing capacity in the region and eventually become a node in the international renewable energy network. The projects already in existence will be sustained under the umbrella of the centre.

Government is willing to provide some initial financing to set up the centre and to procure the necessary equipment; but there is a need of further funding. Institutional arrangements are still to be finalised but it is expected that the centre will be established as an extension of the currently existing UWI (CERMES) solar project. The centre will enlist the expertise of qualified professionals in all of the Renewable Energy specialty areas.

5.3.7.2. Energy Conservation Programmes in Barbados

The Energy conservation is an important aspect of any programme aimed at sustainable energy use. The Government of Barbados has been addressing the issue of energy conservation in a number of ways. At present, the Demand Side Management Feasibility Study, in conjunction with Barbados Light and Power Co Ltd, has been completed.

The Study was undertaken with a Canadian Consultancy firm. The consultants carried out a number of audits in both the commercial and industrial sectors and analyzed energy use patterns; and their report contained a number of recommendations for the utilities, government and energy industry.

The largest use of energy in the commercial and industrial sectors was for air conditioning. A number of recommendations have been offered to reduce the conditioning and refrigeration loads. The leading suggestions in the report are calls for improved maintenance (eg. cleaning of fans and regular changing of refrigerant to improve efficiency of existing machines), and the use of electronic controls and occupancy sensors, to better control the shutting off of air conditioners in vacant rooms, significantly reducing energy use, particularly in the hotel sector.

The second most critical area for improved cost effectiveness is lighting. In many cases the use of T8 fluorescent lamps to replace existing T12 fixtures could save up to 20% of the lighting load. The use of compact fluorescent lights to replace incandescent lighting applications is also seen as a major potential energy saver.

Energy Conservation technologies have been slow to take off due mostly to the high cost and low availability of the energy efficient technologies. The Government of Barbados will have a role to play if the programme is implemented by the local power company. The cost of energy conservation equipment is still astronomically high compared to its mainstream counterparts. It is therefore recommended that existing duties be removed to make energy conserving equipment competitive. In order to support these programs, the Energy Division is exploring, with assistance from the Barbados National Standards Institute, the possibility of the implementation of energy efficient standards to provide a basis of energy efficiency legislation.

The Energy Division also has an active energy conservation programme focusing on the schools as well as the general public. National Energy Awareness week is held in November and the issues relating to energy conservation and renewable energy are highlighted. There are many activities and competitions held for the schools, including a quiz competition, poster competition and a lecture series.

The Government of Barbados has also recognized that the long-term success of the energy conservation process is contingent on a general attitudinal and behaviourial change of the Barbadian population as a whole to energy consumption.

5.3.7.3. The Natural Gas Sector in Barbados

Constitution and Purpose of the National Petroleum Corporation

The National Petroleum Corporation (NPC) is a public corporation established as successor to the Natural Gas Corporation by the National Petroleum Corporation Act Cap 280, which came into effect on April 1, 1981. Its primary function is the sale of natural gas for domestic, commercial and industrial use through its pipeline network.

The purpose of the enterprise is to provide and maintain an adequate, reliable, competitive, safe and efficient gas service to existing and potential customers at a reasonable cost.

Classification of Customers

At the end of March 2001, the Corporation had 13,069 active customers; 12,511 domestic, 556 commercial and 2, classified as "special customers".

A domestic customer is defined as a client whose consumption does not exceed 150m^3 (5000cf) per month. This type of customer represents a typical household, whereas commercial customers represent all businesses ranging from a small bakery to a large manufacturer. "Special customers", as it relates to NPC, are those customers who the Government of Barbados has determined, because of national interest, should not be billed through the regular rate structure. These two customers are the Queen Elizabeth Hospital and the Barbados Light and Power Company Limited.

Transmission and Distribution Systems

The gas is transported to customers via the transmission and distribution systems. The transmission system consists of 13.59km (44579ft) of 6" steel pipe and 12.52km (41077ft) of 4" steel pipe, operating at pressures between 100psig and 150psig (6.9 - 10.34 bars). These pipelines were commissioned to operate at 300psi. The total length of pipe in the distribution system at March 1999 was 401.22km (249.32miles). The operating pressures are 30psig (2.07bar) and 1/4 psig (0.02bar) respectively in the high and low pressure areas.

Gas Reserves

The reserves estimates for April 2001, quoted by the Barbados National Oil Company Limited (BNOCL), were 4.0 billion cubic feet (Bcf). This represents a total supply of 6 years given the current annual average usage of 645 million cubic feet (MMcf). 645MMcf represents NPC's purchases from BNOCL for the last decade.

BNOCL is scheduled to begin another drilling program in January 2002, to boost local gas production.

Limitations and Future Projects of NPC

NPC is faced with a number of factors which are hindering expansion of its service, including the following:-

- High capital cost associated with the expansion of its distribution network.
- High cost of tools and materials to provide a safe and efficient gas supply. All materials and tools are imported.
- Competition from other petroleum products, for example industrial diesel, kerosene, fuel/gas oil and L.P.G.
- High cost of natural gas equipment compared to electrical and other petroleum products' equipment.

Despite these limitations, the NPC is still exploring potential markets for natural gas such as:-

- Air conditioning for the commercial offices and hotel industry
- Cogeneration projects in the hotel industry
- Electricity generation in the manufacturing sector as this sector seeks to improve its effi ciency
- Compressed natural gas (CNG)/Liquefied natural gas (LNG) vehicles
- Industrial cooling projects.

5.3.8. BARRIERS TO THE IMPLEMENTATION OF RENEWABLE TECHNOLOGIES IN BARBADOS

A summary of the main barriers to the implementation of renewable technologies is as follows (taken from Hinds,1999):

5.3.8.1. Financial and Economic Barriers

While the existence of technology had been considered the critical barrier in the 70s and 80s, a key barrier at present is the lack of financial viability of many of these applications. Often there is a large payback time on initial investment for a renewable technology

5.3.8.2. Barriers related to awareness of technology

The lack of awareness and confidence in the technology is often a deterrent to the use of renewable energy technology. This is particularly relevant since many unproven renewable energy technologies were introduced into the region by international development agencies, without adequate research into the appropriateness of the technologies, such that even to date, there is some residual mistrust of new technologies.

Through its experience with solar water heating, however, the Government of Barbados is aware of the need of familiarizing the population as a whole in order to gain acceptance of a new technology.

5.3.8.3. Barriers related to higher local operational costs

The financial viability of renewable energy technologies is almost always quoted from data obtained in developed countries. These costs differ from the local Caribbean costs in terms of cost of the system and the operational and maintenance costs. The cost of the system in the developed world is usually significantly less than local investment cost, due to the added costs derived by shipping, insurance and taxes during the importation of the new technology.

In the case of the operation and maintenance there is also the issue of the availability of local experts and the cost of accessing the relevant expertise. In addition the question of ancillary services and supplies that may contribute to the cost of operations in the developed world would be different in the Caribbean as a whole.

5.3.8.4.Barriers related to Government policy

The critical success of renewable energy technology in Barbados has been due to the application of government policy.

The success of the Solar water heater industry in Barbados was due to government policy as well as the determination of the first manufacturer of the systems. When the austerity measures during the local recession of the early nineties forced the government to re-impose duties on water heater manufacturing inputs, the resultant higher costs of the systems resulted in a dramatic fall in the purchases on solar water heaters. The Barbados experience clearly demonstrates that in an environment where technology and other barriers are removed, government policy can play a significant role in the viability of renewable energy technologies

In Barbados, as in much of the Caribbean, the electric utilities consume the majority of the fossil fuel, with the concomitant result that they are the largest single source of greenhouse gas emissions. These utilities are in most cases monopolies, supported by government policy. In

Barbados, this situation prevents the independent supply of electricity to the national grids; and because these policies were established at time when fossil fuels were cheaper and their impact on global climate change was not known, it makes it that much more difficult to introduce new technologies, and to introduce the power they can potentially generate into the national power grid.

In Barbados a draft policy (white paper) is poised to significantly liberalize the energy sector by allowing secondary producers access to the national electric grid; thus creating a niche for renewable technologies to enter the national power generation system.

International policy can also be influential; particularly where a foreign financier, perhaps from a nation where Renewable Energy Policy is more advanced, might, mandate that there be a certain amount of investment in renewable energy projects in the recipient country, if they are to receive funds for country development projects.

5.3.8.5. Barriers related to the Global Environmental cost of fossil fuels

In quantifying the economic viability of various energy sources, it has been generally accepted that there is a cost for the generation of the environmentally harmful green house gases; and this holds true for the use of fossil fuels. Although, the addition of the environmental cost to the fossil fuels would make the renewable energy technologies more competitive, very few developing countries can afford to this, since the use of fossil fuels is often still cheaper than alternatives.
In developing its own Renewable Energy Programme, the Government of Barbados has exhibited a clear commitment to reducing its own greenhouse gas emissions; even though developing countries are not currently bound to doing so.

Although agencies such as the Global Environmental Facility (GEF) exist to aid in the incremental costs associated with renewables, many developing countries often find the GEF process extremely tedious, and so do not make adequate use of this facility, thus delaying the implementation of newer, greener technologies.

5.3.8.6. Barriers related to training

One of the most cost effective methods of increasing understanding of a technology is through training. Training bridges the gap between having a general awareness on the type of decision that should be made, and having the ability to make the specific detail decisions during the implementation process.
There are few graduate practitioners of renewable energy still active in the region as a whole. Thus, in order to help create the levels of awareness of renewable energy technologies and to respond to the resultant demands for decision-making, there is need for a cadre of experts at various levels of training, ranging from graduate to technician and teacher level. This will serve to hasten the decision-making process in Barbados and the rest of the region considerably.

5.3.9. WORK TO REMOVE BARRIERS TO RENEWABLE TECHNOLOGY: REGIONAL RENEWABLE ENERGY PROJECT

The Governments of the Caribbean have realised that the true benefits of renewable energy technologies can only be achieved if island states work as a unified group. The Caribbean Energy Information System was set up in order to enhance the linkages between energy entities in the region. In 1998, the organisation developed a project with UNDP and GEF, aimed at removing barriers to renewable energy development. The barriers identified were financing, capacity, awareness and policy. It is expected that this project will strengthen the energy institutional frameworks and prepare Caribbean countries to better explore and implement renewable energy technologies.

5.4 TECHNOLOGICAL NEEDS AND REQUIREMENTS

While Barbados has made major advances in the area of renewable energy, for Barbados assessing vulnerabilities and adaptation options is clearly the priority. The Caribbean Planning for Adaptation to Climate Change (CPACC) project has provided initial capacity building in the area of vulnerability and adaptation. The Government of Barbados views the work of the CPACC as extremely important in allowing Barbados to examine adaptation options.

The continuation of work started by the CPACC project is therefore of extreme importance to the Government of Barbados, as there is still a great deal of work to be done in the areas of vulnerability and adaptation. The Government of Barbados views the establishment of a Regional Climate Change Centre as extremely important in achieving this goal, and in guiding the very national development of Barbados and the region as a whole.

Crtically, there is a need for the downscaling of the global climate models or the development of regional models, which will allow a more insular and comprehensive understanding of how the changing climate will impact Barbados and other countries in the region. It is hoped that the establishment of the Regional Climate Change Centre will aid in furthering much of the initial work of CPACC, to better ensure that climate change activities become integrated into the development activities of countries in the region, since climate change is, ultimately, a development issue for many countries. It is hoped that the international community will provide the relevant resources to allow the establishment of the Centre, which a necessity for all countries in the region.

There is a need for major capacity building in Barbados, particularly in the area of agriculture and climate change. There is also a need for capacity building in coastal zone issues and water issues. The initial national communications of Barbados has not addressed the area of climate change and health, and the socio-economic impacts of climate change, as there is a dearth of research in these areas. This indicates the urgent need for capacity building and funding to allow in depth studies of these components in addressing climate change issues.

There will also be a requirement for significant financial resources to finance the evaluation and implementation of adaptation options. Already Barbados has a number of coastal adaptation options identified, the implementation of which will require funding. Implementation of adaptation options will be critical to development of Barbados.

In addition, the impacts of climate change on the insurance sector, both global and local (as the two are inextricably intertwined), needs to be carried out, since the region as a whole has seen increases in premiums, and refusals of the industry to cover certain types of coastal structures in light of changes in the frequency of weather-related impacts. This also affects those islands that are not frequently hit by storm systems and natural disasters as a whole, simply because of the way in which the entire region is rated by the insurance sector, such that frequently hit areas such as Miami, Florida, U.S.A., where billions of storm damage has been incurred in the last few decades, are included in the regional assessment of the insurers as they consider the risks of providing coverage.

A number of proposed renewable energy options have been identified in this document. Abatement options have also been identified. Hence there are a number of potential projects identified for inclusion in the Clean Development Mechanism of the UNFCCC. One area, which may be very attractive in terms of the Clean Development Mechanism, is the vital tourism sector. It has been stated that due to the low-seasonality type of tourism in Barbados, there is an annual presence of 400,000-500,000 persons in the form of visitors. Considerable amounts of energy are expended, directly, and indirectly on this tourist population, who for the most part, are from industrialized countries, and arrive with their first-world energy consumption practices. Thus a reduction of GHG emissions from this source will result in a considerable reduction in the overall emissions of Barbados.

Barbados is in the process of establishing a renewable energy centre to aid in promoting and developing renewable energy technologies. Funding from developed countries is required to aid in the establishment of this centre, benefits from which should set Barbados well on the path to cutting its dependence on fossil fuels, at the same cutting its foreign exchange expenditure, to better stabilize its economy.

There is also a need for a sustained, effective public education programme for the populace on global climate change and the social, economic and cultural impacts which might be sustained by the island and its people.

Appendices

Appendix 1 - Summary Table for Barbados' 1990 Greenhouse Gas Inventory

Appendix 1: Summary Tables for Barbados' 1990 Greenhouse Gas Inventory

TABLE 7A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES 1990
(Sheet 1 of 3)

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)														
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs		PFCs		SF_6	
									P	A	P	A	P	A
Total National Emissions and Removals	**1,564**	**-11**	**79**	**0**	**2**	**19**	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 Energy	**1,387**	**0**	**0**	**0**	**2**	**19**	**4**	**0**						
A Fuel Combustion (Sectoral Approach)	1,387		0	0	2	19	4							
1 Energy Industries	1,032		0	0	0	0	0							
2 Manufacturing Industries and Construction	96		0	0	0	0	0							
3 Transport	225		0	0	2	16	4							
4 Other Sectors	34		0	0	0	0	0							
5 Other (please specify)	0		0	0	0	0	0							
B Fugitive Emissions from Fuels	0		0		0	0	0	0						
1 Solid Fuels			0											
2 Oil and Natural Gas			0		0	0	0	0						
2 Industrial Processes	**177**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A Mineral Products	177					0	0	0						
B Chemical Industry	0		0	0	0	0	0	0						
C Metal Production	0		0	0	0	0	0	0	0	0	0	0	0	0
D Other Production	0				0	0	1	0						
E Production of Halocarbons and Sulphur Hexafluoride									0	0	0	0	0	0
F Consumption of Halocarbons and Sulphur Hexafluoride									0	0	0	0	0	0
G Other (please specify)	0		0	0	0	0	0	0				0		0

P = Potential emissions based on Tier 1 Approach. A = Actual emissions based on Tier 2 Approach.

TABLE 7A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES 1990

(Sheet 2 of 3)

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)														
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs		PFCs		SF_6	
									P	A	P	A	P	A
3 Solvent and Other Product Use	0			0			0							
4 Agriculture			1	0	0	0								
A Enteric Fermentation			1											
B Manure Management			0	0										
C Rice Cultivation			0											
D Agricultural Soils				0										
E Prescribed Burning of Savannas			0	0	0	0								
F Field Burning of Agricultural Residues			0	0	0	0								
G Other (please specify)			0	0										
5 Land-Use Change & Forestry	(1) 0	(1) -11	0	0	0	0								
A Changes in Forest and Other Woody Biomass Stocks	(1) 0	(1) 0												
B Forest and Grassland Conversion	0		0	0	0	0								
C Abandonment of Managed Lands		-11												
D CO_2 Emissions and Removals from Soil	(1) 0	(1) 0												
E Other (please specify)	0	0	0	0	0	0								
6 Waste			77	0	0	0	0	0						
A Solid Waste Disposal on Land			7											
B Wastewater Handling			71	0										
C Waste Incineration														
D Other (please specify)			0	0										
7 Other (please specify)														

(1) The formula does not provide a total estimate of both CO_2 emissions and CO_2 removals. It estimates "net" emissions of CO_2 and places a single number in either the CO_2 emissions or CO_2 removals column, as appropriate. Please note that for the purposes of reporting, the signs for uptake are always (-) and for emissions (+).

TABLE 7A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES 1990

(Sheet 3 of 3)

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)															
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs		PFCs		SF_6	
									P	A	P	A	P	A
Memo Items														
International Bunkers	919		0	0	0	0	0	0						
Aviation	360		0	0	0	0	0	0						
Marine	559		0	0	0	0	0	0						
CO_2 Emissions from Biomass	0													

Appendix 2 - Summary Table for Barbados' 1994 Greenhouse Gas Inventory

Appendix 2: Summary tables for Barbados' 1994 Greenhouse Gas Inventory.

TABLE 7A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES 1994
(Sheet 1 of 3)

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)														
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs		PFCs		SF_6	
									P	A	P	A	P	A
Total National Emissions and Removals	1,914	-12	65	0	0	0	1	0	0	0	0	0	0	0
1 Energy	1,876	0	0	0	0	0	0	0						
A Fuel Combustion (Sectoral Approach)	1,876		0	0	0	0	0							
1 Energy Industries	1,403		0	0	0	0	0							
2 Manufacturing Industries and Construction	42		0	0	0	0	0							
3 Transport	257		0	0	0	0	0							
4 Other Sectors	166		0	0	0	0	0							
5 Other (please specify)	7		0	0	0	0	0							
B Fugitive Emissions from Fuels	0		0		0	0	0	0						
1 Solid Fuels			0											
2 Oil and Natural Gas			0		0	0	0	0						
2 Industrial Processes	36	0	0	0	0	0	1	0	0	0	0	0	0	0
A Mineral Products	36					0	0	0						
B Chemical Industry	0		0	0	0	0	0	0						
C Metal Production	0		0	0	0	0	0	0	0	0	0	0	0	0
D Other Production	0				0	0	1	0						
E Production of Halocarbons and Sulphur Hexafluoride									0	0	0	0	0	0
F Consumption of Halocarbons and Sulphur Hexafluoride									0	0	0	0	0	0
G Other (please specify)	0		0	0	0	0	0	0				0		0

P = Potential emissions based on Tier 1 Approach. A = Actual emissions based on Tier 2 Approach.

TABLE 7A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES 1994

(Sheet 2 of 3)

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)															
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs		PFCs		SF_6	
									P	A	P	A	P	A
3 Solvent and Other Product Use	0			0			0							
4 Agriculture			1	0	0	0								
A Enteric Fermentation			1											
B Manure Management			0	0										
C Rice Cultivation			0											
D Agricultural Soils				0										
E Prescribed Burning of Savannas			0	0	0	0								
F Field Burning of Agricultural Residues			0	0	0	0								
G Other (please specify)			0	0										
5 Land-Use Change & Forestry	(1) 0	(1) -11	0	0	0	0								
A Changes in Forest and Other Woody Biomass Stocks	(1) 0	(1) 0												
B Forest and Grassland Conversion	0		0	0	0	0								
C Abandonment of Managed Lands		-11												
D CO_2 Emissions and Removals from Soil	(1) 0	(1) 0												
E Other (please specify)	0	0	0	0	0	0								
6 Waste			84	0	0	0	0	0						
A Solid Waste Disposal on Land			8											
B Wastewater Handling			76	0										
C Waste Incineration														
D Other (please specify)			0	0										
7 Other (please specify)														

(1) The formula does not provide a total estimate of both CO_2 emissions and CO_2 removals. It estimates "net" emissions of CO_2 and places a single number in either the CO_2 emissions or CO_2 removals column, as appropriate. Please note that for the purposes of reporting, the signs for uptake are always (-) and for emissions (+).

TABLE 7A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES 1994

(Sheet 3 of 3)

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)														
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs		PFCs		SF_6	
									P	A	P	A	P	A
Memo Items														
International Bunkers	**360**		**0**	**0**	**0**	**0**	**0**	**0**						
Aviation	340		0	0	0	0	0	0						
Marine	20		0	0	0	0	0	0						
CO_2 Emissions from Biomass	**0**													

Appendix 3 - Summary Table for Barbados' 1997 Greenhouse Gas Inventory

Appendix 3: Summary tables for Barbados' 1997 Greenhouse Gas Inventory

TABLE 7A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES 1997

(Sheet 1 of 3)

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)														
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs		PFCs		SF_6	
									P	A	P	A	P	A
Total National Emissions and Removals	2,198	-11	66	0	0	0	1	0	0	0	0	0	0	0
1 Energy	2,027	0	0	0	0	0	0	0						
A Fuel Combustion (Sectoral Approach)	2,026		0	0	0	0	0							
1 Energy Industries	1,626		0	0	0	0	0							
2 Manufacturing Industries and Construction	40		0	0	0	0	0							
3 Transport	252		0	0	0	0	0							
4 Other Sectors	108		0	0	0	0	0							
5 Other (please specify)	0		0	0	0	0	0							
B Fugitive Emissions from Fuels	0		0		0	0	0	0						
1 Solid Fuels			0											
2 Oil and Natural Gas			0		0	0	0	0						
2 Industrial Processes	171	0	0	0	0	0	1	0	0	0	0	0	0	0
A Mineral Products	171					0	0	0						
B Chemical Industry	0		0	0	0	0	0	0						
C Metal Production	0		0	0	0	0	0	0	0	0	0	0	0	0
D Other Production	0				0	0	1	0						
E Production of Halocarbons and Sulphur Hexafluoride									0	0	0	0	0	0
F Consumption of Halocarbons and Sulphur Hexafluoride									0	0	0	0	0	0
G Other (please specify)	0		0	0	0	0	0	0				0		0

P = Potential emissions based on Tier 1 Approach. A = Actual emissions based on Tier 2 Approach.

TABLE 7A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES 1997
(Sheet 2 of 3)

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)														
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs		PFCs		SF_6	
									P	A	P	A	P	A
3 Solvent and Other Product Use	0			0			0							
4 Agriculture			1	0	0	0								
A Enteric Fermentation			1											
B Manure Management			0	0										
C Rice Cultivation			0											
D Agricultural Soils				0										
E Prescribed Burning of Savannas			0	0	0	0								
F Field Burning of Agricultural Residues			0	0	0	0								
G Other (please specify)			0	0										
5 Land-Use Change & Forestry	(1) 0	(1) -11	0	0	0	0								
A Changes in Forest and Other Woody Biomass Stocks	(1) 0	(1) 0												
B Forest and Grassland Conversion	0		0	0	0	0								
C Abandonment of Managed Lands		-11												
D CO_2 Emissions and Removals from Soil	(1) 0	(1) 0												
E Other (please specify)	0	0	0	0	0	0								
6 Waste			85	0	0	0	0	0						
A Solid Waste Disposal on Land			9											
B Wastewater Handling			76	0										
C Waste Incineration														
D Other (please specify)			0	0										
7 Other (please specify)														

TABLE 7A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES 1997

(Sheet 3 of 3)

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)														
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs		PFCs		SF_6	
									P	A	P	A	P	A
Memo Items														
International Bunkers	65		**0**	**0**	**0**	**0**	**0**	**0**						
Aviation	2		0	0	0	0	0	0						
Marine	63		0	0	0	0	0	0						
CO_2 Emissions from Biomass	**0**													

References

Caribbean Conservation Association Environmental Profile for the Caribbean, 1991. Carib Research & Publications Inc. pp161.

IPCC Climate Change 2001- Impacts Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change

Headley, O. St.C. 2000. Use of Photovoltaic Systems in the Caribbean. Centre for Resource Management and Environmental Studies (CERMES), Faculty of Science and Technology, University of the West Indies, Cave Hill, Barbados.

Headley, O. St.C. 2001. Barbados Renewable Energy Scenario Current Status and Projections to 2010. Centre for Resource Management and Environmental Studies (CERMES), Faculty of Science and Technology, University of the West Indies, Cave Hill, Barbados.

Hendriks C.A et al. Emission Reduction of Greenhouse Gases from the Cement Industry. Greenhouse Gas Control Technologies Conference Paper –Cement. www.ieagreen.org.uk

Hinds, W. 1999. Barriers to the Application of Renewable Energy Technology in the Caribbean. (In Draft) .Centre for Resource Management and Environmental Studies (CERMES), Faculty of Science and Technology, University of the West Indies, Cave Hill, Barbados.

Howard, Michael. 1989. Dependence and Development in Barbados, 1945-1985, Bridgetown. Carib Research & Publications Inc. pp 161.

Jennings, V.B. Concept Paper: Transition to the Use of Electric Vehicles and Hybrids as part of the Strategy to Reduce the Emission of Greenhouse Gases in Barbados. (In Draft).

Klohn-Crippen Consultants Ltd 1997 Report on Task 2 Reliable Yield Analysis. Water Resources Management and Water Loss Studies. Barbados Water Authority, Government of Barbados

Klohn-Crippen Consultants Ltd 1997 Report on Task 3 Water Quality Analysis. Water Resources Management and Water Loss Studies. Barbados Water Authority, Government of Barbados

Klohn-Crippen Consultants Ltd 1997 Water Resources Management and Water Loss Studies. Barbados Water Authority, Government of Barbados

Mahesha, A., 1995 Parametric studies in advancing interface in coastal aquifers due to linear variation of the freshwater level . Water Resources Research 31 (10) 2437-2442

Reid, Raymond, 1994 Water Quality and Conservation, Division of Health and Environment, PAHO; paper presented at the Health and Environment in Sustainable Development, 26th April 1994

SedleyJ, Gabor, A Ruthen, P. Agriculture Background Report. Report produced by Wilms & Shier, Prinicipal Consultants to the Government of Barbados on the Environmental Management and Land Use Planning for Sustainable Development Project.

Stanley Associates et. al. 1994. Solid Waste Characterization Study. Draft Technical Addendum No. 2 to the Comprehensive Solid Waste Management Plan, Government of Barbados.

Summary for Policymakers: A Report of Working Group 1 of the Intergovernmental Panel on Climate Change.

Other Documents Used

Rowe, A.(2001) Report on the Potential Impacts of Sea Level Rise on the Coastline of Barbados, Caribbean Planning for Adaptation to Climate Change

Oderson D (2001) An Assessment of the Adequacy of the Legal Framework to Cope with the Potential Effects of Sea Level Rise in Barbados. Caribbean Planning for Adaptation to Climate Change

Ifill A (2001) Investigation of the Potential Contamination of the Groundwater in Barbados by Saline Intrusion due to Sea Level Rise –draft . Caribbean Planning For Adaptation to Climate Change.