2009

Antigua and Barbuda's Second National Communication on Climate Change

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Acronyms

AB	Antigua & Barbuda
ac-ft.	Acre-foot
APC	Antigua Power Company
APUA	Antigua Public Utilities Authority
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon Dioxide
DW	Desalination Water
EC$/1000gal.	Eastern Caribbean dollars per thousand gallons
Gg	Gigagram
GHG	Greenhouse gas
GW	Groundwater
Ha	Hectare
HCFC	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
IMG	Imperial Million Gallons
INC	Initial National Communication
IPCC	Inter-governmental Panel on Climate Change
Kg	Kilogram
LAMPs	Local Area Management Plans
MALF	Ministry of Agriculture, Lands and Fisheries
MG	Million gallons
MG/mo	Million gallons per month
Mm^3	Million cubic meters
Mm^3/yr.	Million cubic meters per year
MSW	Municipal solid waste
N_2O	Nitrous Oxide
NMVOC	Non-methane volatile organic compounds
NOx	Nitrogen Oxides
NSWMA	National Solid Waste Management Authority
PFC	Perfluorocarbons
RH	Rainwater Harvesting
SF_6	Sulphur hexafluoride
SIRMM	Sustainable Island Resource Management Mechanism
SNC	Second National Communication
SO_2	Sulphur dioxide
SW	Surface Water
UNFCCC	United Nations Framework Convention on Climate Change
US$/$m^3$	United States dollars per cubic meters
US$M	United States dollars in millions
WIOC	West Indies Oil Company

EXECUTIVE SUMMARY

This Second National Communication reflects the current climate change situation impacting Antigua and Barbuda and its projected impact in the future. It also details the impact climate change will have on climate dependent and climate sensitive economic sectors. This report also details the implementation of Antigua And Barbuda's obligations under the UNFCC, including development of relevant climate change data base, implementation of monitoring programmes, research programmes and economic instruments and policies. s well as development of an inventory of GHG. This Second National communication was based on not only national programmes but also on international and regional research work, a significant portion of which emanates from the Caribbean based climate change research centres and working groups, as well as on support structures and work that were granted financial support by the GEF via UNDP and the Implementing Agency. The Environment Division, within the Government of Antigua and Barbuda, coordinated the preparation of this report.

I. BACKGROUND

Antigua and Barbuda is a twin island state located in the Caribbean Sea approximately 250 miles Southeast of Puerto Rico and is the most central of the Leeward Island chain. There are several tiny uninhabited islands surrounding Antigua; Redonda (0.6 sq. miles or 1.6 sq km) being the largest. The precise coordinates of Antigua is 17^{o}10' latitude, 61^{o}55' longitude, Barbuda is 28 miles north of Antigua at latitude 17^{o}35' and longitude 61^{o}48'. Antigua is roughly round and has an area of 108 sq. miles (280 sq. km) and Barbuda 62 sq. miles (160 sq. km). Antigua and Barbuda has an exclusive economic zone of 110,071 sq. km.

During the last Ice Age (Pleistocene 1.8 M – 10,000 BC), sea levels were 300 ft lower than they are today and at that time Antigua and Barbuda was one large island mass. At the end of the Ice Age and the warming of the earth (Holocene Period ca. 10,000 BC) the sea levels began to rise and continue to do so creating a 28 mile separation of water between the islands, as seen in present times.

The first settlements were known to be made by the Archaic Age people of Antigua, incorrectly called the Siboney. They caught and ate birds, land crabs, fish, shell fish and sea turtles and occupied the islands for 3000 years. Over 75 Archaic Age sites have been identified on Antigua, the oldest site dating back to 3,106 BC at Little Deep in Mill Reef and the latest site dating back to 1,378 BC located at Deep Bay. In Barbuda, there was a settlement dating back to 1,875 BC at River Site. The Archaic age came to an end at 300 BC with the arrival of the advanced Ceramic Age Arawaks and Caribs.

On his second voyage in September 1493, Christopher Columbus sighted Antigua from the Southwest. He named the island after the shrine of the virgin Santa Maria la Antigua found in the Cathedral in Seville, Spain. The first English colonist were dependent on the Amerindian crops such as corn, cassava and sweet potato and also the cash crops tobacco, cotton, ginger and indigo. Sugar cultivation soon became the alternative cash crop. By 1675, the small farmers of tobacco, ginger, indigo were replaced by large scale sugar production. By the mid 1700's, Antigua was largely deforested and sugar was grown. Because sugar production was labour intensive; a large labour force was needed. These labour requirements lead to the grand scale escalation of slavery in the Caribbean and African slaves were imported by the thousands to work on the sugar plantations.

In 2001, when the last census was conducted Antigua and Barbuda had a combined population of 76,886 people, 47% male and 53% female. Individually, Antigua had 75,561 people and Barbuda had 1,325 people in 2001. The National Statistics Office conducts national censuses every ten years, however, they have projected that in 2007, Antigua and Barbuda should have a combined population of 84,330 people (9.7% more than the 2001 population).

II. GEOGRAPHY

Antigua can be described as undulating. The highest point in Antigua is Mt Obama 1,319 ft (402 m) in the southeast where the other steepest slopes are located. Slopes of 11^{o} – 20^{o} are common in this region but in localized areas in the south, slopes up to 30^{o} exist. Antigua (Fig 1.3a) has three topographic zones. The first zone considered is the mountainous southwest volcanic region. It is comprised of hard igneous rocks in the uplands and sedimentary material in associated valleys. The valley systems of this volcanic region consist of sandy loams or loams of near neutral ph which is conducive to tree growth. The second zone is the relatively flat Central Plains. This region is comprised of heavy clays which are not readily drained and near neutral ph, some calcareous clays are found in parts. In general, these soils are hard to work. The third zone can be described as the rolling limestone hills and valleys of the North and East. The limestone areas in the North have high clay content but possess good structure and have a high base structure and high base saturation, ph 8.2. These soils are generally productive. However, the limestone areas in the East consist of complex shallow and deep calcareous soils and the drier climate restricts productivity.

Barbuda is relatively flat with some low lying hills rising to just under 125 ft (40m) in the Highlands area. Slopes are mostly under 2^{o}. Barbuda is dominated by coralline limestone rocks. On the western side of the island is the Codrington Lagoon averaging about one and a half miles in width and separated from the sea by a narrow spit of sand. Barbuda's topography is relatively uniform, sand dunes are present but the land is generally covered by limestone and sand.

Antigua has a variety of vegetation types, however, due to the fact that in the 1760's, under colonial rule, the island was virtually cleared of all forests to increase the size of sugar plantations, the biodiversity of vegetation is not as robust as it once was. Cactus scrub can be found on two thirds of the total land. These areas are used for settlement and livestock grazing. Dry woodland can be found in the East coast and in Northern pockets of the island. Moist forests are located in the volcanic region in the South and Southwest. Mangrove woodland and swamps are found in coastal areas.

In Barbuda, dry woodland covers the highland of the northern section of the island and the western coast sand bar separating the sea from the Codrington Lagoon. Cactus scrub is also found on most of the island. There is a coconut plantation only in Palmetto Point. There are mangrove-fringing areas of the Codrington Lagoon.

The islands of Antigua and Barbuda are emergent parts of a 3400 sq. km sub-marine platform. The depth of water between the two islands is 27 -33 m. The coastline of Antigua is indented with numerous islands, creeks, inlets, associated sand bars and wet lands. A large portion of the east, north and south coasts are protected by fringing reefs. On the west coast, there are large areas of sandy bottom in shallow water, with sandy bottom between fringing reefs and the shore. The coastline of Barbuda is less varied but has extensive reef systems especially off the east coast. The Codrington Lagoon is bordered by mangroves and sand ridges. This area is of significant importance to the fisheries and wildlife of Barbuda.

III. LAND USE

The latest available published data indicating land use was completed by the Developmental Control Authority (DCA) in 1995. However, no data was available for Barbuda. In 1985 an Agricultural Census was carried out by the Ministry of Agriculture, which included details of Barbuda.

The land used for Agricultural crops increased from 5,501 to 7,740 acres over the ten year period (1985 -1995). However, the Agriculture livestock grazing land (improved pasture, rough grazing, mixed scrub and rough grazing) decreased from 26,252 to 13,482 acres, in that same period. Woodland areas (limestone hills, volcanic areas) decreased slightly from 23,645 to 22,024 acres from 1985 to 1995. Urban/Rural areas increased dramatically from 6,627 to 17,189 acres, with the increase in residential areas. Industrial acreage also increased but not as dramatically from 381 to 584 acres. Hotels and Golf courses acreage increased from1,133 to 2,699 acres. Recreation and Historic Areas also increased from 714 to 1,558 acres. Airport and Military land decreased from 935 to 763 acres. Swamp and Mangrove acreage remained almost the same during that ten year period, 2,164 acres in 1985 to 2,142 acres in 1995.

In Barbuda (1985), less than 1 % (269 acres) of land area is occupied by human settlement and related uses, 19,521 acres is occupied by dry forest areas (Limestone Highlands) and 9,214 acres are occupied by swamps and mangroves.

IV. COASTAL ZONE

Antigua and Barbuda has the most extensive mangrove wetlands in the Eastern Caribbean. There are thirty-six (36) mangrove sites in Antigua and nine (9) sites in Barbuda. In Antigua, the sites range from very small single layer stands of trees to large, complex swamps. In Barbuda, there are luxuriant 352 ha fringe mangrove of Codrington Lagoon and narrow scrubby borders of mangroves around salt ponds. Four kinds of mangroves exist in Antigua and Barbuda. They are Rhizophora (red), Avincenis (black), Laguncularia (white) and Conorcarpus (buttonwood).

Mangroves essentially are vital to maintaining healthy beach and reef systems. They act as natural breakers and buffer zones which protect the coastline from erosion during storms. The level of protection depends on the width of mangrove. Additionally, the mangroves act as sediment traps, protecting the reefs from being smothered by eroded soil and other geological material from the land. Finally they act as nurseries, breeding and feeding grounds and provide a habitat for both marine and terrestrial wildlife.

Climate Change will significantly disrupt the mangrove ecosystem, especially, since these areas are already under stress from natural (hurricanes, droughts) and anthropogenic sources (pollution & destruction – caused by dredging and filling).

There are extensive areas of seas grass beds in shallow waters around the coasts of Antigua and Barbuda. Turtle grass (*Thalassiatestudinum),* manatee grass (*Syringodiumfilforme)* and shoal grass (*Halodulewrightii*) are common in these shallow coastal areas (less than 20 m deep). The grasses provide shelter for the juveniles of the commercially important queen couch (*Strombusgigas*) and spiny lobster (*Panulirusargus)*. Seagrasses also act as source of food for some herbivores and also provide surfaces for epiphytic plants upon which other species may graze. Calcareous algae (Halimedaspp) are found among sea grasses and are believed to be a major source of white sand. The sea beds have many functions, one of which is to stabilize loose sand and retard coastal erosion. After intense storm surge from Hurricanes in the region it is not uncommon for some of this sea grass to appear washed up on the sea shores.

Antigua and Barbuda sits on a shallow rock-floored 'shell' covered by a variety of reefs. The edge of the 'shell' is at depths of 90 – 180 m where it drops to oceanic depths. Along the south coast of Antigua the shelf is very narrow; it drops to over 305 m within a mile (1.6 km) of the shore. The coral reefs thrive on this shelf. There are approximately 25.24 sq. km of reef coverage fringing around Antigua. On the windward east coast there is better reef development due to the high wave energy providing circulation of nutrients and flushing with absence of fine muddy sediment. However, on the leeward west coast the reefs are poorly developed because of lack of circulation and abundance of fine sediment.

The optimal temperature for reef growth is 29^{o}C (Brown 1989). Presently sea surface temperatures of approximately 30^{o}C have been found around Antigua and Barbuda. It is at temperatures of 30^{o}C and above that bleaching of the corals takes place. Prolonged exposure to high temperatures can result in irreversible bleaching of the corals. Further negative climate change events are also impacting the corals, mainly sea level rise. The greater the depth of water the less sunlight the corals receive and the symbiotic algae are unable to photosynthesize and provide nutrients for the coral.

Coral Reefs and Sea Grass beds are vulnerable to climate change and the former are already succumbing to bleaching. Any further increase in sea temperature and sea level will destroy the reefs completely. The predicted increase in intensity and frequency of storms will lead to the rapid demise of an already stressed reef system and sea grass bed. Once the reefs have been destroyed, it is predicted that the sea grass beds will follow and this will expose the coastline in general and the beaches in particular to the damaging effects of the pounding waves.

V. BIODIVERSITY

From the earliest colonial period to the 1960's, the sugar industry dominated the land use patterns of Antigua and resulted in major changes to terrestrial habitats and the island's biodiversity. Nearly three centuries of deforestation and land clearing for intensive agricultural use have resulted in removal or degradation of the original vegetation and lead to habitat destruction and subsequent loss of species richness. Presently, uncontrolled livestock grazing continue to have a detrimental effect on native plant communities. Additionally, intensive tourism development has resulted in major biophysical alterations to the coastline, leading to the destruction of coastal and marine habitats directly affecting the richness of biodiversity residing in these areas.

There are 1158 species from 149 families (Lindsay &Horwith 1997b) of plants found in Antigua and Barbuda. This includes 45 species of ferns and fern allies; 4 species of gymnosperms and 1,109 species of flowering plants.There are 71 freshwater fish species and 400 marine fish species.There are only two native species of amphibians; namely a tree frog (*Eleutherodactylusjohnstonei)* and a marine toad (*Bufomarinus).*

Existing are 19 species of terrestrial reptiles, one of which is endangered; namely the Antigua Racer Snake (*Alsophisantillensisantiguae)*. The Iguana delicatissima was also on the endangered list but is now extinct in this country but still exist in neighbouring islands such as Anguilla. The Antigua Racer Snake is the rarest snake in the world, with only about two hundred living. It is found on Bird Island, an island off the coast of Antigua. Antigua and Barbuda has three endangered species of turtles which nest on the beaches, namely the hawksbill, green and leatherback (the loggerhead is known to traverse the waters).

There are approximately 182 species of birds recorded. Two-thirds of the population is migratory leaving 60 resident. There are only two island endemic sub-species: Antigua's broad-winged hawk and Barbuda's Adelaide's warbler.

Bats are the only native terrestrial mammals, with seven species of bats resident in these islands. There are several introduced species of mammal species, for example, the European Fallow deer (endangered) and the Indian mongoose. There are 26 recognized Cetacean (marine mammals) species.

There is no research available on invertebrates present in Antigua and Barbuda.

VI. GOVERNANCE

Antigua and Barbuda is a constitutional monarchy with a British-style parliamentary system of government. The head of state is an appointed Governor General who represents the reigning British monarch. The government has three branches, which are the Legislative, the Executive and the Judicial Branch. The Legislative Branch consists of the House of Representatives and the Senate. The House of Representatives has seventeen members and is responsible for introducing legislation. The seventeen member Senate reviews and gives assent to proposed legislation. The members of the House of Representatives are elected by popular vote (constitutionally mandated every five years), while the members of the Senate are appointed. The Governor General appoints the members of the Senate. Eleven of the members of the Senate are appointed under the advice of the Prime Minister, who is the leader of the party that commands the support of the majority of members in the House of Representatives.One of theeleven must be a native Barbudan. Four members of the Senate are appointed under the advice of the leader of the Opposition who is recognized constitutionally, one member of the Senate is appointed under the advice of the Barbuda Council, and one member of the Senate is appointed as an independent member representing business at the sole discretion of the Governor General. The Executive Branch is derived form the Legislative Branch. This branch consists of the Cabinet headed by the Prime Minister. The members of Cabinet are appointed by the Prime Minister and must be members of either the House of Representative or the Senate. The Judicial Branch is independent of the other two branches, with judges and appeal court judges appointed by an independent judicial commission as part of a subregional judiciary serving all the members of the O.E.C.S. The magistrates will shortly be appointed by this regional commission replacing the present arrangement of their appointment by the Attorney General, who is a member of the Executive Branch. The judiciary consists of the Magistrates Court for minor offences and the High Court for major offences. Beyond the High Court is the Eastern Caribbean States Supreme Court, whose members are appointed by the OECS. The final court of appeal for Antigua and Barbuda is the Judicial Committee of the Privy Council, located in London. However, the Caribbean Court of Justice has been proposed to replace the Privi Council as the final court of appeal. The Court was created in 2003 under the 2001 Revised Treaty ofChaguaramasof the Caribbean Community (CARICOM). The treaty is an instrument for the establishment of the Caribbean (CARICOM) Single Market and Economy (CSME) and was signed by the various CARICOM heads of government.

VII. ECONOMY

In 2005, Antigua and Barbuda had a GDP of US$ 874.9 million, with a growth rate of 7.07% and an inflation rate of 2%. The economy of Antigua and Barbuda is service based. Tourism and government services represent the key sources of employment and income. Tourism accounted for more than half of the GDP in 2005 and is also the principle earner of foreign exchange. However, the tourism industry is vulnerable to environmental factors such as violent Hurricanes which are expected to increase in intensity and occurrence because of climate change. When Antigua and Barbuda experienced several devastating hurricanes from 1995 – 1999, the economic growth rate plummeted. Tourism has also shown a vulnerability to external shocks, for example in 2001, the tragic September 11th terrorist attack kept most would be tourist at home for fear of further attacks. Efforts to diversify the economy by encouraging growth in transportation, communications, and internet gambling and financial services may have acted as a catalyst to the renewed economic growth.

VIII. CLIMATE CHANGE

Clearly Antigua and Barbuda's survival depends on its natural resources and climatic condition. Without appropriate adaptation, climate change could have an extremely harmful impact on the sustainability of the development process with the coastal zone being most vulnerable. The following are the projected changes to Antigua and Barbuda's climate due to global warming.

1. There is evidence to suggest that the climate of Antigua and Barbuda is changing. Both maximum and minimum temperatures have increased in the recent past.
2. The warming trend is expected to continue. The country is projected to be 1 to 3.5 degrees warmer by the end of the century.
3. Winter months will see marginally larger increases in temperature than summermonths.
4. The frequency of very hot days will increase, while very cool nights willdecrease.
5. There is a likelihood that the country will be drier (in the mean) by the end of the century.
6. Climate change will likely make the dry periods early in the year and in June/July drier.

7. The seasonality of Antigua and Barbuda will be largely unchanged. The cooler (with respect to late season temperatures) dry early months and wet hotter late months will still prevail.
8. Hurricane intensity is likely to increase but not necessarily hurricane frequency.
9. Caribbean Sea levels are projected to rise by up to 0.5 m by the end of the century.

Table 4.1 Climate Projections for Antigua and Barbuda and the Insular Caribbean

Climate Parameter	Predicted change for the Insular Caribbean[1]	Predicted change for Antigua and Barbuda[2]
Air temperature	Increase of 1.8 - 4.0°C by 2099	**1.3°C by the 2050s** **1 - 3.5°C by the end of the century**
Sea surface temperature	~1.7°C by the end of the century	**Up to 2°C by the end of the century**
Sea level rise	Rise of 0.18 – 0.59 m by 2099	**Rise of 0.24 m by 2050[3]**
Carbon dioxide	Reduction in pH of the oceans by 0.14 - 0.35 units by 2099	**An increase in carbon dioxide emissions through 2050.**
Hurricanes	More intense with larger peak wind speeds and heavier precipitation	**More intense with larger peak wind speeds and heavier precipitation. (not necessarily increased frequency)**
Precipitation	**Unclear**	**Drier (in the mean) by the end of the century**

Depending on local conditions, climate change will have varying effects on the coastal areas. Box 4.1 summarises the major impacts of climatechange. The major

Box 4.1 A summary of the impacts of climate change on the coastal zone in Antigua and Barbuda includes:

- Destruction of /damage to critical habitats (beaches, mangroves, sea grass beds, coral reefs)
- Climate change impacts may contribute directly to overfishing, pollution, and loss of wetlands and nurseries
- Increased coral bleaching as a result of a 2°C increase sea surface temperature by 2099
- Sea-level change can cause loss of coastal wetlands and land area in general
- Destruction to coastal infrastructure, loss of lives and property
- Changes in coastal pollutants will occur with changes in precipitation and runoff
- In extreme conditions, the possible loss of a livelihood, and
- General economic losses to the country

Sources:(APO, 2008; Cambers, Claro, Juman, & Scott, 2008; Creary, 2003; Crocker, 2008; Delaney, Michael, & Murray, 2000; Everett, 2007; IPCC, 2007a; IPCC, 2007b; James P. A., 2008; Mahon R. , 2002; Nurse 2008; Yohe et al. 2007) impacts are more dominant within the ecological environment.

IX. ADAPTATION AND MITIGATION MEASURES TO CLIMATE CHANGE

Antigua and Barbuda has taken several measures to adapt and mitigate the impacts of climate change. The fundamental pillars of mitigation are based on energy use, energy efficiency and utilisation of renewable energy. Adaptation strategies engages a variety of mechanisms to reduce loss and damage from disasters made worse by climate change, including disaster risk management, insurance and other compensatory schemes, building and development codes enforcement, and water storage, supply (ground water and desalination) and efficiency in usage, including irrigation technology and public education. Recent works included the use of natural ecosystems to adapt to extreme weather events such as flooding.

Regional and international negotiations to put in place a comprehensive GHG reduction treaty is a critical and perhaps the most potent component of this micro Island state Mitigation and adaptation efforts. In this regard and as an integral member of the international climate change negotiation process, Antigua And Barbuda joins forces with other nation states that support inter alia, the following climate change negotiations standards:

- long term stabilisation of GHG below 350ppm CO2 equivalent levels,
- global average surface temperature increase to be limited to levels below 1.5C above pre industrial levels,
- GHG emissions peak by2015 then decline,
- reducing GHG emissions by greater than 85% below 1990 levels by 2050;
- Annex I parties to UNFCCC reduce collective GHG emissions by 45% below 1990 levels by 2050, and
- providing SIDS with adequate new, predictable,with direct access to grant financing and technology transfer to assist in fast-tracking their mitigation and adaptation efforts

X. GREEN HOUSE GAS INVENTORY

The Government of Antigua and Barbuda, a Non-Annex 1 party to the United Nations Framework Convention on Climate Change (UNFCC) submitted a greenhouse gas (GHG) emissions inventory for the year 1990 as a component of its Initial National Communication to the UNFCCC. This report presents the GHG emissions inventory for the year 2000 which will be included in Antigua and Barbuda's Second National Communication in compliance with Articles 4 and 12 of the UNFCC.

Antigua and Barbuda is not a producer of primary fossil fuels. Imported fossil fuels are used primarily for electricity generation and transport. The industrial sector is minimal and made up primarily of the food and beverage industry and asphalt production. In the agriculture sector, GHG emission sources are limited to domestic livestock and agricultural soils sub sectors. 22% of the country is covered by seondary forest. The original forests were cleared to establish the sugar plantations during the early colonial settlement of the islands. Additionally, this island state is relatively dry and flat, therefore, lush tropical rainforests are not common. In the waste sector, GHG emissions are limited to methane from solid waste disposal sites and to indirect nitrous oxide emissions from human waste.

A summary of the GHG inventory for 2000 is shown in Table 1. National emissions in 2000 were carbon dioxide 383 Gg, methane 6.60 Gg, nitrous oxide 0.16 Gg and hydro fluorocarbons 0.0037 Gg. The uncertainty in the overall estimate was 40%.

Gaps in the activity data required for the inventory arose mainly because records were not maintainedfor sufficient periods and in some cases because the statisticswerenotcompiled. This is especially true for the land use and land use change sectors. Agencies are now aware of the shortfalls and are prepared to take steps to establish record keeping protocols and to compile and maintain records.

Table 1 SUMMARY OF ANTIGUA & BARBUDA GREENHOUSE GAS EMISSIONS AND REMOVALS (Gg) FOR 2000

GHG SOURCE AND SINK CATEGORIES	CO_2	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs
	Emissions	Removals							
Total National Emissions and Removals	**383**	**0**	**6.6**	**0.159**	**2.3**	**11.9**	**2.7**	**2.8**	**0.0037**
1 Energy (Reference Approa	**412**								
(Sectoral Approa	**371**		**0**	**0.003**	**2.3**	**11.9**	**2.3**	**2.8**	
A Fuel Combustion	371		0	0.003	2.3	11.9	2.2		
B Fugitive Emissions from Fuels	0		0		0.0	0.0	0.0	0.0	
2 Industrial Processes	**0**		**0.0**	**0.000**	**0.0**	**0.0**	**0.4**	**0.0**	**0.0037**
3 Solvent and Other Product Use	**0**			**0.000**			**0.0**		
4 Agriculture			**1.1**	**0.152**	**0.0**	**0.0**			
5 Land-Use Change & Forestry	**11**	**n/a**	**0.0**	**0.000**	**0.0**	**0.0**			
6 Waste			**5.4**	**0.004**					
7 Other (None)	**0**	**0**	**0.0**	**0.000**	**0.0**	**0.0**	**0.0**	**0.0**	
Memo Items:									
International Bunkers	**199**		**0.0**	**0.006**	**0.7**	**0.0**	**0.0**	**0.0**	
Aviation	199		0	0	0.7	0	0	0	
Marine	0		0	0	0	0	0	0	
CO_2**Emissions from Biomass**	**0**								

CHAPTER 1

NATIONAL CIRCUMSTANCES

CHAPTER 1 – NATIONAL CIRCUMSTANCES

1.1 INTRODUCTION

Map 1.1 :Map showing location of Antigua and Barbuda

Source: GraphicMaps.com

1.1.1 PHYSICAL SETTING:

Antigua and Barbuda is a twin island state located in the Caribbean Sea approximately 250 miles Southeast of Puerto Rico and is the most central of the leeward island chain which starts with the Virgin islands in the West and ends with Dominica in the South (Fig 1.1). There are several tiny uninhabited islands surrounding Antigua; Redonda (0.6 sq. miles or 1.6 sq km) being the largest. The precise coordinates of Antigua is $17^{o}10'$ latitude, $61^{o}55'$ longitude, Barbuda is 28 miles north of Antigua at latitude $17^{o}35'$ and longitude $61^{o}48'$. Antigua is roughly round and has an area of 108 sq. miles (280 sq. km) and Barbuda 62 sq. miles (160 sq. km). Antigua and Barbuda has an exclusive economic zone of 110,071 sq. km.

Map 1.2 (b): Map of the Barbuda

BARBUDA

1.1.2 Topography and Soil types[4,5,6,7] (map 1.3 a & b):

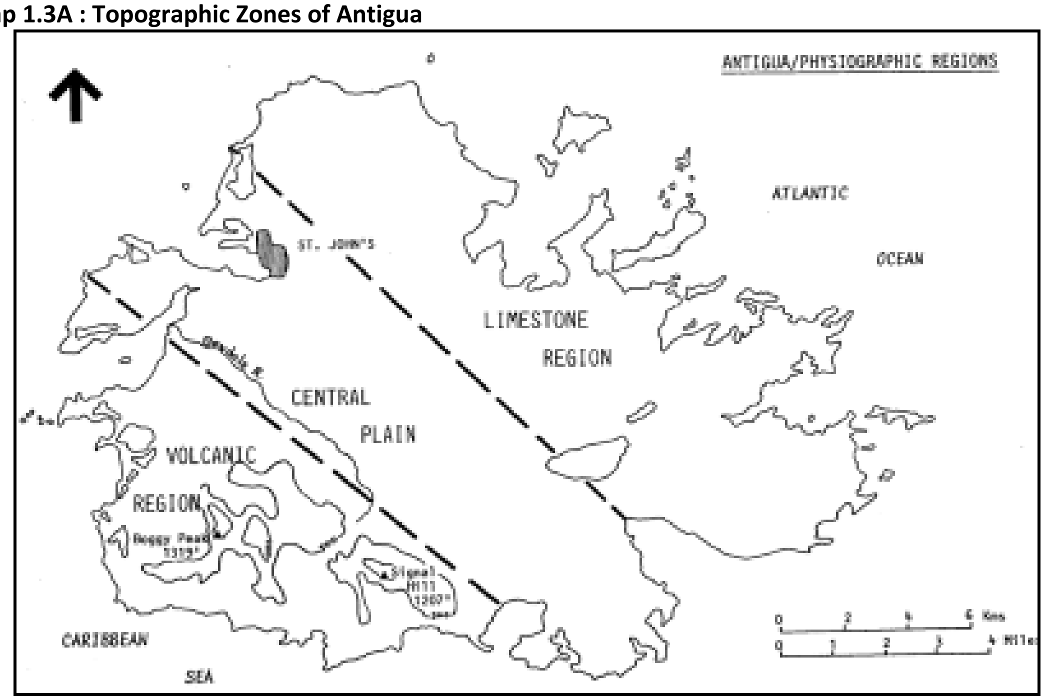
Antigua can be described as undulating. The highest point in Antigua is Mt. Obama 1,319 ft (402 m) in the southeast where the other steepest slopes are located. Slopes of 11^o – 20^o are common in this region but in localized areas in the south, slopes up to 30^o exist. Antigua (Fig 1.3a) has three topographic zones. The first zone considered is the mountainous southwest volcanic region. It is comprised of hard igneous rocks in the uplands and sedimentary material in associated valleys. The valley systems of this volcanic region consist of sandy loams or loams of near neutral ph which is conducive to tree growth. The second zone is the relatively flat Central Plains. This region is comprised of heavy clays which are not readily drained and near neutral ph, some calcareous clays are found in parts. In general, these soils are hard to work. The third zone can be described as the rolling limestone hills and valleys of the North and East. The limestone areas in the North have high clay content but possess good structure and have a high base structure and high base saturation, ph 8.2. These soils are generally productive. However, the limestone areas in the East consist of complex shallow and deep calcareous soils and the drier

[4] Environment Division, Integrating Management of Watersheds & Coastal Areas in Small Island Developing States of the Caribbean - National Report for Antigua & Barbuda:(January 2001), p 1-8
[5] Caribbean Conservation Association, Antigua and Barbuda, Country Environmental Profile : (Barbados, 1991), pp 12-17
[6] H.C. Multer, M.P. Weiss & D.V. Nicholson, Antigua – Reefs, Rocks and Highroads of History: (1986), p 1-4
[7] Martin Kaye, Reports On the Geology of the Leeward and Virgin Islands West Indies, Antigua: (1959) p 1

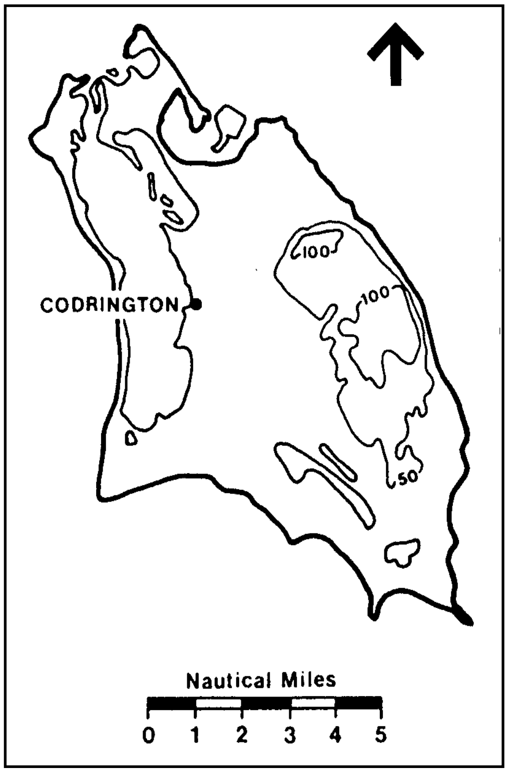
climate restricts productivity. Negative Climate Change events such as reduced precipitation have exacerbated the effects of having such a dry climate.

Barbuda is relatively flat with some low lying hills rising to just under 125 ft (40m) in the Highlands area. Slopes are mostly under 2^{o}. Barbuda is dominated by coralline limestone rocks. On the western side of the island is the Codrington Lagoon averaging about one and a half miles in width and separated from the sea by a narrow spit of sand. Barbuda's topography is relatively uniform, sand dunes are present but the land is generally covered by limestone and sand.

Map 1.3A : Topographic Zones of Antigua



Barbuda (map 1.3b) can also be divided into three topographic zones, although, they are not as marked as those in Antigua. The first zone to be considered is the Highlands limestone area, which consists of hard limestones which contain caverns and sink holes. The soil in this zone is a reddish clay loam. The second zone is the Codrington limestone region which comprises of sandy and fossiliferous sediments less crystalline than the Highland limestone. The soil is a brown clay loam. The third zone is the Palmetto Point Series which overlies the Highlands and Codrington formations in coastal areas and is composed of beach sands and ridges with shelly horizons. The soil in this region is dark coloured montmorillonitic clay.



Map 1.3B : Topographic Zones of Barbuda

1.1.3 Vegetation[8,9,10,11]:

Antigua has a variety of vegetation types, however, due to the fact that in the 1760's, under colonial rule, the island was virtually cleared of all forests to increase size of sugar plantations, the biodiversity of vegetation is not as robust as it once was. Cactus scrub can be found on two thirds of the total land. These areas are used for settlement and livestock grazing. However, overgrazing may lead to the whole island being covered by cactus scrub. Dry woodland can be found in the East coast and in Northern pockets of the island. Moist forests are located in the volcanic region in the South and Southwest. Mangrove woodland and swamps are found in coastal areas.

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8 Watts 1993
9 Environment Division, Antigua and Barbuda's Compendium of Environmental Statistics: (2003) p 31
10 Environment Division, National Implementing Agenda 21 Issues In Antigua & Barbuda: (Sept. 2001), Chap. 7.
11 Caribbean Conservation Association, Antigua and Barbuda, Country Environmental Profile : (Barbados, 1991), pp 17 - 22

In Barbuda, dry woodland covers the highland of the northern section of the island and the western coast sand bar separating the sea from the Codrington Lagoon. Cactus scrub is also found on most of the island. There is a coconut plantation only in Palmetto Point. There are mangrove-fringing areas of the Codrington Lagoon.

With the expected prolonged periods of drought and increase in frequency and intensity of hurricanes as a result of climate change, there may be even further loss of fragile vegetation with replacement by hardier cactus scrub.Coastal Features[12]:

The islands of Antigua and Barbuda are emergent parts of a 3400 sq. km sub-marine platform. The depth of water between the two islands is 27 -33 m. The coastline of Antigua is indented with numerous islands, creeks, inlets, associated sand bars and wet lands. A large portion of the east, north and south coasts are protected by fringing reefs. On the west coast, there are large areas of sandy bottom in shallow water, with sandy bottom between fringing reefs and the shore. The coastline of Barbuda is less varied but has extensive reef systems especially off the east coast. The Codrington Lagoon is bordered by mangroves and sand ridges. This area is of significant importance to the fisheries and wildlife of Barbuda.

1.1.4 Land Use[13,14]:

The latest available published data indicating land use was completed by the Developmental Control Authority (DCA) in 1995. However, no data was available for Barbuda. In 1985 an Agricultural Census was carried out by the Ministry of Agriculture, which included details of Barbuda.

The land used for Agricultural crops increased from 5,501 to 7,740 acres over the ten year period (1985 -1995). However, the Agriculture livestock grazing land (improved pasture, rough grazing, mixed scrub and rough grazing) decreased from 26,252 to 13,482 acres, in that same period. Woodland areas (limestone hills, volcanic areas) decreased slightly from 23,645 to 22,024 acres from 1985 to 1995. Urban/Rural areas increased dramatically from 6,627 to 17,189 acres, with the increase in residential areas. Industrial acreage also increased but not as dramatically from 381 to 584 acres. Hotels and Golf courses acreage increased from1,133 to 2,699 acres. Recreation and Historic Areas, also increased from 714 to 1,558 acres. Airport and Military land decreased from 935 to 763 acres. Swamp and Mangrove acreage remained almost the same during that ten year period, 2,164 acres in 1985 to 2,142 acres in 1995.

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[12] Environment Division, Integrating Management of Watersheds & Coastal Areas in Small Island Developing States of the Caribbean - National Report for Antigua & Barbuda:(January 2001), p 8

[13] Caribbean Conservation Association, Antigua and Barbuda, Country Environmental Profile : (Barbados, 1991), pp 135-138

[14] Environment Division, Antigua and Barbuda's Compendium of Environmental Statistics: (2003) p 20

In Barbuda (1985), less than 1 % (269 acres) of land area is occupied by human settlement and related uses, 19,521 acres are occupied by dry forest areas (Limestone Highlands) and swamps and mangroves occupy 9,214 acres.

1.2 MARINE RESOURCES

Mangroves[15,16,17]: (Picture 1.1, Fig 1.4 a & b)
Antigua and Barbuda has the most extensive mangrove wetlands in the Eastern Caribbean. There was an estimated 4,900 ha of mangroves found in the twin island state,

Picture 1.1 : Red Mangroves at Swamp on South western side of Antigua

In 1991. There are thirty-six (36) mangrove sites in Antigua and nine (9) sites in Barbuda. In Antigua, the sites range from very small single layer stands of trees to large, complex swamps. In Barbuda, there are luxuriant 352 ha fringe mangrove of Codrington Lagoon and narrow scrubby borders of mangroves around salt ponds. Four kinds of mangroves exist in Antigua and Barbuda. They are Rhizophora (red), Avincenis (black), Laguncularia (white) and Conorcarpus (buttonwood).

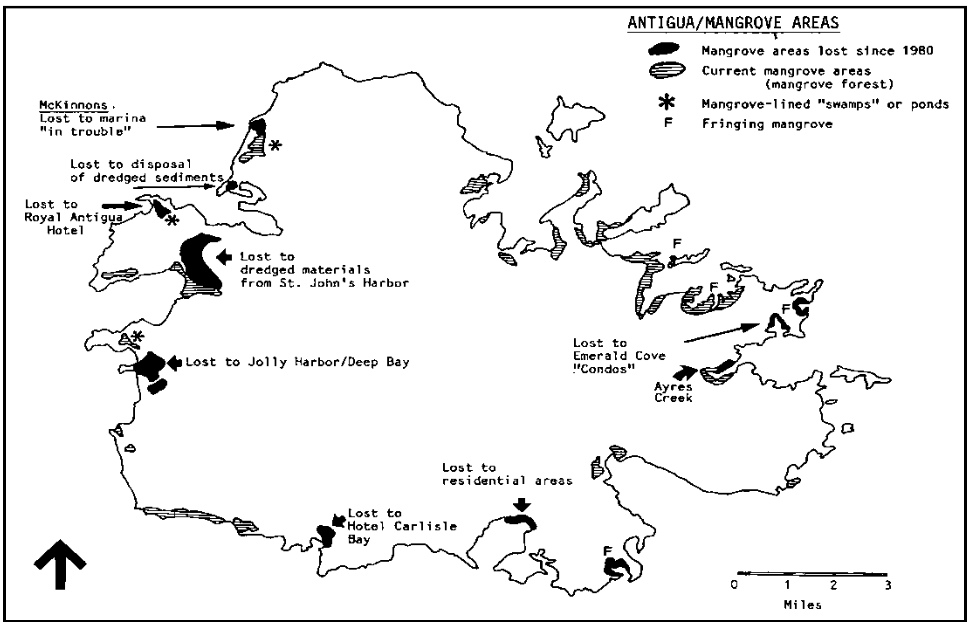
Mangroves essentially are vital to maintaining healthy beach and reef systems. They act as natural breakers and buffer zones which protect the coastline from erosion

[15] Caribbean Conservation Association, Antigua and Barbuda, Country Environmental Profile : (Barbados, 1991), pp 87 - 90
[16] Environment Division, Integrating Management of Watersheds & Coastal Areas in Small Island Developing States of the Caribbean - National Report for Antigua & Barbuda:(January 2001), p 8
[17] Office of the Prime Minister, Antigua and Barbuda's First National Report to the Convention on Biological Diversity: (April 2001) pp 20-21

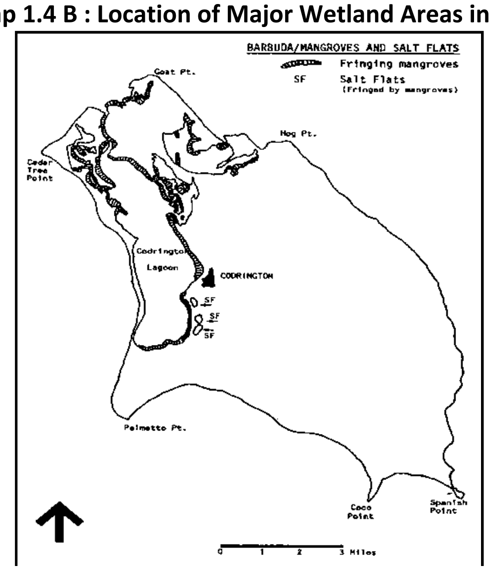
during storms. The level of protection depends on the width of mangrove. Additionally, the mangroves act as sediment traps, protecting the reefs from being smothered by eroded soil and other geological material from the land. Finally they act as nurseries, breeding and feeding grounds and provide a habitat for both marine and terrestrial wildlife.

Climate Change will significantly disrupt the mangrove ecosystem, especially, since these areas are already under stress from natural (hurricanes, droughts) and anthropogenic sources (pollution & destruction – caused by dredging and filling).

Map 1.4 A: Location of Major Wetland Areas in Antigua (Source: CEP 1991)



Map 1.4 B : Location of Major Wetland Areas in Barbuda (Source: CEP 1991)



1.2.1 Sea Grass[18]:

There are extensive areas of seas grass beds in shallow waters around the coasts of Antigua and Barbuda. Turtle grass (*Thalassiatestudinum),* manatee grass (*Syringodiumfilforme)* and shoal grass (*Halodulewrightii*) are common in these shallow coastal areas (less than 20 m deep). The grasses provide shelter for the juveniles of the commercially important queen couch (*Strombusgigas*) and spiny lobster (*Panulirusargus)*. Seagrasses also act as a source of food for some herbivores and also provide surfaces for epiphytic plants upon which other species may graze. Calcareous algae (Halimedaspp) are found among sea grasses and are believed to be a major source of white sand. The sea grass beds have many functions one of which is to stabilize loose sand and retard coastal erosion. After intense storm surge from Hurricanes in the region it is not uncommon for some of this sea grass to appear washed up on the sea shores.

1.2.2 Coral Reefs [19,20](Picture 1.2, map 1.5a & b)):

Antigua and Barbuda sits on a shallow rock-floored 'shell' covered by a variety of reefs. The edge of the 'shell' is at depths of 90 – 180 m where it drops to oceanic depths. Along the south coast of Antigua the shelf is very narrow; it drops to over 305 m within a mile (1.6 km) of the shore. The coral reefs thrive on this shelf. There are approximately 25.24 sq. km of reef coverage fringing around Antigua. On the windward east coast there is better reef development due to the high wave energy providing circulation of nutrients and flushing with absence of fine muddy sediment. However, on the leeward west coast the reefs are poorly developed because of lack of circulation and abundance of fine sediment.

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[18] Caribbean Conservation Association, Antigua and Barbuda, Country Environmental Profile : (Barbados, 1991), pp 85 - 87

[19] Office of the Prime Minister, Antigua and Barbuda's First National Report to the Convention on Biological Diversity: (April 2001) pp 18-19

[20] H.C. Multer, M.P. Weiss & D.V. Nicholson, Antigua – Reefs, Rocks and Highroads of History: (1986), pp 3-1, 3-2

Picture 1.2: Dead and Dying Coral Reefs along the Northwest Coast of Antigua

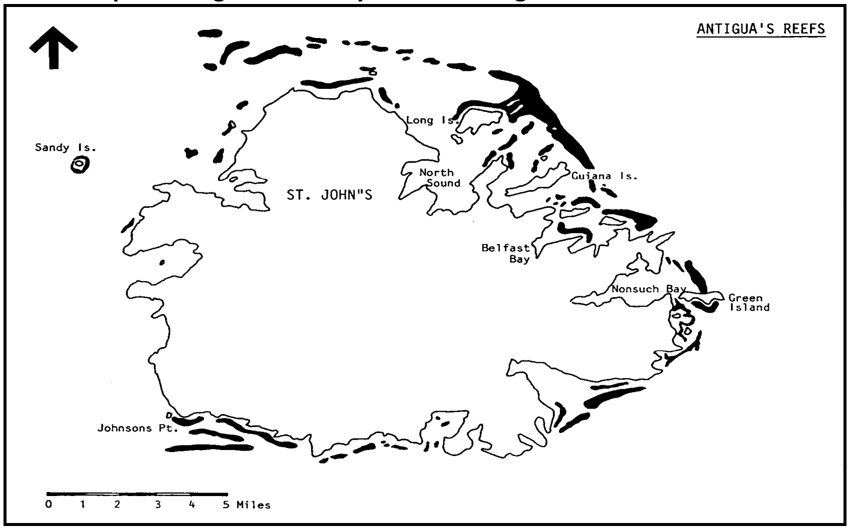
Source: Courtesy of Chere Reade 2007

There are four main types of coral reefs found in Antigua and Barbuda. The first type is the Barrier reef located on the Southern shore of Antigua parallel to a steep slope at the edge of the narrow shelf. The second type is the Bank Barrier reef that is predominant off shore Antigua and located on the North eastern and South western flanks. The Fringing reefs are the third type and is found protecting the eastern, northern and southern coast. Patch reefs are mainly found in Barbuda.

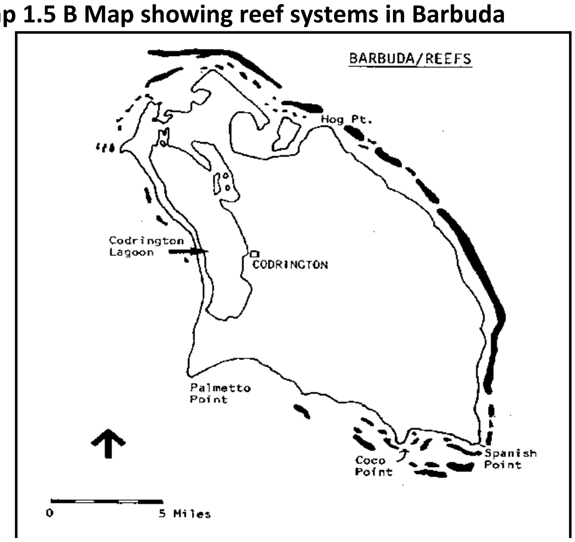
The optimal temperature for reef growth is 29^{o}C (Brown 1989). Presently sea surface temperatures of approximately 30^{o}C have been found around Antigua and Barbuda. It is at temperatures of 30^{o}C and above that bleaching of the corals takes place. Prolonged exposure to high temperatures can result in irreversible bleaching of the corals.

The Coral Reefs and Sea Grass beds are already vulnerable to climate change. The coral reefs are already succumbing to bleaching and any further increase in sea temperature and sea level will destroy the reefs completely. The predicted increase in intensity and frequency of storms will lead to the rapid demise of an already stressed reef system and sea grass bed. Once the reefs are gone the shores will be even more open to the greatly damaging effects of the pounding waves.

Map 1.5A: Map showing main reef systems of Antigua



Map 1.5 B Map showing reef systems in Barbuda



1.2.3 Beaches[21] (Picture 1.3):

Beaches and sand bars provide a major barrier to the constant force of coastal erosion. Antigua and Barbuda boasts 365 beaches and is a corner stone of its tourism industry and culture. The beaches provide a habitat for nesting turtles and other animals and plants. Unfortunately, the beaches are illegally used as a source of fine aggregates in construction; therefore, sanding mining is a significant concern in addition to the potential impacts of Sea Level Rise and other climate influenced coastal erosion events. Additionally, another major source of coastal erosion is the building of concrete structures too close to the shore line and the use of poorly designed and unregulated sea defences.

[21] Fisheries Division, Wise practices for coping with Beach Erosion; Antigua and Barbuda

On the northwest coast, the coastline is gradually eroding away. The Dickenson Bay shoreline eroded at a rate of 2m/yr between 1992 and 1999 (Source: Fisheries Division, Antigua & Barbuda). The shoreline at Fort James eroded at a rate of 0.5 m/yr. However, although the northern end of Runaway Bay was found to be eroding the southern end accreted by 0.2 m/yr during 1992 – 1999. The northwest coast is especially known for the large numbers of concrete buildings in close proximity to the shore line. The concrete structures and general slope of the land considerably restrict drainage in the area. The mean profile for this area has decreased by 10% between 1992 and 1995. It should be noted however that Hurricane Luis (1995) and other storms have significantly contributed to this severe erosion.

Picture 1.3: Concrete Buildings too close to the shoreline on Northwest Coast of Antigua

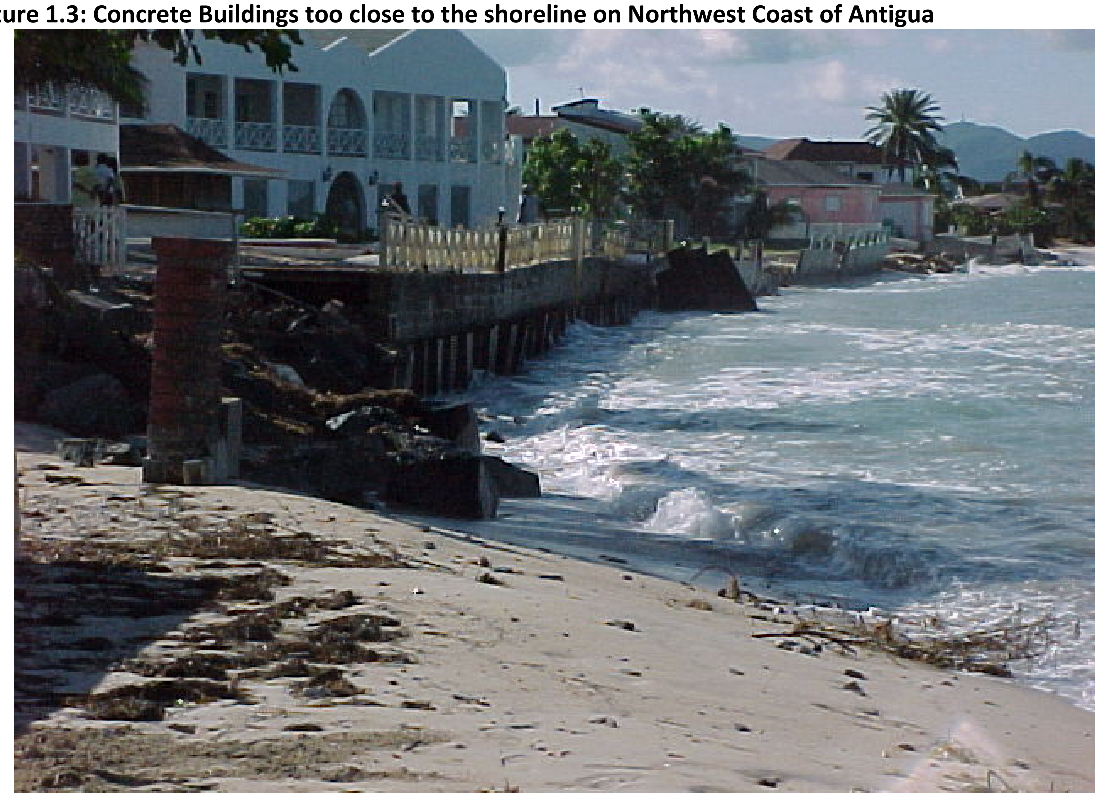


Photo courtesy of the EAG

1.2.4 Watersheds[22,23]:

A watershed is a topographically defined area having a common drainage system. Watersheds are used as the fundamental units to assess hydrological budgets and erosion and to provide for land use planning and management.

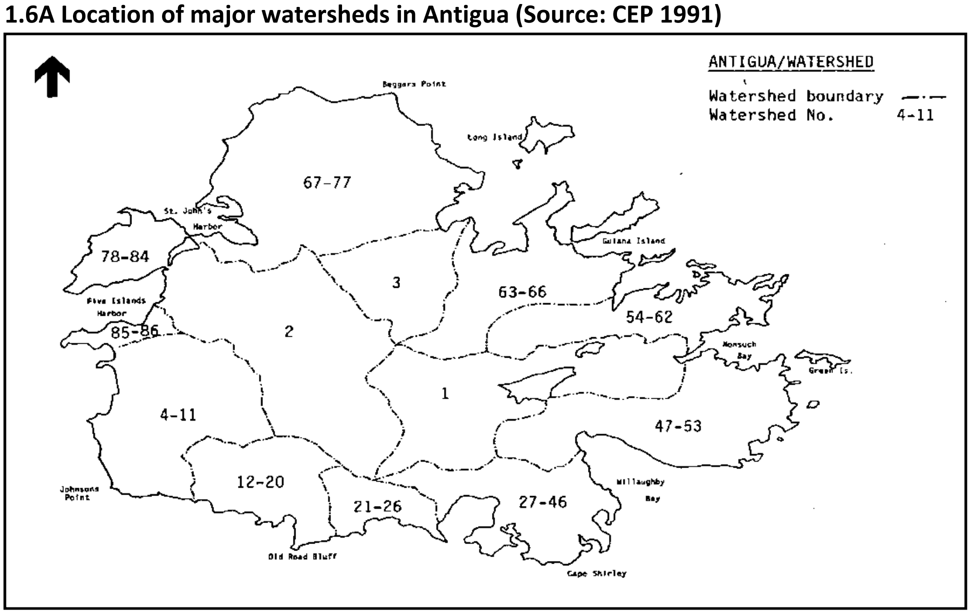
[22] Caribbean Conservation Association, Antigua and Barbuda, Country Environmental Profile : (Barbados, 1991), pp 58-72

[23] Environment Division, Integrating Management of Watersheds & Coastal Areas in Small Island Developing States of the Caribbean - National Report for Antigua & Barbuda:(January 2001), p 19 - 21

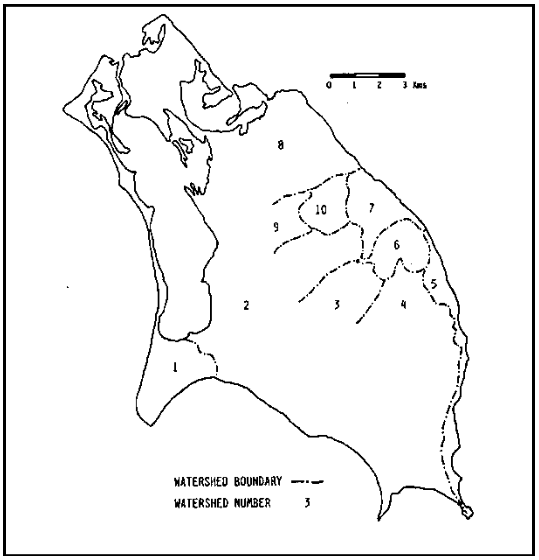
Antigua has 86 watersheds which were recognised by the Halcrow study (Halcrow 1977) and then grouped by McMillan (1985) into are 13 larger watershed groups. These are depicted in Figure 1.6a. The two largest watersheds are Potworks and Big Creek. The Potworks Watershed drains the northern slopes of the south west volcanic region and the Big Creek Watershed drains main parts of the Central Plain to the east and west. Fitches Creek drains into North Sound. Christian Valley, Parham and Bethesda are also important watershed groups. These six watersheds occupy 43 percent of the land area and contain 80 percent of the groundwater supplies and 90 percent of surface water storage. Within these watersheds are found 50 percent of the island's forest land, 90 percent of its crop production, 60 percent of livestock production and 70 percent of the population (Fernandez 1990). In Antigua, all the watersheds are quite short, the largest being not more than 11 km in length. The two largest have areas of 4000 ha and 3,160 ha respectively. Considerable portions of many watersheds are close to the coast and salt water intrusion is a factor in the quality of some surface storage and ground water supplies in many aquifers.

Barbuda has been divided into 10 watersheds as shown in Figure 1.6b. The relatively flat nature of the topography and permeable nature of the soils in Barbuda make surface runoff minimal and surface catchments impractical.

Map 1.6A Location of major watersheds in Antigua (Source: CEP 1991)



Map 1.6B Location of major watersheds in Barbuda. (Source: CEP 1991)



1.3 WATER RESOURCES[24,25,26]:

Antigua and Barbuda has been plagued by severe droughts every 5 – 10 years since recorded history. Therefore, its water resources are regarded as precious. Groundwater sources in Antigua consist of approximately 50 active wells with major well fields. There is also surface water storage in the form of 10 medium to small reservoirs, 550 ponds and earth dams with the combined capacity of 6 Mm^3 (6000 acre-feet/1.6 billion imperial gallons). Most households have cisterns and other water storage containers. Additionally, there are two Desalination Plants located on the northeast coast. However, due to the expensive nature of desalinated water it is prioritized for domestic and tourism sectors, leaving the agricultural sector to fend for itself.

Barbuda's primary source of freshwater is shallow aquifers that underlie 650 ha of sands in the Palmetto Point Area. However, the removal of sand deposits in the Palmetto Area has raised the effective water table by several feet and exposed part of the shallow fresh water aquifer and as a consequence some of the aquifer is drying out. It should also be noted that the sand mining activities have also increased the vulnerability of the island to saline intrusion and impacts of storm surges. Recently, there has been a desalination plant installed in Barbuda to meet the needs of thedomestic and tourism sectors.

[24] Caribbean Conservation Association, Antigua and Barbuda, Country Environmental Profile : (Barbados, 1991), pp 58-72

[25] Environment Division, Integrating Management of Watersheds & Coastal Areas in Small Island Developing States of the Caribbean - National Report for Antigua & Barbuda:(January 2001), p 21 - 24

[26] Environment Division, National Report Implementing Agenda 21 Issues In Antigua & Barbuda: (Jan. 2002) p 2-21

1.4 BIODIVERSITY[27,28,29]:

From the earliest colonial period to the 1960's, the sugar industry dominated the land use patterns of Antigua and resulted in major changes to terrestrial habitats and the island's biodiversity. Nearly three centuries of deforestation and land clearing for intensive agricultural use have resulted in removal or degradation of the original vegetation and lead to habitat destruction and subsequent loss of species richness. Presently, uncontrolled livestock grazing continues to have a detrimental effect on native plant communities. Additionally, intensive tourism development has resulted in major biophysical alterations to the coastline, leading to the destruction of coastal and marine habitats directly affecting the richness of biodiversity residing in these areas.

There are 1158 species from 149 families (Lindsay &Horwith 1997b) of plants found in Antigua and Barbuda. This includes 45 species of ferns and fern allies; 4 species of gymnosperms and 1,109 species of flowering plants.

There are 71 freshwater fish species and 400 marine fish species.

There are only two native species of amphibians; namely a tree frog (*Eleutherodactylusjohnstonei)* and a marine toad (*Bufomarinus).*

Existing are 19 species of terrestrial reptiles, one of which are endangered; namely the Antigua Racer Snake (*Alsophisantillensisantiguae)*. The Iguana delicatissima was also on the endangered list but is now extinct in this country but still exist in neighbouring islands such as Anguilla. The Antigua Racer Snake is the rarest snake in the world, with only about two hundred living. It is found on Bird Island, an island off the coast of Antigua. Antigua and Barbuda has three endangered species of turtles which nest on the beaches, namely the hawksbill, green and leatherback (the loggerhead is known to traverse the waters). Additionally, there are 182 species of birds.

There are approximately 182 species of birds recorded. Two-thirds of the population is migratory leaving 60 residents. There are only two island endemic sub-species: Antigua's broad-winged hawk and Barbuda's Adelaide's warbler.

Bats are the only native terrestrial mammals, with seven species of bats resident in these islands. There are several introduced species of mammal species, for example, the European Fallow deer (endangered) and the Indian mongoose. There are 26 recognized Cetacean (marine mammals) species.

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[27]Caribbean Conservation Association, Antigua and Barbuda, Country Environmental Profile : (Barbados, 1991), pp 74-79

[28]Environment Division, National Report Implementing Agenda 21 Issues In Antigua & Barbuda: (Sept. 2001)

[29] Environment Division, Integrating Management of Watersheds & Coastal Areas in Small Island Developing States of the Caribbean - National Report for Antigua & Barbuda:(January 2001), pp 17 - 18

There is no research available on invertebrates present in these islands.

1.5 CLIMATE[30,31,32,33,34] (TABLE 1.1, GRAPHS 1.1 – 1.4)

Antigua and Barbuda experiences a moderately arid tropical maritime climate. There is a marked wet (July – November) and dry (December – April) season. The average rainfall across the island in the direction of prevailing northeast tradewinds is about 33 inches in the northeast to over 50 inches per year in the southwest. The average rainfall per year is approximately 44 inches. Pan evaporation averages are about 77 inches per year and open water evaporation is estimated at 65 inches per year.

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[30] Antigua and Barbuda Meterological Station, Govt. of Antigua & Barbuda
[31] Caribbean Conservation Association, Antigua and Barbuda, Country Environmental Profile : (Barbados, 1991), pp 9-12
[32] Environment Division, National Report Implementing Agenda 21 Issues In Antigua & Barbuda: (Jan. 2002) p 2-10
[33] Martin Kaye, Reports On the Geology of the Leeward and Virgin Islands West Indies, Antigua: (1959) p 1
[34] Sir William Halcrow and Partners, Climate Section 2.3 -2.4

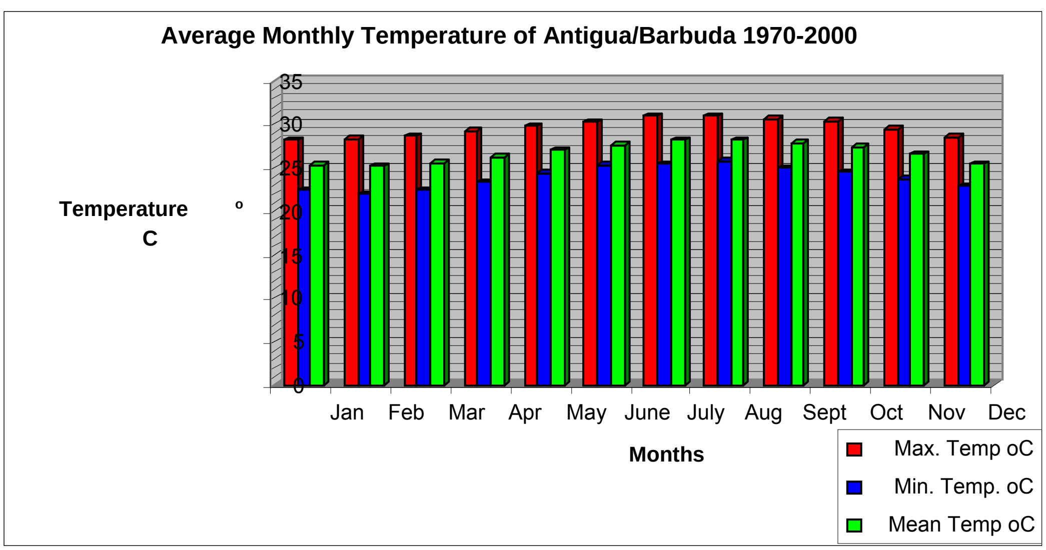
Table 1.1 : Climatological Data for the V.C. Bird International Airport (Station Coordinates 63˚ 43' 51.88" W, 17˚ 08' 15.17" N) over a thirty year period 1970 - 2000

Month	Average Wind Speed	Average Max. Temp °C	Average Min. Temp. °C	Average Mean Temp °C	Average Relative Humidity %	Average Rainfall (mm)
Jan	12.5	28.2	22.4	25.3	77.7	58.3
Feb	12.3	28.3	22.0	25.2	77.2	41.5
Mar	12.1	28.7	22.4	25.5	76.2	46.8
Apr	11.7	29.2	23.3	26.3	77.7	70.3
May	12.0	29.8	24.4	27.0	79.0	107.5
June	13.2	30.3	25.3	27.6	79.0	51.8
July	13.7	30.9	25.4	28.2	79.8	79.0
Aug	12.7	30.9	25.8	28.2	80.2	103.6
Sept	10.6	30.6	25.0	27.8	81.1	150.8
Oct	9.7	30.4	24.5	27.4	81.6	138.7
Nov	10.5	29.5	23.7	26.6	80.0	147.1
Dec	11.6	28.5	22.9	25.4	78.7	93.4

Source: Adapted from the Antigua & Barbuda Meteorology Station

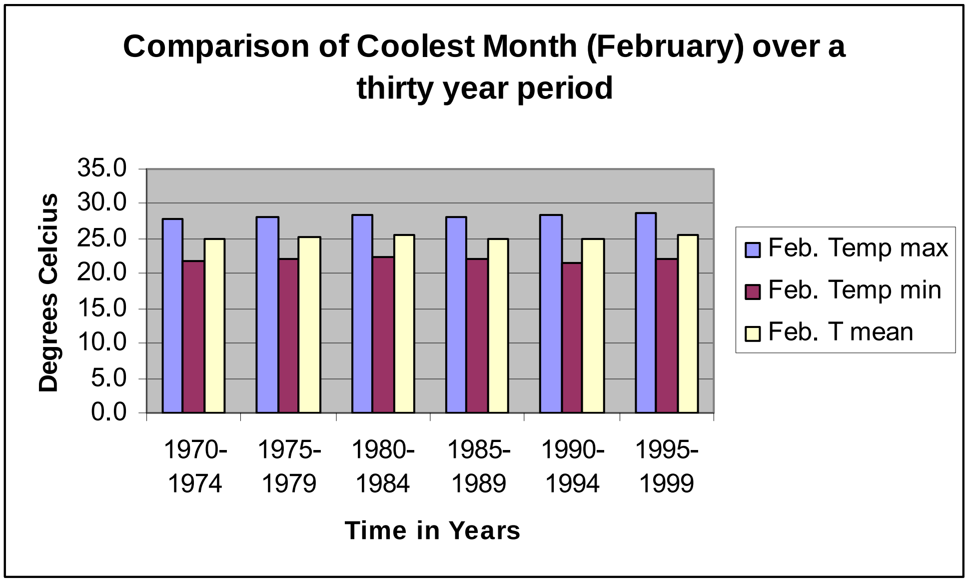
There is little variation in daily seasonal temperatures. Average monthly temperatures are 29.6 °C maximum and 23.9°C minimum (Graph 1.1a). Over a thirty year period, the average temperatures of the coolest month (February Graph 1.1b) and the hottest month (August – Graph 1.1c) were compared but very little change was noted.

Graph 1.1a: Average Monthly Temperature over a thirty year period (1970 – 2000)



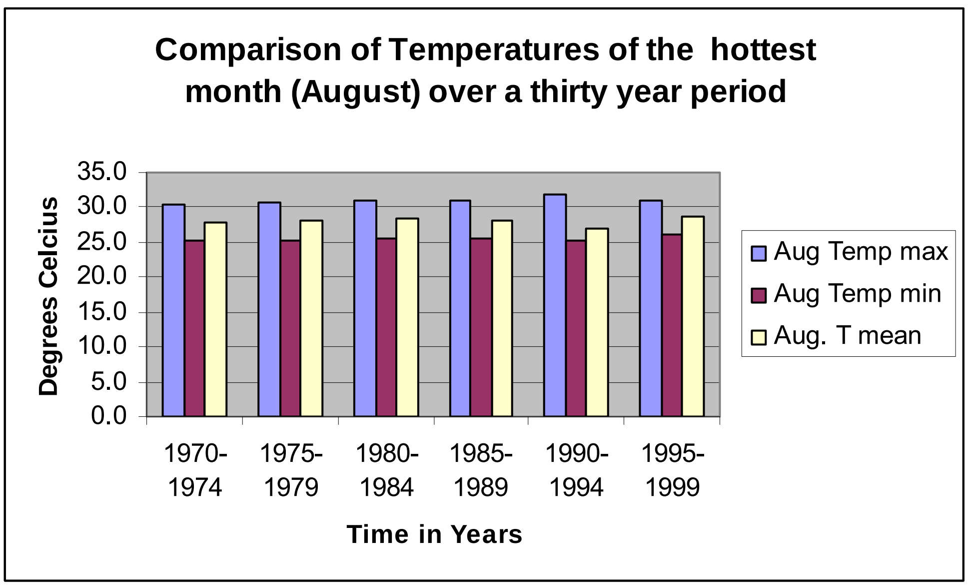
Source: Adapted from the Antigua & Barbuda Meteorology Station

Graph 1.1b Comparison of Average Temperatures of the Coolest Month over a thirty year period



Source: Adapted from the Antigua & Barbuda Meteorology Station

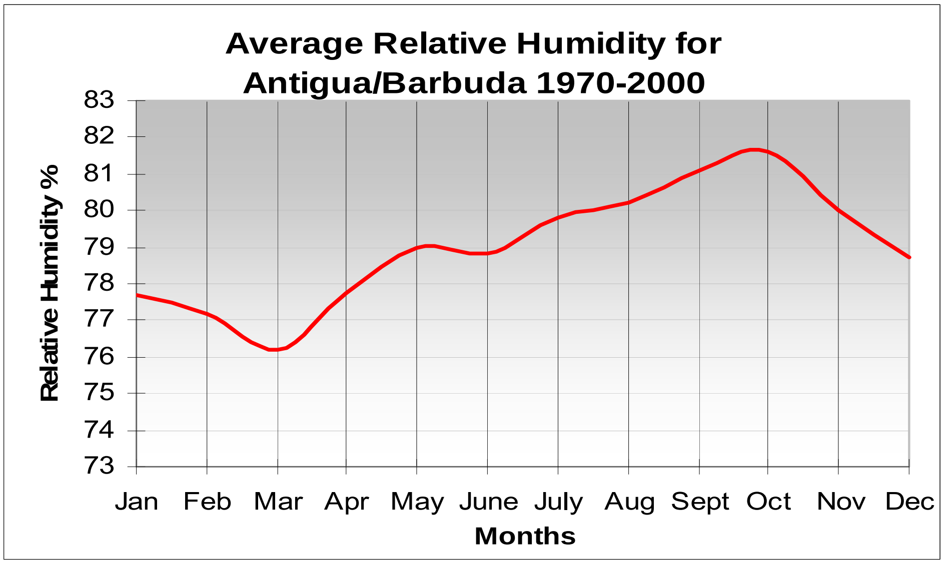
Graph 1.1c Comparison of Average Temperatures of the Hottest Month over a thirty year period



Source: Adapted from the Antigua & Barbuda Meteorology Station

Relative humidity averages lows of 72 – 78% in the mid afternoon to early morning highs of, 81 -85%. Graph 1.2 indicates that September and October are the most humid months and this may be explained by the fact that it is the most active months of the hurricane season. From January to April the humidity is the lowest with March having the least humidity.

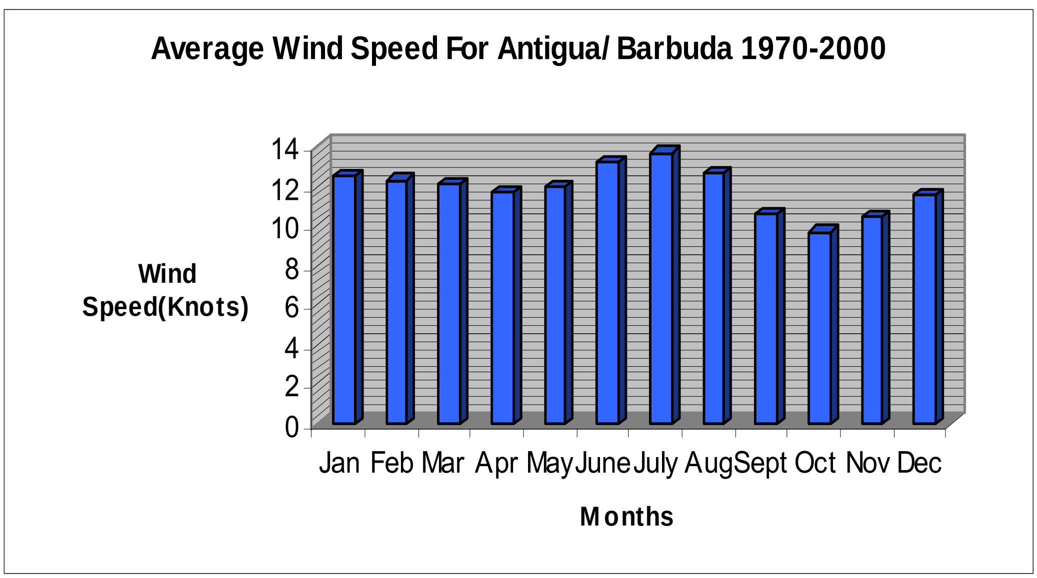
Graph 1.2: Relative Humidity over a thirty year period (1970 – 2000)



Source: Adapted from the Antigua & Barbuda Meteorology Station

Antigua and Barbuda is in the path of the northeast trade winds and is accustomed to fairly steady winds off the Atlantic ranging from northeast to southeast. Monthly average wind speeds are at 11.9 knots (Graph 1.3a). The lowest wind speeds occur from September to November.

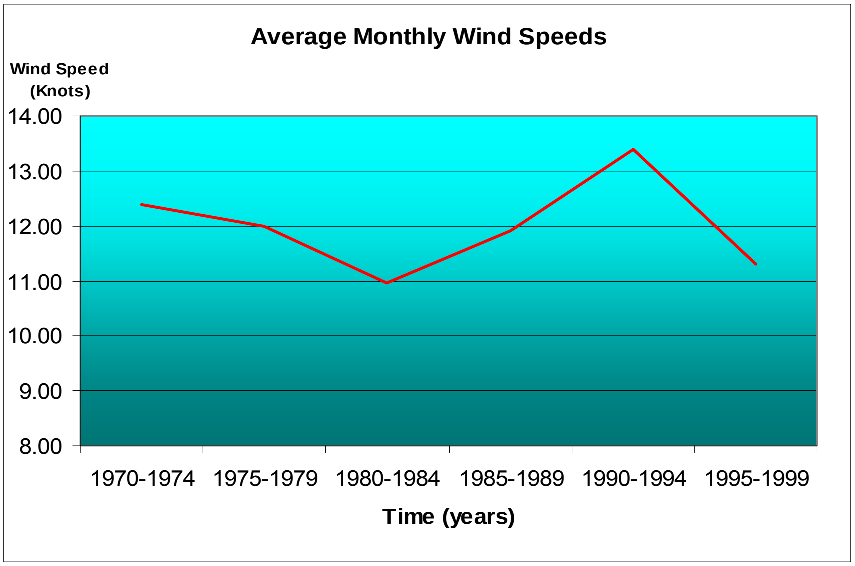
Graph 1.3a: Average Wind Speed over a thirty year period (1970 – 2000)



Source: Adapted from the Antigua & Barbuda Meteorology Station

Graph 1.3 b indicates that the time period of 1990 – 1994 had the highest recorded wind speeds.

Graph 1.3 b: Comparison of Wind Speeds in five year periods over a thirty year time span

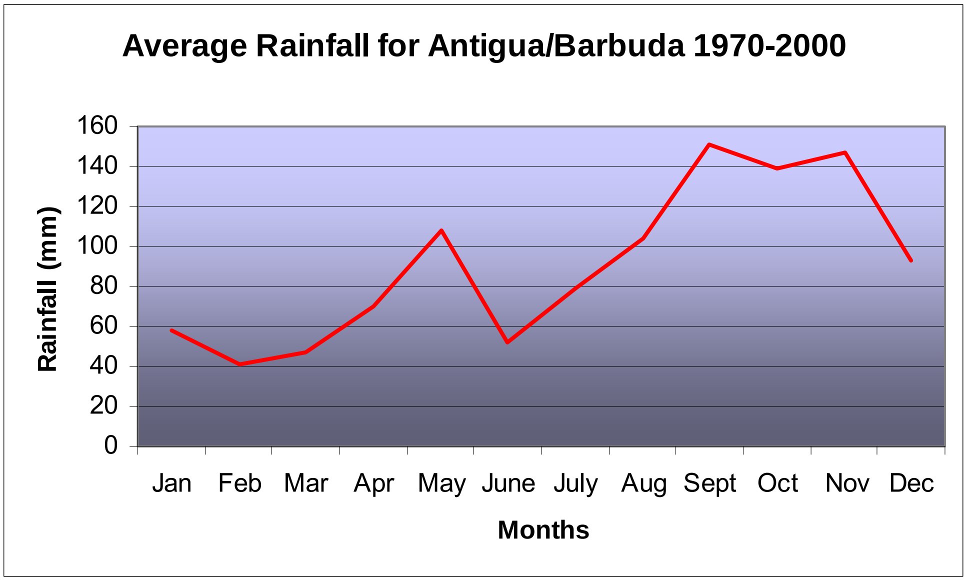


Source: Adapted from the Antigua & Barbuda Meteorology Station

Rainfall tends to be variable, with severe droughts occurring every 5 – 10 years. Evapotranspiration rates are high. During the drought of 1983 – 1985, less than 1000mm of rain occurred over 21 months. All surface reservoirs had dried up and the supply of groundwater produced only $1/6^{th}$ of national demand, water had to be imported from neighboring islands. More recent droughts have been nearly as severe but the availability of desalinized water has made the impact less visible. Antigua has an average monthly rainfall of 90.7 mm and an annual rainfall of 1089 mm (43inches). Barbuda has a lower rainfall average. The following are the years since 1874 which have been recorded as drought years (Source: Antigua & Barbuda Meteorological Station): 1874, 1875, 1882, 1890, 1905, 1910, 1912, 1920, 1921, 1922, 1923, 1925, 1928, 1930, 1939, 1947, 1983/84, 1988, 1993/4, 2001. A drought year occurs when the annual precipitation for that year falls below the mean annual precipitation. Therefore, it can be seen that this twin island state has long been accustomed to insufficient rainfall. Heavy rains after periods of severe droughts lead to removal of top soil, formation and deepening of gullies and general soil erosion. The impact is greatest on land previously cleared for human consumption. The resulting eroded material is in turn deposited downstream causing siltation and further degradation of coastal areas, watercourses, marine and aquatic breeding areas.

Over a thirty year period (1970 – 2000), it was noted that the months of September through to November have the highest records of rainfall (Graph 1.4a). This can be explained as this period coincides with the more active part of the hurricane season.

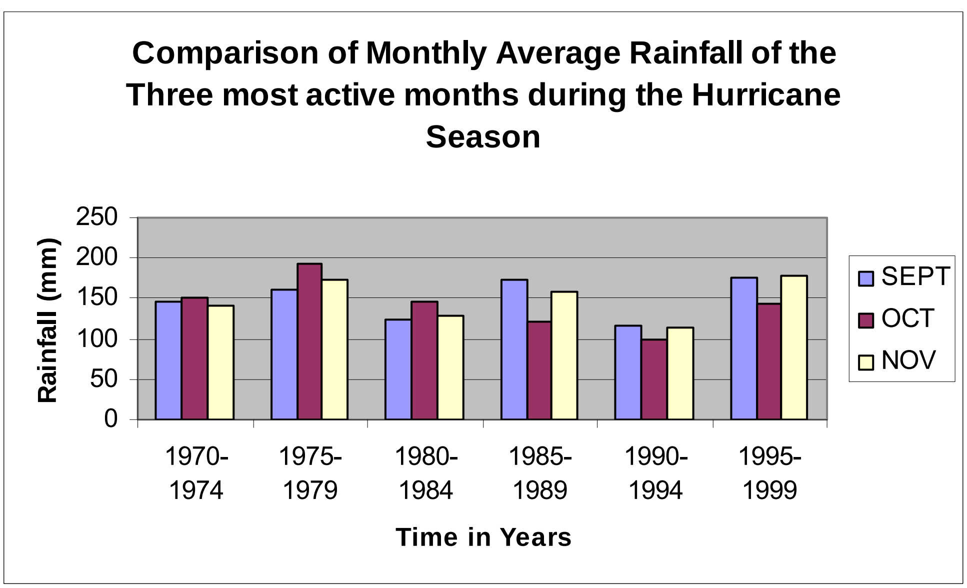
Graph 1.4 a: Average Monthly Rainfall over a thirty year period (1970 – 2000)



Source: Adapted from the Antigua & Barbuda Meteorology Station

Graph 1.4 b shows the comparison of monthly average rainfall of the three most active months of the Hurricane Season. It shows that rainfall levels in each five year period are variable, with the one of the highest levels of rainfall occurring during the 1995 – 1999, a period where several devastating hurricanes hit Antigua.Graph 1.4 c showsthecomparison of the Average Lowest Rainfall Month (February) to the Average Highest

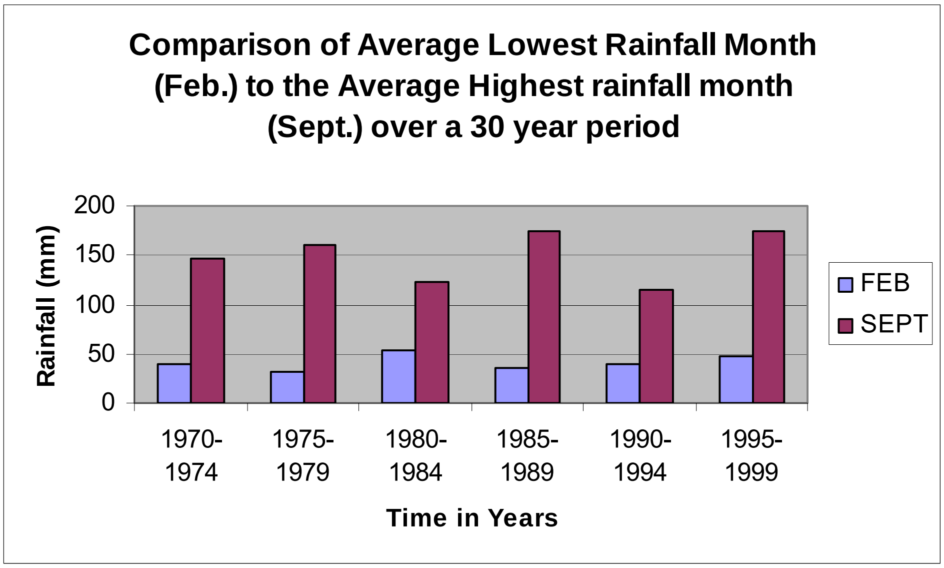
Graph 1.4 b: Comparison of Monthly Average Rainfall of the three most active months of the Hurricane Season



Source: Adapted from the Antigua & Barbuda Meteorology Station

Rainfall Month (September) over a thirty year period. This graph shows that February, the typically driest month had a record high of 54.2 mm of rainfall in 1980-1984 and a record low in 1975-1979 of 31.7 mm. Additionally, September, the wettest month had a record high in both periods of 1976-1979 and 1995-1999 with 174 mm of rainfall and a record low in the period 1990 – 1994 of 115 mm of rainfall.

Graph 1.4 c: Comparison of Average Lowest Rainfall Month (FEB.) to the Average Highest Rainfall Month (SEPT.) over a thirty year period



Source: Adapted from the Antigua & Barbuda Meteorology Station

Tropical Waves, Depressions, Storms and Hurricanes are relatively common in this region.[35,36] These storms form just off the coast of Africa during the Hurricane season (June – November) and usually pass somewhere through the leeward island chain on a north westerly course depending, of course, on the atmospheric conditions. Even if the islands do not receive direct hits the storm surge is usually enough to create significant damage to the coastal regions. Antigua and Barbuda survived a forty- five year reprieve of direct hits by dangerous storms. In 1950, two severe hurricanes stuck these islands in the space of twelve days causing great damage. In 1995, Category 4 Hurricane Luis devastated Antigua on the 4th - 5th Sept. to be followed ten days later by Category 1 Hurricane Marilyn. The damage was in the millions of dollars. The forty-five year reprieve lead to little attention being paid to design standards and the development of known hazardous areas. There was closure and loss of revenue in all major tourism facilities along the coast, 17% decrease in tourist stayover arrivals (Graph 1.5) and 7000 persons were left unemployed. The total cost of damages was EC$ 346.54 million or 30.49% of the GDP at factor cost in 1994. In 1998, Category 2 Hurricane Georges struck Antigua

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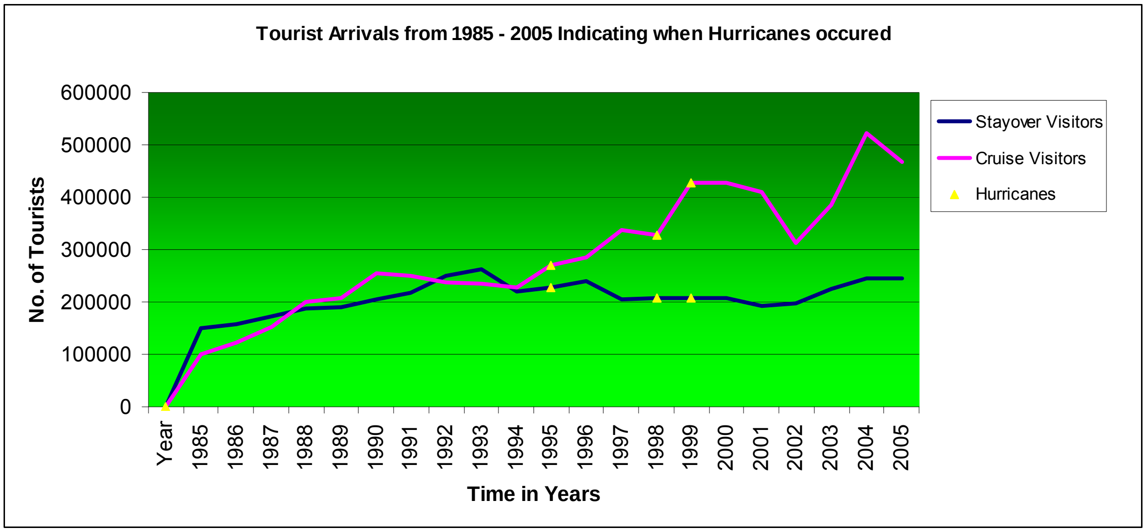
[35] National Office of Disaster Services, Govt. of Antigua & Barbuda

[36] Cordell Weston, Hurricane the Greatest Storm on Earth, (Antigua Archives Committee) pp 4-8

and Barbuda causing damage estimated at EC$200 million. In 1999, Category 2 Jose hit Antigua in October and Hurricane / Tropical Storm Lenny hit in November, the combined estimated damage was EC$ 247.43 million.

Graph 1.5: Tourist Arrivals from 1985 – 2005 indicating when Hurricanes occurred



Graph 1.5[37,38,39,40,41,42,43,44,45] illustrates that the tourism industry, in terms of the numbers of stay over tourist visiting Antigua and Barbuda only began to recover in 2005.

The number of cruise ship arrivals was not as affected since accommodations were not required and it was less expensive for the supporting tourist related activities to get off the ground again than for the hotels to be rebuilt. Additionally, the mobility of cruise ships and hence their flexible routes allows them to avoid storm warning zones and impacted destinations where the level of damage has compromised excursion facilities. Also note in Graph 1.5, the sudden drop off in both stay over and cruise visitors that occurred just after the 9/11 Terror attacks.

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[37] OAS- Dept. of Regional Development, The Revitalization of Downtown St. John's, Antigua & Barbuda – Street Infrastructure Improvements: pp 65-79

[38] CICERO, Developing Strategies for Climate Change: (Report 2000:2) p 16

[39] Caribbean Tourism Organization, Caribbean Tourism Statistical Report; (1998) pp101-104

[40] Ministry of Tourism, Govt. of Antigua & Barbuda

[41] "Cruise Passenger Arrivals 1990 – 1999", Caribbean Tourism Organization, http://www.onecaribbean.org/

[42] "Historical Data on Tourist Arrivals to the Caribbean 1991 -2001", Caribbean Tourism Organization, http://www.onecaribbean.org/

[43] Sharon Ann Thomas, The Development of Plans and Policies Toward the Preservation of the Historic Urban Core of St. John's, Antigua: (1991) pp 24 - 26

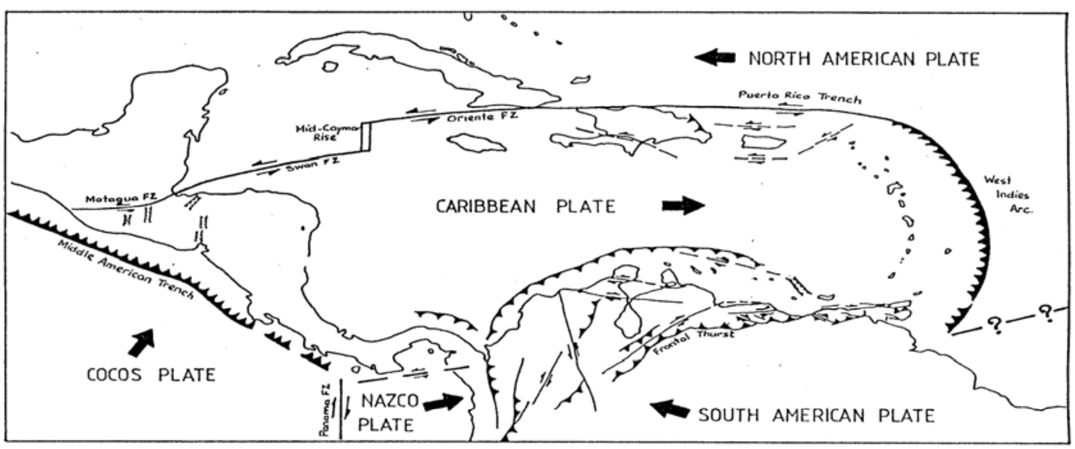
[44] "Antigua and Barbuda: Selected Tourism Statistics, 2001-05", IMF, ww.**imf**.org

[45] Caribbean Conservation Association, Antigua and Barbuda, Country Environmental Profile : (Barbados, 1991), pp 111 – 117

1.6 *SEISMIC ACTIVITY*[46]

Although seismic activity does not fall within the ambit of direct climate change events, small islands, like Antigua and Barbuda, are mindful of the fact that climate influenced events sea level rise and coastal erosion can be further enhanced in the short term by singular seismic episodes and other natural hazards. “Seismic events in the Eastern Caribbean are principally associated with a subduction zone at the junction of the Caribbean Plate and the North American Plate. The North American Plate dips from east to west beneath the Caribbean Plate along a north-south line just east of the main island arc. This leads to a moderate level of inter-plate seismicity. Superimposed on this is a pattern of intra-plate activity. There is a concentration of such activity in the Leeward Islands where the subduction of the Barracuda Rise imposes additional stresses on both the "subducted" North American Plate and the overriding Caribbean Plate.” (Source Natural Hazards of the Caribbean, Tony Gibbs – Director CEP) (Map 1.7). The most recent severe earthquake occurred on Oct. 8th 1974. It measured 6.7 on the Richter scale. The estimated cost of damage was EC$10 - $15million. Damage to the oil refinery caused a pollution hazard.

Map 1.7: Tectonic Setting of the Caribbean Region



Tectonic Setting of the Caribbean
(after Molnar and Sykes, 1969)

[46] National Office of Disaster Services, Govt. of Antigua & Barbuda

1.7 SOCIO-ECONOMIC ENVIRONMENT

1.7.1 HISTORICAL BACKGROUND[47,48,49,50,51,52,53,54]:

During the last Ice Age (Pleistocene 1.8 M – 10,000 BC), sea levels were 300 ft lower than they are today and at that time Antigua and Barbuda was one large island mass. At the end of the Ice Age and the warming of the earth (Holocene Period ca. 10,000 BC) the sea levels began to rise and continue to do so creating a 28 mile separation of water between the islands, as seen in present times.

The first settlements were known to be made by the Archaic Age people of Antigua, who have been incorrectly called the Siboney. They caught and ate birds, land crabs, fish, shell fish and sea turtles and occupied the islands for 3000 years. Over 75 Archaic Age sites have been identified on Antigua, the oldest site dating back to 3,106 BC at Little Deep in Mill Reef and the latest site dating back to 1,378 BC located at Deep Bay. In Barbuda, there was a settlement dating back to 1,875 BC at River Site. The Archaic age came to an end at 300 BC with the arrival of the advanced Ceramic Age Arawak. The Arawaks were peace loving people and frequently came under attack by the more aggressive Caribs who ranged all over the Caribbean.

On his second voyage in September 1493, Christopher Columbus sighted Antigua from the Southwest. He named the island after the shrine of the virgin Santa Maria la Antigua found in the Cathedral in Seville, Spain. The first English colonist were dependent on the Amerindian crops such as corn, cassava and sweet potato and also the cash crops tobacco, cotton, ginger and indigo. Sugar cultivation soon became the alternative cash crop. By 1675, the small farmers of tobacco, ginger, indigo were replaced by large scale sugar production. By the mid 1700's, Antigua was largely deforested and sugar was grown. Because sugar production was labour intensive; a large labour force was needed. These labour requirements lead to the grand scale escalation of slavery in the Caribbean and African slaves were imported by the thousands to work on the sugar plantations (Picture 1.4).

Modern Antigua and Barbuda achieved its full independent status in 1981.Antigua and Barbuda is a constitutional monarchy with a British-style parliamentary system of government. The head of state is an appointed Governor General who represents the reigning British monarch. The government has three branches, which are the

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[47] Antigua and Barbuda Museum Exhibit
[48] Environment Division, National Report Implementing Agenda 21 Issues In Antigua & Barbuda: (Jan. 2002) p 2-11
[49] "The Government System" www.ag.gov.ag
[50] Caribbean Conservation Association, Antigua and Barbuda, Country Environmental Profile : (Barbados, 1991), pp 22-25
[51] Environment Division, Integrating Management of Watersheds & Coastal Areas in Small Island Developing States of the Caribbean - National Report for Antigua & Barbuda:(January 2001), p 10
[52] Environment Division, Antigua & Barbuda National Report on Actions to Combat Desertification, April 22nd 2000
[53] Antigua 1959 & 1960, p 55
[54] Antigua 1959 & 1960 – Colony Biennial Report

Legislative, the Executive and the Judicial Branch. The Legislative Branch consists of the House of Representatives and the Senate. The House of Representatives has seventeen members and is responsible for introducing legislation. The seventeen member Senate reviews and gives assent to proposed legislation. The members of the House of Representatives are elected by popular vote (constitutionally mandated every five years, while the members of the Senate are appointed. The Governor General appoints the members of the Senate. Eleven of the members of the Senate are appointed under the advice of the Prime Minister, who is the leader of the party that holds the majority of support of members in the House of Representatives.One of the eleven must be a native Barbudan. Four members of the Senate are appointed under the advice of the leader of the Opposition who is recognized constitutionally, one member of the Senate is appointed under the advice of the Barbuda Council, and one member of the Senate is appointed as an independent member representing business at the sole discretion of the Governor General.

The Executive Branch is derived from the Legislative Branch. This branch consists of the Cabinet headed by the Prime Minister. The members of Cabinet are appointed by the Prime Minister and must be members of either the House of Representative or the Senate. The Judicial Branch is independent of the other two branches, with judges and appeal court judges appointed by an independent judicial commission as part of a sub-regional judiciary serving all the members of the O.E.C.S. The magistrates will shortly be appointed by this regional commission replacing the present arrangement of their appointment by the Attorney General who is a member of the Executive Branch. The judiciary consists of the Magistrates Court for minor offences and the High Court for major offences. Beyond the High Court is the Eastern Caribbean States Supreme Court, whose members are appointed by the OECS. The final court of appeal for Antigua and Barbuda is the Judicial Committee of the Privy Council, located in London. However, the Caribbean Court of Justice has been proposed to replace the Judicial Committee of the Privy Council as the final court of appeal. The Court was created in 2003 under the 2001 Revised Treaty ofChaguaramasof the Caribbean Community (CARICOM). The treaty is an instrument for the establishment of the Caribbean (CARICOM) Single Market and Economy (CSME) and was signed by the various CARICOM heads of government.

Antigua and Barbuda is a member of the United Nations, the Commonwealth of Nations, the Caribbean Community, the Organisation of Eastern Caribbean States, the Organization of American States, the World Trade Organization and the Eastern Caribbean's Regional Security System.

Antigua and Barbuda is also party to several Conventions apart from the UN framework on Convention Climate Change (UNFCCC) and its Kyoto Protocol. These conventions are the United Nations Conventions to Combat Desertification (UNCCD), the Convention on Biological Diversity (CBD), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Vienna Convention and its Montreal Protocol on

Substances which deplete the Ozone Layer and the Basal Convention on the Transboundary Movements of Hazardous Wastes.

1.7.2 DEMOGRAPHIC BACKGROUND[55,56]:

In 2001, when the last census was conducted Antigua and Barbuda had a combined population of 76,886 people, 47% male and 53% female. Individually, Antigua had 75,561 people and Barbuda had 1,325 people in 2001. The National Statistics Office conducts national censuses every ten years, however, they have projected that in 2007, Antigua and Barbuda should have a combined population of 84,330 people (9.7% more than the 2001 population).

The population has definitely grown since the last Census in 1991. In the 1991 Census, there was a population of 65,000 persons and as mentioned previously the 2001 Census showed a population of 76,886, which would indicate an annual growth rate of 1.0.

In Antigua, most of the population can be found in the city of St. John's.
St. John's City also has the highest population density of 8,431, even though it occupies the smallest land area of 2.90 sq. miles. Barbuda has the least number of people in the largest land area. There are significantly less people who live in the parishes outside of St. John's. This most likely has occurred because people like to live close to their workplaces and also to areas of entertainment.

The age structure of the population is as follows; 9.4% of the people are between 0 – 4 years, 18.8% of the people are 5 – 14 years of age, 49.4% of people are 15 – 44 years, 15.% of the population are 45 – 64 years of age and 6.9% of the people are over 64 years.

The 2001 Census showed that the predominant ethnicity is of African decent (91%) (Pie Chart 1.1. Additionally, 92% of the population claim to be Christian. Also, in 2001, 69% of the population originated from Antigua and Barbuda but 25% originated from other Caribbean islands.

1.7.3 SOCIAL INDICATORS:

Antigua and Barbuda has a Labour Force of 45,260 people. More people are working in the Tourism sector and Tourist related services, than any other sector. The Construction sector also has a high level of workers which would correlate with the increase of the contribution to the GDP by this sector. Also, as expected, Agriculture has one of the lowest numbers of workers,

[55] National Statistics Division, Govt. of Antigua & Barbuda
[56] National Statistics Division, Census 2001, Govt. of Antigua & Barbuda

1.7.3.1 Poverty Estimates[57]:

The indigent population was estimated at 5% of the population, constituting 4.4% of the households in the country. An indigent person was defined as someone whose expenditure was below EC$2449 (US$917) per annum, since this amount should provide an adult male with 2400 kilocalories per day.The Poverty Line was estimated at EC$6318 (US$2366) per annum (adjustments made for non-food expenditure). 18.4% of the population fell below the poverty line, indicating that 18.4% of the population is unable to meet basic needs. However, it is customary to include into the poverty line, the percentage of vulnerable persons, that is, persons who are likely to be at risk of falling into poverty if there is a shock to the economy, which may occur with climate change.

Therefore, it is estimated that the cumulative total of 28.3% of the population is estimated to be at risk. These results are amongst the lower range when compared to other Caribbean countries.

1.7.3.2 Level of Health Care[58,59]:

Antigua has one main public hospital with 164 beds which is struggling to meet the growing demands of the public. Barbuda also has one public hospital. However, the addition of public primary care clinics in many of the villages around the island, are helping with the load of patients requiring assistance. Antigua also has four private clinics that are able to hospitalize patients and at least two other outpatient clinics that can provide X-rays, MRIs and Cat Scans at a cost. There are many private doctors and specialist in a wide variety of fields. Many medical laboratories exist that can carry out a large number of diagnostic test and the option to ship samples to specialized laboratories overseas is always readily available. The variety of health care available to Antiguans and Barbudans has enabled this country to have a reasonable life expectancy rate. The life expectance rate for males is 72 years and for females 74 years.

Please see Graphs 1.7 a – e indicating ten top causes of death in the period 2000 – 2004. The data on these charts indicate that for that five year period the top two causes of death were Malignant Neoplasms and Heart Diseases.

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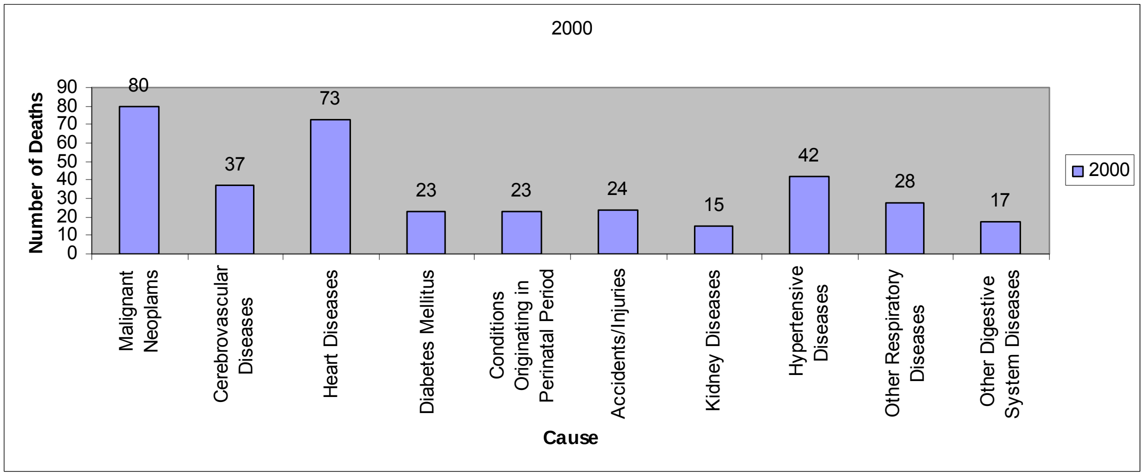
[57] Social Development, Draft Report on the Country Poverty Assessment (2006): Govt. of Antigua & Barbudapp 1 -13

[58] Health Information Division, Ministry of Health, Govt. of Antigua & Barbuda

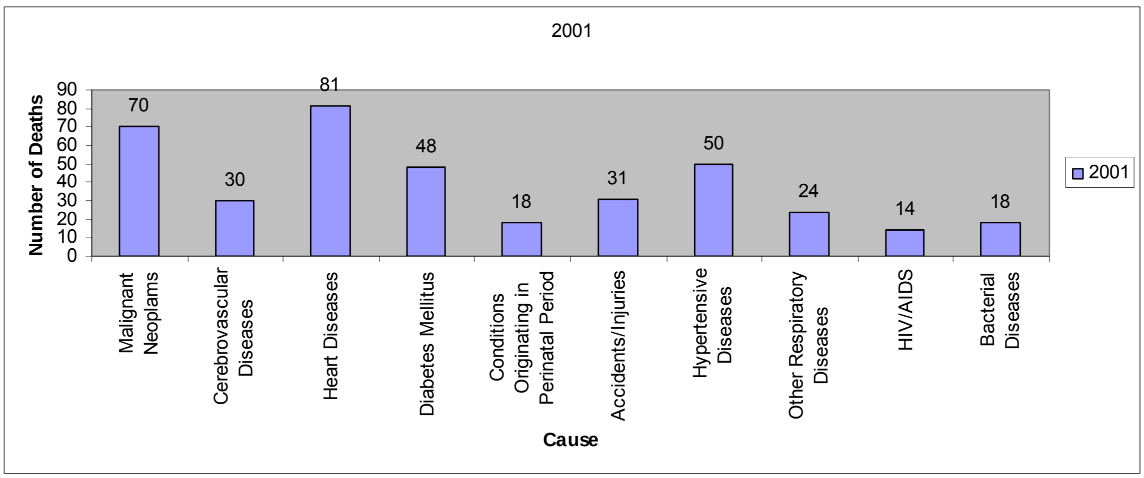
[59] National Statistics Division, Govt. of Antigua & Barbuda

Graph 1.7a: Ten Top Causes of Death in the year 2000 (See Optional Graph 1.7 in accompanying doc.)



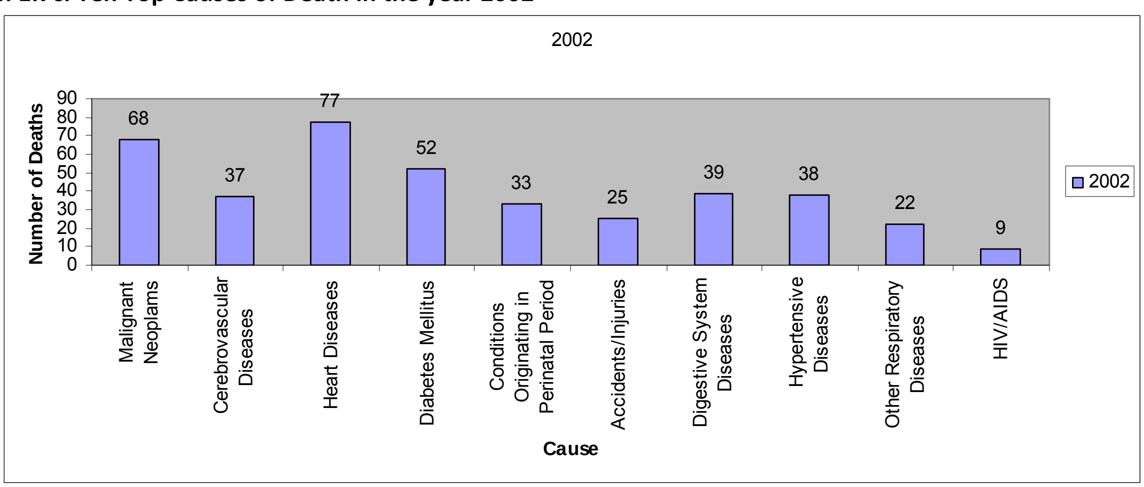
Source: Health Information Division

Graph 1.7b: Ten Top Causes of Death in the year 2001



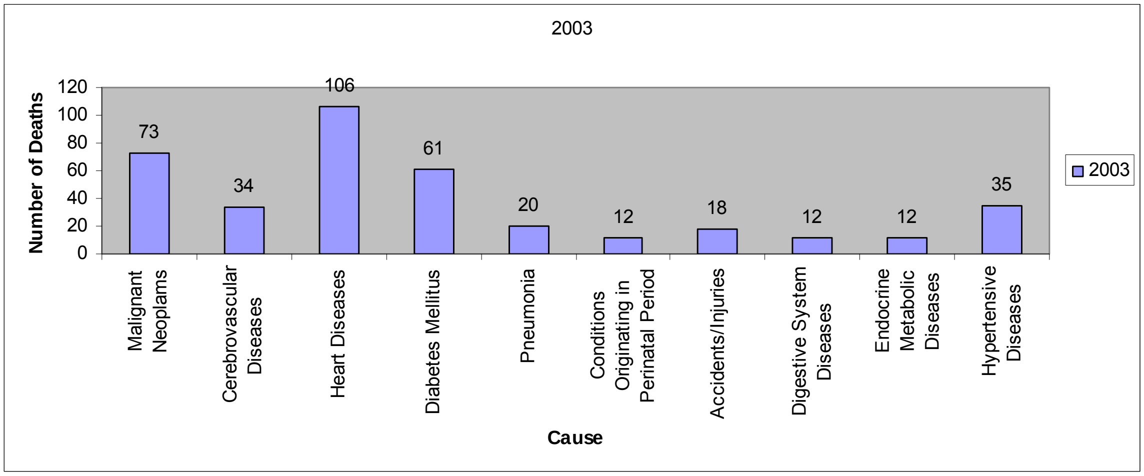
Source: Health Information Division

Graph 1.7c: Ten Top Causes of Death in the year 2002



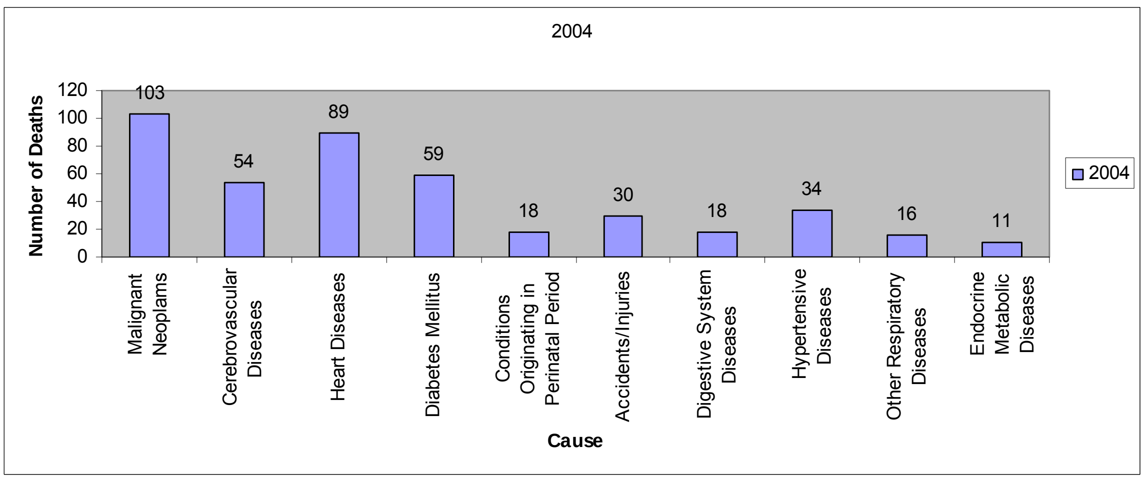
Source: Health Information Division

Graph 1.7d: Ten Top Causes of Death in the year 2003



Source: Health Information Division

Graph 1.7e: Ten Top Causes of Death in the year 2004



Source: Health Information Division

1.7.4 Education[60,61,62,63]:

The second Millenium Development Goal (MDG) of the United Nations is to achieve Universal Primary Education or more specifically, "to ensure that by 2015 all children (both boys and girls) will be able to complete a full course of primary schooling". Primary or elementary education consists of the first years of formal, structured education that occur during childhood. Within the Caribbean universal free and compulsory primary education is nearly achieved by all countries, but with a marked gender performance gap in favor of girls. In Antigua and Barbuda, this was found to be the case in that primary education is both free and compulsory. In 2005, out of the 974 children that passed the Common Entrance Exam (exam taken at the end of the primary

[60] National Statistics Division, Govt. of Antigua & Barbuda
[61] Ministry of Education, Govt. of Antigua & Barbuda
[62] "Education", http://portal.unesco.org/education
[63] "Antigua & Barbuda, Background", www.unicef.org/infobycountry

education) 57% were girls and 43% were boys, indicating that there is a slightly better performance of girls.

1.7.5 Economic Growth[64,65,66,67,68]

In 2005, Antigua and Barbuda had a GDP of US$ 874.9 million, with a growth rate of 7.07 and an inflation rate of 2.10. The economy of Antigua and Barbuda is service based. Tourism and government services represent the key sources of employment and income (Table 1.10). Tourism accounted for more than half of the GDP in 2005 and is also the principle earner of foreign exchange. However, the tourism industry is vulnerable to environmental factors such as violent Hurricanes which are expected to increase in intensity and occurrence because of climate change. When Antigua and Barbuda experienced several devastating hurricanes from 1995 – 1999, the economic growth rate plummeted (Table 1.9). In 2001, the tragic September 11th terrorist attack kept most would be tourist at home for fear of further attacks. However, the growth rate seems to be on an upward swing again. Efforts to diversify the economy by encouraging growth in transportation, communications, internet gambling and financial services may have acted as a catalyst to the renewed economic growth.

Provisional data provided by the ECCB (Eastern Caribbean Central Bank) indicates that the real GDP in Antigua and Barbuda has increased by 11.5% in 2006, following a 5.3% expansion in 2005. Growth was driven by vibrant activity in the construction sector and also in the tourism industry in preparation for the 2007 Cricket World Cup. The upturn in the tourism industry contributed to the improved performances in the transport and wholesale and retail sectors. The consumer price index was virtually unchanged during 2006. According to the ECCB, the construction sector expanded by 35.0% in 2006. Construction growth increased because of improved activity in the public and private sectors. Major public sector projects included the Sir Vivian Richards Stadium, road works and infrastructural development in the area of the stadium in preparation for Cricket World Cup (CWC) 2007. Private sector activity focused on residential housing and on building and renovating hotels, villas ad other tourist facilities. Activity in the tourism industry, as proxied by value-added in the hotels and restaurants sector, increased by 4.0% in 2006, in contrast to a 1.1% decline in 2005. The expansion in construction and tourism activity generated spill over effects in some of the other service sectors, which provided stimulus for growth. The wholesale and retail trade sector grew by 15.0%, far above the 3.2 % recorded in 2005. The transport sector

[64] ECCB, "Annual Economic and Financial Review" , 1995 – 2006
[65] ECCB, "Economic and Financial Review" March 2007
[66] National Statistics Division, Govt. of Antigua & Barbuda
[67] Antigua Hotels & Tourist Association

[68] The CIA World Factbook, U.S. Department of State, Area Handbook of the US Library of Congress

expanded by 10.6% in 2006, after contacting by 1.5%. Value-added in the banking and insurance, and communications sectors grew by 5.7% and 5.0% respectively.

Insurance rates from property to health have increased globally due the negative effects of climate change such as flood damage, hurricane damage to property and land, storm surge damage to coasts and increased temperatures leading to a variety of problems, for example, health problems such as hyperthermia in both humans and animals which can be fatal. In the case of insurance for properties, this recorded over 500% increase since 1999. It is expected that this will become a serious impediment to investments and the financial sector in a few short years.

Agriculture at one time was one of the major contributors to the GDP because of large scale sugar production along with its by-products, molasses and rum. Several factors caused its decline namely the shrinking international market, inadequate water (severe droughts), destructive hurricanes and the inability of the sector to lure labour forces away from the tourism sector which proved more immediately lucrative. However, some agriculture production still occurs. There are less than 300 acres of sea island cotton under production. The major crops produced are vegetables, food crops, vine fruits and tree fruits. The Local Antigua Black Pineapple is one of the tourist favorites. The market for most agricultural products is domestic. Livestock production (5000 cattle, 28,000 goats, 15,000 sheep)[69] is difficult because of severe droughts and low international market value of the animals even though they are organically grown. Owners have taken to allowing their animals to stray unimpeded. This practice has lead to severe environmental damage; goats have debarked and destroyed trees on hill sides and sheep have overgrazed. The combined effects have lead to land slippage and loss of top soil during heavy rains.

Fisheries make the greatest contribution to the agricultural sector (51%) with its Lobster and fish exports. Barbuda depends significantly on its fishery sector as a source of income.

Communications is also a notable direct and indirect contributor to the GDP. In the 90's, there was a significant increase in offshore business in Antigua; including off-shore gaming and betting, benefiting from the high quality telecommunications and internet services available.[70] Since the late 80's, the telephone service was upgraded from old "switching" technology (analogue) to a more modern digital system DMS 100 (Antigua & Barbuda was one of the few Caribbean islands with updated telecommunications at that time). Investments were maintained and many upgrades were installed over the years to keep the telecommunications system up to date; for example the Centrex system. The local telecommunications company APUA (Antigua Public Utilities Authority), in consultation with Cable & Wireless, installed fiber optic cables underground island wide

[69] Veterinary & Livestock Division, Ministry of Agriculture, Govt. of Antigua & Barbuda, June 2007

[70] Environment Division, Integrating Management of Watersheds & Coastal Areas in Small Island Developing States of the Caribbean - National Report for Antigua & Barbuda:(January 2001), p 14

encased in conduits. Although, the major hurricanes of the mid to late 90's destroyed much of the telephone wiring above ground, the major network cables were unharmed being buried. Once the wiring above ground was replaced, the telecommunications system was up and running. The increase in the number and intensity of storms that is expected with climate change is a motivating factor to bury as many cables as possible but at this stage it would be more expensive to bury even more cables than to replace above ground cables annually.

Manufacturing is declining partly due to high cost of production(mainly labour utilities and high port and shipping charges), small local market and intense regional and international competition. Most of the raw materials for manufacturing have to be imported. However, paints, furniture, household fitting and garments are still manufactured along with soft drinks, water rum, and a nascent cottage agro processing sub sector.

Table 1.11: Percentage Contribution Gross Domestic Product by Economic Activity at Basic Prices in Current Prices

Source: The Statistics Division and the ECCB

Sector	1997	1998	1999	2000	2001	2002	2003	2004	2005
Agriculture	4.11	3.97	3.95	3.93	3.80	3.79	3.77	3.69	3.62
Mining & Quarrying	1.68	1.72	1.72	1.72	1.69	1.71	1.72	1.42	1.68
Manufacturing	2.22	2.24	2.26	2.26	2.26	2.30	2.32	2.14	2.02
Electricity & Water	3.18	2.57	3.16	2.98	3.87	3.11	2.93	2.88	2.93
Construction	11.10	11.77	12.24	12.80	13.36	13.84	14.11	13.85	16.23
Wholesale & Retail Trade	10.64	10.77	10.76	10.92	10.43	10.13	10.27	10.10	9.93
Hotels & Restaurants	13.33	12.13	11.99	11.48	10.16	9.52	10.03	10.06	9.85
Transport	12.92	12.45	12.10	12.13	11.68	11.69	12.44	13.75	12.83
Communications	7.92	8.14	9.00	8.39	8.48	8.35	8.10	7.91	7.98
Banks & Insurance	9.46	9.90	9.30	9.34	8.85	9.77	9.19	9.46	8.95
Real Estate & Housing	6.76	6.77	6.81	6.99	7.12	7.30	7.33	7.27	7.16
Government Services	16.91	18.45	17.52	17.45	17.39	18.03	17.73	17.42	16.75
Other Services	7.46	7.38	7.39	7.59	7.36	7.55	7.33	7.26	7.05
Less Imputed Service Charge	7.68	8.25	8.19	7.97	6.45	7.09	7.28	7.19	6.98

Source: National Statistics Office and the ECCB

1.8 INSTITUTIONAL ARRANGEMENTS FOR CLIMATE CHANGE

15 years ago the responsibilities for implementation of the UNFCCC initially resided within the Office of the Prime Minister. The then day-to-day management and coordination of these responsibilities rested with a Project Coordinator appointed on a contractual basis and reporting directly to the Permanent Secretary. These arrangements changed in 2005 when the Environment Division became the technical agency for the implementation of the provisions of the Convention. The Ministry of Foreign Affairs specifically the Permanent Mission to the UN still remains as the Focal point.

The Initial National Communication (INC) which is a requirement of the UNFCCC, was implemented by a consultant with technical guidance from a steering committee. The committee comprised representatives from many of the government agencies involved in various aspects of work related to climate change. Agencies involved in the steering committee included the Meteorological Office, the Antigua Public Utilities Authority (APUA), the National Office of Disaster Services (NODS), the Environment Division, the Fisheries Division, the Ministry of Planning, Director of Statistics, as well as the Environmental Awareness Group (an NGO).

Internationally funded projects such as the GEF and others were initially implemented in an ad hoc manner. This approach evolved further after the implementation of the now completed Caribbean Planning for Adaptation to Climate Change (CPACC) project, and its successor projects. This project was one of the largest regional projects of the GEF for climate change and at the national level was implemented by the Fisheries Division within the Ministry of Agriculture. The project achieved important strides in building capacity for climate change through various workshops and the development of a draft policy for management of climate change impacts. Further the project established equipment for data collection at the national level and an informal regional network of technicians to analyze the data as it became available.

The institutional capacity at the national level was further improved with the participation of most of these same technicians in meetings held under the auspices of the UNFCCC. These regional and international linkages offered opportunities for cooperation in project implementation (for example through use of common consultants), have fostered the use of tried and tested best practices, and allowed for development of harmonized or common regional positions on climate change issues.

These initial steps towards the institutionalization of the UNFCCC were still ad hoc and needed further commitment by the Government. With the increase in awareness, and better national understanding of the conventions the Government took steps to improve the institutional arrangements for the implementation of the provisions of the convention at the national level. These steps included the establishment of a coordinating mechanism for all conventions including the UNFCCC, the building the capacity of the GEF responses at the National level and finally in 2010 the establishment of an Energy Desk that is tasked to address the sector that is the greatest emitter of green house gas.

In terms of coordination with other environmental conventions, the Climate Change Coordinator has participated in, and on several occasions provided written and oral reports to, the National Coordinating Mechanism (NCM) on Environmental Conventions coordinated by the Environment Division. Representatives of the Fisheries Division have also participated in the proceedings of the NCM.

International negotiations and attendance at meetings is the responsibility of the Environment Division, the Metrological Office (focal point for the IPCC) and the Ministry of Foreign Affairs (New York Mission). Technical meetings/Workshops are usually attended by agencies that will be directly impacted on the issues being discussed.

These initial listed here for the institutional arrangements for Climate Change are fully expected to evolve into a more robust approach to implementation of the commitment of this convention. It is expected that the evolution will result in the production of a national climate change policy and enabling legislation and institutional support for its implementation. There is already a draft Climate Change Strategy, an output of the MACC project, but this is yet to be finalized and adopted by the Cabinet.

The energy desk was formed in 2010 and has been task with the mandate to provide the Cabinet with an energy policy and legislation for its adoption by the end of 2011. The draft energy policy has been presented to the Cabinet and is under consideration by the same. The desk consists of a director and an engineer and several administrative staff. Since its inception it has received national recognition and support from the population and the private sector alike. It is anticipated that the energy policy will be adopted by the end of 2011.

The Ministry of Foreign affairs, which is within the Prime Minister's Ministry, is the focal point for the UNFCCC. The negotiations for the convention is coordinated from Antigua and Barbuda's representative, Dr. John Ashe, who is based in the UN offices in New York. This Ministry takes all policy decisions and negotiating positions for this convention.

Other agencies that participate in the international and national work of the convention are the Environment Division, The Meteorological Office, and the Fisheries Division. There are other agencies that are involved from time to time.

The Environment Division has been charged with the responsibility of assistingthe Ministry of Foreign Affairs with the climate change negotiations, access funding from the GEF and other sources and to monitor the implementation of plans and programs to facilitate reporting to the Convention and coordinate the implementing obligations.

CHAPTER 2

NATIONAL INVENTORY OF GREENHOUSE GASES FOR ANTIGUA AND BARBUDA

CHAPTER 2

NATIONAL INVENTORY OF GREENHOUSE GASES FOR ANTIGUA AND BARBUDA

2.1 CHAPTER SUMMARY

In accordance with Articles 4 and 12 of the UNFCCC, the Government of Antigua and Barbuda has compiled a GHG emissions inventory for the year 2000 as part of its Second National Communication. Although this report was also expected to update the GHG emissions inventory (for the year 1994) it was not possible as the baseline data was not available.

Antigua and Barbuda is not a producer of primary fossil fuels. Imported fossil fuels are used primarily for electricity generation and transport. The industrial sector is minimal and made up primarily of the food and beverage industry and asphalt production. In the agriculture sector, GHG emission sources are limited to domestic livestock and agricultural soils subsectors. The forest cover of Antigua and Barbuda is limited since most of the original forests were cleared to establish the sugar plantations during the early colonial settlement of the islands. Additionally, this island state is relatively dry and flat, therefore, lush tropical rainforests are not common. In the waste sector, GHG emissions are limited to methane from solid waste disposal sites and to indirect nitrous oxide emissions from human waste.

A summary of the GHG inventory for 2000 is shown in Table 2.1. National emissions in 2000 were carbon dioxide 383 Gg, methane 6.60 Gg, nitrous oxide 0.16 Gg and hydrofluorocarbons 0.0037 Gg. The uncertainty in the overall estimate was 40%.

Gaps in the activity data required for the inventory arose mainly because records were not maintained for sufficient periods and in some cases because of statistics were not compiled. Agencies are now aware of the shortfalls and are prepared to take steps to establish record keeping protocols and to compile and maintain records.

Table 2.1 : SUMMARY OF ANTIGUA & BARBUDA GREENHOUSE GAS EMISSIONS AND REMOVALS (Gg) FOR 2000

GHG SOURCE AND SINK CATEGORIES	CO_2	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs
	Emissions	Removals							
Total National Emissions and Removals	**383**	**0**	**6.6**	**0.159**	**2.3**	**11.9**	**2.7**	**2.8**	**0.0037**
1 Energy (Reference Approa	**412**								
(Sectoral Approa	**371**		**0**	**0.003**	**2.3**	**11.9**	**2.3**	**2.8**	
A Fuel Combustion	371		0	0.003	2.3	11.9	2.2		
B Fugitive Emissions from Fuels	0		0		0.0	0.0	0.0	0.0	
2 Industrial Processes	**0**		**0.0**	**0.000**	**0.0**	**0.0**	**0.4**	**0.0**	**0.0037**
3 Solvent and Other Product Use	**0**			**0.000**			**0.0**		
4 Agriculture			**1.1**	**0.152**	**0.0**	**0.0**			
5 Land-Use Change & Forestry	**11**	**0**	**0.0**	**0.000**	**0.0**	**0.0**			
6 Waste			**5.4**	**0.004**					
7 Other (None)	**0**	**0**	**0.0**	**0.000**	**0.0**	**0.0**	**0.0**	**0.0**	
Memo Items:									
International Bunkers	**199**		**0.0**	**0.006**	**0.7**	**0.0**	**0.0**	**0.0**	
Aviation	199		0	0	0.7	0	0	0	
Marine	0		0	0	0	0	0	0	
CO_2**Emissions from Biomass**	**0**								

2.2 INTRODUCTION

The Government of Antigua and Barbuda, a Non-Annex 1 party to the United Nations Framework Convention on Climate Change (UNFCCC) is providing an emissions inventory of greenhouse gases (GHG) for the year 2000 in accordance with the Inter-Governmental Panel on Climate Change (IPCC) and in compliance with Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCC).

This report describes the methodologies used and the analysis and interpretation of the GHG emissions inventory for the year 2000 for Antigua and Barbuda's Second National Communication (SNC). Unfortunately, sufficiently detailed records of the information used to compile the 1994 GHG inventory for the Initial National Communication (INC) were not available to allow an update of the 1994 inventory.

The IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories: Volume 1 – Reporting Instructions, Volume 2 – Workbook and Volume 3 – Reference Manual along with the accompanying software were used to carry out the necessary calculations and to compile the GHG emissions and removals. *IPCC Good Practice Guidance* complementary to the *Revised 1996 IPCC Guidelines* was used to update emission factors or other default conversion factors where sufficient data were available. In an effort to ensure that sufficient data is compiled and available for future inventories a cross-section of technicians from a number of agencies were trained in accordance with IPCC Revised 1996 Guidelines. It is expected that through the coordination of the Technical Focal Point that these technicians will routinely compile the necessary data. This should therefore ensure a full and reliable dataset for future inventory reviews.

The gases included in the inventory are the direct GHGs namely Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), and partially fluorinated hydrocarbons (HFCs) and the indirect GHGs - Non-Methane Volatile Organic Compounds (NMVOC), Carbon Monoxide (CO), Sulphur Dioxide (SO_2) and Nitrogen Oxides (NO_x).

The sectors considered in this inventory, according to the IPCC guidelines are the following: Energy, Industrial, Agriculture, Land Use with Forestry and Waste. In accordance with the Guidelines set out by the IPCC, CO_2 emissions from International Bunkers and burning of biomass are not included in the national totals, but are reported separately as Memo Items in the Inventory.

2.3 ENERGY SECTOR

Antigua and Barbuda is not a producer of primary fossil fuels. A very small refinery (5,000 barrels/day) operated for part of 2000 to produce a small amount of secondary products. The islands are therefore dependent on the importation of fossil fuels which are used primarily for electricity generation and transport.

For the Energy Sector, GHG emissions are estimated using both the Reference Approach (based on import data) and the sectoral approach (based on consumption). Energy sector activities in Antigua and Barbuda are almost exclusively due to fuel combustion. Fugitive emissions (e.g., from primary and secondary fossil fuel production) are negligible and arise from the small refining activity and the distribution of fuels.

2.3.1. Methodology

Country-specific energy sector activity data were provided by the following agencies and businesses:

- West Indies Oil Company (WIOC) provided information on the quantities of liquefied petroleum gas (LPG), motor gasoline, diesel, jet fuel and fuel imports and sales to commercial and residential customers.
- Antigua Public Utilities Authority (APUA) provided fuel consumption data for electricity generation including that from Antigua Power Company (APC).
- Statistics Division, Government of Antigua and Barbuda provided import data for fossil fuels and products.
- Two of the five local marinas provided data on the purchase and sales of fuel.
- Data on wood and charcoal consumption were obtained from surveys of all known wood-burning bakeries and all known charcoal producers.

Default values for emission and conversion factors from the Revised 1996 IPCC Workbook were used.

2.3.2. CO_2 Emissions

CO_2emissions estimated by the sectoral and reference approaches are summarized in Table 2-1. The discrepancy between the sectoral and reference approaches is relatively large and is due to the unavailability of information on the disposition of crude oil imports. Import data were obtained from two sources (WIOC and Statistics Division) and there were significant discrepancies (up to 20%) in the amounts reported and also in the range of fuels reported. Where there were common fuels reported, data from WIOC were used since there were also data for consumption (assumed to be equal to sales) from WIOC. The CO_2 emissions from energy industries (electricity generation) and transport account for 47.7% of the CO_2 emissions while the residential and commercial sectors respectively account for 1.5 and 2%.

2.3.3. Non-CO_2 Emissions

The non-CO_2emissions are summarized in Table 2-2. The sectoral contributions are similar to those for CO_2.

Table 2-1 Summary of Antigua and Barbuda CO2 Emissions in 2000 for the Sectoral and Reference Approaches

	Sectoral Approach		Reference Approach
Sector	**Gg (CO_2)**	**%**	**Gg (CO_2)**
Total Energy	371		412
Energy Industries	177	47.7%	
Manufacturing Industries & Construction	0.00	-	
Transport (Road)	182	49.1%	
Commercial/ Institutional	5.52	1.49%	
Residential Sector	7.36	1.98%	
Agriculture, Forestry; Fishing (Mobile)	0.00	-	
Total	**371**	**100.0%**	**412**
Memo Items: International Aviation Bunkers	199	-	-

Table 2-2 Summary of Antigua and Barbuda Non- CO2 Emissions in 2000

Non- CO_2 from Fuel Combustion by Source Categories (Gg)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Total National Emissions and Removals						
1 Energy	**0.04**	**0.00**	**2.27**	**11.85**	**2.28**	**2.75**
A Fuel Combustion (Sectoral Approach)	0.04	0.00	2.27	11.85	2.24	2.74
1 Energy Industries	0.01	0.00	0.47	0.04	0.01	2.45
2 Manufacturing Industries and Construction	0.00	0.00	0.00	0.00	0.00	0.00
3 Transport	0.03	0.00	1.78	11.79	2.23	0.29
4 Other Sectors	0.00	0.00	0.02	0.03	0.00	0.00
5 Other (please specify)	0.00	0.00	0.00	0.00	0.00	0.00
B Fugitive Emissions from Fuels	0.00	0.00	0.00	0.00	0.04	0.01
1 Solid Fuels	0.00	0.00	0.00	0.00	0.00	0.00
2 Oil and Natural Gas	0.00	0.00	0.00	0.00	0.04	0.01

2.4 INDUSTRIAL SECTOR

The industrial sector in Antigua & Barbuda is minimal and no data were available for the fuels used in the few industries that are present. Because of the limited industrial activity carbon dioxide emissions are negligible.

Data were available to estimate NMVOC emissions from the Food and Beverage Industry and asphalt production and HFC emissions from refrigeration and air-conditioning units.

2.4.1. Methodology

Country-specific activity data were provided by the following agencies and businesses:

- Asphalt production data from the Antigua & Barbuda Hotmix Asphalt Plant, Ministry of Works.
- Alcoholic beverage production from local rum and beer manufacturers.
- Bread and cake production from local bakeries and flour importers.
- Meat and poultry production from the Veterinary & Livestock Division, Ministry of Agriculture.
- Fish production from the Fisheries Division, Ministry of Agriculture.
- Imports of refrigerators and air conditioning units from the Statistics Division, Government of Antigua and Barbuda
- Local suppliers of refrigerator and air conditioning equipment provided information on the estimated charge of HFCs in refrigerators and air conditioning units.

Default values for NMVOC emission factors were used from the Revised 1996 IPCC Workbook and the Tier 1 method was used to estimate HFC emissions.

2.4.2. Non-CO_2 Emissions

The non-CO_2 emissions are summarized in Table 2-3.

Table 2-3 Summary of Antigua and Barbuda Non-CO2 Emissions in 2000

Sector	Gas	Emissions (Gg)
Asphalt used in road paving	NMVOC	0.00056
Alcoholic beverage production	NMVOC	0.03
Bread and other food production	NMVOC	0.39
Refrigeration and air conditioning units	HFCs	3.68

2.5 AGRICULTURE SECTOR

In the agriculture sector, GHG emission sources are limited to the Domestic Livestock and Agricultural Soils subsectors. The other three subsectors normally considered; Rice Cultivation (flooded Rice Fields), Prescribed Burning of Savannahs and Field Burning of Agricultural Residues, were excluded because they are not present or applicable to Antigua and Barbuda.

The GHGs released from the agriculture sector are methane (CH_4) and nitrous oxide (N_2O) from enteric fermentation and manure management and N_2O from agricultural soils, direct soil emissions from animal production and indirect emissions from nitrogen fertilizers.

2.5.1. Methodology

Country-specific activity data were obtained from the following agencies. The Veterinary & Livestock Division provided accurate census data for each of the livestock species and the Statistics Division provided information on fertilizer imports in the year 2000.

Default values for the emission factors for enteric fermentation and manure management were obtained from the Revised IPCC 1996 Workbooks and values for Nitrogen Excretion (kg/head/yr) and the Fraction of Manure Nitrogen per Animal Waste Management System (Latin American Figures) were obtained from the Revised 1996 IPCC Reference Manual.

2.5.2. Methane and Nitrous Oxide Emissions

The CH_4 and N_2O emissions from the agriculture sector are summarized in Table 2-4.

Table 2-4 Summary of Antigua and Barbuda CH4 and N2O Emissions from the Agriculture Sector in 2000

	N_2O	CH_4
Subsector	(Gg)	(Gg)
Domestic Livestock	-	1.13
Direct emissions from Agricultural Soils	0.02	-
Direct soil emissions from animal production	0.08	-
Indirect emissions for atmospheric deposition of NH_3 and NO_X	0.01	-
Indirect emissions from Nitrogen used in agriculture	0.15	-
Total	**0.26**	**1.13**

2.6 LAND-USE CHANGE AND FORESTRY SECTOR

The forest cover of Antigua and Barbuda is limited since most of the original forests were cleared to establish the sugar plantations during the early colonial settlement of the islands. It was reported in the Initial National Communication that the total forest area was 13.45 kilohectares (kha) and consisted of Moist Tropical Forest (2.2 kha), Dry Tropical Forest (10.75 kha) and Mangroves (0.50 kha). At that time it was also reported that open savannah accounted for about 10 hectares and non-forest trees numbered about 12,000.

Data sourced from the Food and Agricultural Organisation (FAO) and the World Bank, indicated that in 2000, Antigua and Barbuda had 9 kha of total forest cover. The data also indicated that out of the 44 kha of land; 4% (1.76 kha) was forests, 19% (8.36 kha) shrub lands, savannah and grasslands, 40% (17.6 kha) cropland and crop/natural vegetation, 1% (0.44 kha) sparse or barren vegetation and 35% (15.4 kha) wetlands and water bodies and 0.4% (0.176 kha) urban or built up areas.

The most recent locally available data, from the Forestry Division, Ministry of Agriculture, are data for 2003. These data indicate that Antigua has a forest cover of 5.60 kha consisting of 0.52 kha of Cactus Scrub, 1.09 kha of Deciduous Seasonal Forests, 0.57 kha of Evergreen Seasonal Forests, 0.044 kha of Littoral Woodland, 0.44 kha of Mangroves, 1.52 kha of Semi Evergreen, 1.09 kha of Thorn and 0.33 kha of Citronella. The data does not include Barbuda.

2.6.1. Methodology

Activity data in terms of types of forest cover and area (hectares) of forested landmass were obtained from the Forestry Division, Government of Antigua and Barbuda. These data were mapped into the IPCC categories consistent with the 1990 data.

Calcium oxide (lime) import data were obtained from the Statistic Division, Government of Antigua & Barbuda.

IPCC default values for conversion and emission factors as they relate to carbon fraction, biomass before and after conversion/expansion and fraction of biomass oxidized were used. The 1990 data along with the 2003 data were used to estimate the area converted annually.

2.6.2. CO_2 Emissions / Removals

The estimated emissions and removals for the Forestry Sector are indicated in Table 2-5.

2.6.3. Non-CO_2 Emissions:

Negligible burning takes place hence there are no emissions of CH_4, CO, N_2O or NO.

Table 2-5 Summary Report for Land Use Change and Forestry CO2 Emissions and Removals

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CO_2
	Emissions (Gg)	Removals (Gg)
Land-Use Change & Forestry	**11.2**	**0**
A Changes in Forest and Other Woody Biomass Stocks	0	-45.8
B Forest and Grassland Conversion	57.0	0
C Abandonment of Managed Lands	0	0
D CO_2 Emissions and Removals from Soil	0	0
E Other (please specify)	0	0

2.7 WASTE SECTOR

In the Waste Sector, GHG emissions are limited to CH_4 from solid waste disposal sites and to indirect N_2O emissions from human waste.

Since 1995, solid waste has been managed by the National Solid Waste Management Authority (NSWMA) which a Statutory Board under the Ministry of Health.

The NSWMA is responsible for the management of the only sanitary landfill in Antigua – the Cooks Sanitary Landfill in St. John's. Records for the classification and weights of solid waste placed in this landfill have been available only since 2005. Earlier data (i.e., for 2000) were assumed to be the same as for 2005. There are small unmanaged waste disposal sites in rural areas on Antigua and a site in Barbuda but the amounts of waste disposed of in these sites are unknown but were assumed to be negligible.

There are no municipal sewage and wastewater treatment facilities in Antigua and Barbuda. Most private residences have a septic tank, from which sewage is removed at appropriate intervals (every few years) and taken to the Cooks Sanitary Landfill. Some private residences have a pit latrine. Hotels and some commercial enterprises have their own micro sewage treatment facilities, but again no records are kept as to amounts of sewage entering the facilities. The practice of applying sewage to soil may be regarded as non-existent.

2.7.1. Methodology

Country-specific activity data for municipal solid waste disposal were obtained from the National Solid Waste Management Authority (NSWMA).

The per capita protein consumption (kg/person/yr) was obtained from the FAO year book at http://www.fao.org/statistics/yearbook/vol_1_1/pdf/d01.pdf and population data were obtained from the Statistics Division

The following IPCC default factors were used: the fraction of nitrogen in protein (to estimate the emissions of N_2O from Human Sewage); the methane correction factor, fraction of carbon which degrades, the fraction of DOC in MSW (Central America), and the fraction of carbon released as methane (for the estimation of methane emissions from solid waste disposal systems).

2.7.2. CH_4 Emissions

The net annual methane emissions from solid waste disposal were estimated at 5.6 Gg.

2.7.3. Indirect Nitrous Oxide Emissions from Human Sewage:

Nitrous oxide emissions from human sewage were estimated to be negligible (0.01 Gg) in the year 2000.

2.8 UNCERTAINTIES

Uncertainties in the inventory arise from both emission factors and the activity data. Since default emission factors were used throughout the inventory their uncertainties are those recommended in Table A1-1 of the IPCC Reference Manual Volume 1.

Uncertainties in the activity data were due mainly to the unavailability of data either because records were not maintained or not compiled at all. The factors that lead to uncertainties in the activity data in the various sectors are discussed in the following sections.

2.8.1. Energy

Although fuel import data were available for two sources in neither case were data for all fuels recorded and there were discrepancies in the amounts recorded for some fuels. Record for the disposition crude oil imported (i.e., refinery production) were not available and this accounted for most of the difference between the CO_2emissions estimated using the reference and sectoral approaches. Although small quantities of peat were imported it was assumed that none of it was burned and hence all imported peat was allocated as stored in products. It was assumed that 50% of lubricants imported were used in transportation. This is because no data were available to indicate otherwise.

End use consumption data for diesel and to lesser extent gasoline were not compiled hence allocation of fuel used for road transport and at marinas could not be reliably estimated. In the case of diesel fuel accurate data for the amount used in electricity production are available and accounted for about 27% of the total consumption. The remainder was allocated to road transportation since the amounts used at marinas and for other purposes (boilers or standby diesel generators was unknown and were assumed to be small.

Data for fuel use in the domestic aviation (between Antigua and Barbuda) were not available due to changes in management and loss of data. The wood and charcoal data was determined from interviewing all known wood burning bakeries and charcoal producers.

2.8.2. Uncertainties: Industrial Sector – Non-CO_2 Emissions

The factors below contribute to the uncertainties in estimating the NMVOC and HFC emissions:

- Since production data were not available from local bakeries estimates were made based on flour imports
- Compound-specific import data for bulk halocarbons were not available so estimates were based on a Tier 1 approach

2.8.3. Uncertainties: Agriculture

The factors below contribute to a degree of uncertainty in estimating the methane emissions from the Agriculture sector.

- It was assumed that the nitrogenous based fertilizer imports in 2000 were the same as consumption
- There were reliable census data for cattle, sheep, goats and poultry but expert judgement was used to estimate data for horses, donkeys and swine.
- It was assumed that 100% of poultry and swine are raised in a pen and that 100% of ruminants (cattle, sheep, and goats) and equine (horses, mules/asses) are reared in pastures. The uncertainties in these assumptions are considered low.

2.8.4. Uncertainties: Land Use And Land Use Change

The Forestry Division lost many of its experts who had gathered forestry data extensively over the years. There are no longer any managed forest lands and data with regards to abandonment of managed lands are not available. The change in forest cover between 1990 and 2003 was assumed to be to grassland or settlements.

There is considerable uncertainty (estimated at +/-50%) in the available data for the amount of charcoal produced and the amount of wood used by wood-oven bakeries.

Biomass burned on site or off-site was assumed to be negligible.

2.8.5. Uncertainties: Waste Sector

1.8.1.1 Methane Emissions

The following factors contribute to the uncertainties in activity data used to estimate the methane emissions from municipal solid waste (MSW) disposal:

- Reliable MSW data have been available only since 2005 hence the MSW disposed in 2000 was estimated by scaling the 2005 data by the ratio of the population in 2000. The annual amounts of MSW should be available in the future.

- There are no MSW data available from Barbuda and because of the small population (~1,300 persons); emissions for Barbuda were considered negligible.

In Antigua and Barbuda, there are no national wastewater and sludge handling facilities and hence no useful information is available.

1.8.1.2 Nitrous Oxide Emissions

The four factors below contribute to a degree of uncertainty in estimating the Nitrous Oxide emissions:

  - There are no national Sewage and wastewater treatment facilities or regulations that require submission of data and hence no information on wastewater treatment is available.
  - The amount of sewage derived nitrogen applied to soils as sewage sludge could not be determined, as no records for this exist.

1.8.2 Overall Uncertainties

The uncertainties in the emission inventory are summarised in Table 2-6.

1.8.2.1 Table 2-6 Uncertainties in the Antigua and Barbuda Emissions Inventory for 2000

	Sector	IPCC Source Category	Gas	CO_2eq Gg	U_E %	U_A %	U_T %
1.A.1	Energy	CO_2Emissions from Stationary Combustion (Liquid-A)	CO_2	177	7	10	12
1A.3	Energy	CO_2Mobile Combustion: Road Vehicles	CO_2	182.0	7	15	17
1A.4	Energy	Other Sectors: Residential CO2	CO_2	7.4	7	25	26
1A.4	Energy	Other Sectors: Commercial CO2	CO_2	5.5	7	15	17
5A	LULUCF	Forest and Grassland Conversion	CO_2	57.0	50	25	56
5B	LULUCF	Changes in Forest and Other Woody biomass stocks	CO_2	-45.8	50	15	52
1A.1	Energy	CH_4 (Non-CO2) Emissions from Stationary Combustion	CH_4	0.1	50	20	54
1A.3	Energy	CH_4 Mobile Combustion: Road Vehicles	CH_4	0.7	50	20	54
1A.4	Energy	Other Sectors: Residential CH4	CH_4	0.024	50	20	54
1A.4	Energy	Other Sectors: Commercial CH4	CH_4	0.018	50	20	54
1B.2	Energy	CH_4 Fugitive Emissions from Oil and gas Operations	CH_4	0.009	50	25	56
4.A	Agriculture	CH_4 Emissions from Enteric Fermentation in Domestic Livestock	CH_4	22.7	20	20	28
4.B	Agriculture	CH_4 Emissions from Manure Management	CH_4	1.0	30	20	36

6.A	Waste	CH_4 Emissions from Solid Waste Disposal Sites	CH_4	113.9	45	15	47
1.A.1	Energy	N_2O (Non-CO2) Emissions from Stationary Combustion	N_2O	0.4	170	20	171
1.A.3	Energy	N_2O Mobile Combustion: Road Vehicles	N_2O	0.5	170	20	171
1.A.4	Energy	Other Sectors: Residential N_2O	N_2O	0.02	200	20	201
1.A.4	Energy	Other Sectors: Commercial N_2O	N_2O	0.0	200	20	201
4.D	Agriculture	N_2O (Direct and Indirect) Emissions from Agricultural Soils	N_2O	47.0	500	10	500
6.B	Waste	N_2O Emissions from Wastewater Handling	N_2O	1.3	5	20	21
2.F	Industrial Processes	HFC Emissions from Substitutes for Ozone Depleting Substances	HFCs	43.1	25	25	35
	ALL	**Total**		**43682**			**40.4**

CO_2eqCO_2 equivalent; U_E Uncertainty in emission factor; U_A Uncertainty in activity; U_T Total uncertainty

2.9 RECOMMENDATIONS

2.9.1. Energy

The Customs and Statistics Division should be encouraged to accurately record and summarise import data for all fuels and all other petroleum based products.

Fuel consumptions by end use and type of fuel needs to be recorded to allow the determination of fuels used not only for electricity production but also for road transport, marinas, domestic air travel, international bunkers and industry.

2.9.2. Industrial Sector Non-CO2 Emissions

The Customs and Statistics Division should be encouraged to record the following information:

- Compound-specific quantities (to distinguish between HFCs, HCFCs etc.) of halocarbons imported. This will also allow end-use information (e.g., for refrigeration, air conditioning, fire extinguishers/fire suppression, aerosols etc.) to be derived.

2.9.3. Land Use and Forestry

Land use data needs to be updated and maintained so that allocation among land use categories and the changes in these categories over time can be made. The Government of Antigua and Barbuda is currently seeking to develop a National Physical Development Plan which should address this short coming.

2.9.4. Waste Sector

It is recommended that before sewage is dumped at the Cooks Landfill, it should be weighed and recorded.

2.10 CONCLUSION

Antigua and Barbuda is not a producer of primary fossil fuels. Imported fossil fuels are used primarily for electricity generation and transport. The industrial sector is minimal and made up primarily of the Food and Beverage Industry and Asphalt production. In the agriculture sector, greenhouse gas emission sources are limited to mainly domestic livestock and agricultural soils subsectors. The forest cover of Antigua and Barbuda is limited since most of the original forests were cleared to establish the sugar plantations during the early colonial settlement of the islands. Additionally, this island state is relatively dry and flat, therefore, lush tropical rainforest are not common. In the waste sector, greenhouse gas emissions are limited to methane from solid waste disposal sites and to indirect nitrous oxide emissions from human waste.

The main findings for the GHG inventory are as follows: the total emissions for the direct GHGs are $CO_2$383 Gg, CH_4 6.60 Gg, N_2O 0.16 Gg and HFCs 3.68 Gg. For the indirect GHGs the total emissions were NMVOCs 2.70 Gg, CO 11.85 Gg, $SO_2$2.75 Gg and NOx 2.27 Gg.

The uncertainties in the emissions estimates for the direct GHGs are 54% for $CO_2$and CH_4, 235% for N_2O and 35% for HFCs. Taking into account the Global Warming Potentials (GWPs), the total emissions were 570 Gg and the overall uncertainty in theinventory is 35%.

CHAPTER 3 GREENHOUSE GAS MITIGATION ASSESSMENT

3.1 Approach

The mitigation assessment is a national-level analysis of the impacts of various technologies and practices that affect greenhouse gas emissions. The assessment provides policy makers with an evaluation of those technologies and practices that can a) affect GHG emissions, b) identify policies and programs that could enhance their adoption and c) contribute to national development objectives.

This mitigation assessment should be followed by more detailed evaluation of specific policies, programs, or projects designed to encourage implementation of selected technologies and practices.

The scope of this assessment covers projections of GHGs for the period 2009 to 2030 and uses historical data for the period 2000 (the base year) to 2008 in order to calibrate where feasible, the bases for the projections. Three scenarios are developed to project emissions – a Reference Scenario and two other scenarios (Scenario 2 and Scenario 3) characterised primarily by increasingly aggressive mitigation measures. The Reference Scenario only includes activities and projects that are currently under way and does not include any additional GHG mitigation.

The other scenarios describe various possible and plausible energy use and development strategies and activities that are required to satisfy the demand for energy based on population growth and national development goals. Various mitigation options (technologies and measures that can affect GHG emissions) are included in these scenarios.

3.2 GHG EMISSIONS AND MITIGATION OPPORTUNITIES

The potential opportunities for reductions in Antigua and Barbuda's GHG emissions can be determined by examination of the GHG emission inventory. The GHG emissions for 2000 (see Table 3-3) show that CO2 dominated the emissions (383 Gg) most (~97%) of which were from the energy sector. Emissions of methane (CH4) were 6.6 Gg or 139 Gg CO2 equivalents (CO2e) when the global warming potential for CH4 is taken into account. Most (82%) of the CH4 emissions are from the waste sector (landfills) and the remainder from agriculture. In view of the dominance of GHG emissions from the energy and waste sectors mitigation opportunities will be examined for these sectors.

3.2.1 ENERGY SECTOR RESOURCE PROFILE

Antigua and Barbuda has no known primary petroleum or coal reserves and imports all of its petroleum requirements. Solar and wind energy resources have been estimated at 47 MW and 900 MW respectively[5]. Use of solar energy is negligible (water heaters). A very small refinery (5,000 barrels/day) operated for part of 2000 to produce a small amount of secondary products. There is limited use of wood and charcoal for domestic use (cooking) and wood for commercial use (bakeries). Heavy fuel oil and diesel oil are used to produce electricity. Other petroleum fuels imported are liquefied petroleum gas (LPG) used for domestic cooking and in commercial establishments, gasoline for transportation and diesel for transportation and industrial use. The CO2 emissions in 2000 from the energy sector (see Table 3-4) show that emissions from energy industries (electricity generation) and transportation are similar (47.7% and 49.1% respectively) and between them account for just over 96% of the CO2 emissions in the sector.

TABLE 3-3 Antigua & Barbuda's Emissions (Gg) And Removals of Direct GHGs for 2000

GHG SOURCE AND SINK CATEGORIES	CO2	CO2	CH4	N20	HFCs
	Emissions	Removals			
Total National Emissions and removals	383	0	6.6	0.159	0.007
1 Energy (reference Apporach)	412				
(Sectoral Approach)	371		0	0.003	
A Fuel Combustion	371		0	0.003	
BFugitive Emissions from Fuels	0		0		
2 Industrial Processes	0		0.0	0.000	0.0037
3 Solvent and Other Product Use	0			0.000	
4 Agriculture			1.1	0.152	
5 Land-Use Change & Forestry	11	0	0.0	0.000	
6 Waste			5.4	0.004	
7 Other (None)	0	0	0	0.000	

Summary of Antigua and Barbuda CO2 Emissions in 2000

	Sectoral Approach	
Sector	Gg (CO2)	%
Total Energy	371	
Energy Industries	177	47.7%
Manufacturing Industries & Construction	0.00	
Transport (Road)	182	49.1%
Commercial/ Institutional	5.52	1.49%
Residential Sector	7.36	1.98%
Agriculture, Forestry; Fishing (Mobile)	0.00	
Total	371	100.0%

3.2.2 KEY NATIONAL POLICIES AND INITIATIVES

The key national policies that are relevant to mitigation are those associated with the sectors that affect GHG emissions or are potentially affected by climate change. These sectors are energy (electricity production and associated demand categories), tourism and waste management. As is the case with other small island states, Antigua and Barbuda contributes negligibly to global GHG emissions but is disproportionately affected by climate change impacts. The climate change adaptation and mitigation policy are important to set the national planning and development context for adaptation to climate change.

Antigua and Barbuda Tourism Strategic Policy and Plan (2005-2009)
In recognition of the contributions of tourism to GDP (50%), employment (26% of the labour force plus other indirect employment) and visitor expenditures and also recognising the leakage from the economy through imports associated with tourism, the tourism strategic policy and plan[6] makes a case for increased public and private sector commitment to the development of the Antigua and Barbuda tourism industry.

The guiding principles and values underpinning the Tourism Strategic Policy and Plan are:

- Sustainability

  To maximize the social and economic benefits to tourism stakeholders and the general population, with minimum negative impact on local culture, human values and the natural environment.
- Collaboration

  To encourage and support a continuous multi-stakeholder dialogue that ensures the participation of all stakeholders and communities in the planning and development of all tourism projects.
- Quality

  To deliver excellent quality tourism services and products in a manner that enhances the unique brand of Antigua and Barbuda tourism in the wider Caribbean market.

The plan established growth targets in room capacity as well as in stay over visitors and cruise arrivals and associated visitor expenditures.

Sustainable Energy Policy (under development)
A National Energy Task Force was established early this year to gather data and consult with stakeholders in order to fulfill its mandate of producing a comprehensive and strategic National Sustainable Energy Policy.

3.3 METHODOLOGY FOR THE MITIGATION ASSESSMENT

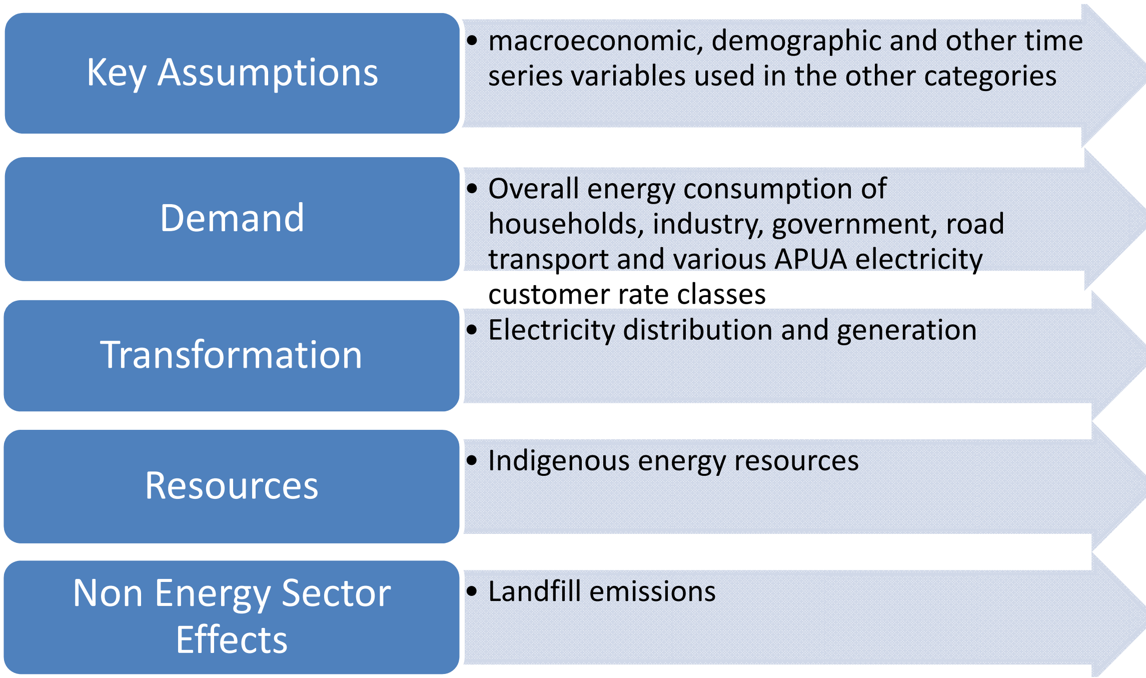
A mitigation assessment seeks to provide a national level analysis of the various practices and technologies that have the potential to affect GHG emissions over time. The assessment will include the development of long term scenarios that quantify how future GHG emissions can be reduced relative to one or more baseline scenarios.

The mitigation analysis used the Long-Range Energy Alternatives Planning System (LEAP) model[7] and examined the demand, transformation, resources and non-energy sector emissions and effects. LEAP is a scenario-based energy-environment modeling tool based on comprehensive accounting of how energy is consumed, converted and produced in a given region or economy under a range of alternative assumptions. Scenarios are self-consistent story lines of how a future energy system might evolve over time in a particular socio-economic setting and under a particular set of policy options defined for example by specific projects and measures. Scenarios in LEAP can be compared to assess their energy requirements, environmental impacts and social costs and benefits.

The base year used in this analysis is 2000 - the same year used for compilation of the national GHG emission inventory and is the year preferred by UNFCCC for reporting Second National Communications. The first projection year for all scenarios was 2009 and the last 2030. Historical data between 2000 and 2008 were used in the so called Current Account (LEAP model terminology).

Projections for the years 2009 to 2035 were made for three groups of scenarios: the ReferenceScenario and two others called Scenario 2 and Scenario 3. The input data for the LEAP model are grouped into five categories called modules (see Figure 3-1).

Figure 3-1 Modules in the LEAP Model



The subcategories or branches in each of these modules were determined by the level of detailed data that were available. The subcategories in the model are shown in Table 3-5. The information sources for the data used in the five categories are described below.

3.3.1 Information Sources

Since the emission sources in Antigua and Barbuda are limited to the energy sector, the information required for the mitigation assessment consists of electricity generation and the associated demands for electricity and other petroleum fuels. Industrial activity in Antigua and Barbuda is limited and energy use is primarily in the form of electricity and diesel fuel use. The demand for energy was therefore broken down into the categories for which data are available (electricity demand for household, government, industrial, commercial customers) and fuels used in transportation. GHG emissions associated with agriculture and forestry sectors are small and the potential for mitigation in these sectors is limited and were therefore excluded from the analysis.

The key information sources included the Statistical Department, Antigua Public Utilities Authority (APUA) and West Indies Oil Company (WIOC).

3.3.2 Modules used in the Analysis

3.3.2.1 Key Assumptions Module

This module contains macroeconomic (GDP and GDP growth rate) and demographic (population, population growth rate, household size) data. Historical and projected gross domestic product (GDP) data were obtained or derived from data published by the Statistic Department and other sources (see footnotes in Tables 3-2 and 3-3).

3.3.2.2 Demand Module

The demand module requires activity and energy intensity data such that the product of the two gives the energy consumption. The demand module was broken down into various "branches" namely, domestic households, commercial, government, industry and transport. These branches were selected because fuel and electricity end use and other activity data are available for them and/or subcategories within them. The methodologies applied for the various demand branches are described below. Additional details for future activity and energy intensity information are provided in the following section on scenarios.

Domestic Households

The 2001 census[8] and the Living Conditions in Antigua and Barbuda: Poverty in a Services Economy in Transition[9] and the National Information and Communications Technology (ICT) Survey[10] provided detailed household (residential) data for the numbers of households that have or use various types of household amenities or appliances. These amenities or appliances are used as the sub-branches indicated in Table 3-3. Appliances with small penetration (low percentages of households that have them) and either low annual energy use or little prospect for increased penetration were grouped into the sub-branch "All other".

Country-specific energy intensity data for residential (household) appliances (i.e., average annual electricity consumption for various appliances) used in Antigua and Barbuda are not available and so U.S. or Canadian energy intensity data were used since nearly all appliances used are imported from north America.

Future energy intensity data used in scenarios S2 and S3 were based on existing and proposed voluntary energy standards for the appliances used in the U.S. and/or Canadian Energy Star programs but with later implementation (by 2 years) or penetration for Antigua and Barbuda. Import data for various appliances and the typical and maximum lifetimes of appliances together with policy initiatives were taken into consideration in estimating the penetration of energy efficient appliances in scenarios S2 and S3.

Industrial, Commercial and Government

The only reliable energy consumption data available for these sub branches is the electricity consumption. The amount of diesel fuel used by the industrial sector is not tracked and had to be estimated (see below).

Transportation

Limited fleet composition and gasoline consumption data were also available. The fleet data did not include the breakdown between gasoline and diesel fuelled vehicles but vehicle import data (available only for 2005 and 2007 and 2008) allowed allocations by weight class and fuel type. Allocations of vehicles to fuel type were made based on gasoline and diesel consumption for road transportation and other purposes (e.g., marine use and domestic aviation).

3.3.2.3 Transformation Module

Although the transformation module includes only electricity generation the data available only included the total energy output. There is limited use of wood and charcoal (charcoal is used in <2% of households) and so was excluded from the analysis.

3.3.2.4 Resources Module

The indigenous energy resources available in Antigua and Barbuda are charcoal, solar energy, wind and municipal waste but currently there is very limited use of these resources.

Charcoal and fuel wood are used for cooking by less than 2% of households. There is also very limited commercial use of wood in bakeries. Data on fuel wood use and charcoal production are not compiled and estimates are subject to large uncertainties. Use of wood and charcoal is expected to decline further. Mitigation scenarios include use of solar, wind and municipal solid waste. Expanded use of solar water heating for example in hotels would reduce the need for energy derived from fossil fuel combustion.

3.3.2.5 Non-Energy Sector Effects

The methane generated from landfill emissions is the only significant non-CO2 GHG emission. Simple projections of these emissions were made based on population growth.

Table 3-5 Subcategories in the Five Modules in the LEAP Model Input Data

Key Assumptions	Demand	Transformation	Resources	Non-Energy Sector Effects
Population Household Size Population growth rate Household size	Transportation Commercial Household Cooking Lighting Refrigeration Television Computer equipment All other APUA Government Industrial	Transmission & Distribution Electricity Generation	Primary Wind Solar Municipal Waste	Landfill emissions

3.3.3 Scenarios

Three groups of scenarios were defined: Reference, S2 and S3. The Reference scenario does not have any mitigation measures. The S2 and S3 scenarios include options based on demand (S2Hyb for hybrid vehicles) and on transformation (S2Coal – coal used for electricity generation).

Demand
Three scenarios are developed to project emissions – a Reference Scenario (Ref) and two other scenarios - Scenario 2 (S2) and Scenario 3 (S3). The Reference Scenario does not include any initiatives to mitigate GHG emissions and assumes historical demand growth patterns will continue.

S2 and S3 assumed progressively aggressive mitigation measures. S2 is subdivided into S2 and S2HYB with the former assuming the use of liquefied petroleum gas (LPG) in the vehicle fleet and the latter involving hybrid vehicles only. S3 entails the use of hybrid vehicles only. No structural changes in the economy are anticipated and it is expected that there would be continued reliance on tourism and the main source of employment and the key contributor to GDP.

Transformation
All scenarios assume the construction of a 30 MW medium speed diesel plant in 2011.

The S2 and S2HYB scenarios have the electricity generation mix:
• 10 MW distributed photovoltaic (PV) systems between 2012 and 2030
• Municipal solid waste (MSW) plant in 2015 (2.5 MW in S2 and 3.5 MW in S3)
• 10 MW wind in 2015

The S3 scenario assumes:

- 15 MW distributed PV between 2012 and 2030
- 3.5 MW MSW plant in 2015
- 10 MW wind in 2015 and an additional 5 MW in 2025
- Interisland connection 15 MW in 2025

The S3Coal scenario has no interisland wind or distributed PV and therefore assumes:

- 3.5 MW MSW plant in 2015
- 10 MW wind in 2015 and an additional 5 MW in 2025
- 10 MW circulating fluidised bed (CFB) coal plants in each of 2020, 2023, and 2026

Tables 3-6 and 3-7 summarise the assumptions in developing the mitigation scenarios for the demand and transformations modules.

Table 3-6 Scenarios for the Demand and Non-Energy Sector Effects

Category	Reference (REF)	Scenario 2 (S2,S2Hyb)	Scenario 3 (S3)
Key Parameters			
Population	Growth at 1.87% declining to 1% in 2030	Same as Reference	Same as Reference
Household size	Decreasing from 2.709 in 2008 to 2.5 in 2030.	Same as Reference	Same as Reference
GDP Growth rate	Real GDP growth of 4, 4.5, 4.5 and 4.6 for 2009 to 2012 and 4% after 2012.	Same as Reference	Same as Reference
Demand			
Households (HH)	Number of households based on population and household size (above)	Number of households based on population and household size (above)	Number of households based on population and household size (above)
Residential Customers	Growth at 2.3% on 2008, 3% from 2009 to 2012, 2% from 2013 to 2016 and 1% to 2030 Percentages of households with cooking, lighting, refrigerators, TVs and Computer Equipment from Poverty Assessment Survey, 2001 Census and National ICT Household	Growth at 2.3% on 2008, 3% from 2009 to 2012, 2% from 2013 to 2016 and 1% to 2030 Same as Reference	Growth at 2.3% on 2008, 3% from 2009 to 2012, 2% from 2013 to 2016 and 1% to 2030 Same as Reference

	Survey		
Cooking	LPG in 96.2% of HH in 2006; Electric stoves from 0.7% of HH; charcoal and firewood flat	No change in penetration or energy intensity	No change in penetration or energy intensity
Refrigeration	No energy efficient refrigerators. Note – recent imports used to determine growth in number of refrigerators.	No change in penetration [% of HH with more energy efficient refrigerators increases from 0% in 2012 to 30% in 2020, and 40% in 2030.]	No change in penetration [% of HH with more energy efficient refrigerators increases from 0% in 2012 to 40% in 2020, and 60% in 2030.]
Lighting	CFLs in use but penetration unknown (assume 40%??). No LED; Kerosene decreases from 1.6% of HH in 2006 to 0.1% of HH in 2015	Kerosene decreases from 1.6% of HH in 2006 to 0.1% of HH in 2015 [Additional introduction of CFLs penetration to 60% of HH by 2015). Introduction of LED lighting after 2015 (10% of HH by 2020).]	Kerosene decreases from 1.6% in 2006 to 0% in 2020 [Additional introduction of CFLs (penetration to 80% of HH by 2015). Introduction of LED lighting after 2012 to 45% of HH by 2030 at the expense of CFL which decrease from 80% of HH in 2009 to 50% of HH by 2030.]
Computer equipment	Assume current (2006) penetration rate (47% of HH) remains the same	Penetration to 80% of HH by 2015 [More energy efficient equipment]	Penetration to 90% of HH by 2015 [More energy efficient equipment]
TV, stereo, radio	Penetration rate remains same (97% for TVs, etc.)	No change in penetration [More energy efficient appliances (TVs) after 2015 to 25% reduction in 2030]	No change in penetration [More energy efficient appliances (TVs) after 2015 to 50% of HH in 2030]
All other	Includes items such as air conditioners and washing machines whose penetration rates are unknown as well as other small appliances. Assume current	[Assume 10% reduction in energy efficiency by 2030]	[Assume 20% reduction in energy efficiency by 2030]

	penetration rates remain the same Energy efficiency – no change		
Commercial (including hotels)	Electrical energy and LPG fuel used	Reduction in electricity and LPG use: 10% by 2015; 15% by 2030 Reduction in LPG use: 10% by 2015; 15% by 2030 [Efficient HVAC and additional solar water heating]	Reduction in electricity and LPG use: 15% by 2015; 25% by 2030 Reduction in LPG use: 15% by 2015;25% by 2030 [efficient HVAC and additional solar water heating]
Industry	Electrical energy and diesel fuel used No change in energy intensity	10% Reduction in overall energy by 2015 and 15% by 2030 due to energy conservation measures (education) Flat after.	15% Reduction in overall energy by 2015 and 25% by 2030 due to energy conservation measures (education) Flat after.
Government	No change	10% Reduction in overall energy use by 2015 and 15% by 2030 due to energy conservation measures (education) Flat after.	15% Reduction in overall energy use by 2015 and 25% by 2030 due to energy conservation measures (education) Flat after.
APUA		10% Reduction in overall energy use by 2015 and 15% by 2030 due to energy conservation measures (education) Flat after.	15% Reduction in overall energy use by 2015 and 25% by 2030 due to energy conservation measures (education) Flat after.
Transportation			
Fleet divided into 7 vehicle classes (LDGV, LDDV, LDGT, LDDT, HDGV, HDDV, MC) plus off road. Separate marine category also. Historical assignment of vehicle stocks to vehicle classes based on vehicle inspections data and sales based on import data. Note – no CNG but LPG instead for LDVs. No mitigation for MC. Assumed annual mileage accumulation rates or vehicle miles travelled (VMT) are included for comment since no data are available.			
Growth in fleet	1% to 2012, 0.5% to 2020, 0.1% to 2035	Improved mass transit Import restrictions and tax incentives to promote more fuel	Improved mass transit Import restrictions and tax incentives to

		efficient vehicles and hybrid	promote more fuel efficient vehicles and hybrids
Fuels	Only gasoline and diesel E10, biodiesel and low sulphur diesel and gasoline not considered		
LDGV 8000 mi	All gasoline	LPG: 15% of LDGV by 2022 S2 Hybrid: 20% of Hybrid vehicles by 2022	Hybrid: 30% of fleet Hybrid by 2030
LDDV 8000 mi	All diesel	LPG: 15% of LDDV by 2022 S2 Hybrid: 20% of Hybrid vehicles by 2022	Hybrid: 30% of fleet Hybrid by 2030
LDGT 8000 mi	All gasoline	LPG: 15% of LDGT by 2022 S2 Hybrid: 20% of Hybrid vehicles by 2022	Hybrid: 30% of fleet Hybrid by 2030
LDDT 9000 mi	All diesel	LPG: 15% of LDDT by 2022 S2 Hybrid: 20% of Hybrid vehicles by 2022	Hybrid: 30% of fleet Hybrid by 2030
HDGV 8000 mi	All gasoline	LPG: 15% of HDGV by 2022	Hybrid: 35% of fleet Hybrid by 2030
HDDV 9000 mi	All diesel	LPG: 15% of HDDV by 2022	LPG: 35% of HDDV by 2030
MC 5000 mi	All gasoline	All gasoline	All gasoline
Off Road	Assumed all gasoline	LPG: 15% of Off Roads by 2022	LPG: 50% of Off Roads by 2030
Non-Energy Sector Effects			
Landfill Emissions	MSW to landfills based on population growth projections	Diversion of ~60%? of MSW to landfills after 2015	Diversion of ~80% MSW to landfills after 2015

E10 – Gasoline with 10% ethanol.
Energy intensity is the annual energy use per appliance or per unit activity

Table 3-7 Scenarios for Transformation and Energy Resources

Transformation Category	Reference (REF)	Scenario 2 (S2)	Scenario 3 (S3, S3Coal)
Transmission & Distribution			

Electricity Distribution	Losses reduced from 24.4% in 2008 to 10% in 2017	Losses reduced from 24.4% in 2008 to 10% in 2017	Losses reduced from 24.4% in 2008 to 10% in 2017
Electricity Generation			
Additional thermal plants **HFO Diesel** **Coal**	30 MW in 2011	30 MW in 2011	30 MW in 2011 10 MW each in 2020, 2023, 2026 (S3Coal only)
Distributed photovoltaic	None	10 MW by 2030	15 MW by 2030 S3 only
Wind	None	10 MW in 2015, 15 MW in 2025	15 MW in 2015, 20 MW in 2025 (S3 only)
MSW Waste to Energy	None	2.5 MW in 2015	3.5 MW in 2015
Interconnection with **Nevis or Dominica**	None	None	20 MW in 2025 (S3 only)

3.3.4 CONSTRAINTS AND DATA GAPS

The analysis is constrained by the following:

- The currently available breakdown of diesel fuel use is between electricity generation and other uses – the majority of which would be used for transportation. A breakdown of diesel fuel use by industry (boilers) and transportation (road, marine) is not available.
- Fuel use data for domestic marine activities were not available. Marinas at Jolly Harbour, English Bay and Falmouth Bay likely account for significant domestic and international marine fuel consumption but a breakdown of marine fuel consumption by fuel type of activity (domestic, fishing recreation, international) is not available.
- Assuming that the fleet data are accurate and using US EPA city values for average mileage values for vehicles, the LEAP estimates for fuel consumption indicate that there must be considerable amounts of diesel and gasoline used other than for on-road transportation. Based on the value (in EC$) of fuel sales to various groups of customers in 2008 and 2009 (no volume data available), estimates of the volumes of gasoline and diesel sold to marinas and of diesel sold to industrial client were made. This allowed better matching of the GHG CO2 emissions inventory with the LEAP model.
- Although there was much information on electricity demand (sales in GWh by type of customer and the numbers of customers), data for the electricity generation by plant[2] between 2000 and 2008 was extremely limited. Data for the latter were obtained from several sources that used different names for plants and it was not feasible to determine plant capacities and their outputs. This precluded calibration of outputs during the current account period (2000 to 2008). Data for electricity generation by unit

between 2001 and 2006 were not available and were estimated by interpolation and are therefore tenuous and need to be verified.

- Projections related to HFC emissions are not included
- Cost data for mitigation options and for some processes were not always available and hence costs were not modeled.

3.4 RESULTS

3.4.1 SCOPE OF RESULTS PRESENTED

The results of the analysis will focus on presenting the environmental loadings (GHG emissions) and the energy demand broken down by category and branch within the categories where appropriate. LEAP allows presentation of the emissions either a) where they occur in the various branches (demand, transformation and non-energy sector effects) or b) by allocating the emissions in the transformation categories back to the demand branches. Alternative b) gives the final energy demand (or final environmental loadings) by allocating emissions used by various appliances and/or categories in proportion of the average mix of supply side (electricity generating) processes and the associated emissions. The presentation of the environmental loadings for all three scenario projections includes the current account period (2000 to 2008) so that comparisons can be made with the GHG emissions inventory and/or energy consumption over this period.

3.4.1.1 Constraints and Data Gaps

The analysis is constrained by the following:

- Reliable fuel use data for domestic marine activities were not available. Some of the gasoline and diesel sold in retail outlets (gas stations) is likely used for fishing and other domestic marine activities in addition to direct deliveries to marinas.
- Reliable diesel fuel use data for industrial facilities were not available.
- In view of the above, transportation diesel and gasoline fuel use and industrial diesel fuel use had to be estimated. Gasoline and diesel fuels used at marinas and `diesel used by industry were based on dollar sales data for 2008 and 2009 and estimates of fuel used by the on-road fleet.
- Historical data for electricity generation by generating unit were not readily available. Data gleaned from various sources had inconsistent terminology for the names of generating stations and there were significant gaps in the data.

3.4.2 ENERGY BALANCE

LEAP's outputs include annual energy balances and those for 2000 and 2008 by fuel type for the Reference scenario respectively are shown in Figure 3-1 and 3-2.

3.4.3 OVERVIEW OF PROJECTIONS

3.4.3.1 Environmental Loadings

The final environmental loadings (emissions of CO2, N2O and CH4) – all in CO2 equivalents (CO2e) for all scenarios are shown in Figures 3-3 to 3-5. For all gases the Reference scenario has the highest emissions since there are no mitigation initiatives. The differences between the S2 and S2Hyb scenarios are small indicating no significant advantage (in terms of emissions) between using LPG (S2) and hybrids (S2Hyb) in the on road fleet. [The penetration (% of vehicles that use LPG or are hybrids were the same in the S2 and S2Hyb scenarios.] The lower emissions in S3 compared to S2 or S2Hyb are due to the greater amounts of distributed PV and wind for electricity generation. The emissions for S3Coal are understandably higher than those for S3 (as well as S2 and S2Hyb) since S3Coal uses coal while S3 uses non-CO2 emitting wind and distributed PV.

3.4.3.2 Overview of Final Energy Demand Projections

The final energy demand for all scenarios is shown in Figure 3-6. The Reference scenario has the highest demand – again because there are no mitigation measures – compared to S2 or S3 scenarios. The electricity generation capacities and peak electricity demands are respectively shown in Figures 3-7 and 3-8. [The capacity data need to be reviewed since information on nameplate or derated capacities and historical and planned retirements were not available.]

3.4.3.3 Detailed Analysis of Selected Environmental Loadings

The environmental loadings for selected years in the Reference Scenario are shown in Figure 3-9. The emissions from the transportation and commercial categories in the year 2000 are similar (24.8% and 23.8% respectively of the total) but by 2030 the CO2 emissions from transportation accounts for ~34% of the emissions.

3.4.3.4 Transportation Branch

The environmental loadings (CO2 emissions) in selected years from the transportation branch for the Reference scenario are shown in Figure 3-10. Not surprisingly the light duty gasoline vehicles (LDGV) which comprise ~82% of the fleet account for 49% of the emissions. This is because of the better fuel economy for these vehicles. By 2030 the LDDVs are projected to account for 76% of the emissions.

The effects of using LPG or hybrids on CO2 emissions are illustrated in Figure 3-11. The S2Hyb emissions are lower than those for S2 but despite the higher penetration of hybrids in S3 (30% in 2030) compared to S2Hyb (20% as of 2022) the emissions in S3 are not much lower. Figure 3-12 illustrates the differences in emissions relative to the Reference scenario. For example there are

27 Gg (27 thousand tonnes) CO_2 less than the Reference scenario in 2026 for both the S3 and S2Hyb scenarios.

3.4.3.5 Antigua Public Utilities Authority (APUA) and Government

The loadings for the APUA and Government categories are based on electricity alone and have similar mitigation measures due solely to conservation measures (S2: 10% reduction by 2015 and 15% by 2030, flat after; S3: 15% reduction by 2015 and 25% by 2030).

The reductions are illustrated in Figure 3-12 for APUA but the shape of the graph will be similar for the Government category.

Figure 3-1 Energy Balance for Antigua and Barbuda: 2000

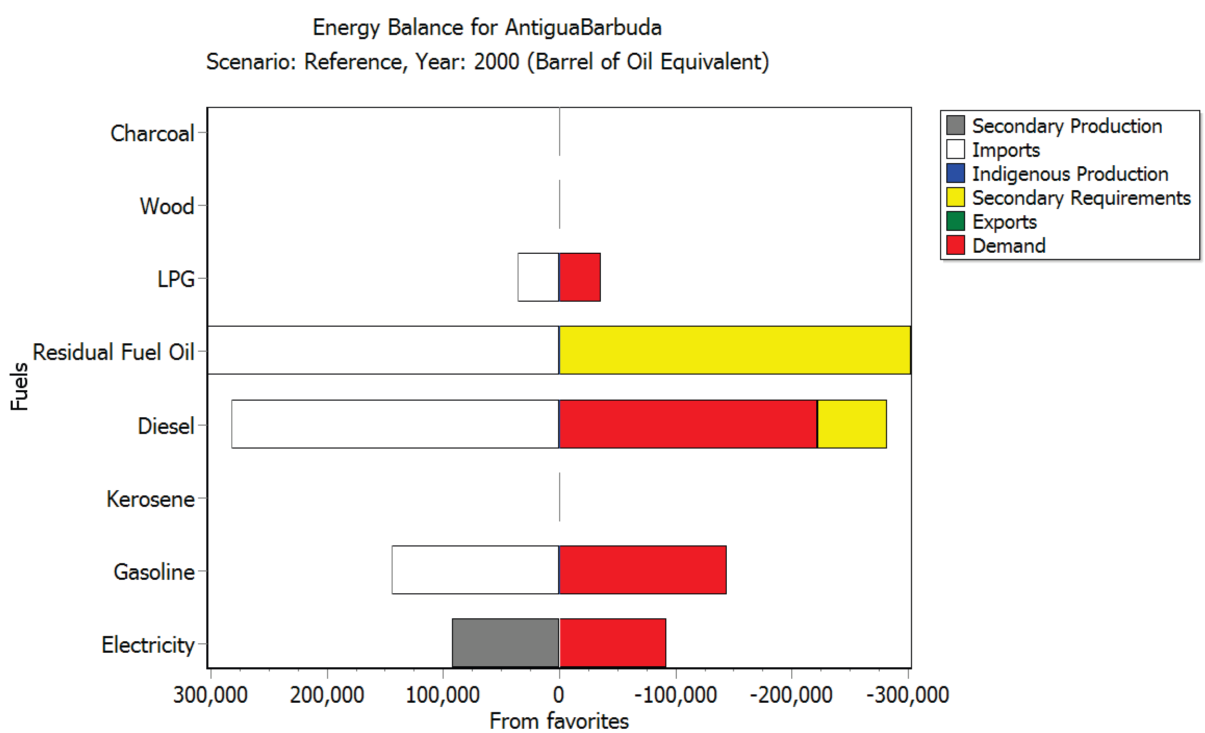


Figure 3-2 Energy Balance for Antigua and Barbuda: 2009

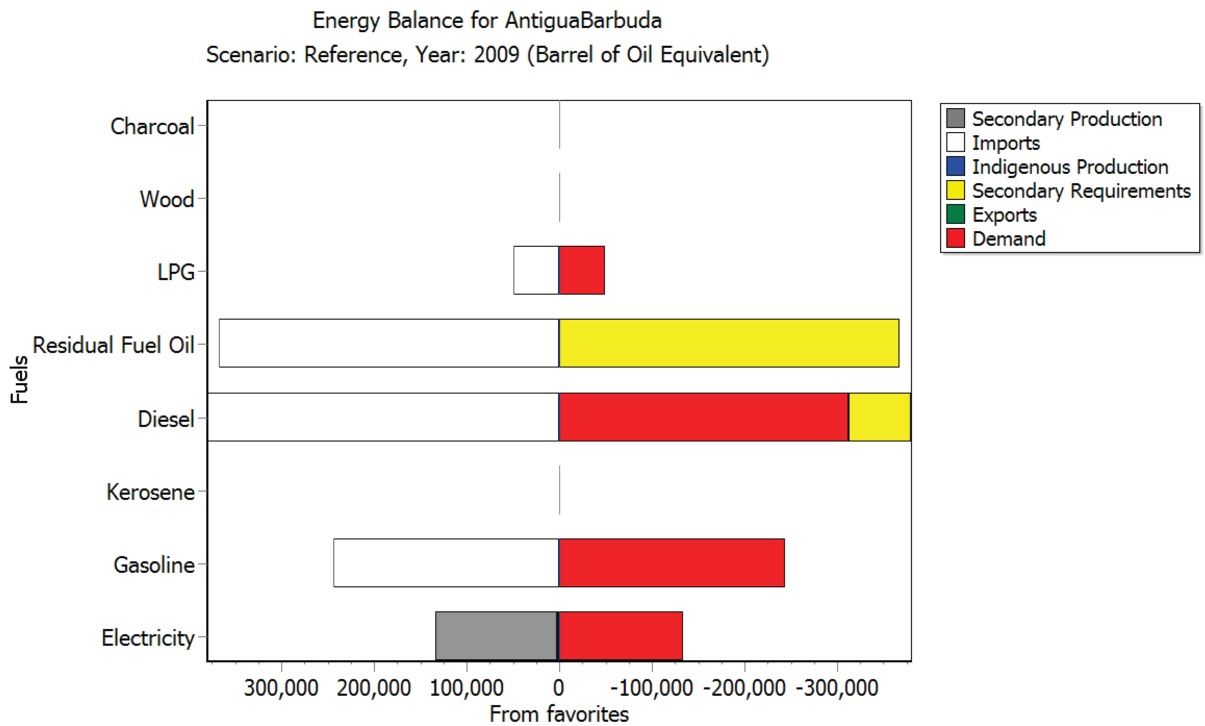


Figure 3-3 Final Environmental Loading for Antigua and Barbuda, 2009 – 2030: All Scenarios, CO2

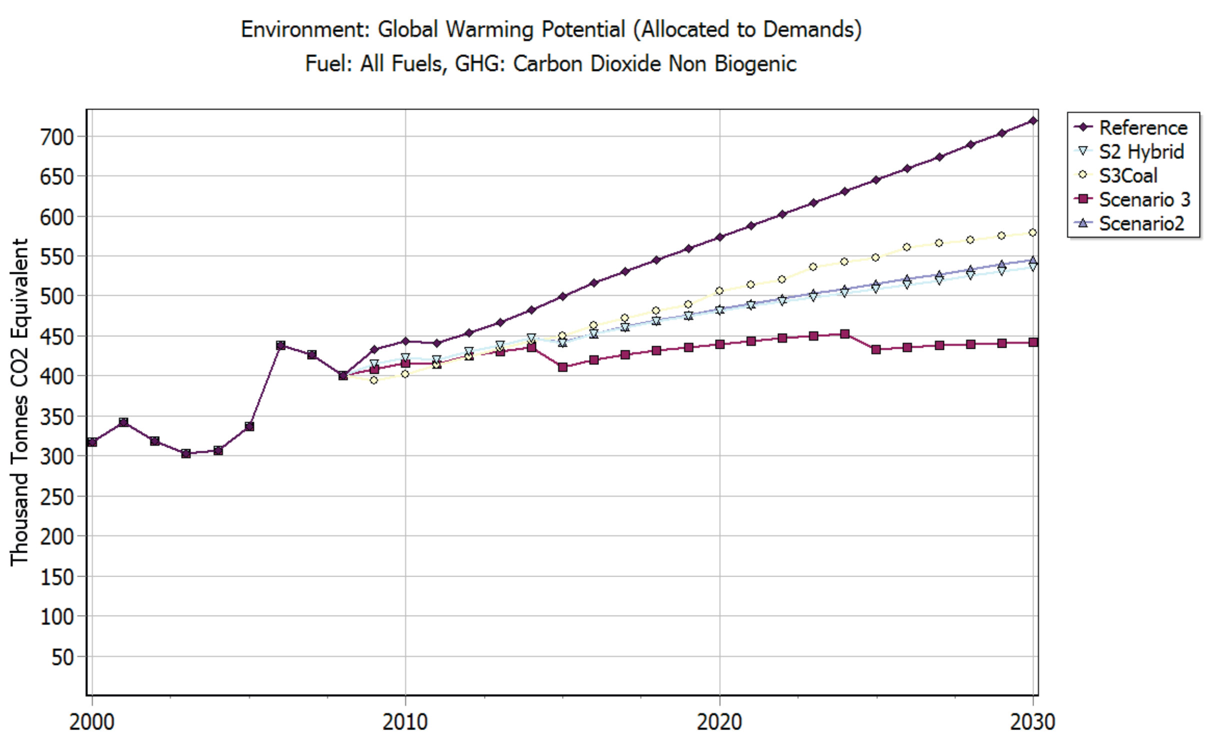


Figure 3-4 Final Environmental Loading for Antigua and Barbuda, 2009 – 2030: All Scenarios, CH4

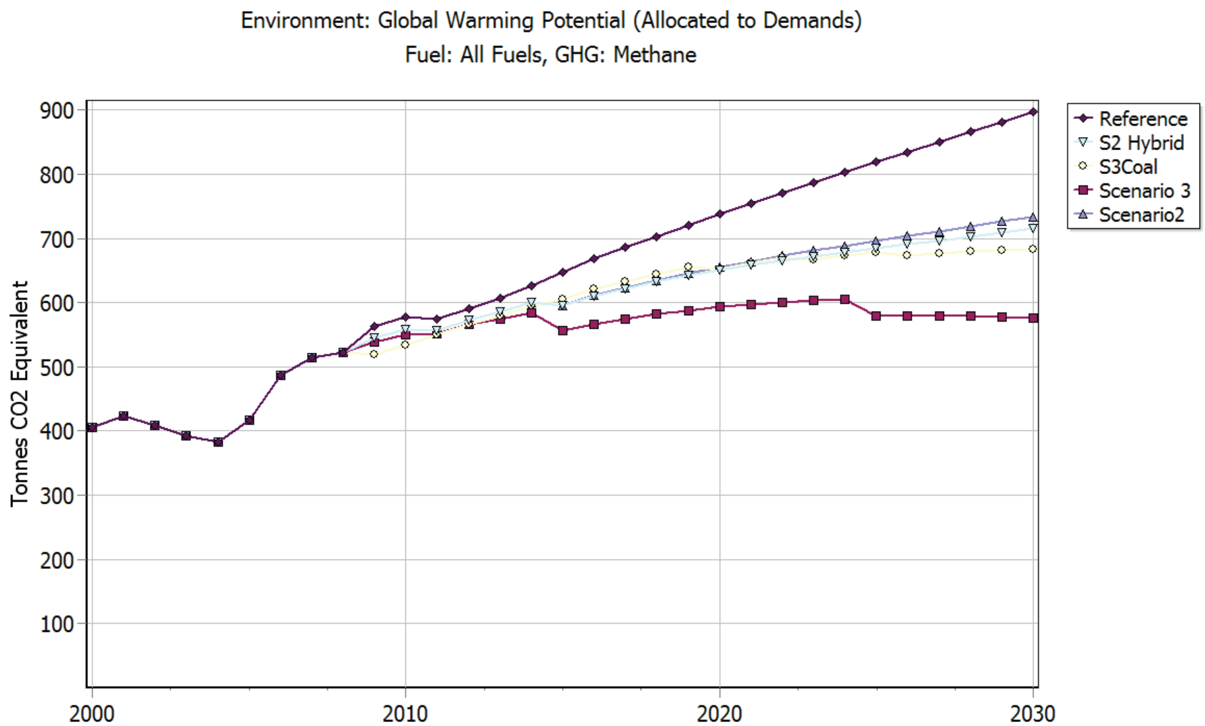
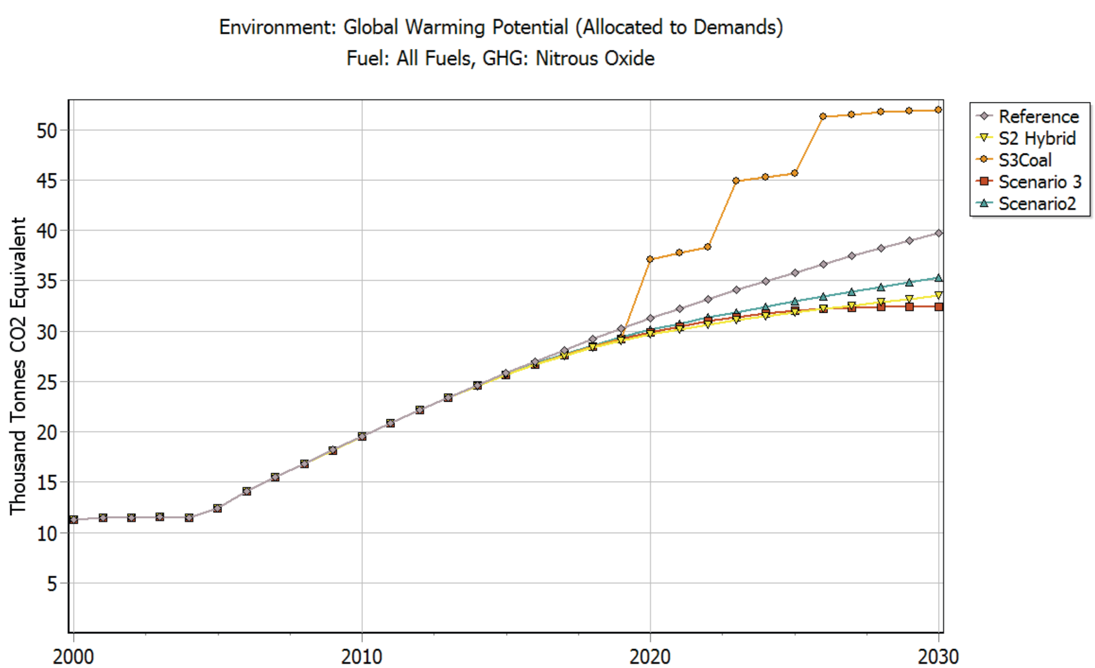


Figure 3-5 Final Environmental Loading for Antigua and Barbuda, 2009 – 2030: All Scenarios, N2O



3.4.3.6 Commercial

The commercial category uses both electricity and LPG and the mitigation measures for electricity use is based on the reduction in electricity and LPG use by 10% by 2015 and by 15% in 2030 for Scenario S2. The reductions for S3 are 25% by 2030 (instead of 25%). The changes in CO2 emissions for the commercial category are illustrated in Figure 3-13.

Figure 3-6 Final Energy Demand Projections for Antigua and Barbuda, 2009 – 2030: All Scenarios

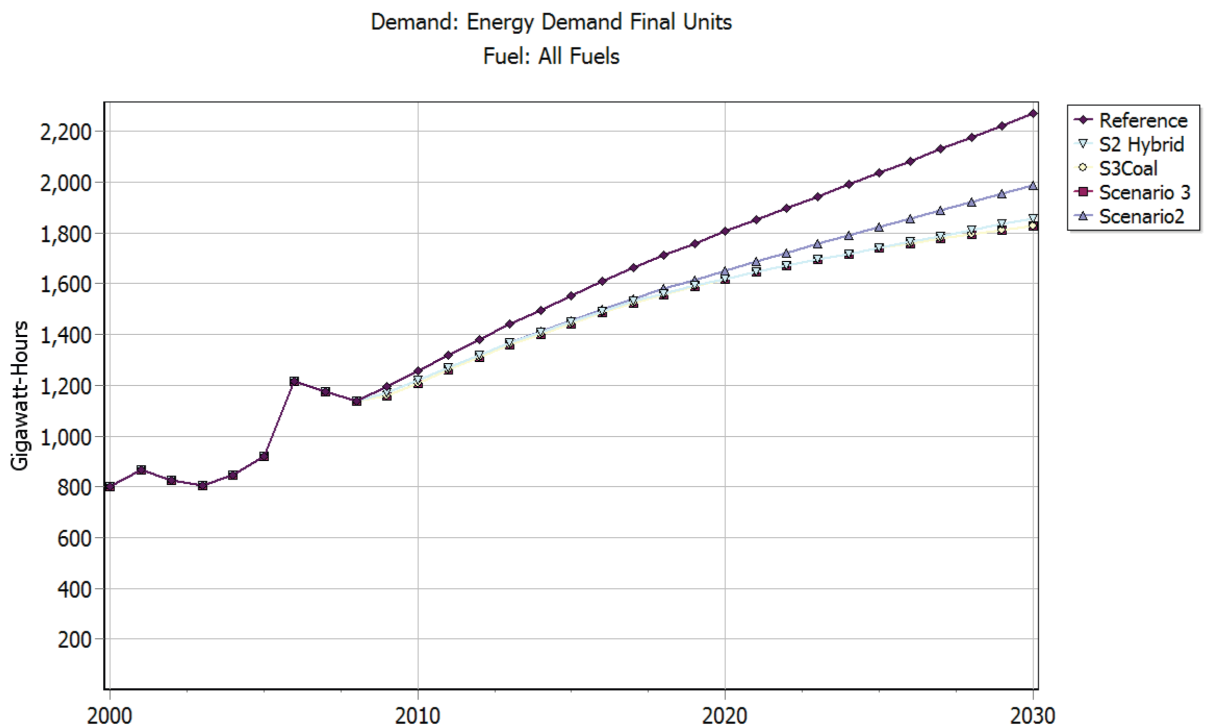


Figure 3-7 Electricity Generating Capacities, 2009 – 2030: All Scenarios

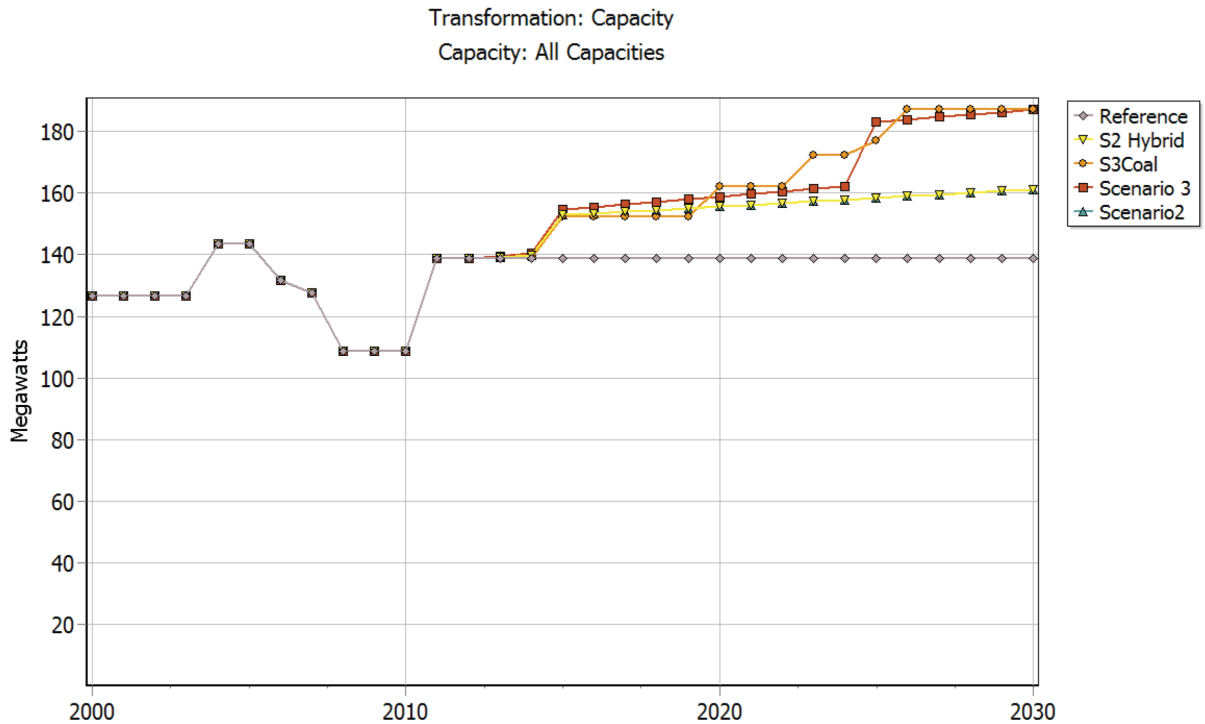


Figure 3-8 Electricity Peak Power Requirements, 2009 – 2030: All Scenarios

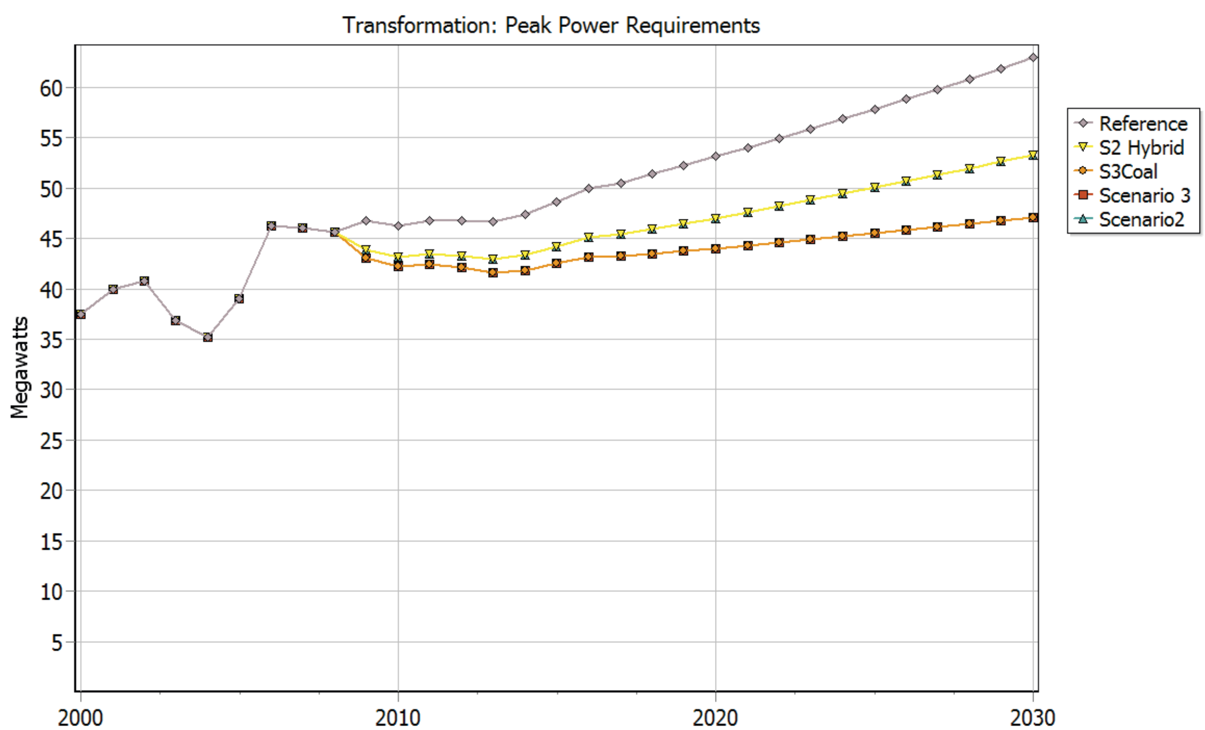


Figure 3-9 Environmental Loadings of Demand Branches in Selected Years for the Reference Scenario in Selected Years

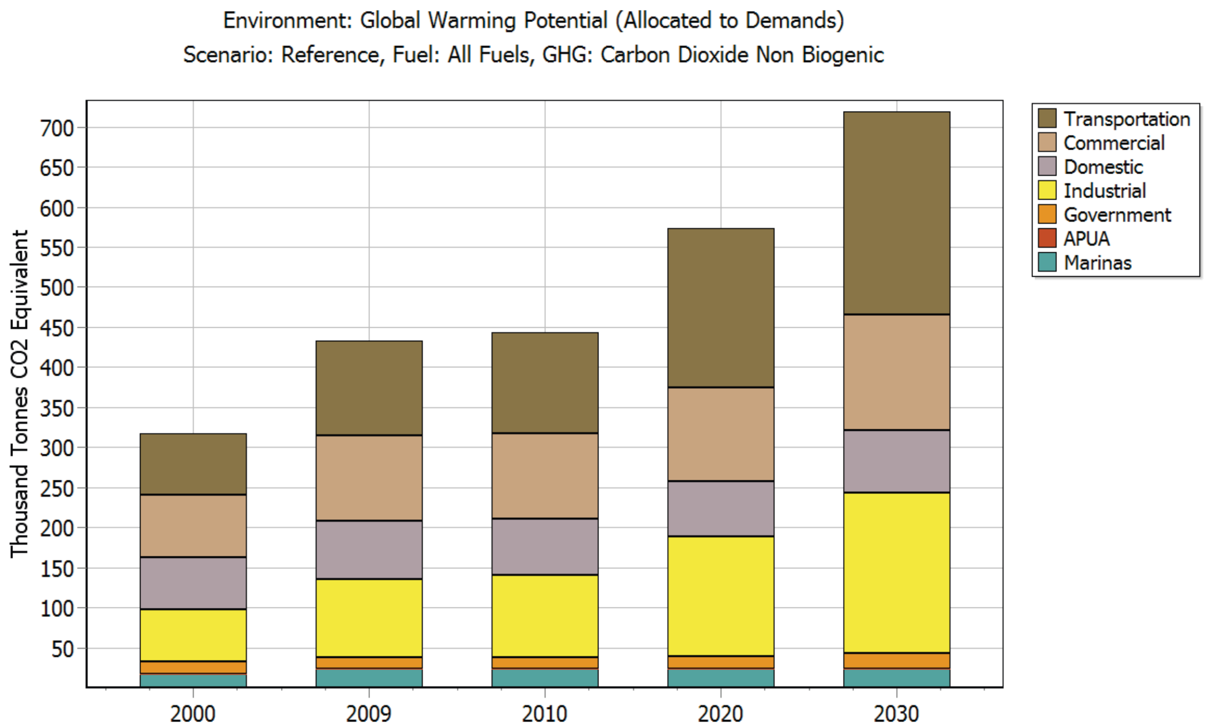


Figure 3-10 Environmental Loadings of Transportation Branches in the for the Reference Scenario in Selected Years

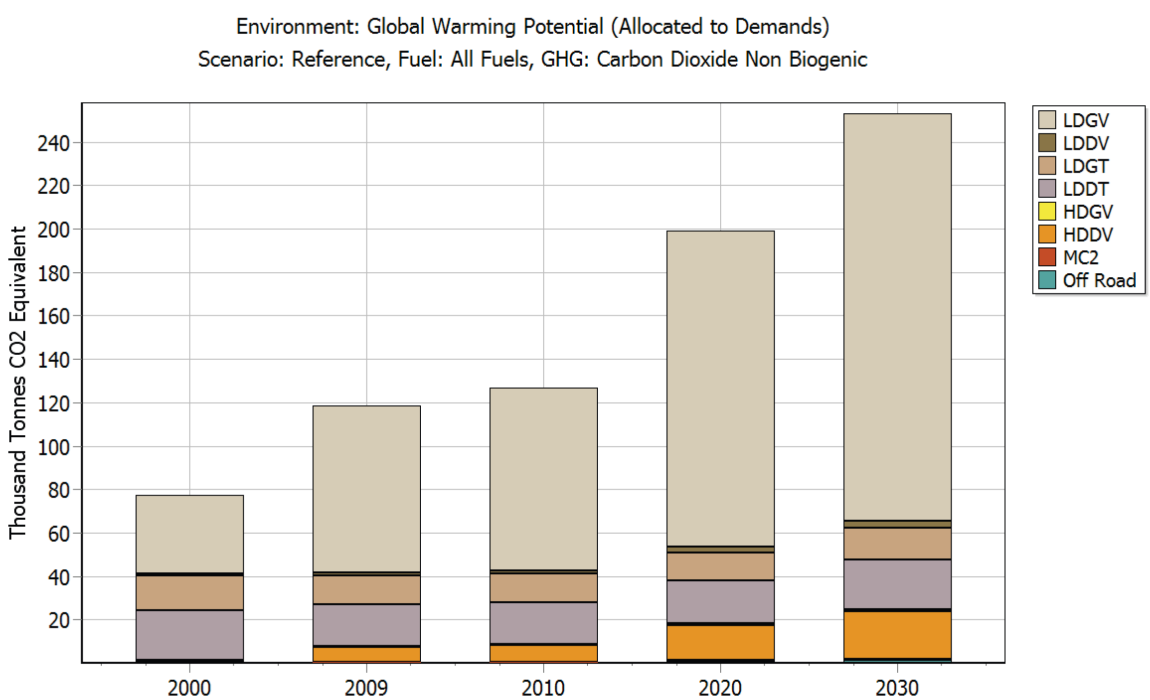


Figure 3-11 Environmental Loadings of Transportation in the for all Scenarios

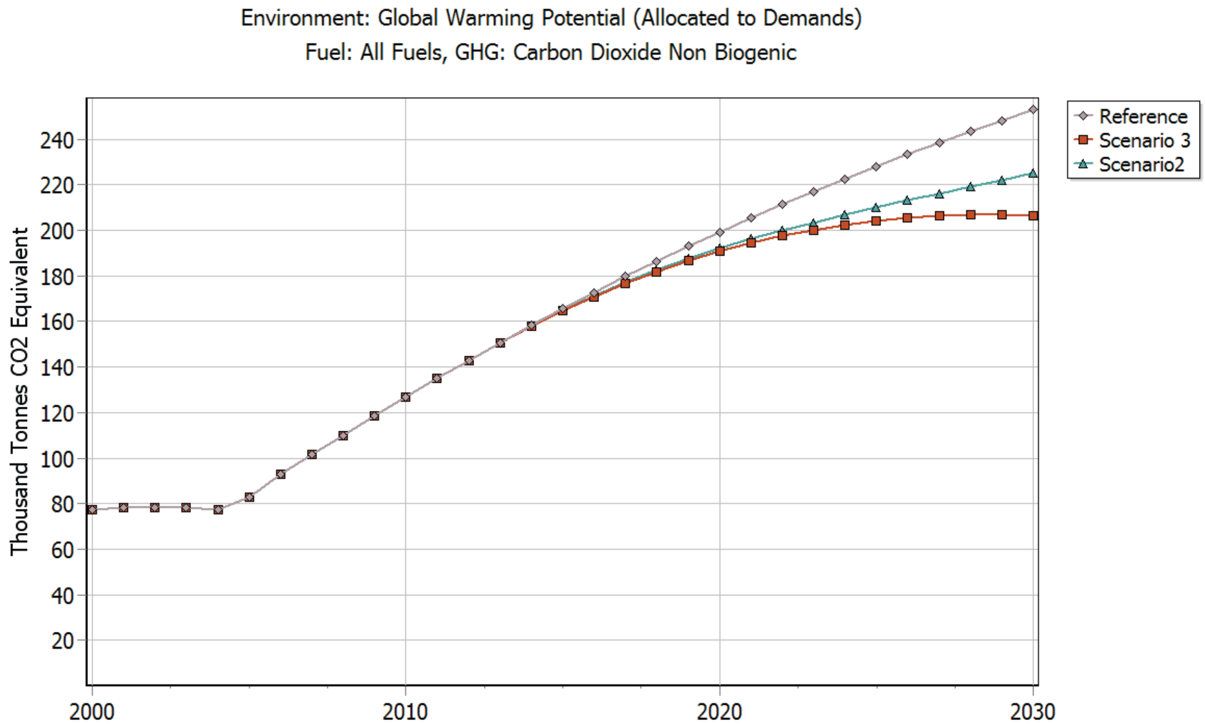


Figure 3-12 Environmental Loadings of Transportation for all Scenarios Relative to the Reference Scenario

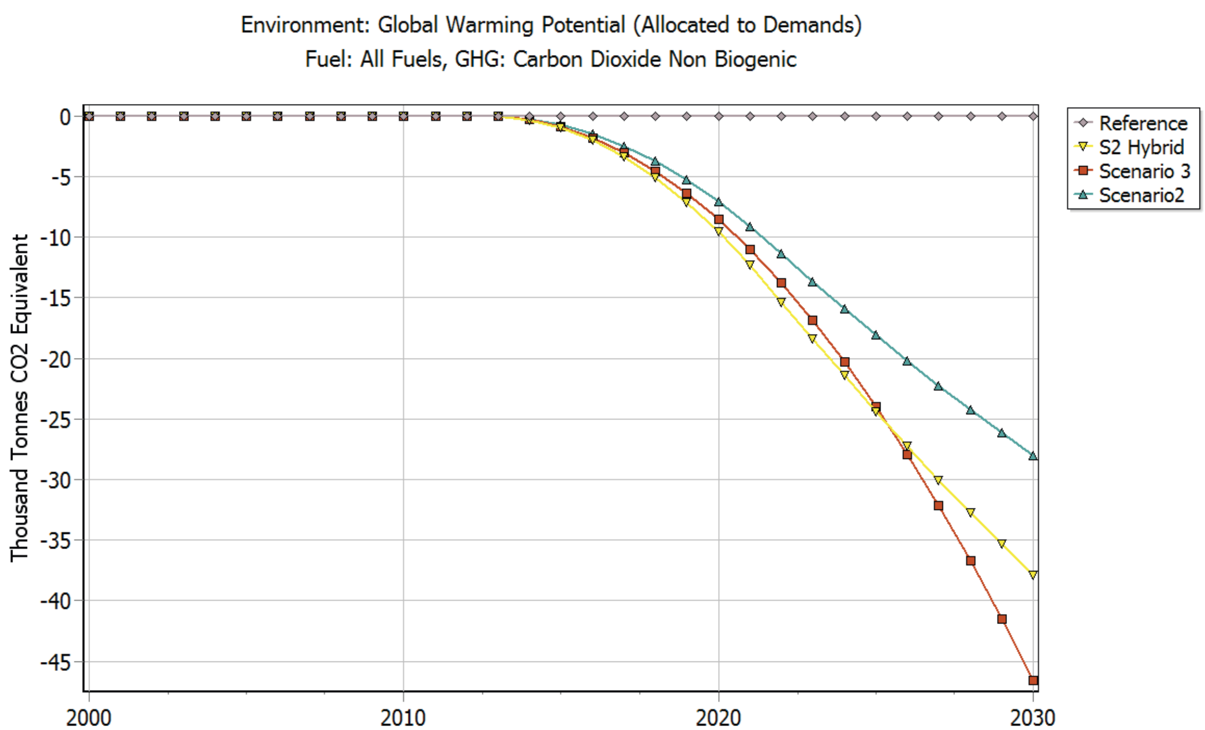


Figure 3-13 Environmental Loadings of APUA for all Scenarios

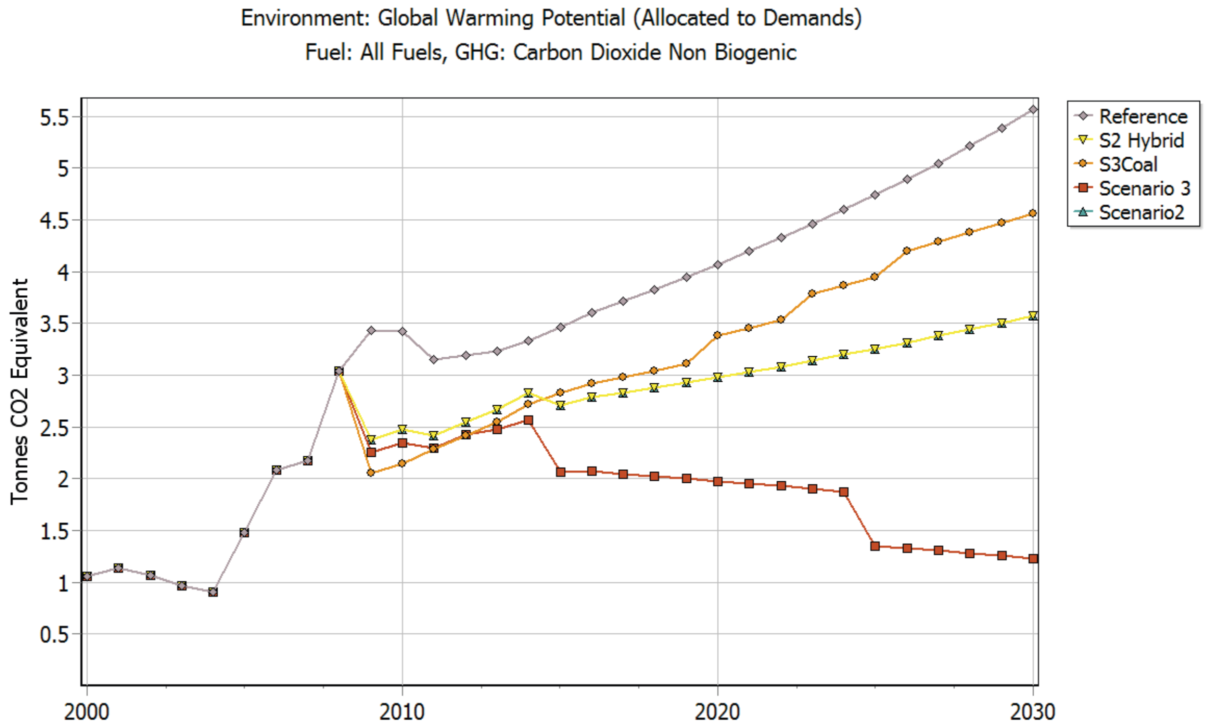
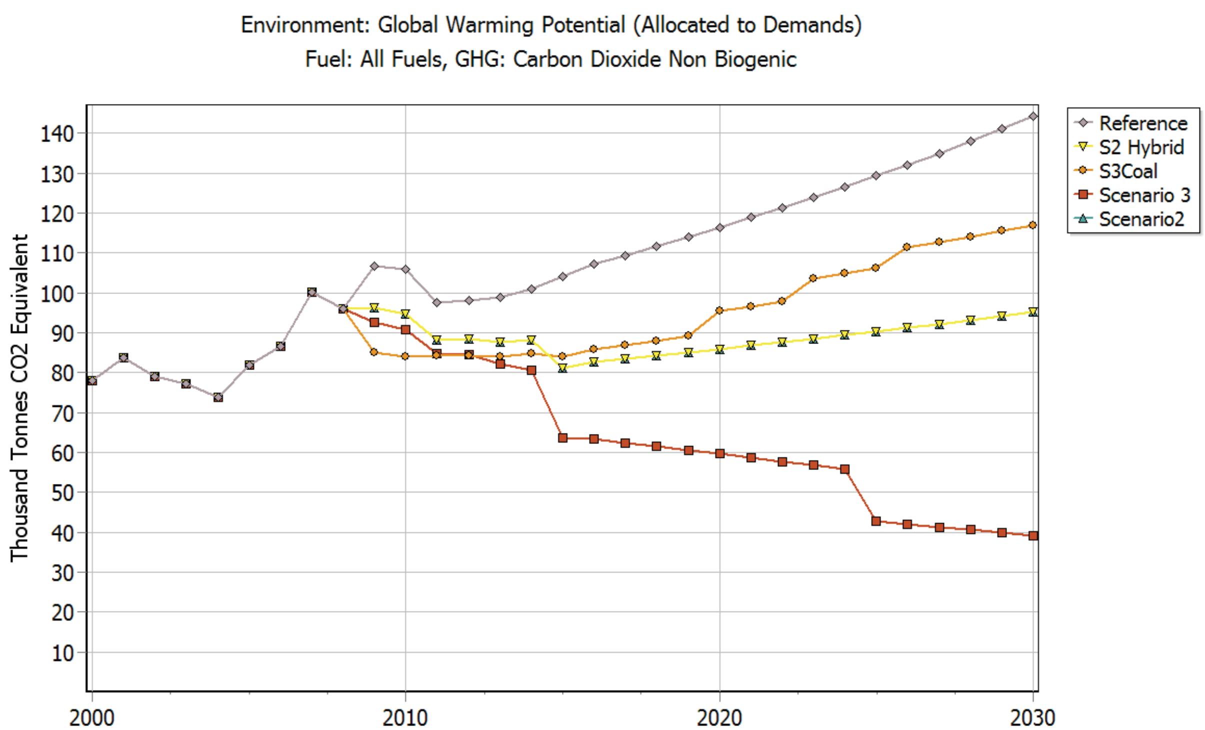


Figure 3-14 Environmental Loadings for the Commercial Category: All Scenarios



3.4.3.7 Domestic Category

The mix of fuels used in the domestic category for selected years in the Reference scenario is illustrated in Figure 3-15. The amounts of charcoal, wood and kerosene are negligible (<1%) and the fuel use is dominated by LPG for cooking and electricity for all other uses. (The percentage of households using electric stoves is small (~0.7%).

It was assumed that there were no mitigation measures for LPG use by cooking and this limits the potential for overall mitigation in the domestic category (because LPG use is ~25% of overall energy use). Since Antigua and Barbuda already had a compact fluorescent light (CFL) bulb replacement program between 2006 and 2008, there are limited gains to be obtained from additional CFL use. It was also assumed that computer equipment use would increase from 47% of households in 2006 to 80% by 2015 - thereby resulting in an increase in energy use from computer equipment. The growth in the number of households (electricity customers) offsets the energy reduction by mitigation measures. The overall result is that there are limited reductions in energy demand from the domestic category for S2 and S3 relative to the Reference scenario (see Figure 3-16). However, because of the mix of alternate energy sources in S2 and S3, the reductions in environmental loadings (CO2 emissions) for S2 and S3 relative to the Reference scenario are more pronounced (see Figure 3-17).

3.4.5.8 TRANSFORMATION

Transmission

The transformation module includes electricity transmission and generation. In all scenarios, transmission losses were assumed to be reduced from ~24% in 2009 to 10% in 2017. Since the loss reductions are the same in all scenarios the relative impacts on emissions will be identical.

Electricity Generation

All scenarios include the establishment of 30 MW medium speed diesel in 2011. The key features of the mitigation measures for electricity generation in scenarios S2 and S3 are as follows:

- Waste to energy plant in 2015 (2.5 MW for S2 and 3.5 MW for S3)
- 10 MW wind in 2015 and an additional 5 MW in 2025 for S2 and 15 MW in 2015 and an additional 5 MW in 2025 (S3)
- Starting in 2012, aggressive establishment of a distributed photovoltaic (PV) electricity generation 10 MW by 2030 (S2) and 16 MW by 2030 (S3)
- Interisland connection 20 MW by 2025 (S3)
- 10 MW coal in each of 2020, 2023 and 2026.

The CO2 emissions for these scenarios are shown in Figure 3-18. The benefits from the introduction of wind and the PV system in Scenario 3 would result in 20% lower emissions by 2030 compared to 2000 (65.7 Gg in 2000 versus 43.4 Gg in 2030.)

The changes in the mix of fuels [oil products (heavy fuel oil, diesel), renewables (wind, photovoltaic, municipal solid waste] and electricity (from island interconnection) between 2000 and 2030 for each scenario are illustrated in Figure 3-19.

Figure 3-15 Energy Demand by Fuels for the Domestic Category: Reference Scenario

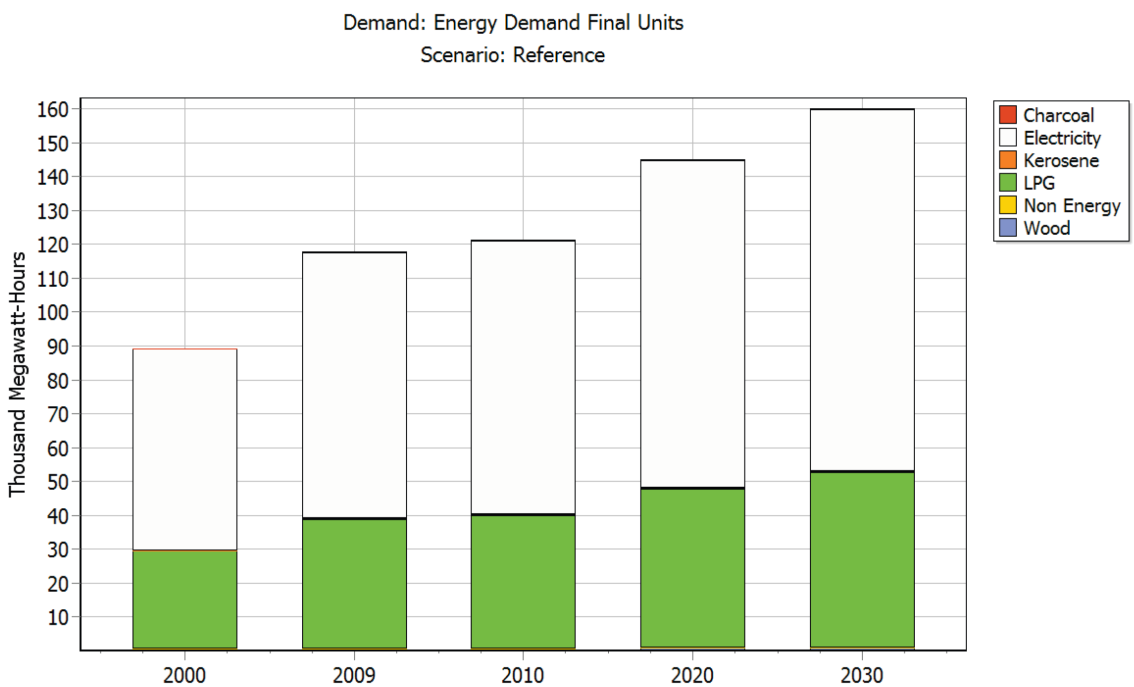


Figure 3-16 Final Energy Demand for the Domestic Category: All Scenarios

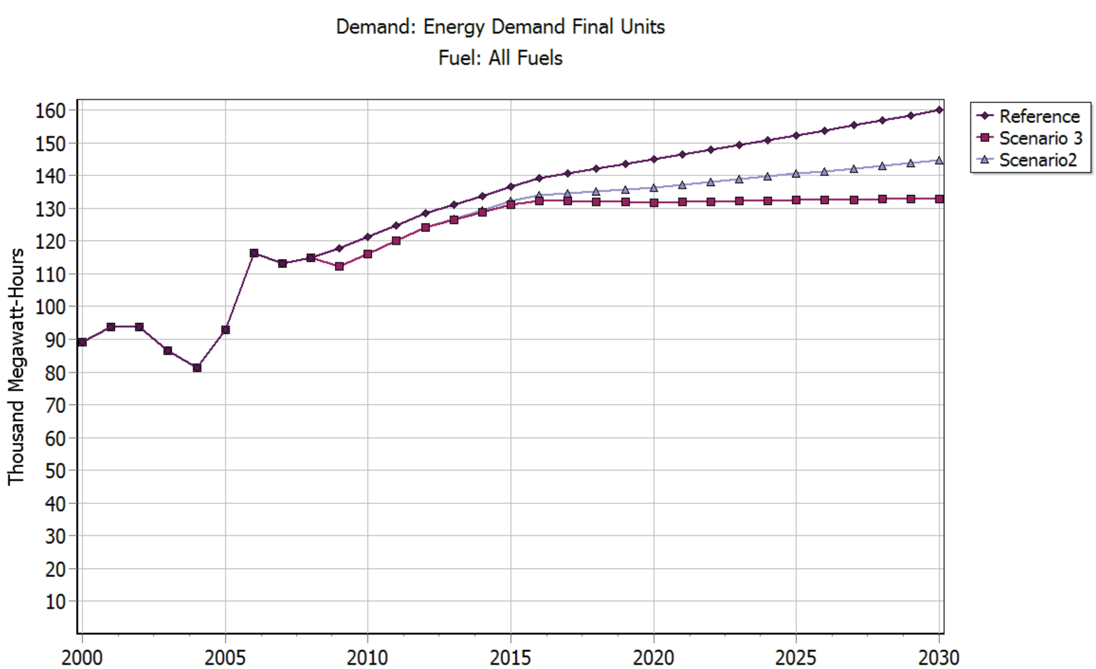


Figure 3-17 Environmental Loadings for the Domestic Category: All Scenarios

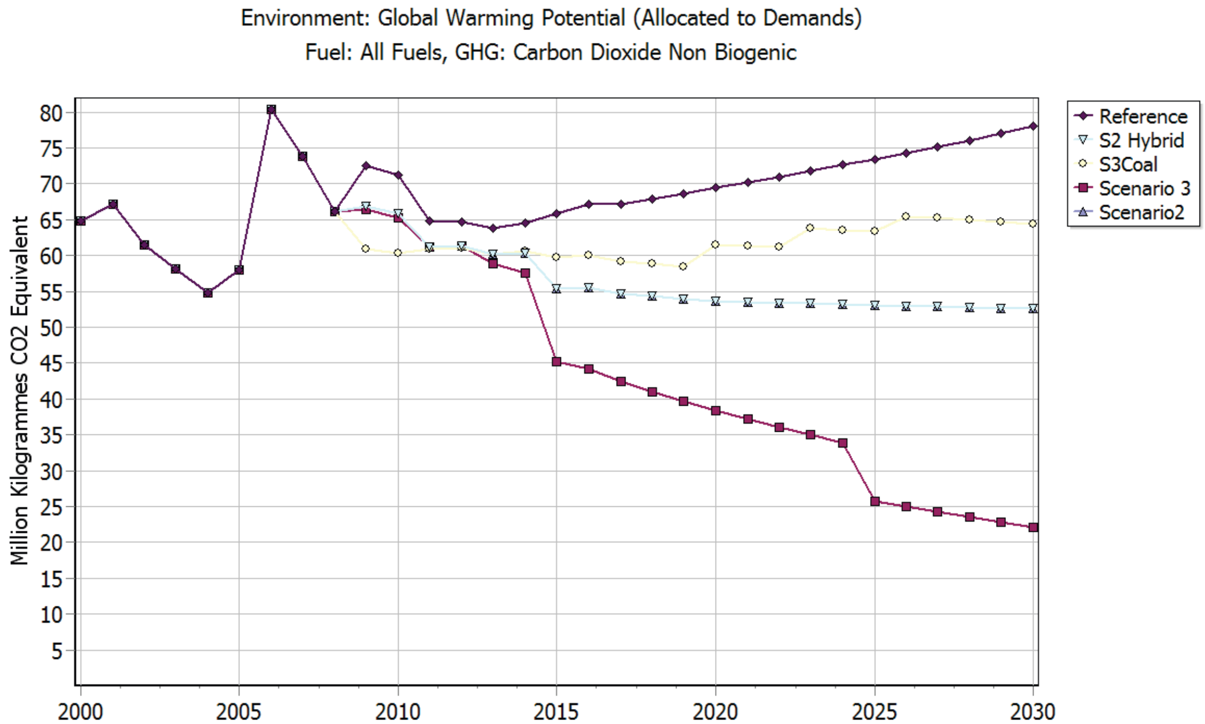


Figure 3-18 Environmental Loadings From Electricity Generation: All Scenarios

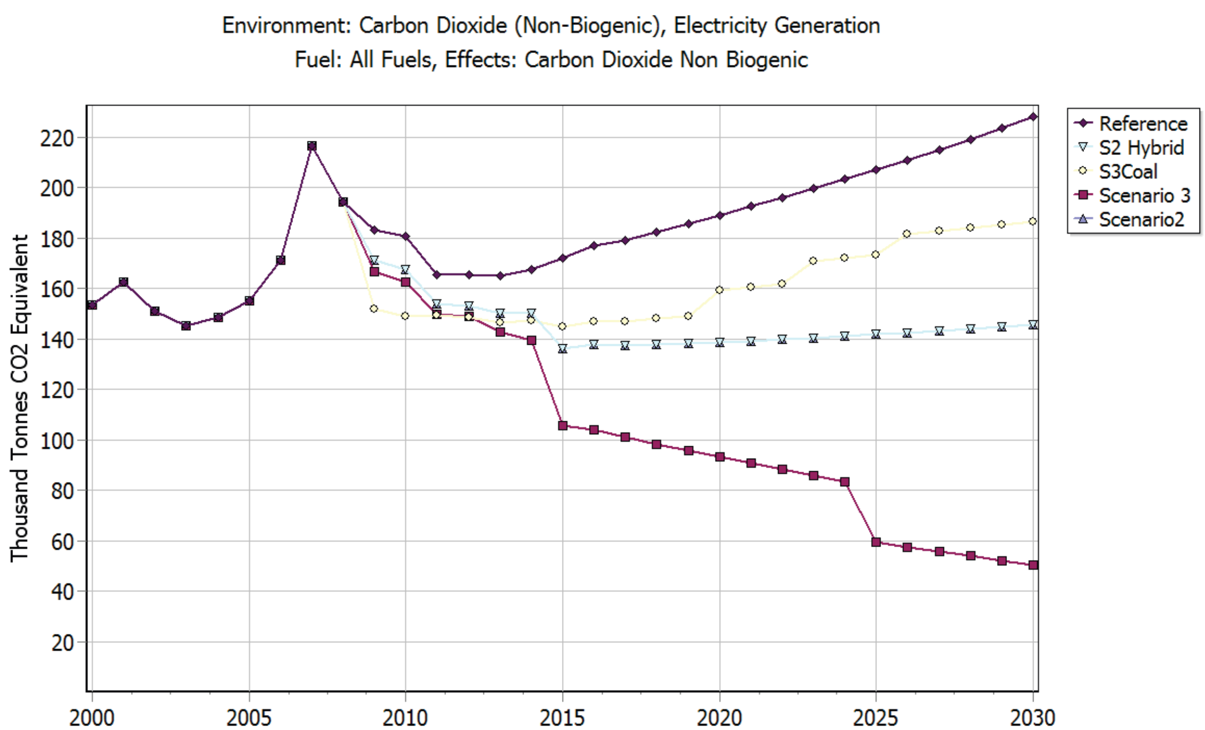
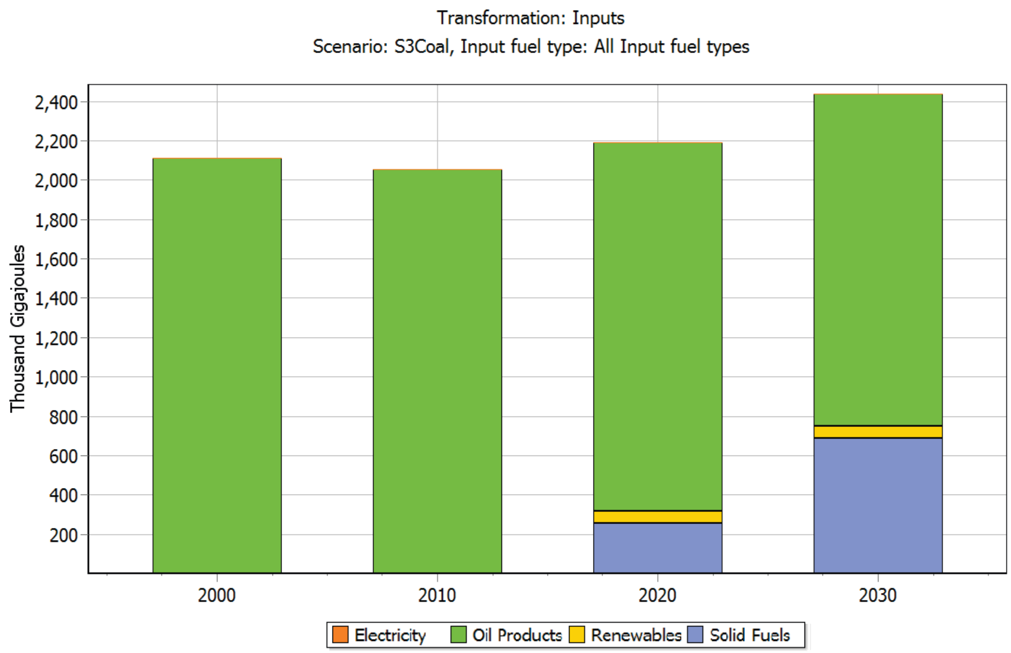
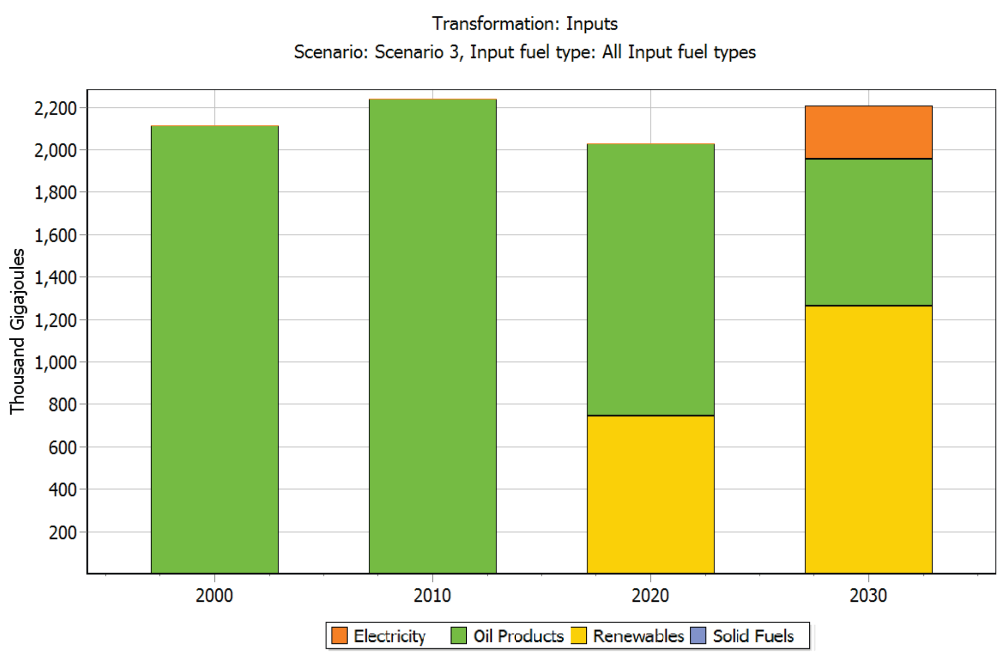
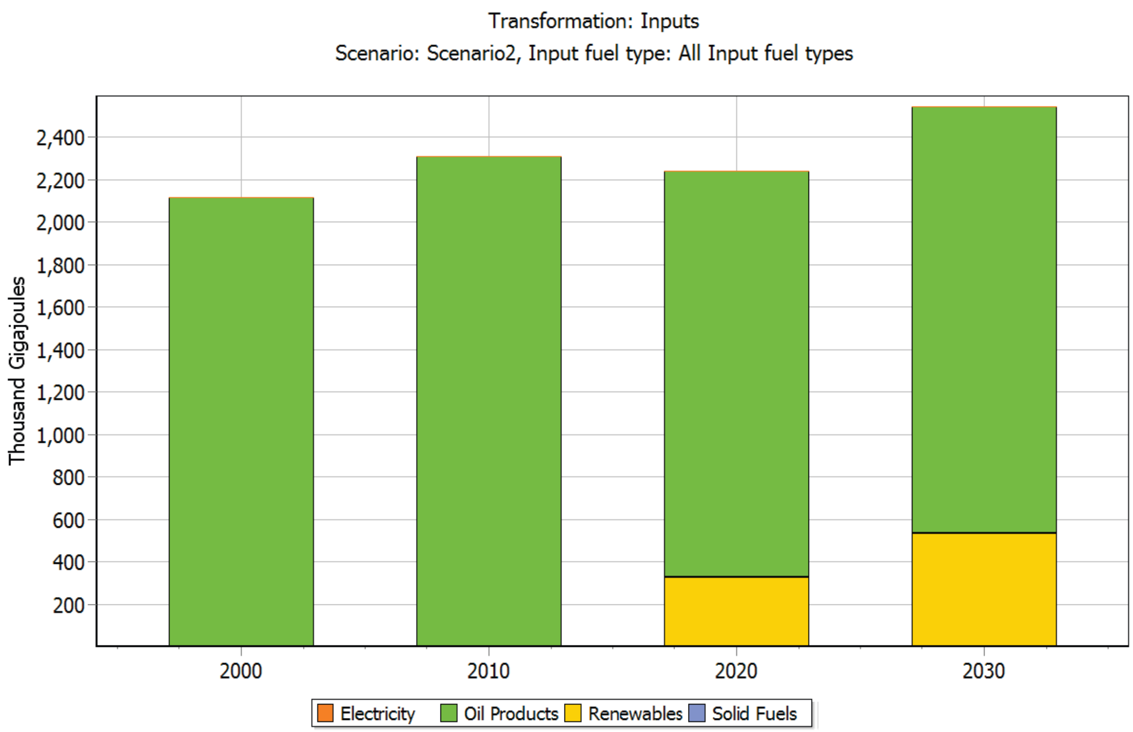


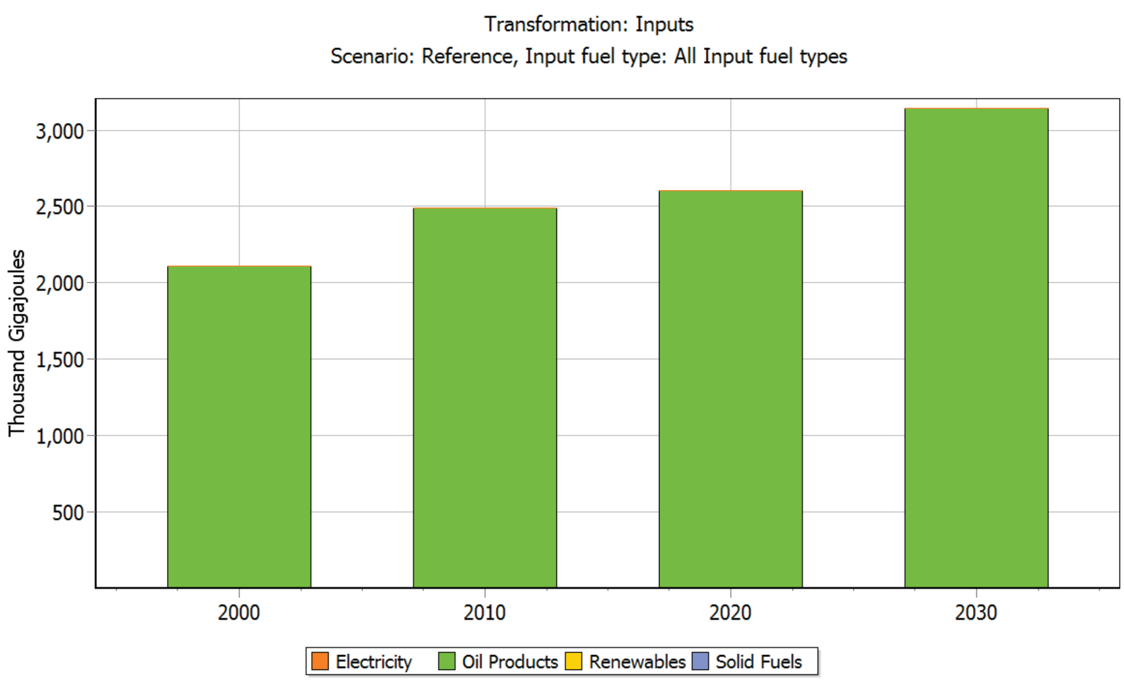
Figure 3-19 Percentages of Fuel Types in the Reference, S2, S3 an d S3Coal Scenarios







Transformation: Inputs
Scenario: Scenario2, Input fuel type: All Input fuel types
Thousand Gigajoules
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
2000
2010
2020
2030
Electricity
Oil Products
Renewables
Solid Fuels



Transformation: Inputs
Scenario: Reference, Input fuel type: All Input fuel types
Thousand Gigajoules
3,000
2,500
2,000
1,500
1,000
500
2000
2010
2020
2030
Electricity
Oil Products
Renewables
Solid Fuels

3.5 MITIGATION ACTIVITIES FOR IMPLEMENTATION

This section:

- describes the main and supporting energy sector institutions and policies that will be involved in the implementation of mitigation activities;
- indicates the main requirements for implementing mitigation measures;
- identifies some of the gaps, and
- provides specific recommendations for implementing some of the mitigation measures.

Climate change and mitigation issues affect nearly all public and private sector institutions as well as all individuals. Because of this it will be necessary to focus on those institutions and their policies under whose portfolios are the highest GHG emissions and the greatest opportunities for mitigation.

The highest GHG emissions occur in the transport and transformation (electricity generation) sectors and so focus initially will be on the institutions directly associated with these sectors. The greatest demands for electricity are from commercial and domestic customers so it will be necessary to focus on these customers. Implementation of mitigation activities invariably will need facilitating and supporting roles from other institutions to provide suitable financial incentives and monitoring, assessment and analysis of outcomes, public relations and public education.

3.5.1 ENERGY SECTOR INSTITUTIONS

The government agencies, ministries and other institutions involved in the energy policy are as follows:

- Office of the Prime Minister and Foreign Affairs
  - National Energy Task Force;
  - National Energy Unit; and
  - Antigua Public Utilities Authority.
- Ministry of Works and Transport
- Ministry of Agriculture, Lands, Housing and the Environment
- Ministry of Tourism, Civil Aviation and Culture
- Independent Power Producers

The **Office of the Prime Minister and Foreign Affairs** has portfolio responsibility for energy and the Antigua Public Utilities Authority.

The **National Energy Task Force** will be responsible for providing a comprehensive and strategic National Sustainable Energy Policy and will assist the government in implementing the Energy Policy.

The **National Energy Unit** will compile energy information for use in sectoral planning and evaluation activities, provide advice on energy related issues and activities and recommend various approaches and measures related to electricity sector generation.

The **Antigua Public Utilities Authority (APUA)** is a statutory government agency established to ensure that consumers receive the best possible value in telecommunications, electricity and water services. APUA has exclusive right for the generation, transmission and distribution of electricity and fuels and may subcontract such aspects as deemed necessary or appropriate. For example fuel storage is currently sub-contracted to the West Indies Oil Company Ltd and some of the island's electricity is supplied by the Antigua Power Company under build, own, operate and transfer (BOOT) conditions. Policy formulation and introduction of legislation as required to successfully fulfill APUA's mission comes from the Minister of Public Utilities. It is not clear if the ministry has or exercises oversight on APUA.

Electricity for Antigua and Barbuda is provided by eight (8) thermal power plants all of which use high speed or low speed diesel engines. APUA operates three stations and independent power producers operate the remainder. Table 3-1 provides details on the stations.

Table 3-1 Details of Thermal Power Plants

Facility Antigua	Location	Owner	Capacity (MW)	Year Built	GWh [2009]
Frairs Hill	Frairs Hill	APUA	2 x 13.0 Now derated to 8 MW	1981	7,598.5
Crabbs Diesel Station	Crabbs	APUA	1 x 5.1 Now derated to 4 MW	1987	6,609.8
West Indies Oil	Frairs Hill	IPP	2 x 5.2 Now derated to 0?	????	5,460.8
Aggreko Friars Hill	Frairs Hill	IPP	2 x 13.0? Now derated to 8 MW	????	23,706.7
Aggreko Crabbs	Crabbs	IPP	1 x 13?	2006?	3,455.1
Antigua Power Company/1	Crabbs	IPP	17 MW 4 x 5 (now derated to 15 MW) 1 x 17 Now derated to 0 MW		148,614.0
Antigua Power Company/2	Crabbs	IPP	2 x 6.5 2 x 7.9 (now derated to 20 MW)	1997 2004	128,226.0
EGD (Barbuda)	Barbuda	APUA	2x3.6	????	2,712.5
Total					326,383.4

The **Ministry of Works and Transport** has portfolio responsibility for the Transport Board and Vehicular control as well as the Port Authority. Like most countries transportation accounts for a large percentage of GHG emissions and policies related to transportation sources will be important in mitigation of GHG emissions.

The **Environment Division** falls under the Ministry of Agriculture, Lands, Housing and the Environment.

The **Ministry of Tourism and Civil Aviation** includes the tourism sector which is one of the mainstays of the Antigua and Barbuda economy. Energy use by the tourism sector is included in the commercial sector and it should be noted that all transportation related to tourism is included in transportation sector (on and off road mobile sources, marine and aviation sources).

Independent Power Producers operate under licences issued by APUA and currently there are two IPP's - Antigua Power Company and West Indies Oil Company (WIOC) - that operate electricity generating stations.

Draft Antigua and Barbuda National Energy Policy

The National Energy Policy is currently being drafted. The ultimate aim of the energy policy is to create a stable, efficient and sustainable energy sector that fosters national economic and social development by establishing an enabling environment that exploits indigenous energy resources and reduces the total dependence on fossil fuels. The overall goal of the National Energy Policy is "to sustainably meet the energy needs of the present generation without compromising the ability for future generations to meet their own energy needs." The mandate to establish affordable, efficient, socially sound, reliable and accessible forms of energy will be supported by the policy.

Achievement of the goal would be met by the following strategies:

- Energy cost reduction
    - Energy audits
    - Public education
    - Utilisation of regional natural resources, inter island connections
- Diversification and efficient use of energy
    - Renewable energy (wind, sustainable biomass (agricultural waste), municipal solid waste, solar (grid and distributed PV, solar thermal concentrators) and a target share for renewables
    - Demand side management, increased solar water heating, energy efficient electrical equipment (lighting, appliances, motors, air conditioners etc.)
    - More efficient transport (fuel efficiency), lower emission standards, support for hybrid, flex fuel or electric vehicles
    - Use of regional biofuels, cleaner fuels (LNG)

- Electricity reliability
    - National grid upgrades
    - Increased operational efficiency
- Environmental protection
    - Environmental standards
- Stimulation of new economic/business opportunities
    - Self generation, cogeneration, net metering
    - Transparency in the electricity generation market

3.5.2 IMPLEMENTATION OF MITIGATION MEASURES

The mitigation measures include both demand and transformation initiatives. Successful implementation of the mitigation measures will depend on several factors including the following:

- implementing a public education programme to increase awareness and encourage energy conservation in the public and private sectors and in the general public;
- Stronger institutional capacities in the energy and environment sectors
- Legislative changes to allow net metering and electricity pricing mechanisms to promote alternate energy sources
- Development of programmes designed to influence market behaviour towards more efficient use in energy across all sectors
- Development of mechanisms to efficiently share energy related information and for public and private sector entities to collaborate on energy related projects
- Promotion of strategic partnerships between the public and private sectors to finance and develop energy diversification projects
- Systematic and aggressive means to take advantage of carbon trading, international grants and other assistance to implement alternate energy systems
- Provision of incentives and other measures to promote the switch to energy efficient vehicles, domestic appliances and commercial and industrial equipment
- Implementation of other energy related policies that will support the achievement of the goals of the national energy policy – namely the biofuels policy, waste-to-energy policy and the carbon emissions trading policy.
- Creating relevant legislation to support required investments in efficiency;
- Providing adequate infrastructure for transition to alternative energy vehicles;
- Increasing mass transit opportunities and utilization; and
- Introducing financial incentives for solar technologies (solar hot water heating and cooling, PV systems) in the domestic, public and private sectors and in communities.

The Draft National Energy Policy should provide the framework within which the mitigation measures indicated in Scenarios 2 and 3 will take place. All of the initiatives included in the scenarios are included or implied in the Energy Policy.

3.5.3 GAPS

Implementation of renewable energy measures and programs offers the potential for carbon trading. Extension of the Clean Development Mechanism (CDM) (or its equivalent) offers the potential to offset the higher costs of renewable energy technologies (PV, MSW, solar cooling). The lack of a CDM office and associated supporting policies and legislation is a major gap.

The current monopoly control of electricity generation, distribution and transmission is likely to hinder the entry of new players (offering renewable (RE) energy projects) in the electricity market. A policy that would promote RE technologies by offering incentives, tax relief, full social costing of electricity or other financial instruments will be vital for implementing mitigation measures.

An independent entity – not engaged in the electricity generation - that would oversee the entry into the market of renewable energy and IPPs – would afford greater transparency and eliminate apparent conflicts of interest.

3.5.4 RECOMMENDATIONS

For several countries, particularly developed countries with emission reduction targets, their energy policy is linked to or framed within the context of climate change mitigation and moving towards a low carbon economy. Although developing countries such as Antigua and Barbuda do not have emission reduction targets at present, "no regrets" mitigation actions such as energy conservation and development of renewable energy sources have positive impacts in terms of economic, social and environmental considerations. This section provides specific recommendations to improve the enabling environment, build institutional and human resource capacity, encourage adoption of suitable energy conservation/GHG mitigation technologies and fill data gaps that will facilitate cost effective energy use and implementation of GHG mitigation measures.

3.5.4.1 Enabling Environment

Improving the enabling environment within which GHG mitigation and other energy sector activities take place will entail streamlining some legislation or policies and in some cases additional legislation. These include the following.

- Develop and implement the regulatory framework to allow carbon trading to take place. This should include legislation establishing the designated national authority (DNA) and associated entities and specification of the trading modalities for local and international entities (e.g., licensing, certification or regulation of such entities, owning certified emission reductions (CERs) and Verifiable Emissions Reductions (VERs) etc.)

- Establish an enabling environment to encourage local and foreign financing of energy projects, especially in renewables. This could entail developing policies and programs that will encourage use of solar water heaters, solar cooling and photovoltaic systems. These could for example entail revolving loans, and/or import duty concessions and incentives for energy efficiency improvements
- Adapt/adopt or develop energy efficiency standards for consumer and industrial electrical equipment (e.g. by adopting the Energy Star program) and base import duties for such equipment in part on energy efficiency standards.
- Develop regulations and safety standards in anticipation of the introduction of LPG infrastructure and LPG use in industry and in vehicles
- Revise the bases for tax/customs duties so that they are based on vehicle weight class and fuel type (not cc rating)
- Develop a building code that will include promoting minimal use of air conditioning

3.5.4.2 Capacity-building Needs

Capacity building in the energy sector institutions will be required if mitigation measures are to be effectively implemented. The capacity building needs in the public sector centre on strengthening institutional arrangements for the collection, compilation, reporting and analysis of energy information and for public education. Implementation of private sector measures requires increased private sector technology awareness and capability and an environment that facilitates and encourages investment for implementation of mitigation measures. Public sector agencies with regulatory or other responsibility for the energy and environment must also be aware of the technologies, be able to assess them and to develop policies that are responsive to private sector and national needs.

The following specific capacity building needs are identified:

- Enhance capacity to compile GHG (and other) emission inventories and the capacity to perform energy and GHG emissions forecasting/modeling
- Develop an energy information clearing house
- Train staff to perform functions of the DNA and the supporting institutions (National Carbon Trading Promotional organization)
- Develop the capacity of local companies to improve their processes and energy efficiencies and to take advantage of carbon trading opportunities

3.5.4.3 Adoption of Clean and Energy Efficient Technologies

- Implement incentives/disincentives to enable the development and use of innovative technologies to improve energy efficiencies in the tourism sector and in households
- Encourage the use of solar powered water pumping

- Mandate that all new hot water installations be solar in all public buildings
- Promote more widespread use of solar water heating in the hotels
- Promote the adoption of solar powered cooling/air conditioning especially in the hotel/tourism sector
- Implement demand side management programme including the use of energy efficient appliances, equipment, and building designs, setting and enforcing standards for public sector organizations, public awareness and educational programmes

3.5.4.4 Address Data and Information Gaps

- Improve motor vehicle fleet database (include fuel type including designation for hybrids, model year, gross vehicle weight, add off road categories); clearly distinguish between non-motorised trailers and motorised trailers,.
- Compile statistics for annual vehicle kilometres travelled (VKMT) through periodic surveys or routinely collect and record odometer readings during vehicle inspections for certificates of fitness
- Survey industrial and commercial customers for end use equipment
- Conduct residential energy use survey
- Develop and sustain Public Education on energy efficiency and conservation
- Review the sustainable development and energy conservation curriculum needs in the primary, secondary and tertiary levels in the educational system and enhance the curriculum accordingly

CHAPTER FOUR:

CLIMATE TRENDS

AND

PROJECTIONS

CHAPTER 4: CLIMATE TRENDS AND Projections

4.1 CURRENT CLIMATE: GENERAL FEATURES

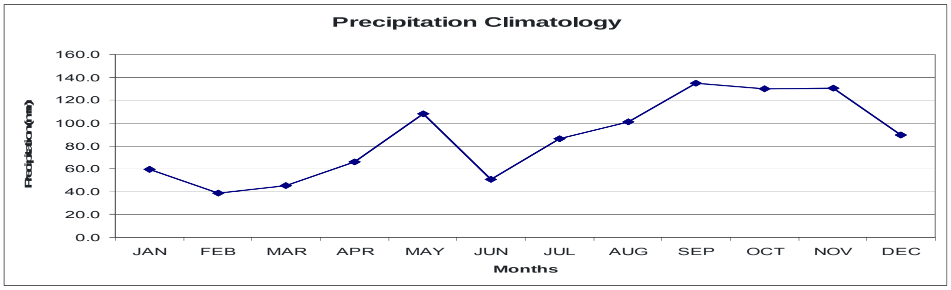
The climate of Antigua and Barbuda is typically that of a small tropical island. The combination of its size, location and low lying topography results in its climate being strongly influenced by features of the north tropical Atlantic. In the course of a year, the country's climate is strongly modulated by the migration of the north Atlantic subtropical high, the eastward spreading of the tropical Atlantic warm pool, the fairly steady easterly trades, and the passage of tropical waves, depressions, storms and hurricanes. The resulting climate regime is one characterized by a dry winter-wet summer pattern and high and fairly uniform temperatures year-round.

4.1.1 Rainfall

The country is among the driest in the eastern Caribbean. Antigua receives on average only 114 cm of rain, while Barbuda receives 89 cm. The rainfall climatology depicted in Figure 1.1 shows a dry season from January through April and a primary wet season from August through November. The primary wet season coincides with peak tropical storm activity. There is a distinct bimodality to the climatology as May tends to be a wetter month prior to the onset of the main rainy period. As is evident, more than half the rainfall received in the course of the year, occurs in the primary rainfall season.

There is also considerable inter-annual variability in the rainfall record. 1983 was among the driest years on recent record (less than xxx cm) while 1979 was amongst the wettest (in excess of 170 cm). [71] There is evidence that some of the variability may be driven by global climatic fluctuations such as the El Niño Southern Oscillation (ENSO) or by large scale gradients in tropical Atlantic and Pacific sea surface temperatures. Fluctuations in the May rains can be statistically linked to both Caribbean and tropical Pacific sea surface temperature fluctuations. The ENSO influence during the primary rainy season later in the year arises from that phenomenon's known modulation of tropical storm and hurricane activity formation in the north tropicalAtlantic basin (Gray et al. 1994).

[71]Meteorological data (1960-2001) provided by the National Meteorological Service for VC Bird International Airport.



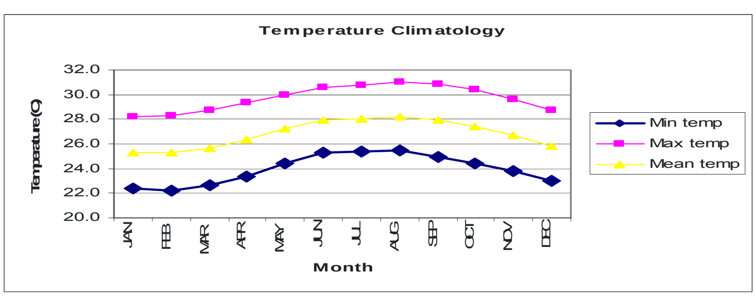
Graph 4-0-1: Mean annual monthly rainfall for Antigua (VC Bird Airport 1960 -2001). Units are mm/month.

There is no statistically significant trend in the mean annual rainfall data i.e. toward either increasingly wetter or drier conditions, though dry and wet year spells exist. Peterson et al. (2002) found this pattern i.e. of significant year to year variability but no statistically significant long term trend, to be generally true for Caribbean precipitation over the past 50 years.

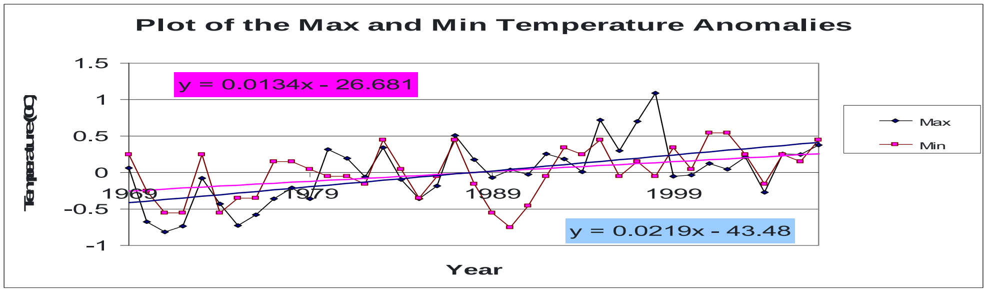
4.1.2 Temperature

The annual variation in maximum, minimum and mean temperatures is shown in Figure 4.1.2. The annual range is small for the mean temperature (less than 4 degrees), with peak temperature values occurring between July and September. Maximum temperature values may reach as high as 32^{o}C in these months, while minimum temperature values may drop to 22 ^{O}C in January/February.

Unlike the rainfall, both the maximum and minimum temperature records show a statistically significant warming trend (0.5 – 1^{o}C) over the past 35 years (Figure 1.3). This is consistent with the rest of the Caribbean (Peterson et al. 2002) and the globe (Alexander et al. 2006). However, unlike the global averages, maximum temperatures for Antigua and Barbuda are increasing at a slightly faster rate than minimum temperatures.



Graph 4-1-2: The climatology of minimum, maximum, and mean temperature for Antigua (VC Bird Airport 1969 -2007). Units are ^{O}C.



Graph 4-1-3: Annual maximum and minimum temperature anomalies for Antigua (VC Bird Airport 19xx -20xx). Anomalies are with respect to a 196xx-20xx baseline period. Trend lines added.

4.1.3 Other Climate Variables

Relative humidity across the country tends to be generally high year round (mid 70%) and predictably highest during the main rainfall period.

Winds are generally from the E or ESE, and wind speed is strongest (~6 metres per second) in the dry period from December through April. During this period the north Atlantic high is a persistent and dominant influence on the region. Notwithstanding, strong wind gusts are also common from June to November during the passage of tropical waves, depressions, storms or hurricanes.

4.1.4 Hurricanes

After a near thirty year lull (1961-1989) in direct hits, the country experienced the effects of six hurricanes (direct hits or near brushes) between 1990 and 2000.

In general, north Atlantic hurricane frequency is characterised by a multidecadal cycle which yields active and inactive phases lasting 10 or more years (Goldenberg et al. 2001). Since 1995, the north Atlantic has swung into an active hurricane phase. 5 of the country’s 6 recent hurricane experiences occurred in the current active phase of the north tropical Atlantic (1995, 1996, 1998, 1999, 2000).

There is also significant year to year modulation of hurricane frequency and track by ENSO events. El Niño conditions prove unfavourable to hurricane development due to the strong vertical shear that results. La Niña conditions favour hurricane development.

Since 2000 there has been a lull in hurricane impact on the country though the current active hurricane phase continues in the north tropical Atlantic.

4.2 DETERMINING FUTURE CLIMATE

4.2.1 Introduction

The strong linkages between climate and society provide adequate justification for attempts at projecting Antigua and Barbuda's future climate. Factors such as the impact of drought spells on water availability and a tourism driven economy (tourism being an inherently climate sensitive sector) point to the usefulness of rainfall, temperature, and seasonality projections. The sensitivity of important coastal infrastructure to storm and hurricane activity (particularly wind and surges) indicate the usefulness of projections of future storm activity and sea level rise.

4.2.2 GCMs, RCMs and Statistical Models

Global Circulation Models (GCMs) are useful tools for providing future climate information. GCMs are mathematical representations of the physical and dynamical processes in the atmosphere, ocean, cryosphere and land surfaces. Their physical consistency and skill at representing current and past climates make them useful for simulating future climates under differing scenarios of increasing greenhouse gas concentrations (Scenarios are discussed further below).

Projections of rainfall and temperature characteristics for Antigua and Barbuda through the end of the century are extracted from two GCM projects. In each case data from multiple GCMs were analysed (9 in one instance and 3 in the other) and it is the consensus results which are presented. Details of both projects are provided in the Appendix at the end of the chapter.

An inherent drawback of the GCMs, however, is their coarse resolution relative to the scale of required information. The size of Antigua and Barbuda precludes it being physically represented in the GCMs, and so there is a need for *downscaling* techniques to provide more detailed information on a country or station level. The additional information which the downscaling techniques provide do not however devalue the information provided by the GCMs especially since (1) Antigua and Barbuda's climate is largely driven by large-scale phenomenon (2) the downscaling techniques themselves are driven by the GCM outputs, and (3) at present the GCMs are the best source of future information on some phenomena e.g. hurricanes.

Data from two downscaling methods are applied. *Dynamical* downscaling employs a regional climate model (RCM) driven at its boundaries by the outputs of the GCMs. Like GCMs, the RCMs rely on mathematical representations of the physical processes, but are restricted to a much smaller geographical domain (the Caribbean in this case). The restriction enables the production of data of much higher resolution (typically < 100 km).

Available RCM data for Antigua and Barbuda were obtained from the PRECIS (Providing Regional Climates for Impact Studies) model (Taylor et al. 2007). Details of the PRECIS project are provided in the Appendix. The PRECIS model resolution is 50 km.

Statistical downscaling enables the projection of a local variable using statistical relationships developed between that variable and the large scale climate. The relationships are premised on historical data and are assumedto hold true for the future. Statistical downscaling is especially useful for generating projections at a location, once sufficient historical daily data are available.

Statistical downscaling was undertaken for rainfall and temperature data for VC Bird Airport station. The process was facilitated using the Statistical Downscaling Model (SDSM) (Wilby et al. 2002) for which details are provided in the Appendix.

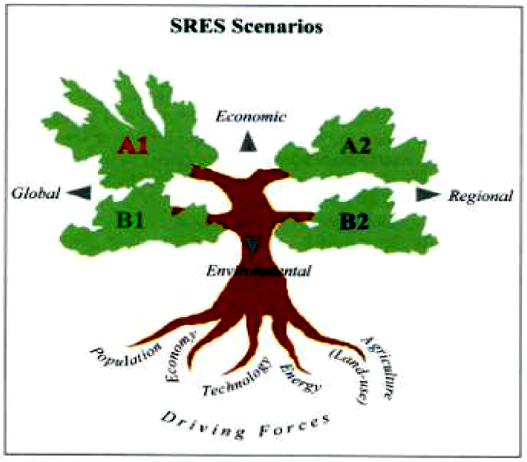
4.2.3 Scenarios

The GCM, RCMs, and statistical downscaling model are run using the Special Report Emission Scenarios (SRES) (Nakicenovic et al. 2000).[72] Each SRES scenario is a plausible storyline of how a future world will look. That is, the scenarios explore pathways of future greenhouse gas emissions, derived from self-consistent sets of assumptions about energy use, population growth, economic development, and other factors. They however explicitly exclude any global policy to reduce emissions to avoid climate change. Scenarios are grouped into families according to the similarities in their storylines as shown in Figure 4.1.4.

Since there is an equal probability of each storyline becoming the future, the results presented in the following section cover a range of scenarios, namely the A2, B1, B2 and A1B (see again Figure 4.1.4). A2 and B2 are representative of high and low emissions scenarios respectively (see Figure 4.1.5), while A1B is a compromise between the two. The A1B scenario is characterized by an increase in carbon dioxide emissions through mid century followed by a decrease.

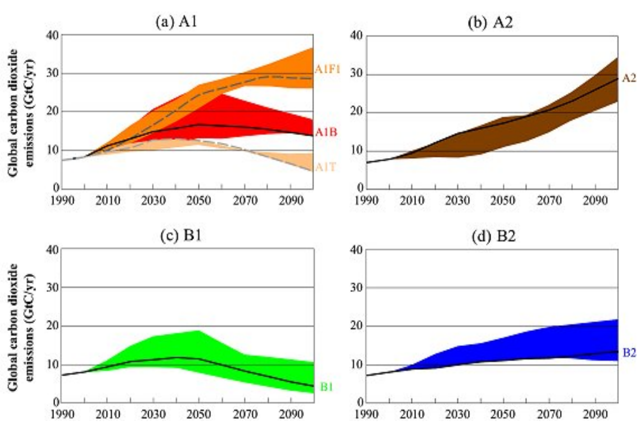
The future climate is presented as absolute or percentage deviations from the present day climate which is in turn represented by averaging over 30 year periods, usually 1961-1990 or 1971-2000.

[72]In 2000, the Intergovernmental Panel on Climate Change (IPCC) published a Special Report on Emissions Scenarios (SRES), presenting multiple scenarios of greenhouse gas and aerosol precursor emissions for the 21st century.



- A1 storyline and scenario family: a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies.
- A2 storyline and scenario family: a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines.
- B1 storyline and scenario family: a convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.
- B2 storyline and scenario family: a world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development.

Figure 4-1.4:: Special Report on Emission Scenarios (SRES) schematic and storyline summary (Nakicenovic et al, 2000).



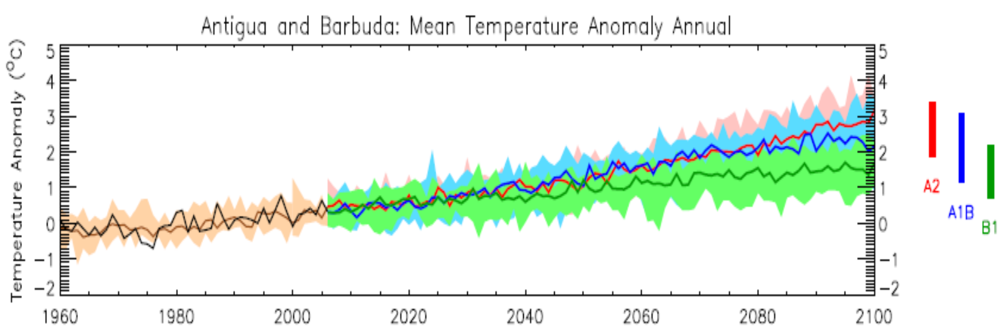
Graph 4-1-4: Total global annual CO_2 emissions from all sources (energy, industry, and land-use change) from 1990 to 2100 (in gigatonnes of carbon (GtC/yr) for the families and six SRES scenario groups (Nakicenovic et al, 2000).

4.3 FUTURE CLIMATE: RESULTS

4.3.1 Temperature

The annual mean temperature of Antigua and Barbuda is projected to increase irrespective of scenario, model or methodology used. The GCMs suggest that the increase is between 0.3°C (low emission B2 scenario) and 1.4°C (high emission A2 scenario) by mid century (2050's) and between 1°C and 3.5°C by the end of the century (2100) (Figure 1.6). The RCM shows a similar rate of increase with n annual temperature change of 2–2.5°C by the 2090s.

This range of increase is consistent with IPCC projections for the Caribbean which show annual mean temperatures increasing by 1.4°C to 3.2°C, with a median increase of 2.0°C by 2100. The increase is however slightly less than the anticipated global average warming.



Graph 4-1-5: Annual mean temperature anomaly 1960-1990. Units are °C. Black line: Average of observational datasets for current climate. Brown line and brown shading: Ensemble median and range for model projections of recent climate. Coloured lines and shading: Ensemble median and range of projections under 3 emissions scenarios. Bars at the far right demonstrate the change by 2080-2100 under each emissions scenario. All values are given as an anomaly from 1971-2000 mean climate.

The projections also suggest slightly less warming during the summer months (June-July) when compared to March-May. March-May is the period of greatest warming. Though the GCMs suggest that the difference in the projected increases for the two time periods is only 0.2°C for the country as a whole, SDSM analysis suggests up to a 1°C difference for the VC Bird Airport station. This has implications for the concept of seasonality (see below). Maximum temperatures at theVC Bird Airport station are also increasing at a faster rate than minimum temperatures, which is consistent with the previously noted historical trend.

The percentage frequency of occurrence of very hot days approaches 50% by the 2050's and 80% by the century's end. In contrast the percentage frequency of occurrence of very cool nights falls to near zero by 2100. A very hot day is defined as one with temperatures greater than the hottest 10% of days in the current climate. Similarly, very cool nights are those with temperatures less than the coolest 10% of nights in the current climate.[73]

4.3.2 Rainfall

There is much less consensus in the projected rainfall patterns for Antigua and Barbuda. This is illustrated in Figure 4.1.7 for three GCMs. Through the 2030's the projected change in mean annual rainfall ranges from +15% change to -20% dependent on model and scenario. There is more consensus in the sign of the trend toward the end of the century, with most models and scenarios indicating that Antigua and Barbuda will be drier in the mean. This is consistent with IPCC projections of a drier Caribbean by the century's end.

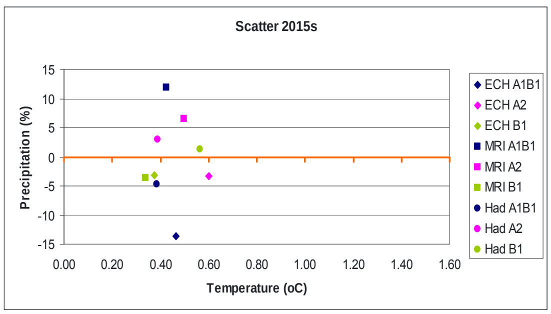
There is, however, more consistency in the rainfall pattern for some seasons during all time periods. For the 3 GCM study[74], all models show a general reduction in rainfall for the beginning months of the year (January–March) by the 2050s. The reduction averages 20% but approaches 25% in March for the high emissions (A2) scenario. There issimilar consensus about rainfall changes in the secondary period of June/July. These months exhibit the largest reduction in projected rainfall in the course of a year under all scenarios - up to 30% by the 2050s. The RCM captures this trend in June/July but is more severe in its projections, indicating 50-80% reduction in rainfall by the end of the century. The trend is for the dry periods to become drier.

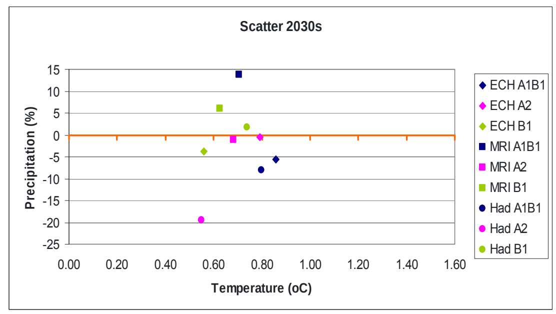
Very little can however be confidently said about changes in the rainy seasons due to the wide variations in the projected change, dependent on model and scenario. SDSM analysis does, however, show a general intensification of the early wet season at the VC Bird Airport station, with greatest increase occurring one month prior in April. This might imply a shift in seasonality.

[73] From the Climate Change Country Profile Project. See Appendix for details.
[74] From the Caribbean Model Intercomparison Project. See the Appendix for details.

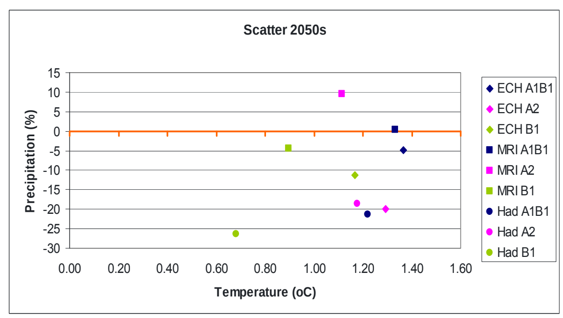
4.3.3 Seasonality

The seasonality of Antigua and Barbuda's climate can be represented by plotting the average monthly temperature throughout the year against the average monthly precipitation (Figure 4.1.8). All the seasonality features are captured by the resulting polygon including the cool-dry first three months of the year, the rainfall peak in May (which is accompanied by modest warming), the drying in June and July, the hot wet late summer months (August-September), and the gradual return to cool dry conditions. Changes in the polygon shape or position (e.g. elongation or flattening or vice versa) under global warming conditions would suggest a shift in seasonality.





Graph 4-1-6Scatter plot of projected change in mean annual rainfall and temperature for 3 GCMs (Had, MRI and ECH) run under A2, B1 and A1B SRES scenarios. Each marker indicates the change produced for a model run under a different scenario. Diagrams are for the 2015s, 2030s and the 2050s. Markers below the orange line indicate a projection of drier conditions.

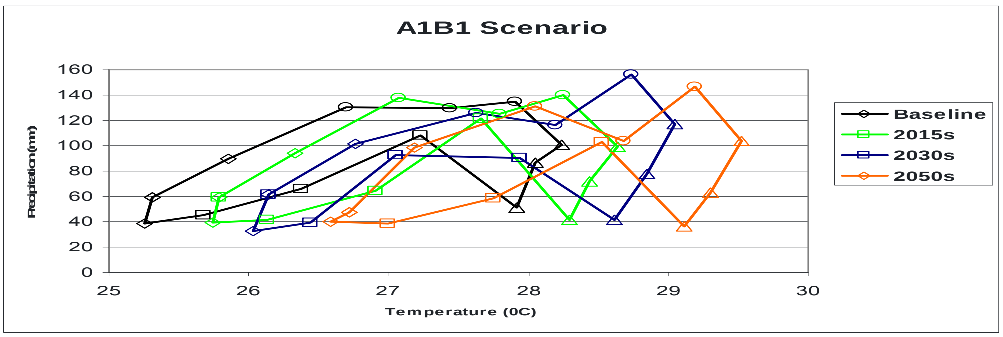


Results are shown for the A1B scenario.

In general the seasonality of Antigua remains the same in the future i.e. the pattern of cooler winter-hot wet late summers will still prevail, though monthly temperatures will be on average 2 degrees higher by the 2050's (as indicated by the rightward shift of the polygons). Other discernible changes in the polygon shape are accounted for by the previously mentioned drying in June and a slight increase in September rainfall by the 2050's in most (but not all) scenarios. The projected larger increase in winter temperatures versus those in summer is not well represented in the diagrams.

4.3.4 Hurricanes

Since the models examined do not explicitly model hurricanes, it is the IPCC's projections which are relied on. Based on a range of models, the IPCC suggests that future hurricanes of the north tropical Atlantic will *likely*[75] become more intense, with larger peak wind speeds and more heavy precipitation. This they associate with ongoing and projected increases of tropical sea surface temperatures. There is however less confidence in model projections of a global decrease in the numbers of tropical cyclones.



DJF - ◊ MAM - □ JJA - Δ SON - O

Graph 4-7: Seasonality diagrams for Antigua and Barbuda. Polygons show the variation in mean rainfall and temperature for a given year. Plots are for current climate (baseline), the 2015's, 2030's and 2050's.

4.3.5 Sea level Rise

As for hurricanes it is the IPCC's projections which are relied on to make statements about potential sea level rise. Large deviations among the limited set of models addressing the issue make estimates of sea level change across the Caribbean uncertain. Whereas it is not possible to presently address projected sea level rise for Antigua and Barbuda specifically, the changes in the Caribbean as a whole are expected to be near the global mean. Under the A1B scenario, expected sea level within the Caribbean is expected to be between 0.17 m and 0.24 m by 2050 (IPCC 2007). For comparison, global sea level rise is expected to average 0.35 m (0.23 to 0.47 m) by the end of the century (relative to the period 1980-1999). It is important

[75] In the IPCC Summary for Policymakers, the following terms have been used to indicate the assessed likelihood, using expert judgement, of an outcome or a result: *Virtually certain* > 99% probability of occurrence, *Extremely likely* > 95%, *Very likely* > 90%, *Likely* > 66%, *More likely than not* > 50%, *Unlikely* < 33%, *Very unlikely* < 10%, *Extremely unlikely* < 5%.

to note, however, that changes in ocean density and circulation, will ensure that the distribution of sea level rise will not be uniform across the region.

4.4 CONCLUSION

In summary the following can be noted about the climate of Antigua and Barbuda:

10. There is evidence to suggest that the climate of Antigua and Barbuda is changing. Both maximum and minimum temperatures have increased in the recent past.
11. The warming trend is expected to continue. The country is projected to be 1 to 3.5 degrees warmer by the end of the century.
12. Winter months will see marginally larger increases in temperature than summer months.
13. The frequency of very hot days will increase, while very cool nights will decrease.
14. There is a likelihood that the country will be drier (in the mean) by the end of the century.
15. Climate change will likely make the dry periods early in the year and in June/July drier.
16. The seasonality of Antigua and Barbuda will be largely unchanged. The cooler (with respect to late season temperatures) dry early months and wet hotter late months will still prevail.
17. Hurricane intensity is likely to increase but not necessarily hurricane frequency.
18. Caribbean sea levels are projected to rise by up to 0.5 m by the end of the century.

APPENDIX

The data used in this chapter were from four modelling projects.
In the **Climate Change Country Profile Project** output from 9 GCMs is examined to determine temperature and rainfall changes through the end of the century. Changes are with respect to the 1970-2000 mean climate. For the observed climate, gridded station datasets (from CRU, University of Delaware and GPCC) (0.5˚ resolution), plus NCEP and ERA-40 re-analysis (temperature only) are used. In calculating extreme indices, the HadEX dataset (UK met office) is used and indices are calculated from daily observed data and gridded datasets, as well as from 5 of the 9 GCMs. The A2, A1B, and B1 scenarios are analysed.

The **Caribbean Model Intercompariosn Project** uses output from 3 GCMs. The GCMs are HadCM3 (UK), MRI-CGCM2 (Japan) and ECHAM 5/MPI-OM (Germany). Climate change is determined relative to a 1960-1999 baseline climate. The A1B1, A2 and B1

scenarios are analysed for three 10 year future time slices cantered on the 2015’s, 2030’s and 2050’s.
Available RCM data are obtained from the **PRECIS** (Providing Regional Climates for Impact Studies) model which was run at the University of the West Indies (Taylor et al., 2007). PRECIS has a 50 km resolution and is restricted to a Caribbean domain. The model is forced at its boundaries by HadCM3 data and results extracted for the baseline (1960-1999) and for a future time slice (2070-2099) for the A2 and B2 scenarios.

For further downscaling of the HadCM3 model results, the **Statistical Downscaling Model** (SDSM) (Wilby et al. 2002) was used. Projections were done using the A2 and B2 scenarios for the 2015s, 2030s and 2050s. SDSM used to assess regional scale predictor impacts on weather conditions (maximum and minimum temperature and precipitation) at the VC Bird International Airport.

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CHAPTER FIVE

COASTAL ZONE

CHAPTER5: Coastal Zone

5.1 INTRODUCTION

Climate change is one of the key issues facing the international community. There is no doubt that the Earth's climate is changing and as a result will produce sea level rise and other climatic impacts within the Caribbean region. However the rate at which these affect the coastal regions of Antigua and Barbuda is somewhat unpredictable. It is also evident that even without climate change the coastal zone is affected by natural agents which produce dramatic changes on the physical and socio-economic landscape.

It is generally recognised that the various ecological and socio-economic systems undergo multiple stresses which produce net environmental consequences which are expected to change with time (Yohe, et al., 2007). Ecological systems, including the coastal and marine environments have been impacted by factors such as climate change, population increase and economic development. Climate change is therefore only one driver of change. There are always uncertainties involved with predicting the impacts of climate change and other associated phenomena such as climate variability or even sea level rise (SLR). There are uncertainties related to accuracy of data and measurements, assumptions used in climate modelling and even the prediction of the contributions of bio-physical relationships that exist between climate change and the different sectors. This makes it more difficult to determine the impacts of climate change on the coastal zone.

It is therefore necessary that the possible scenarios be examined critically so that the best adaptation strategies can be adopted for the future development and sustainability of Antigua and Barbuda.

5.1.1 Methodology

This chapter provides an analysis of the likely effects of climate change impacts on the coastal zone in Antigua and Barbuda. It involves an overview of the existing physical conditions around the coast and socio-economic stresses and other major issues facing these areas and likely implications for climate change. In the context of future scenarios of climate change, possible adaptation strategies and measures are identified.

The assessment incorporates a combination of approaches, including, the United Nations Development Programme (UNDP) Adaptation Policy Framework (APF) that seeks to identify and respond to existing climate related stresses that are likely to be exacerbated by climate change. Extensive work related to impacts of climate change on the coastal zone, has been done within the Caribbean, through the Caribbean Planning for the Adaptation to Climate Change (CPACC) project and later extensions of CPACC such as Adapting to Climate Change in the Caribbean (ACCC) and most recently Mainstreaming Adaptation to Climate Change (MACC). However, there is a paucity of reference materials specifically for Antigua and Barbuda. Reference will be made to available studies and specific data for Antigua and Barbuda. However, it is important to recognize that uncertainty forms a critical element of climate change assessments, no matter the scale.

In relation to the coastal zone uncertainties arise from a number of climatic and non-climatic factors. Uncertainties include:

- Those related to accuracy of data and measurements, assumptions used in climate modelling and even the prediction of the contributions of bio-physical relationships involved in climate change and coastal changes.
- Uncertainty arising from natural and anthropogenic variability and uncertainties associated with global climate change projections and their local validity (Mimura, 2007). There are uncertainties surrounding regional projections of climate change, particularly precipitation
- Uncertainty in the magnitude of climate change impacts and the extent and timing of climate change
- Uncertainty as to the social and economic forces that contribute towards development and sustainability of coastal systems
- Uncertainty as to what future public policy and other initiatives may do to affect the extent of climate impacts on the country's natural environment as well as on coastal development. This is particularly significant considering the vulnerability of coastal areas.

The task of assessing impacts of climate change on the coastal zone therefore becomes more difficult considering the paucity of existing data on various elements of the coastal zone. [76]. Available evidence from published sources will be used where appropriate to support arguments.

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[76] See "UNFCCC Compendium on Methods and Tools to Evaluate Impacts of Vulnerability and Adaptation to Climate Change". At http://unfccc.int/adaptation/nairobi_workprogramme/compendium_on_methods_tools/items/2674.php

5.2 OVERVIEW OF THE COASTAL ZONE

5.2.1 PHYSICAL FEATURES

Antigua and Barbuda with a land area of 440 km^2 (170 sq. miles) is enclosed by about 260 km (160 miles) of coastline, including Redonda (with 1.6 km^2 or 0.6 sq. miles of land space) and several smaller surrounding coastal islands. The coastal zone shows marked variations in its topography, geology, socio-economic and ecological characteristics. The size, location and low lying topography of the islands provide almost uniform climatic conditions throughout Antigua and Barbuda.

Antigua's south and southwest coast are characterized by hilly volcanic formations while limestone dominate along the undulating or low lying north and east coasts including the offshore islands and Barbuda. Barbuda is relatively flat with some low lying hills rising to just under 125 ft (40m) in the Highlands area. A marked feature, of the low-lying coastal areas, bays and lagoons, is the wide distribution of mangroves.

White, sandy beaches are a typical feature of the coastline of Antigua and Barbuda. Sea grass beds and coral reefs predominate in the shallow waters, especially within sheltered areas. The coastal and marine habitats provide the basis for the survival of important animal and plant species within these areas.

The coastal zone is one of the primary providers of ecosystem goods and services to Antigua and Barbuda. Reefs, mangroves, sea grasses and beaches are all part of an interconnected system, each playing a critical role in supporting the health of neighboring habitats and of important fish and other marine species. The extensive coral reefs and mangrove systems which line the coasts provide critical protection against wave erosion and cushion the direct effects of storms and hurricanes. Traditionally, they have supported fishing communities as a source of food and livelihood for many people and more recently provides important services to the tourist industry.

The climate of Antigua and Barbuda may be classified as tropical marine with average annual temperature and rainfall being 28°C (81°F) and 40 inches (100 cm), respectively. Generally, there are marked wet and dry periods for any given year, and the wet season usually coincides with the hurricane season when the country is influenced by the passage of tropical waves, depressions, storms and hurricanes.

Rapidly expanding coastal development, destructive fishing practices and pressures from tourism are direct threats to the country's reefs and mangroves. Reefs and mangroves also protect coastal properties from erosion and wave-induced damage. Currently, even without specific economic valuation studies, investments in protecting the coastal zone are considered relatively low when compared to the contribution of these coastal resources to the national economy.

5.2.2 Major Issues facing the Coastal Zone

There are various issues facing the coastal zone of Antigua and Barbuda, even without considering climate change and sea level rise. Major issues include:

- Sustainable/Wise use of coastal resources including encouraging sustainable livelihoods in coastal communities
- Maintenance of coastal biodiversity, including the conservation of coastal landscapes, habitats, and species
- Balancing tourism development and environmental (including habitat) protection.
- Promotion and support of coastal planning
- Protection and enhancement of public access to the coast
- Communicating with resource users, the public and government about coastal issues and
- Engagement of local communities in coastal stewardship.

In spite of the need for wise use of coastal resources, sustainability has always been a major issue. Beach sand mining, although reduced in its extent, is still a problem in Antigua. The sand dunes are still commercially mined in specific locations on Barbuda. Though curtailed, removal of mangroves for hotel, marina or other coastal development, continues to be a significant threat. In some areas, mangroves are replaced by (built) beaches which may disrupt the natural transition of coastal vegetation. In addition, there is destruction of sea grass beds and coral reefs in some areas, either due to effects of coastal development or to unsustainable (uses) practices including inappropriate and destructive fishing methods.

These issues in most parts are being addressed by the relevant authorities, including the Development Control Authority (DCA) and the Fisheries and Environment Divisions.

The current situation of coastal resources and uses indicate that there are local factors affecting their vulnerability to existing climate conditions. These are mainly related to the types and amount of activities within the coastal zone and sources of stress whether from land or sea, as illustrated in Table 4.1.

Table 5.1Major Stresses currently within the Coastal Zone of Antigua and Barbuda

Stress Source	Major Stresses
Terrestrial - based Uses	***Tourism / Marina Development*** • Overcapacity of resources • Mass coastal infrastructure (too close to coastline) • Damage to beaches, mangroves, sea grass, coral reefs • Sewage and other waste disposal ***Settlement***

	• coastal infrastructure (built close to coastline) • Effluents: sewage and other waste disposal (chemicals) • Pollution from manufacturing and other industries • Solid waste disposal ***Agriculture*** • Sedimentation from poor land management practices
Marine-based Uses	***Tourism related*** • Occasional sewage and other waste disposal • Occasional oil spills ***Fishing*** • Poor fishing practices (spear fishing, nets and traps set directly on reefs, etc.,) • Commercial vessels (traffic in shallow areas) • Oil spills

Mass tourism is translated in a need for more hotel rooms and recreational facilities to cater to their needs. Coastal space is limited on Antigua and Barbuda, where there is already a high concentration of the population and activities on or near the coast. As a result there is greater pressure on the natural resources, including beaches, sea grass beds, mangroves and coral reefs. In addition, there is sedimentation and introduction of sewage and other wastes from land into the sea. The fisheries resources have been negatively affected by inappropriate fishing activities, especially within the near shore areas of Antigua and Barbuda.

5.2.3 Institutional Arrangements

Antigua and Barbuda, share similar economic and sustainable development challenges with other small island developing states (SIDs), including limited natural and other resources, a small but rapidly growing population, susceptibility to natural disasters, a high dependence on international trade, and vulnerability to global developments. In addition, there are other issues such as a lack of economies of scale, high transportation and communication costs and costly public administration and infrastructure. In the context of climate change, adaptation and developing adaptive capacity is really a process and not a project (Nurse, 2008). Currently, based on general observations, there are basic capacity limitations of the agencies which manage the coastal zone.

Adaptive capacity for the coastal zone means having the necessary human, financial, informational and other resources to effectively manage the coastal zone. This involves the various components of planning and management, including stakeholder involvement, enforcement, monitoring, evaluation, and also adaptive adjustments over time. In the absence of an institutionalised coastal zone management institution, several government agencies give oversight to the management of the coastal zone. Each agency functions under its own legal mandate and therefore in spite of linkages, cross-cutting and sometimes duplication may occur. The particulars for the various agencies are given in Table 5.2.

Table 5.2Agencies operating within the Coastal Zone of Antigua and Barbuda

AGENCY	GOVERNING LEGISLATION	FUNCTIONS / INVOLVEMENT IN COASTAL ACTIVITIES AND CLIMATE CHANGE
The Barbuda Local Government Council	Barbuda Local Government Act of 1976.	General management of coastal areas, including: the improvement and maintenance of public buildings, wharves and harbour facilities; the promotion of hotel and tourist development and the administration of fisheries.
Development Control Authority (DCA)	Physical Planning Act of 2003.	Development application review and approval; development surveillance.
Lands Division	The Crown Lands (Regulation) Act of 1917	Planning and allocation of government lands for residential, agricultural and other land use purposes; administration of Government of Antigua and Barbuda land leases and rentals.
St. John's Development Corporation	St. John’s Development Corporation Act of 1986	Upgrading of downtown St. John's through urban renewal and implementation of other development projects (e.g. Heritage Quay, a tourism complex including shopping, and hotel and cruise ship berthing facilities).
National Parks Authority (NPA)	National Parks Act (1984) and National Park’s (Amendment) Act of 2004	Development and management (including development control) of national parks, at present limited mainly to Nelson's Dockyard National Park.
Antigua and Barbuda	Port Authority Act of	Development and management of

Port Authority	1973 Oil Pollution of Maritime Areas Act of 1995	lands at St. John's Deep water Port and other ports. Make provision for the discharge or escape of oil into maritime areas.
The Environment Division		
The Fisheries Division	Fisheries Act of 2006	Development and management of fisheries and matters incidental thereto.
The Tourism Department		
Public Works Department	Beach Protection (Amendment) Act of 1993	Beach protection, particularly the removal of sand.
National Office of Disaster Services (NODS)	The Disaster Management Act of 2002.	Preparation for and management of disaster services.
Forestry Unit	Forestry Act of 1941	Conservation and management of forested areas, including mangroves.
National Solid Waste Management Authority	National Solid Waste Management Authority Act of 2005	Management of solid waste including ship generated solid waste.
Antigua and Barbuda Defence Force Coast Guard (ABDFCG)	Dumping at Sea Act of 1975	Control and prevention of dumping waste at sea

Most of the relevant agencies in Antigua and Barbuda recognize the need for integrated coastal zone management in the context of sustainable development. However, different approaches could produce varied results. Effective ecosystem-based management (EBM) is intended to reduce a country's vulnerability to many pressures and hazards by building ecosystem resilience, through enabling: consistency in food production, improvements of the tourism product, protection against natural hazards, greater resistance to negative effects of changing climate and a solid basis for incremental improvement in the overall economy (Innis, 2008).

The Fisheries Division has developed strategies for the promotion of sustainable marine and coastal development throughout Antigua and Barbuda. Regular monitoring programmes are in place for beaches and mangrove systems. Sea grass and coral reefs are monitored on a less regular basis. Co-management programmes have also been developed for stakeholders to participate in the development of marine protected areas (MPAs).

5.3 CLIMATIC AND SOCIO-ECONOMIC SCENARIOS

5.3.1 Introduction

The coastal zone is an extremely dynamic area reflecting the constantly evolving and complex interaction of marine and terrestrial ecosystems. At the same time pressures for use and exploitation of coastal and marine resources means that the complex nature of human interactions with the coastal zone are also constantly changing.

An assessment of future impacts of climate change on the coastal zone therefore also requires an understanding of possible socio-economic developments that might impact on the coastal zone. The aim here is to look at some of the developments in the coastal zone that can be expected to arise independently of climate change.

5.3.2 Socio-Economic Scenarios

With the coastal zone being the primary location of socio-economic activities, including tourism, in Antigua and Barbuda, the country's economy becomes even more fragile in the face of climate change. It is anticipated that sustaining current economic growth rates and reducing the rate of unemployment and poverty will pose major challenges. In addition, there may be external shocks as a result of rising energy and fuel prices, fluctuating commodity prices, escalating costs of external credit, the reduction of preferential market arrangements including subsidies and the introduction of strict regulations governing trade including sanitary and phyto-sanitary conditions.

The economic outlook for Antigua and Barbuda, considering climate change impacts in coastal areas, can be expected to incorporate the following:

- The economy of Antigua and Barbuda remains highly dependent on coastal based tourism. Coastal tourism, especially its infrastructure[77], is highly vulnerable to the adverse impacts of climate change and sea level rise.
- Small coastal settlements which are dependent on agricultural production will be affected since many of the crops are highly vulnerable to anticipated future climate change scenarios (increased temperatures, droughts, changes in mean rainfall and increased incidences of pests and diseases).
- External price shocks are anticipated to exacerbate well into the future. This can be attributed to rising cost of imported food items and fuel. Antigua and Barbuda is heavily reliant on these commodities to feed its population that is concentrated along the coast.
- Antigua and Barbuda, under the influence of the global economic crisis, continues to increase its debt burden. At the same time, there is a decline in foreign direct investments (FDI) which in most cases go directly to the tourist industry and overseas development assistance (ODA) for specific projects.

Focus should be on effects, if any, that crisis will have on the population within the coastal zone. The economic conditions will pose certain social challenges, including:

- Increased unemployment, crime, drug trafficking and addiction and possibly higher poverty levels. This has implications for coastal populations who will be less likely to adapt to climate change impacts.
- Continued rise in the incidence of the HIV/AIDS virus and other viral diseases that decreases the adaptive capacity of coastal populations.
- Greater migration of skilled and semi-skilled professionals which will eventually affect the country's productive capacity.

The situation will be further compounded by harsh environmental conditions, including: rising sea levels causing inundation of productive land in some areas and increased coastal erosion resulting in loss of land. Strong winds and flooding during storms or hurricanes can cause physical damage to coastal structures and natural vegetation. This could eventually cause added stress to the population in affected areas and loss of lives, in the worst case scenario.

[77]Hotels and other structures built on or close to the coastline are open to the direct (physical) impact of hurricanes and storm surge.

5.3.3 Future Climate Scenarios

Table 5.3 gives the main future climate predictions for Antigua and Barbuda. Both air and sea surface temperatures will continue to increase. Periodicity and amount of precipitation is anticipated to be more varied with drier conditions probably becoming more dominant. There is no clear indication that hurricane frequency will change but wind speeds are expected to have higher peaks producing a general increase in intensity by approximately 5-10% by the 2050s (IPCC, 2007; IPCC, 2007b). Climate change and sea level rise will produce severe impacts on the coastal zone. Box 4.1 provides a summary of the major impacts.

Table 5.3: Climate Projections for Antigua and Barbuda and the Insular Caribbean

Climate Parameter	Predicted change for the Insular Caribbean[78]	Predicted change for Antigua and Barbuda[79]
Air temperature	Increase of 1.8 - 4.0°C by 2099	1.3°C by the 2050s 1 - 3.5°C by the end of the century
Sea surface temperature	~1.7°C by the end of the century	Up to 2°C by the end of the century
Sea level rise	Rise of 0.18 – 0.59 m by 2099	Rise of 0.24 m by 2050[80]
Carbon dioxide	Reduction in pH of the oceans by 0.14 - 0.35 units by 2099	An increase in carbon dioxide emissions through 2050 followed by a decrease
Hurricanes	More intense with larger peak wind speeds and heavier precipitation	More intense with larger peak wind speeds and heavier precipitation. (not necessarily increased frequency)
Precipitation	Unclear	Drier (in the mean) by the end of the century

[78]Based on global predictions from IPCC WGI, 2007
[79]Climate Studies Group, Mona. University of the West Indies
[80]Estimate for the Caribbean

5.4 IMPACTS OF CLIMATE CHANGE

Depending on local conditions, climate change will have varying effects on the coastal areas. Box 5.1 summarises the major impacts of climate change within the coastal zone of Antigua and Barbuda. The major impacts are more dominant within the ecological environment.

Box 5.2 A summary of the impacts of climate change on the coastal zone in Antigua and Barbuda includes:

- Destruction of /damage to critical habitats (beaches, mangroves, seagrass beds, coral reefs)
- Climate change impacts may contribute directly to overfishing, pollution, and loss of wetlands and nurseries
- Increased coral bleaching as a result of a 2°C increase sea surface temperature by 2099
- Sea-level change can cause loss of coastal wetlands and land area in general
- Destruction to coastal infrastructure, loss of lives and property
- Changes in coastal pollutants will occur with changes in precipitation and runoff
- In extreme conditions, the possible loss of a livelihood, and
- General economic losses to the country

Sources:(APO, 2008; Cambers, Claro, Juman, & Scott, 2008; Creary, 2003; Crocker, 2008; Delaney, Michael, & Murray, 2000; Everett, 2007; IPCC, 2007a; IPCC, 2007b; James P. A., 2008; Mahon R. , 2002; Nurse 2008; Yohe et al, 2007)

5.4.1 Temperature Changes

Increased temperatures, especially sea surface temperatures can cause major changes in the natural coastal environment. Evidence of impacts of climate change on reefs include coral bleaching, reduced calcification potential leading to a slowdown or reversal of reef building and loss of reef in the future, diseases of corals and other organisms[81], widespread losses of major reef-building corals (staghorn and elkhorn) due to white band disease, the current widespread occurrence of aspergillosis, a fungal disease that attacks some species of gorgonians (sea fans), numerous outbreaks of white plague and possible migration (both vertical and horizontal) of fish and other marine life. Elevated sea surface temperatures are a primary cause of coral bleaching. The most severe episodes in the past have coincided with years when the El Niño signal was strongest, for instance in 1983, 1985, 1997/98, 2005/2006. In the 1997/98 event, approximately 25-30% of coral reefs in the Caribbean were affected (Nurse, 2008)

[81]Caribbean-wide die-off of the long-spined black sea urchin *Diademaantillarum*

Coral reefs are particularly important to Antigua and Barbuda because of their high value to fisheries, tourism and coastal protection. They are also particularly vulnerable to the effects of climate change and therefore research is needed to determine the best strategies for building their resilience and capacity for adaptation (James P. A., 2008). Research has also shown that the world's oceans have become approximately 30% more acidic since 1750 - the start of the Industrial Revolution, associated with increasing anthropogenic emissions of CO_2 (IPCC, 1990; IPCC, 2001; IPCC, 2007b; Nurse, 2008). This can result in the reduction of calcium available to marine animals (including corals) for the formation of their skeletons and shells. This can have serious repercussions for the provision of seafood and various ecosystem services especially to coastal communities.

Coastal settlements around Antigua and in Barbuda may not be directly affected by increased atmospheric temperatures. The moderating effects of surrounding oceans could probablybe more dominant in the long run.

5.4.2 Increased Hurricane and Storm Activity

Intensifying hurricane and storm events together with rising sea levels will increase beach-erosion in many areas around Antigua and Barbuda. This can cause a reduction in beach areas available for recreational activity especially for tourism. Of particular concern is the negative impact this will also have on the availability of suitable nesting sites for marine turtles.

Because of their life cycle and their migratory nature, marine turtles have generated Caribbean-wide or even global interest. Many of the beaches around Antigua and Barbuda are known turtle-nesting beaches. Beaches around Antigua and Barbuda have been affected by Hurricane Luis in 1995. Many have lost significant amounts of sand due to excessive erosion. However, some beaches experience erosion during periods of winter swells, particularly between November and March. Palmetto Point in Barbuda has a history of shifting dunes which results in the great fluctuations shown. The winter swells may have even greater effect on this beach. Fishermen have indicated that these swells (ground swells) are becoming quite unpredictable as climate change occurs. The fluctuating trend is expected to continue into the future. The rate at which erosion or deposition occurs along the coastline is uncertain. However, with the eminent threat of climate change and sea level rise to coral reefs[82], it is anticipated that beach area and width will eventually decrease.

Hurricanes and tropical storms can also cause physical damage to mangrove forests and coral reefs. Mangroves form essential nursery habitats for many species and play a critical role in coastal protection during storm events. As with beaches, they are

[82]Coral reefs are the primary source of beach sand in Antigua and Barbuda.

threatened by increasing tourism and other developments on the landward side and rising-sea levels on the seaward side.

Intensified hurricane activity not only causes physical damage to mangroves but probably total loss of the system. Extensive areas of mangroves have been affected between 1995 and 1999, a period of intense storm or hurricane activity. Today some areas show increased growth and productivity of the mangrove area but possible changes in mangrove forest structure have been noticed.

More frequent storms and intense hurricanes can cause major destruction to coastal properties and infrastructure. This may be directly due to increased wind, waves and associated storm surges.

5.4.3 Sea Level Rise

Sea level rise can pose a direct problem to low-lying coastal lands, infrastructural development and settlements[83] located on or close to the coastline. Flooding and inundation of valuable land and property are major impacts. In addition coastal ecosystems may be severely affected.

Increased erosion of important beach areas, reduced seaward margins of the mangroves and loss of protective lagoon bars and sea barriers may be caused by an increase in sea level. In response, there may be relocation and migration of mangroves inland, rather than overall loss. However, this landward migration can be obstructed if the landward margin of the mangrove area is steep or if there are built structures such as seawalls and other developments, thereby reducing the areas of coastal ecosystems.

Increased sea level rise can produce saline intrusion within coastal hydrological systems. This is particular significant in Barbuda which depended on underground fresh water sources for a long time.

5.4.4 Other Impacts

Changes in precipitation as a result of climate change can produce either positive or negative impacts within coastal areas. Increased precipitation on steep coastal slopes can trigger landslides and rock falls. In low-lying coastal areas and wetlands, there may be an elevation in the levels of flooding and associated sedimentation and/or pollution. This could actually lead to the smothering and siltation of sea grass beds and coral reefs. On the other hand, drought conditions could give rise to dust and sand storms along exposed coastal areas particularly on beaches. Most of these effects may only be fully recognised in the long-term.

[83] This is particularly significant for the low-lying island of Barbuda.

5.5 ADAPTATION STRATEGIES AND MEASURES

For Antigua and Barbuda's coastal zone, adaptation strategies include protective measures to restore and/or protect beaches, mangrove systems, sea grass beds, coral reefs and properties along the coast. Partly because there is no single agency totally responsible for the coastal zone and there is no comprehensive coastal development plan, individual property owners have devised their own measures to protect their properties both as an economic strategy and for climate change and related phenomena. These include periodic beach nourishing[84], dune restoration[85] and in some cases littoral drift replenishment[86]. However, most of these activities are presently implemented without appropriate studies or research. Long-term strategies for Antigua and Barbuda's coastal zone include retreat and accommodation options. The retreat option involves the general control of coastal development, including the phasing out of development in vulnerable coastal areas. Settlement expansion in Barbuda extends further inland rather than on the coast. This is possible due to the peculiar land ownership arrangements and the availability of large areas of communal lands. This is more difficult on Antigua where vulnerable communities such as Johnson's Point and sections of Pigotts[87] have been severely affected in the past but return to normal conditions based on the unavailability of feasible alternatives. Preliminary vulnerability assessments, for the First National Communications, indicated that additional efforts are required to evaluate the range of coastal adaptation identified by the IPCC and other agencies. The impact of extreme events also emerged as a primary source of adverse impacts on the coastal resource base. Further technical and scientific work was also recommended in order to understand the impact of climate change on coastal areas (James P. A., 2008; McConney, Nurse, & James, 2009; Cambers, Claro, Juman, & Scott, 2008).

Potential adaptation options for the Coastal Zone in Antigua and Barbuda are given in Box 5.2.

With the constantly changing land-use within the coastal area, there is a need for the development and implementation of strict land-use plans and policies. The Physical Planning Act (2003) and the development planning regulations need to be implemented and strictly enforced. This will ensure that the existing coastal setbacks are

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[84]Coastal development around Mamora Bay, Dickenson Bay and Lignumvitae Bay.

[85]Notable examples at Emerald Cove and Maiden Island.

[86]This is done mainly through the construction of groynes, e.g. at Jolly Beach (Lignumvitae Bay), Dickenson Bay and developments along the northern coastline of Antigua.

[87]Johnson's Point is highly vulnerable to storm surge and tornadoes associated with hurricanes. Sections of Pigotts are particularly vulnerable to flooding.

implemented and enforced. In some areas, with unusually high vulnerabilities, there may be the need to increase coastal setbacks behind the line of permanent vegetation or high water mark (whatever is higher).

Box 5.3 Potential adaptation options for the Coastal Zone in Antigua and Barbuda

Adapting to coastal land loss and erosion:

- The application of beach setbacks for construction and changing land-uses in the coastal zone
- Vulnerability assessment of the coastal zone
- Restore damaged or destroyed coastal ecosystems where technically feasible
- Construction of coastal engineering structures such as sea walls and breakwaters where appropriate

Some sustainable development practices which would constitute responding to climate change:

- The development of coastal hazard maps
- The development of stricter building codes and land use plans and policies.
- The establishment of marine protected areas (MPAs)
- The development and utilisation of alternative fresh water sources.

Other options might include:

- Public education and awareness

In recognition of the importance of coastal habitats, including coral reefs, sea grass beds, beaches and wetlands to Antigua and Barbuda and the implications for climate change impacts on these resources, it is critical that wise use practices within coastal areas of Antigua and Barbuda be developed and promoted. Monitoring programmes within government agencies, NGOs and key stakeholders within the coastal zone should focus on understanding coastal changes and develop appropriate solutions to adapt to or mitigate negative impacts. These programmes should aim at developing in-country capabilities so that Antigua and Barbuda who is economically dependent on coastal tourism, can effectively manage the changing coastal resources and plan for change within a framework of integrated coastal management.

Building codes and standards for structures built within the coastal zone need to be better enforced. All economic appraisals for coastal developments should include environmental considerations and increased risk of storms should be a factor when considering new development projects in the DCA. Critical habitats should be studied and MPAs developed where appropriate. This will help to increase natural resource conservation within the coastal zone. Specific management plans should also be developed and implemented for these areas. Vulnerable areas prone to seasonal flooding may need to be converted back to the natural environment. This may involve the relocation of some areas of settlement.

The provision of better public education and incorporation of climate change, storm planning /disaster management into the national curriculum should be a priority. In addition, special attention should be given to the provision of education for developers within the coastal zone to explain the impacts and associated risks of climate change. Climate change should be mainstreamed into all sectors of the economy and therefore will affect the coastal zone of Antigua and Barbuda.

5.6 CONCLUSION

Within the coastal zone of Antigua and Barbuda, the number and extent of physical structures, along with the number and size of commercial and residential properties and related activities continue to increase. Even with limited evidence from primary scientific data, the expected climatic changes will affect the coastal zone.

There will be primary land and property loss due to increased coastal erosion and inundation. In some areas accretion may occur as a compensatory measure. Increased frequency of flooding in low-lying areas will cause a reduction in the distribution of mangroves, settlement and available land. Whether directly or indirectly, the all important tourism sector will be drastically affected. Coral reefs and sea grass beds will be found in deeper waters thus changing their natural environment. On coastal lands, especially in Barbuda, salt water intrusion will occur mainly as a result of sea level rise. The challenge therefore is to seek and adopt the best adaptation measures.

Adaptation measures to climate change and sea level rise along the coastal zone should include but not limited to the following:

- Conservation of all marine areas, including the establishment of MPAs and the monitoring of all activities within the coastal zone.
- Increased enforcement and direct implementation of land-use plans and policies, especially related to coastal setback and infrastructure and other facilities within the coastal zone.
- Utilisation of alternative fresh water sources for future needs, especially for Barbuda.

Based on the above, the following recommendations are presented for serious consideration, especially by policy makers:

- Further increasing the research capacity of Antigua/Barbuda.
- Greater harmonization of actions among agencies involved with coastal zone management. This could possibly involve the establishment of a Coastal Zone Unit or even a Ministry of Natural Resources.
- Establishment of a national policy for coastal development and ensure that the appropriate regulatory mechanisms for implementation are maintained.
- Appropriate education and training of the relevant personnel (from resource user to the general public) to cope with the impacts of climate change and sea level rise. This could be complemented by a comprehensive public awareness programme.

These recommendations once seriously considered should assist greatly in reducing the negative impacts of climate change and sea level rise on the coastal areas of Antigua and Barbuda as well as increasing the capacity to adapt to such conditions.

CHAPTER 5B: FISHERIES

5B.1INTRODUCTION

5B.1.1 BACKGROUND

The IPCC has confirmed that the human-induced warming[88] over recent decades is already affecting many physical and biological processes. The associated regional changes in the distribution and production of particular fish species are projected to produce adverse effects on aquaculture and fisheries. Globally, substantial effects on human society and natural environments are expected to continue for some time.

Although the social and economic impacts of climate change including climate variability on fisheries are less well-understood, the impacts of climate change on fish availability, fish prices and coastal communities are substantial and can have profound social and economic consequences at all scales (OECD, 2006). The degree to which national economies are vulnerable to the impacts of climate change on fisheries depends on their degree of exposure to climate change, dependence on fisheries, and the capacity to adapt and respond to the opportunities and challenges presented by climate change (OECD, 2006).

In 2008, the Food and Agricultural Organization (FAO) of the United Nations held a high-level conference in an effort to "address food security and poverty reduction issues in the face of climate change and energy security" (FAO, 2008). At the regional level, CARICOM has developed a Task Force on Climate Change and Development to "facilitate and coordinate technical work, advise on policy directions on climate change, and provide support to CARICOM Member States in their preparations for key regional, hemispheric and other global forums and in their negotiations with international development partners" (CARICOM, 2008).

5B.1.2 Methodology

This is an attempt to provide preliminary investigations into the possible effects of climate change impacts on the Fisheries Sector in Antigua and Barbuda. The introduction places the fishery resource within its physical setting and traces the historical developmentof fisheries in Antigua and Barbuda. There is also an indication of

[88]In response to increased temperatures, many fish species may shift their ranges and patterns of migration and egg laying could be influenced.

some of the current stresses and trends as well as adaptive capacities and strategies employed in the fisheries sector in relation to climate change in Antigua and Barbuda. The assessment also includes projections or future scenarios of climate change for Antigua and Barbuda and possible adaptation strategies and measures for the fisheries sector.

In the absence of specific studies on the subject, this assessment relies heavily on related published information for the Caribbean and similar areas. Reference will also be made to student research at the University of the West Indies (UWI).

Various approaches, including, the United Nations Development Programme (UNDP) Adaptation Policy Framework (APF) will be used in this assessment. Although extensive work related to the impacts of climate change on the various sectors has been done within the Caribbean, through projects starting with the Caribbean Planning for the Adaptation to Climate Change (CPACC) project and transitioning into Mainstreaming Adaptation to Climate Change (MACC), there is very little reference materials specifically for the impacts of climate change on the Fisheries Sector in Antigua and Barbuda. However, whatever available reference material that is used, it is important to note the possibility some level of uncertainty that may exist. As the quality and amount of data increases the level of uncertainty is expected to decline.

For the fisheries sector there may be uncertainties as a result of:

- Inaccurate measurements and inherent difficulties related to modelling bio-physical relationships especially those involved in climate change and fisheries. This makes it more difficult to determine the impacts of climate change on small-scale fisheries, as is the case in Antigua and Barbuda.
- Difficulties in adopting regional projections of climate change to local conditions, particularly precipitation, storm surge and winds, and their specific impacts on the Fisheries Sector
- Inherent uncertainties in fisheries worldwide which are expected to be exacerbated by a changing climate
- The reliability of predicting possible future contribution(s) of different technologies employed in the fishing industry
- Changing political and socio-economic conditions in addition to future public policy and other initiatives in Antigua and Barbuda. These may have far reaching implications for the development of the fishing industry as well as the sustainability of the fisheries resources.

Considering that there is not much research on the impacts of climate and climate change on fisheries for the Caribbean, assessing impacts on fisheries in small island communities such as Antigua and Barbuda is more challenging given the paucity of reference material[89].

While the impact of climate change on coastal areas is of prime concern to Antigua and Barbuda, there is also concern that climate change will affect fishery resources and fishing activity in the waters surrounding the islands. The most difficult aspect of detecting climate- induced impacts on the fishery sector of Antigua and Barbuda lies in distinguishing climate- related changes from changes resulting from exploitation. All significant fishery resources found in the waters of Antigua and Barbuda are exploited at different levels.

5B.1.3 Fisheries and Climate Change

The fisheries sector has particular significance for small island states, such as Antigua and Barbuda, since fish is one of the world's most widely traded foodstuffs, a key source of export earnings for many poorer countries, addressing issues such as unemployment, food security and nutrition(APO, 2008; Appleton, Horsford, & James, 2005). Fishers are particularly vulnerable to the direct and indirect impacts of predicted climatic changes, including changes in physical environments and ecosystems, fluctuating fish stocks, infrastructure located in high risk (coastal) areas, reduced fishing operations and unstable livelihoods (Béné, 2006; FAO, 2008). Local supplies of fish can be highly unpredictable given the nature of the resource. Conservative estimates show that in 2004, over 1000 persons (about 2% of the national labour force) were registered as fishers with about 70% involved in active fishing activity[90].

As in other Caribbean countries, the consequences of climate change on fisheries in Antigua and Barbuda are expected to be mostly negative (Nurse, 2008). Adverse impacts on fisheries are likely to manifest themselves through habitat alteration and loss, reduced species abundance and diversity, possible shifts in distribution induced by changes in ocean currents, reduced number of fishing days and possible loss of livelihoods or shift to alternative livelihoods.

Appropriate adaptation options may be adopted for each fishery. These will vary from simple practical cases to more theoretical mainstreaming of climate change into the fisheries sector. The following sections will look at the various elements of the fisheries resource, projected climatic and other changes, possible impacts, and adaptation policies and measures.

[89]Personal observations and research, at UWI, 2007/2008.
[90](Appleton, Horsford, & James, 2005)

5B.2OVERVIEW OF FISHERIES SECTOR

5B.2.1 Physical Setting:

According to the Antigua and Barbuda Fisheries Development Plan 2006 – 2010[91], Antigua and Barbuda established itself as an archipelagic state in 1982 with a 12 nautical mile territorial sea, an Exclusive Economic Zone (EEZ) and a Fishery Zone of 200 nautical miles. The full extent of the EEZ is unknown although it is estimated to be about 110,071 km^2 with a shelf area of about 3,568 km^2[92]. This includes the Antigua and Barbuda shelf (3,400 km^2), South Bank (40 km^2), a section of Anguilla shelf (7 km^2), Redonda shelf (98 km^2), Havers Shoal (5 km^2) and a section of St. Christopher and Nevis shelf (18 km^2). This relatively large sea space is seen by many to offer vast potential for fisheries development especially for the migratory species. There are areas of the Redonda & island Shelf that are not frequently fished by vessels from Antigua and Barbuda, due to, some extent, distance from Antigua and to the perceived prevalence of ciguatoxic fishes found in the area.

The Antigua and Barbuda shelf that both islands emerge from is one of the largest in the Eastern Caribbean. Depths between the islands ranges from 27 to 30 metres, providing the ideal terrain for demersal resources such as reef fish, Caribbean spiny lobster (Panulirusargus) and Queen conch (Strombusgigas).

The coastline of Antigua and Barbuda is about 289 km in length[93]. That of Antigua is highly indented with numerous islands, creeks, inlets, associated sand bars and wetlands. A large portion of the east, north and south coasts of both Antigua and Barbuda are protected by fringing reefs. Large areas of sandy bottom exist in relatively shallow water, mainly along the west coast of the islands. In Barbuda, the Codrington Lagoon is bordered by mangroves and sand ridges. This area is of significant importance to the fisheries and wildlife (particularly frigate birds) of Barbuda. The Codrington Lagoon is the sole designated Ramsar site for Antigua and Barbuda.

Apart from the Codrington Lagoon, several coastal and marine areas have been designated as protected areas. Antigua and Barbuda has also initiated the establishment of a System of Protected Areas.

<u>The Fishery Resource Base</u>

The coastal and marine areas of Antigua and Barbuda comprise a variety of ecosystems (mangroves, coral reefs, sea grass beds and beaches) with natural resources including fisheries resources. The nature and extent of the coastal and marine areas are primary determinants of types, amount and to some extent the distribution of the two main

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[91](Appleton, Horsford, & James, 2005)
[92]

[93]Earthtrends 2003.**http://earthtrends.wri.org**

categories of fisheries (demersals and pelagics) in Antigua and Barbuda. Fisheries production in Antigua and Barbuda is considered to be small scale (Horsford, I., 2008; James P. A., 2008). The demersal fishery (mainly lobster, conch and a large variety of reef fish species) is well developed while the pelagic fishery may be considered underdeveloped.

Demersal resources of the Antigua and Barbuda shelf, including reef fish species, conch and lobster, are closely associated with coral reefs, mangroves and sea grasses which are either adult habitats or nursery areas for juveniles (GOAB/UNEP, 1997). The pelagic resources which are highly mobile, generally migratory and seasonal are of less importance to the fisheries of Antigua and Barbuda mainly because of associated socio-economic factors such as increased operational cost[94] and a cultural tradition of harvesting the demersals[95]. The problems and potential impacts of climate change will therefore differ among these fisheries.

The demersal resources include: the Caribbean spiny lobster (Panulirusargus), the queen conch (Strombusgigas), shallow reef fishes, and deep reef fishes. The pelagic resources are divided into small coastal pelagics found mainly nearshore or around the coast and larger coastal pelagics at the shelf edge and in the oceanic regions of the EEZ. These resource types and the fisheries for them have been summarised in the Antigua and Barbuda Fisheries Management Plan(Appleton, Horsford, & James, 2005). Lobster, conch and a variety of finfishes form the major landings. Most of the lobster is exported to the French West Indian islands, particularly Guadeloupe[96].

Spiny lobster are caught in two main ways: by divers operating from small vessels in shallow areas around Antigua and Barbuda and in traps set for lobsters and finfishes in shallow and deep waters throughout the island shelf areas. Lobsters occupy reef habitats as adults, but juveniles require other habitats, mainly sea grass, rock rubble reefs and mangrove lagoons. The Codrington Lagoon, Barbuda, is known as a highly productive nursery area for lobsters. Reports indicate that the status of the lobster stocks in Antigua and Barbuda is sustainable at the current level of fishing(Horsford & Archibald, 2006).

Conch is harvested mainly from seagrass beds and algal flats by divers operating from small vessels, at depths sometimes over 27m (90ft). They occupy a limited range of habitats which makes them susceptible to overfishing. However, the relatively small number of fishers who target this fishery renders the resource under-fished. Stocks are considered to be relatively healthy and sustainable at the current level of fishing (Horsford, Ian, 2004).

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[94] Expansive shelf area force fishers to travel longer distances to catch these species, especially large pelagics.
[95] Householders generally prefer ‘plate size’ fish.
[96] Fisheries Division Statistics

Shallow reef fishes are harvested from reef and reef related habitats mainly using wire mesh traps. These are set from small vessels making one-day trips near shore and from larger vessels which make longer trips, to fish on the farther areas of the island shelf, and adjacent banks. A wide variety of species are captured including: snappers (Lutjanidae), groupers-(Serranidae) grunts (Haemulidae), squirrel fish, (Holocentridae), surgeonfishes (Acanthuridae), triggerfishes (Balistidae), parrotfishes (Scaridae) and goatfishes (Mullidae). Snappers and groupers are the preferred species with the highest value but their relative abundance appears to have declined[97]. In deep waters however, these two families still contribute most of the catch[98], which is taken by traps, but also increasingly by line gear, often with multiple hooks[99].

Large pelagics include yellowfin tuna, wahoo, kingfish, dolphinfish, blue and white marlin. These species are targeted, mainly by recreational fishers, including charter boats which troll. Recently a few vessels have begun to use longline gear to capture these species. Most of the large pelagics are highly seasonal. Many large pelagic species, which migrate throughout the Caribbean region and beyond, are likely to compensate for climate change by adjusting their migratory routes and distribution patterns.

5B.2.2 Current Stresses

The vulnerability of any sector to climate change is a function of the degree of exposure to the threat, the sector's sensitivity to the risk and the capacity of the sector to cope with or adapt to the threat (FAO, 2005; IPCC, 2001; IPCC, 2007). Any objective assessment of fisheries in Antigua and Barbuda would conclude that exposure and sensitivity to climate change threats are high, while adaptive capacity is relatively low. This conclusion is based on the reasons indicated in Box 5B.1 below.

Existing stresses on the fisheries sector include:

- Pressure from fishing and other marine activities
- Coastal development, particularly the development of hotels and marinas
- Pollution both from land-based and marine sources.
- Fluctuations within the global economy and market conditions.

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97 In some cases, this could be attributed to changes in habitat conditions including possible climate change impacts.

98 This may be due to them being larger in size.

99 This may sometimes be regarded as a variation of long line.

Most scientists agree that corals' ability to adapt to shifting environmental conditions resulting from climate change depends on the severity of other human stresses, such as fishing pressure, coastal development and land-based sources of pollution. Socio-economic conditions within the sector will provide the framework to determine the stresses on the natural environment.

Box 5.3. Vulnerability and Adaptive Capacity Issues within the Fisheries Sector

- Observed and projected negative impacts on the sector due mainly to stresses on critical habitats such as coral reefs, mangroves and sea grasses
- Linkage between ocean warming, the proliferation of harmful algal blooms and various diseases
- Dependence of fisher folk on the sector for employment, revenue generation and human well-being
- In Antigua and Barbuda, many fishers reside and operate in vulnerable, low-lying coastal areas which exposes their physical assets (e.g. boats, gear, homes) to climate-related events such as hurricanes, storm surge and sea-level rise
- While the fisheries sector has demonstrated considerable resilience to climate variability in the past, factors such as lack of consistent governmental control, access to capital on reasonable terms, weak fisher folk organizations and consequently low bargaining power will compromise adaptation capacity in the future
- Lack of insurance and other institutional support to enable the sector to rebound in the aftermath of extreme events, which are projected to become more frequent and/or intense in the future.

The fisheries sector has particular significance for small island states since fish, as a primary protein source, is one of the world's most widely traded foodstuff and a key export earnings generator for many poorer countries (APO, 2008). Some 51% of the contribution of agriculture to the GDP of Antigua and Barbuda is derived from the fisheries sector (Horsford, 2004). Fishers are particularly vulnerable to the direct and indirect impacts of predicted climatic changes, including changes in physical environments and ecosystems, fish stocks, infrastructure, fishing operations and livelihoods (FAO, 2008; Allison, et al., 2009). Additionally, fishing households in general have a high occupational risk in that they are prone to very high levels of vulnerability closely related to their activity (fishing) and associated livelihoods (Béné, 2006). This may be even more severe for part time fishers and occasional workers within the fisheries sector.

5B.2.3 Current Adaptive Capacity and Strategies

The Fisheries Division is mandated with the task of management and development of the fisheries of Antigua and Barbuda. The primary goal of the Fisheries Sector is sustainable development that is capable of contributing its full potential to the overall development of the national economy. With respect to climate change options, the following strategies have been implemented as a means of achieving the goal:

- Improved management capability with trained professional staff
- Strengthening the capability of the Fisheries Division to integrate the sub-sector concerns into Coastal Zone Management and Development Planning through the promotion of the supportive role of the Fisheries Division in Coastal Zone Management.

Specific related programmes include the enactment and enforcing of legislation and regulations for the management and conservation of the marine resources and the provision of seasonal employment when other sectors are less busy or following natural disasters, such as hurricanes and drought.

The Fisheries Act has been upgraded in 2006 and enabling regulations are pending. However, existing legislation seeks to maintain sustainability of the fisheries resources. One key issue that will assist in adapting to climate change is the development of MPAs. Although there is insufficient research on the benefits of MPAs to the fisheries sector of Antigua and Barbuda, the advantages are perceived as outweighing the disadvantages. Additionally, the Fisheries Division offer limited technical and other assistance to fishers, private fisheries-related enterprises and the general fishing community especially in the area of education and public awareness.

Based on the level of investments and involvement in the fishing industry, fishers, investors and the fishing community have different levels of adaptive capacity, in relation to impacts of climate change. While private enterprises and sports fishers can afford some level of insurance to protect properties including fishing vessels and gear most commercial fishers cannot afford such facilities and services[100]. However, with the assistance of the Fisheries Division, on the advisory of an approaching storm or hurricane, commercial fishers generally removes fishing vessels from the water to safe havens. When possible fish traps are also retrieved and returned to land. There are also plans for the official establishments of designated hurricane shelters for fishing vessels.

[100] Sports fishers generally store their vessels on trailers at home or at private marinas. Commercial fishers tend to use public jetties and beaches. Because of the nature of most commercial fishing vessels, insurance companies are reluctant to provide them with general insurance.

5B.3SOCIO-ECONOMIC & ENVIRONMENTAL SCENARIOS

5B.3.1 Socio-economic Senarios

Antigua and Barbuda ranks high among the countries with national economies most vulnerable to the impacts of climate change on fisheries sectors. According to the FAO, in the Least Developed Countries, this is a direct result of high social and economic dependence on fisheries for livelihoods and food. Policy makers are therefore urged to respond by "pursuing a mitigation strategy to limit CO2 emissions, maintaining and building adaptive capacity or .socio-ecological resilience and also by managing natural resources as a portfolio to ensure adaptation in one sector will not have adverse effects on other .downstream sectors"[101]. The degree to which national economies are vulnerable to the impacts of climate change on fisheries depends upon their degree of exposure to climate change, dependence on fisheries, and the capacity to adapt and respond to the opportunities, challenges and dangers presented by climate change.

With fisheries being a primary sector both as an employment provider/income generator and a source of food in Antigua and Barbuda,(particularly for Barbuda), impacts of climate change will only exaggerate the already fragile economy. Sustaining current economic growth rates and reducing the rate of unemployment and poverty will pose major challenges in the face of external shocks as a result of rising energy and fuel prices, fluctuating commodity prices, reduced availability of external credit facilities and of preferential market arrangements including subsidies and the introduction of strict regulations governing trade including sanitary and phyto-sanitary conditions.

The economic outlook for Antigua and Barbuda, considering climate change impacts on the Fisheries Sector, can be expected to include the following:

- The economy of Antigua and Barbuda remains highly dependent on coastal based tourism which has caused major negative impacts on the coastal ecosystems on which fisheries depend. The added stress can only add to the vulnerability of the Fisheries Sector to the adverse impacts of climate change and sea level rise.
- External price shocks are anticipated to exacerbate well into the future. This can be attributed to rising cost of imported food items and fuel. Fuel cost is one of the major inputs of the fishing industry. Salted, dried, smoked and canned fish products are high on the import bill of Antigua and Barbuda.
- Antigua and Barbuda, under the influence of the global economic crisis, continues to increase its debt burden. At the same time, there is a decline in foreign direct investments (FDI) which in most cases go directly to the tourist industry and overseas development assistance (ODA) for specific projects.

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[101] http://www.fao.org/uploads/media/FI20080208_OECD%20Climate%20change%20and%20fisheries%20paper%202006.pdf

The global economic conditions will pose certain social challenges, including:

- Increased unemployment and possibly higher poverty levels. This has implications for all sectors (including Fisheries) of the economy and will be less likely to adapt to climate change impacts[102].

The situation will be further compounded by harsh environmental conditions, including: rising sea levels causing inundation of nurseries in mangrove. Strong winds and flooding during storms or hurricanes can cause physical damage to infrastructures at fish landing sites as well as to fishing vessels and gear. The implications are even more serious, considering very high insurance premiums to cover fishing vessels or in most cases unavailability of insurance coverage.

5B.3.2 Future Scenarios of Climate Change

In an FAO review of the state of world fisheries in 2008, climate change, as a major issue, is considered a "compounding threat to the sustainability of fisheries development with impacts occurring as a result of gradual warming and associated physical changes at the global scale, as well as consequences of the increased frequency of extreme weather events ". The main physical and biological impacts are given in Box 5B.2 below.

Highlights from IPCC Working Group I report in February 2007 projects temperature increases by the end of the century in the range of ~2°F (1.1°C) to ~11.5°F (6.4°C)[103]. The global effects of this warming are apparent over recent decades as it is already affecting many physical and biological processes. It was noted, however, that there are challenges in determining the influence of other factors such as local pollution, invasive species, and land-use change. It is also suggested that u*p to 30* percent of plant and animal species could face extinction if the global average temperature risesmore than ~3 to ~5°F (1.5 to 2.5°C) relative to the 1980–1999 period[104].Many species, including fishes, may have already shifted their ranges to higher latitudes and rising temperatures will also influence the timing of bird and fish migration.

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[102] The Fisheries Sector will be further stressed as a safety net and alternative livelihood for other sectors after major climatic disasters.

[103] http://ucsusa.wsm.ga3.org/global_warming/science/ipcc-highlights2.html

[104] *Many projections suggest the low end of this temperature range could be reached by mid-century*

Box 5B.2 Physical and biological impacts of climate change on Fisheries on a global scale

In terms of physical and biological impacts, climate change is modifying the distribution of marine and freshwater species. In general, warmer-water species are being displaced towards the poles and experiencing changes in habitat size and productivity. In a warmed world, ecosystem productivity is likely to decline in lower latitudes and increase in high latitudes. Increased temperatures will also affect fish physiological processes, resulting in both positive and negative effects on fisheries and aquaculture systems.

Climate change is already affecting the seasonality of particular biological processes, altering marine and freshwater food webs, with unpredictable consequences for fish production. Increased risks of species invasions and the spread of vector-borne diseases raise additional concerns.

Differential warming between land and oceans and between polar and tropical regions will affect the intensity, frequency and seasonality of climate patterns (e.g. El Niño) and extreme weather events (e.g. floods, droughts and storms) and, hence, the stability of marine and freshwater resources adapted to or affected by them.

Sea-level rise, glacier melting, ocean acidification and changes in precipitation, groundwater and river flows will affect coral reefs, wetlands, rivers, lakes and estuaries significantly. Such changes will require adaptive measures in order to exploit opportunities and to minimize negative impacts on fisheries and aquaculture systems.

Source: FAO. (2009). *The State of World Fisheries and Aquaculture 2008*

Table 5B.1Climate Projections for Antigua and Barbuda and the Insular Caribbean

Climate Parameter	Predicted change for the Insular Caribbean[105]	Predicted change for Antigua and Barbuda[106]
Air temperature	Increase of 1.8 - 4.0°C by 2099	1.3°C by the 2050s 1 - 3.5°C by the end of the century
Sea surface temperature	~1.7°C by the end of the century	Up to 2°C by the end of the century
Sea level rise	Rise of 0.18 – 0.59 m by 2099	Rise of 0.24 m by 2050[107]
Carbon dioxide	Reduction in pH of the oceans by 0.14 - 0.35 units by 2099	An increase in carbon dioxide emissions through 2050 followed by a decrease
Hurricanes	More intense with larger peak wind speeds and heavier	More intense with larger peak wind speeds and heavier

[105]Based on global predictions from IPCC WGI, 2007
[106]Climate Studies Group, Mona. University of the West Indies
[107]Estimate for the Caribbean

	precipitation	precipitation. (not necessarily increased frequency)
Precipitation	Unclear	Drier (in the mean) by the end of the century

This view is supported by general perception of fishers across Antigua and Barbuda who have indicated that sea surface temperatures are increasing and may be causing a decline in fish catch. The scientific data supports the temperature increase but the relationship to fish catch is not clear. Other perceptions include:

- It is also believed that more fish is caught during the rainy season. This is mainly attributed to more nutrients reaching the sea as well as mixing of fresh water. Considering the predicted drier conditions, this could have serious implications.
- Tropical storms are noted for their possible destructive nature to fishing vessels, fishing gear and the physical environment in which fish survive. However, most fishers take necessary precautions to weather the effects of storms.
- With climate change occurring, winter swells or ground swells are perceived to be getting stronger and more unpredictable.
- While different species of migratory seabirds are observed, there is no real recognition of changes in populations and migration patterns or relationship to climate change.
- Many fishers are unable to comment on general marine life. Divers, (mainly conch and lobster fishers) however, recognise a general decline in the condition of coral reefs and sea grass in particular.
- Sea level rise is not considered to have much effect on fishing activities.
- While the cost of fishing continues to rise, fuel, ice and bait seem to be the main elements for a fishing trip. There is a general perception that fish landings are decreasing annually. The data on annual landings shows the opposite.

5B.4PROJECTED CLIMATE CHANGE IMPACTS FOR FISHERIES

5B.4.1 Introduction

Several aspects of climate change and climate variability can impact fisheries in Antigua and Barbuda. These factors may operate separately or may function as multiple stressors, with varying effects. A generalised summary of the impacts is given in Table 5B.5.

Table 5B.2 Possible Climate Change Impacts on the Fisheries Sector

Climate Change and / or Related Factor	Impact on the Fisheries Sector
Higher sea surface temperatures and increased frequency of ENSO Increasing atmospheric carbon dioxide	• Reduced coral reef fisheries productivity and changes in productivity • Acidification of oceans producing negative impacts on marine shell forming organisms such as shell fish, corals and their dependent species.
Changes in coastal circulation, either wind driven or due to changes in large scale ocean currents	• Impacting on shelf topography, may affect recruitment
Changes in the weather, particularly in the seasonal cycle	• Affect availability of these resources to fishermen. • Inputs and costs related to fishing could also be affected
Increase in the frequency of storms; Harsher weather conditions	• Less fishing days because of bad weather • Increased time of travel to fishing grounds • Increased fuel costs because of rough seas, • Higher labour costs because of the working conditions, • Higher maintenance costs because of damage to the vessel, equipment and fishing gear.
Ocean acidification	• Declines in production

Habitat alteration and loss, reduced species abundance and diversity, possible shifts in distribution induced by changes in ocean currents, reduced number of fishing days and possible loss of livelihoods or shift to alternative livelihoods are some of the impacts of climate change and associated sea level rise within the coastal zone of Antigua and Barbuda.

Climate change and related weather conditions (e.g. wind & sea surges) will impact different aspects of the fisheries sector, including, the fisheries resource(s), fishing activity, vessels and gear. In addition to potential impacts on biomass and production of fisheries, the availability of fish stock may be affected by climate change. Climate change and variability may affect the availability of fish by altering the distribution of the resource, or by changing the way that they interact with the fishing gear. Evidence shows that weather has considerable influence on the availability of the major demersal resources of the island shelf.

5B.4.2 Temperature Changes

The effects of climate change on marine ecosystems cannot be easily mitigated by engineering measures. The better the quantity and quality of important coastal habitats, the less likely it will be that climate change will affect them and the fisheries that depend upon them. Other effects include declines in fish production due to ocean acidification, changes in production and availability of fished species and potential mismatch between prey (plankton) and predator (fished species) and declines in production as a result of warming of the upper ocean layers and reduced production of coastal marine and freshwater systems and related fisheries (Allison, et al., 2009). In relation to potential outcomes for fish stocks, Allison also noted that there will be changes in timing and levels of productivity across marine and freshwater systems and reduced production of target species in marine and fresh water systems because of higher water temperatures.

Temperature and other variations resulting from climate change are likely to have a negative impact on fisheries in Antigua and Barbuda through reduced income generation and food security for its populations. Unlike most terrestrial animals, aquatic animal species used for human consumption are poikilothermic; therefore, any changes in habitat temperatures can significantly influence their metabolism, growth rate, productivity, seasonal reproduction, and susceptibility to diseases and toxins (APO, 2008). While specific studies have not been identified to prove this statement for specific fish species within Antigua and Barbuda, it is generally recognised that sea surface temperatures are increasing. A recent observational study has also shown that the heat content of the upper ocean has been increasing over the last four decades in all the world's oceans, although the warming rate varies considerably among different ocean basins (Sharp, 2003).

According to the IPCC Fourth Assessment Report, it is projected that atmosphere and ocean temperatures will continue to rise through to the next century. Research has shown that while fish may take refuge from rough conditions through minor changes in distribution, most fish species have a fairly narrow range of optimum temperatures related both to the species basic metabolism and the availability of food organisms that have their own optimum temperature ranges (NOAA, 2008).

Increased temperatures will not only affect the productivity of some marine areas but will also have a negative impact on associated marine ecosystems such as coral reefs (Murray, Peter A., 2005; Van der Meerin, 1998). It is widely recognised that extensive coral bleaching occurred in the Eastern Caribbean over the last 25 years (Donner, Knutson, & Oppenheimer, 2007; Everett, 2007). However, it is difficult to measure direct impacts of climate change as against other elements such as misuse or overuse of coral reefs or other habitats.

Most fishing vessels in Antigua and Barbuda are not equipped to measure sea surface temperatures. However, most fishers believe that there is a general increase in SST contributing to a general decrease in fish catch. The catch may be dominated by species that can tolerate much higher temperature ranges. Fishers have also reported seeing new or unaccustomed species in their catch. This could also be a result of changes in temperature ranges thus varying the (thermal) tolerance levels of the different fish species.

Other aspects of temperature increase impacting fisheries include the effects of ocean acidification and the prevalence of ciguatera. Increased temperatures can contribute to changes in the pH of the ocean. Ocean acidification on the marine biosphere can add stress to coral reefs as progressive acidification of oceans is expected to have negative impacts on marine shell-forming organisms and their dependent species (IPCC, 2007b). Research has shown that the world's oceans have become approximately 30% more acidic since 1750 - the start of the Industrial Revolution, associated with increasing anthropogenic emissions of CO_2(IPCC, 1990; IPCC, 2001; IPCC, 2007b; Nurse, 2008).

Ciguatera fish poisoning is common in marine waters, particularly reef waters. Multiple factors contribute to outbreaks of ciguatera poisoning, including pollution and reef degradation. Warmer sea surface temperatures during El Niño events have been associated with ciguatera outbreaks in the Pacific (Mimura, 2007).

For ecosystems, changes in pelagic fisheries distribution, reduced coral reef fisheries productivity and changes in productivity are anticipated as a result of increased frequency of ENSO events and higher water temperatures (Allison, et al., 2009). For changes related to coastal infrastructure and fishing operations, there are potential implications of sea level rise and increased frequency of storms. Potential outcomes for fisheries will also include increased costs of adaptation making fishing less profitable, increased costs of insurance and/or rebuilding and increased vulnerability of coastal households. There may also be reduced viability of fishing as a livelihood option for the poor and increased costs of insurance.

5B.4.3 Variations in Rainfall

Precipitation patterns are also changing in the Caribbean. The maximum number of consecutive dry days is decreasing and the number of heavy rainfall events is increasing (Mimura, 2007; Peterson, et al., 2002). It is anticipated that precipitation will become more variable (extreme dryness to extreme wetness). Interannual variability in rainfall in the Caribbean is influenced strongly by anomalies in sea surface temperatures of the tropical North Atlantic and it is suggested that the spatial pattern of rainfall is influenced by the El Nino/La Nina phenomenon (Chen & Taylor, 2002). Fishermen tend to believe that more fish is caught during rainy periods. A fish kill that affected several countries in the south-eastern Caribbean was also linked to increased water temperatures and the transport of a pathogen thought to be in the Orinoco discharge (Mahon R. , 2002). The movement and amount of particles within the sea or ocean depends on the supply of sediments and the operation of currents within the water column.

5B.4.4 Storms and hurricane Activity

Storm and hurricane damage has a major impact on the fishing industry. About 16% of the fishing fleet was either destroyed or lost as a result of Hurricane Luis, and another 18% was damaged. Additional information is given in table 4.6. Hurricanes also cause loss of revenue due to disruption of the fishing industry. After a hurricane, many individuals who were unemployed due to the closure of hotels and businesses sought short-term employment in fishing. Most of this short-term effort was probably directed at already highly exploited near-shore areas. Thus the immediate response to hurricanes may lead to further pressure, especially on near-shore resources.

Storm activity is also on the rise in the Caribbean. According to the IPCC First Assessment Report, except for two El Nino years (1997 and 2002)[108], hurricane activity was greater from the 1930s to the 1960s, in comparison with the 1970s and 1980s and the first half of the 1990s. Potential impact could be damage to fishing vessels and gear as well as the physical environment. Upon notification of an approaching storm, fishermen would normally take necessary precautions by storing their vessels in a safe place on land. In most instances, fish traps, especially

[108] El Niño acts to reduce storm activity and La Niña acts to increase activity in the North Atlantic.

Table 5B.3. Recent Hurricanes and Storms affecting Antigua and Barbuda

NAME	YEAR	IMPACTS
Luis	1995	• 70% of houses were damaged or destroyed on Barbuda, and nearly half of the houses on Antigua were eradicated. Government estimated damage to total $350 million (USD).
Georges	1998	• Several hotels along the coast suffered damage. Most of the damages were recorded as "water damage" mainly from rain (a few were due to flooding).
Jose	1999	• Crab's Hill, Five Islands and Cobbs Cross (coastal communities) declared as disaster areas. • Crab´s Hill, 64 of the 81 houses were seriously damaged or destroyed.
Lenny	1999	• Homes of low-income families living in coastal areas were damaged or destroyed • Some Fishermen lost their boats and all their equipment.
Omar	2008	• Approximately 5,160 houses sustained flood damages. Coastal areas suffered severe damages, as crops were lost and fishermen traps were completely destroyed
Source: http://www.reliefweb.int/rw/rwb.nsf/db900sid/ACOS-64DE2H?OpenDocument http://www.hurricanecity.com/city/antigua.htm http://stormcarib.com/georges/gantigua.htm		

those set at a distance, would be left in the water. Based on the dominant type of fishing activity and the distance of operation, a country such as Antigua and Barbuda would suffer more loss to damage of fish traps from a hurricane than say St. Lucia or Barbados[109].

It is anticipated that increased hurricane activity could cause widespread physical damage to habitats such as coral reefs and mangroves areas. In addition, there could be considerable losses in incomes due to fewer fishing days from unfavourable weather conditions (Mahon R. , 2002). Several fishermen have also recorded increased lobster catches following storm activity.

[109] Barbados and St. Lucia rely more heavily on net and line fishing instead of the use of traps.

5B.4.5 Sea Level Rise

According to the IPCC Third Assessment Report, the projected globally averaged sea-level rise at the end of the 21st century (2090 to 2099), relative to 1980 to 1999 for the six SRES scenarios, ranges from 0.19 to 0.58 m(Mimura, 2007). Slight changes in sea level rise may not affect fishing activities but can have severe impacts on the natural environment associated with fishing. For instance, mangrove systems may be affected. It can also affect fisheries infrastructure that are constructed directly along the coastline (Fisheries complexes, etc.).

5B.5ADAPTATION STRATEGIES AND MEASURES

Given the range of impacts and challenges posed by global climate change, responses will require practical measures aimed at building resilience in the sector, exploiting available opportunities and minimizing the economic and social dislocation of fishers (Nurse, 2008). Potential adaptation options for the Fisheries Sector in Antigua and Barbuda are given in Box 5B.3. Appropriate response strategies to climate change may not require radical changes in current approaches to fisheries management but rather more effective implementation of existing and proposed arrangements (Ibid).

While little can be done to reverse the trend of global greenhouse gas emissions and higher sea water temperatures, actions can be taken to improve the resilience of habitats and targeted species to the adverse effects of climate change. Such actions would include (i) strict enforcement of existing marine pollution control protocol sand abatement of contamination from land-based sources (ii) reactivation and expansion of habitat protection and restoration programmes and (iii) control of non-sustainable practices such as overharvesting, and the use of inappropriate harvesting methods (Nurse, 2008). For example, reef areas not subject to these other threats are likely to be more resilient than those that are heavily stressed. Management efforts can be directed toward reducing localized stress. A key management tool will be the development of marine protected areas (MPAs) in which the principles of good governance and co-management operate to provide sustainability of natural resources. Utilisation of the fisheries resources using an integrated management approach will allow fishing to be developed as a livelihood option within a broader environmental and socio-economic context. The fisheries resources should be managed based on the best available scientific information. This information should be shared among all resource users.

Another strategy could involve the use of multipurpose vessels[110] in the development of pelagic fisheries of Antigua and Barbuda. Due to the seasonal nature of pelagic resources, it would be necessary to catch demersal fish in the off-season. However, fishing activity should be treated as a normal business: Fishermen need to plan adequately and prepare for climate change and even climate variation. This may require the mainstreaming of climate change into the entire fisheries sector through institutionalised provisions for climate change issues to be considered in all aspects of the fisheries sector.

Box 5B.3 Potential adaptation options for the Fisheries Sector in Antigua and Barbuda

Coastal land loss and erosion:
- Vulnerability assessment of the Fisheries Sector
- Restore damaged or destroyed coastal ecosystems where technically feasible
- Construction of coastal engineering structures such as sea walls and breakwaters where appropriate

Some sustainable development practices which would constitute responding to climate change:
- The development of sustainable livelihood alternatives
- The implementation of building codes and land use policies for coastal Fisheries infrastructure.
- The establishment of marine protected areas (MPAs)
- The development of a network of hurricane shelters for fishing vessels.
- retiring from fishing and/or engaging in alternative livelihoods such as agriculture, boat building, burning charcoal, aquaculture, construction and tourism activities

Other options might include:
- Public education and awareness.
- The creation of a disaster plan for the Fisheries Sector.
- Mainstreaming climate change considerations into fisheries management

Adapted from(Moore & Trotz, 2001; McConney, Nurse, & James, 2009; Nurse, 2008)

There is a need for the development of appropriate alternatives to present fishing gear and methods ensuring that there are more innovative and cost effective technologies for fishing. This could involve not only changing fishing gear and methods as well as fishing for new species but also the expansion of fishing activities in time and space. While the introduction of new technologies as a means to counter the impacts of

[110]The strategy should aim for the upgrade and retrofitting of existing smaller vessels, rather than replacement or additionsto the fleet and exert additional pressure on demersal resources.

climate change will alter patterns of fishing effort, or increase the effective overall effort, and as a result may increase the vulnerability of ecological and social systems it can also diversify fishing effort and spread risk over a wider area or number of commercial species (McConney, Nurse, & James, 2009).
Other adaptation measures include:

- The development and implementation of management and development plans for the Fisheries Sector with special consideration given to natural resource conservation within the coastal zone and the increased risk of climate change for new fisheries development projects.
- The provision of better public education and the incorporation of climate change and storm planning in disaster management into the national curriculum
- The provision of training courses / education for developers within the Fisheries Sector to explain the risk of storm damage and other aspects of climate change and sea level rise.

5B.6CONCLUSION

The coastal and marine areas of Antigua and Barbuda comprise a variety of ecosystems with natural resources including fisheries. Mangroves, coral reefs, sea grass beds and beaches form the main habitats within the coastal and marine areas. The nature and extent of the coastal and marine areas are primary determinants of the variety of fisheries types which dominate the fishery sector of Antigua and Barbuda.

Based on scientific evidence, we are certain that climate will continue to change and fisheries distributions and abundances within Antigua and Barbuda will continue to be impacted even though we are unsure of the extent of the influences due to our lack of adequate quantitative evidence. There are many interconnected environmental, social and economic factors that affect the fishing industry making it very difficult to pinpoint direct linkages between climate change and fisheries. The problem is exaggerated further when the dynamic nature of climate and elements such as the migratory nature of some fish species are considered.

Possible coping strategies will include:

- Adopting measures to protect coastal areas and to strengthen the resilience of coastal ecosystems and fisheries resources
- Development of a comprehensive Fisheries Management Plan which incorporates natural hazards concerns and guides the location of investments within the Fisheries Sector

- Identification and promotion of alternative fishery and resource use activities where predicted impacts preclude the continuation of traditional activities

There is a need for future research focusing on key ecosystem and other linkages. This is necessary to further understand and wisely manage the fisheries. Fisheries–related areas and possible relationships with long term changes and natural climate variability that have been identified can be studied further. Possible areas for further research can include but not limited to:

- Seasonal variation of current; current movement; Influence of currents on fishing
- Influence of local habitat on different fish species/ how different fish species adapt to different temperature and depth regimes
- Migratory patterns of fish species; Climate change impact on fish migration
- Climate change and marine invasive species, e.g. jellyfish
- Sea Level Rise and Fisheries.

All assessments should be done in consultation with primary stakeholders. Information from such research should also be shared with relevant stakeholders especially fishers and the wider scientific community.

CHAPTER 6

GENERAL DESCRIPTION OF STEPS TAKEN

CHAPTER 6 GENERAL DESCRIPTION OF STEPS TAKEN

6.1 INTRODUCTION

Article 12.1 (b) of the UNFCCC requires States to provide a general description of steps being taken to implement the Convention. The following represents an outline of some of the principal actions being taken by the Government and people of Antigua and Barbuda to meet its obligations under the Convention.

6.2 RESEARCH AND SYSTEMATIC OBSERVATION

The research and systematic observation of weather and climate-related events and systems are important elements of the country's efforts to attain sustainable development and are essential to determining the extent of changes in weather and climate parameters affecting Antigua and Barbuda. This section contains information on climatic system observations undertaken by the Government and draws on data from on ongoing studies and scientific analysis of climate and climate change.

In many developed countries extensive monitoring and research programmes are undertaken with reports on air, sea, water pollution, environment, meteorological monitoring, gamma, beta rays and soil studies glacier, reservoir, river, among several others; all these programmes are tied in with global climate monitoring net work

Under the Global Climate Observing System (GCOS) there are two established networks:

Aerologic network (GCOS Upper Air network - GUAN)

And **surface meteorological network (GCOS Surface network – GSN).**

Operation of the Upper Air network is supervised by the European Center of Medium Weather Forecasts (ECMWF), And the surface meteorological network is supervised jointly by the Japanese Meteorological Agency (JMA) and German Weather Agency (DWD).

The specified centres provide the regular results of network monitoring.

Antigua Barbuda observation network systems and programs are based on the Global Observations System (GOS) of the World Weather Service (WWS), Guidance on the Global Observations System, technical regulations of WMO, and guidelines on the measuring devices and methods.

Regular observations of climatic system are undertaken through national Programs carried out by several agencies with the climate change coordination carried out of the Prime Minister Office and Ministry of Foreign Affairs.

Nevertheless, efforts in this regard are constrained by a variety of technological, financial and other factors.

The national program of climatic data and climate monitoring is aimed at maintenance and management of climatic data. The center piece of the country's climate research and systematic observation resource is the national meteorological service with its headquarters at the V.C. Bird International Airport. The Met office fulfils a number of vital services for Antigua and Barbuda and neighbouring countries in the north eastern Caribbean. These include the systematic collection and analysis of meteorological data, providing information and data services to maritime and aviation interests, and serving as the official source of information for tropical storms and hurricanes.

In fact, within the context of a micro-State with limited technical and scientific capabilities, the Met service is the agency regarded as having the mandate to provide information on a range of natural events and phenomena not directly related to meteorological conditions. These include volcanic, astrological and Seismic activity.

At present, data collected by the Met service consists of hourly values of air temperature, atmospheric pressure, cloud conditions, rainfall events, significant weather events, humidity, wind direction and speed, and visibility. This data is entered into the global weather exchange database for exchange, as well as kept locally as climatologically records. The service has data extending back to the year 1962, as well as some earlier data, mainly rainfall collected by the Ministry of Agriculture and interested private individuals and businesses.

A recent addition to the information base accessible to the national met service is the data provided from a tidal gauge installed as part of the regional CPACC project. This instrument provides data on such parameters as wind speed, wind direction, sea surface temperature, air temperature, atmospheric pressure, rainfall, tidal data, relative and barometric pressure as measured over the sea surface. The tidal gauge forms part of a Regional network providing data and information to a regional data processing and storage centre using real time satellite technology. The CPACC project is funded by the Global Environment Facility (GEF) and implemented by the University of the West Indies Centre for Environment and Development (UWICED) in conjunction with the Organization of American States (OAS).

Since the devastation wrought to the eastern Caribbean by Hurricane Luis in 1995 public appreciation and perceptions of the met service has focused on the vital role that the agency provides in terms of hurricane and disaster preparedness. Presently the forecasting and tracking capabilities of the national met service consist of trained meteorologists hydrologists and forecasters, meteorological observers and technical officers.

At the regional level cooperation in research and systematic observation also includes the programmes of the Caribbean Meteorological Organization and the Caribbean Institute of Meteorology and Hydrology. The Caribbean Climate Change Center in Belize and the Mona Climate Change working group also carry out some important work researching the impact of climate change in the region. These regional centers demonstrate the necessity and benefits from functional regional cooperation sharing and rationalization of climate Change work

Notwithstanding the important strides made in improving technical capabilities, significant gaps remain in terms of enabling the country to adequately assess the processes and impacts of anthropogenic climate change. Financial and technical limitations restrict the geographical scope for data collection, most notably in Barbuda where vulnerabilities and existing climate stresses are already high due to the island's topography and economic dependency. Budgetary constraints impose technical, logistical and personnel restrictions on the work of the Met service.

Efforts for improving research and systematic observation presently underway include:

- Training of a number of persons up to the degree level in meteorology, computer science, mathematics and other areas,
- changing the office structure –meteorologists, climatologists, research officer – to allow for a more specified and specialized approach, and
- In-house development of computer software needed to help solve some problems and to provide information to the public.
- identifying some important areas for research e.g. the investigation of a positive trend in temperature, in support of global warming, sea level rise and the apparent reduction in rainfall over Antigua and Barbuda.

6.3 SEA LEVEL MONITORING

Another effort towards research and systematic observation involves efforts by the Fisheries Department of the Ministry of Agriculture to collect and analyze data on changes in sea-level at various coastal sites. This has been an ongoing programme for a number of years and has already generated useful data on changes in beach profiles indicating that erosion in some coastal areas are at rates far exceeding global averages. The sea-level monitoring programme has been implemented with technical assistance provided through UNEP.

Various other public sector and NGO environmental agencies are also involved in the monitoring and assessment of natural ecosystems sensitive to changes and shifts in weather and climatic patterns.

6.4 IMPROVING ENERGY EFFICIENCY

Antigua and Barbuda government has commissioned a series of studies as inputs into the development of a national energy plan including integrating renewable energy into the national electricity generating grid. An energy saving light bulb replacement programme with financial support of the government of Cuba was executed in 2007. The Cuban government is also assisting in the development of wind power generation in Barbuda.

It is expected that focus will be placed on implementing programmes and policies aimed at improving the effective and efficient use of energy as a means of promoting the reduction of GHG emissions as well as improving the macroeconomic performance and fiscal deficit position of the government.

Work will continue on implementing sustainability development initiatives and continuation of capacity building programs. Public education work will continue in climate change reduction and adaptation initiatives, especially in the areas of individual and private sector energy efficiency programs and in disaster management and construction and development building codes requirements.

CHAPTER 7

TOURISM

CHAPTER 7: TOURISM

7.1. INTRODUCTION

Tourism has been defined as the activities of visitors travelling to and staying in places outside their usual environment for not more than one consecutive year for leisure, business and other purposes. The purpose should not be related to the exercise of an activity remunerated from within the place visited i.e. employment[111]. The World Tourism Organization (WTO) defines tourists as persons who "travel to and stay in places outside their usual environment for not more than one consecutive year for leisure, business and other purposes not related to the exercise of an activity remunerated from within the place visited".

The Caribbean region is one of the most tourism dependent regions in the world and received an estimated 22.2 million visitors in 2005. Tourism represents over 30% of the region's GDP, and the industry is heavily dependent on the region's natural features, particularly its coastal and marine resources, tropical landscapes, and warm sunny climate.
market.

In Antigua and Barbuda the tourism industry encompasses a number of activities within the formal and informal economy. These include economic activity associated with hotels, restaurants, and bars; taxi and other ground transportation providers; commercial enterprises catering to visitors; and a host of other service providers providing various goods and services directly and indirectly to the sector.

The WTO, in a 2007 report on climate change and tourism, points out that "with its close connections to the environment and climate itself, tourism is considered to be a highly climate sensitive sector ….. The regional manifestations of climate change will be highly relevant for tourism destinations and tourists alike, requiring adaptation by all major tourism stakeholders. Indeed, climate change is not a remote future event for tourism, as the varied impacts of a changing climate are

[111]Extracted from "The Development of Tourism Satellite Accounts in CARICOM". Paper presented by the CARICOM Secretariat. 29th Heads of Government Conference, Antigua and Barbuda, 1-4 July 2008.

becoming evident at destinations around the world and climate change is already influencing decision-making in the tourism sector"[112].

Climate influences the length and quality of tourism seasons and plays a major role in destination choice and tourist spending. In most destinations, and certainly in Antigua and Barbuda and the Caribbean, the natural environment provides the basis of the tourism resource. Climate affects a wide variety of the environmental resources that are critical attractions for tourism such as coastal and marine habitats and biodiversity. The WTO report notes that climate also has an important influence on environmental conditions that can deter tourists, including infectious disease, wildfires, insect or water borne pests (eg jellyfish or algal blooms) and extreme events such as tropical cyclones.

7.2 TOURISM/CLIMATE CHANGE LINKAGES

The 2007 WTO report identifies four broad categories of climate change impacts that will affect tourism destinations, their competitiveness and sustainability:

1. ***Direct climatic impacts***. Climate is a principal resource for tourism as it determines the suitability of locations for a wide variety of tourist related activity, is a principal driver of seasonality in tourism demand and has an important impact on operating costs, such as heating/cooling, water supply, and insurance costs. Changes in the length and quality of climate dependent tourism seasons, will affect competition between destinations and affect profitability.

Studies indicate that a warming global climate change is likely to lead to a shift to higher latitudes and altitudes. IPCC projections for climate change impacts in the Caribbean can be expected to affect the tourism industry through increased infrastructure damage, additional emergency preparedness requirements, higher operating expenses (e.g back-up water and power supplies, and evacuations), and business interruptions.

2. ***Indirect environmental change impacts***. Because environmental conditions are so important to the tourism product, a wide range of environmental impacts associated with climate change can be expected to have profound impacts at the destination level. The WTO report points out that these can be expected to include coastal erosion, reduced landscape aesthetics, changes in coastal water quality, biodiversity loss, increased natural hazards, damage to infrastructure, and increasing vector

[112] See Climate Change and Tourism: Responding to Global Challenges. Summary. October 2007. Pages 6-7.http://www.unwto.org/climate/support/en/pdf/summary_davos_e.pdf

borne diseases. Mountain, island and coastal destinations are regarded as particularly sensitive to the indirect impacts of climate change.

3. Impacts of mitigation policies on transportation. There is increasing interest by policy makers in developed markets, particularly in Europe, to reduce greenhouse gas emissions from air transportation. This comes against a background of concern at the projected rate of growth in aviation emissions. This will increase transport costs, particularly for long-haul (such as trans-Atlantic) destinations and could serve to dampen demand. Climate change awareness and the consequent shift to mitigation measures are also likely to encourage shifts to more environmentally friendly transport modes such as rail and away from air transport. These developments can be expected to have implications for Caribbean tourism, with travel from the UK and Europe accounting for over 50 % of travel to Antigua and Barbuda.[113]

4. Indirect social change impacts. The IPCC [114] has identified the potential for economic and social instability in some destinations as a result of disruptions to ecological and socio-economic systems from climate change. This will clearly deter tourism.

The WTO report identifies the Caribbean as a climate change and tourism "hotspot" with future conditions likely to be characterized by a wide range of potential direct and indirect climate change impacts including warmer summers, increase in the number of extreme events, water scarcity, marine biodiversity loss, sea-level rise, disease outbreaks, and travel cost increases. The report indicates that evidence from available studies that have explored the potential impacts of global climate conditions for tourist destinations, suggests that anticipated impacts include a gradual shift to higher latitudes and to higher altitudes in mountainous areas. Tourists from temperate countries that presently dominate international travel are expected to take more holidays in their home country or nearby. More tourists may travel north in winter and less to warmer destinations such as the Caribbean etc.

[113] The European Union has moved to the introduction of an emissions trading scheme for all aircraft operating into and through EU airspace.
[114] Various other governments and organizations have also identified the security issues surrounding climate change. See for example http://www.bostonherald.com/news/international/europe/view.bg?articleid=1081451&srvc=rss

7.3 ADAPTATION TO CURRENT CLIMATE

The sensitivity of tourism to weather and climatic conditions means that over the years the industry has adopted a number of measures to adapt to existing climate stresses. These involve adaptations to temperature, marine conditions particularly coastal surges and beach erosion, storm and hurricane conditions, and drought.

The UNDP APF approach recognizes adaptation to existing weather and climate stresses as an important initial step towards adapting to future climate change. The success, or otherwise, of adaptation to present day stresses provide lessons for adaptation to future climate change and will have consequences for capacity to respond to more extreme weather events associated with future climate change.

7.3.1 Drought

Reflecting the country's historic and long standing vulnerability to drought, it is perhaps in the field of water/drought management that the greatest degree of adaptation has taken place to current climate variability and extremes. This has been through the introduction in the mid 1980s of desalinization plants which now supply most of the national potable water supply. This is especially important for the smaller level tourism establishments – restaurants, bars, boutiques, guest-houses, villas etc – which are dependent on the public supply of water. Nevertheless supply disruptions do occur periodically, particularly during periods of extended drought and high temperatures, so that enterprise level conservation and water management practices are utilized. The Ministry of Health seeks actively to promote hygiene practices for tourism and other public facilities.

At the restaurant, bar, boutiques, and hotel level the first stage of adaptation involves virtually universal capture and storage of water, generally for non-potable uses. Purchase of trucked water is well established and widely utilized. In addition, at present a number of hotels produce water through reverse osmosis or other desalinization methods. This includes the three hotel properties in Barbuda and many of the larger hotel properties on Antigua.

Measures for the conservation and efficient use of limited water supplies (low water consumption flush toilets, low-flow showerheads, drip irrigation etc), including through awareness programmes for guests, are also primary responses to the problem of drought and water scarcity utilized by virtually all hotel and guest house properties.

While adaptation has been largely successful, important stressors do remain. Extended periods of drought can result in supply disruptions, and the cost of water production from reverse osmosis and other methods remains prohibitive.

7.3.2 Coastal Erosion

Coastal hotels and other tourism properties have also developed, or been required to adopt, various adaptation mechanisms for coping with existing risks arising from coastal erosion, storm surge and high seas. Tropical storms and hurricanes generate winds, deep water waves, beach scour (beach or shoreline erosion) and storm surge which periodically inflict damage on coastal areas and properties. Additionally sea conditions arising from heavy seas impact directly on coastal hotels and other properties removing sand, depositing debris, and damaging infrastructure and buildings. These problems occur to a greater or lesser extent at all beaches in Antigua and are most acute in terms of impact on the tourism sector where development occurs too close to the high water mark.

Beaches in Antigua and Barbuda tend to be comprised of small littoral cells, separated by headlands. The beaches constitute an ecological system involving processes of energy and sediment exchange. The beach platforms and sand distribution change from winter to summer in response to directional shifts in dominant waves. Typically sand supply is limited so that beaches are in a relatively precarious equilibrium. Any action, whether natural or anthropogenic, which leads to a negative sediment balance will promote erosion and beach degradation. At beaches such as Dickenson Bay, Runaway Bay, Long Bay, and Crabbe Hill tourism developments have heightened risks of beach erosion.

Over the years, beach erosion, flooding, odor linked to sewerage pollution, and a general deterioration of the landscape have contributed to a notable decline in the status of Runway Bay and to some extent Dickenson Bay as resorts areas. At one time the premier resort zone in the country, Dickenson Bay/Runaway Bay has lost much of its environmental quality with some of the damage caused by land and resource use practices in adjacent areas. However, an acceleration of beach erosion, at Runaway Bay in particular, has followed the passage of hurricanes adversely affecting its tourism potential.

The principal adaptations to such existing features involve measures for beach-setbacks designed to prevent buildings within the active coastal area as well as various forms of hard and soft protective measures such as groynes, offshore breakwaters, and beach/sand nourishment. In Antigua beach setbacks have been developed utilizing available beach erosion data and other empirical evidence. Compliance with these standards remains a challenge for the various environmental protection agencies as seen at various hotel and tourism locations including Dickenson Bay, Crabbe Hill, and Long Bay.

"Hard" engineering solutions such as groynes and breakwaters are also used in Antigua including at Dickenson Bay, Runaway Bay, and Jolly Beach. These types of engineering responses can present various environmental risks by disrupting the natural movement of sand and other materials along the coast and in some instances may result in negative impacts on nearby areas including downstream properties.

7.3.3 Hurricanes

The tourism sector has developed a range of mechanisms for adapting to the weather related risks associated with the annual passage of storms and hurricanes. Particularly since the hurricanes of the 1995 – 1999 period, adaptation to hurricanes and tropical storms has been an important consideration for sector stakeholders in hotel, yacht and cruise sub-sectors.

Hotels and other properties have adopted design and engineering measures aimed at protecting life and property during hurricanes and storms. Emergency plans for evacuation and other measures have been developed and are coordinated with the National Office of Disaster Services. The Caribbean Tourism Organization has promoted hurricane preparedness and response measures for the hotel sector including on-line guidelines and workshops for sustainable tourism. In 1998 the CTO and the Caribbean Hotel Association produced a Hurricane Procedures Manual[115] with information on a wide range of actions in relation to hurricanes including recovery and restoration, structural vulnerability and loss reduction, managing insurance coverage, and communications plans.

Insurance also forms an important element of the tourist industry's response to hurricane and storm activity. However this is costly and subject to significant short term increases. For example the cost of property insurance increased by 25% effective January 2000, by another 20% in 2001 and by a further 5% in 2002. For hurricane and other perils, rates for hotels as given by one of the major companies in the island is EC$24.85 – EC$28.85 per $1000; the lower rate for concrete

[115] See http://www.oas.org/cdmp/document/chaman/chaman.html

structures and the higher for wooden buildings. Large hotels, international chains or companies with multiple properties are generally able to secure the more favourable rates on the regional and international markets. The ability to negotiate rates places such properties at an advantage to small hotels whose options are usually limited to local insurers. One hotel company in the island reportedly uses a hurricane escrow fund as a means to reduce insurance costs[116].

For yachts a number of sheltered anchorages exist that provide protection from waves generated by the storm. In some cases yachts may be dry-docked to prevent damage. Popular sites include English Harbour and the Jolly Harbour marina. In some instances mangrove areas provide important anchorages with the mangrove roots being used in some instances to secure boats. The passage of tropical storms may alter boating channels, prompting the need for clearing and in some instances dredging.

Insurance also constitutes an important adaptation measure for yachts, although this is not universal and Jackson indicates that difficulties in getting affordable insurance for yachts has been one of the reasons for the slow growth in that sub-sector over the years. This has been due to the frequent hurricanes and damages to yachts, particularly by Hurricane Luis in 1995. The hurricane season also contributes to the seasonality of the sector which results in a significant reduction of boating activity in Antigua-Barbuda between May and November.

Cruise lines have been operating in the Caribbean for years and have, by virtue of experience, specific hurricane/tropical storm emergency response plans in effect. These range from designating a bridge officer as the weather monitor during the season, to outfitting ships with state-of-the-art satellites, to backing up onboard efforts with expanded staff at headquarters. The principal decision that cruise lines face when a storm threatens scheduled ports-of-call is finding alternate places to anchor. Most common is that cruise lines whose eastern Caribbean itinerary appears to be impacted by a storm will switch over to a western Caribbean port schedule (and vice versa) or include extra sea days in calm waters.

7.3.4 High Temperatures

Antigua and Barbuda’s tropical maritime climate means that the country experiences warm tropical temperatures throughout the year. Daytime

[116] See Jackson quoted above.

temperatures of 29-31 degrees Celsius, accompanied by high humidity, are common particularly outside of the winter months.

As a moderating influence to high temperatures and humidity, virtually all hotels use air conditioning in their guest-rooms. In addition to air-conditioning, fans and open air designs aimed at facilitating north-easterly trade winds are used to ameliorate warm conditions and provide comfortable surroundings for tourists.
Nevertheless, electricity costs for the tourism sector in Antigua and Barbuda are high and increasing. While middle and larger establishments are generally believed to be relatively efficient in their energy use, many smaller properties are believed to be inefficient in energy costs, a significant proportion of which comes from air conditioning.

Outside of the accommodation sub-sector, use of air conditioning varies. Most tourist shops and services in St Johns are air conditioned. Many smaller establishments use fans and design features such as decorative blocks.

7.3.5 Summary of Existing Adaptations in the Tourism Sector

The ability of enterprises and entities within each component of the tourism sector to adjust to existing stresses is dictated by various factors including the nature of the risk, the physical location of the enterprise, cost and availability of insurance, the economic performance and financial capacity of the entity, and the technological and design options available.

In most cases the adaptations come at a financial cost, with the greater the level of adaptation required the greater the financial cost. These costs are increasing due to the increase in risks (e.g. increased costs for insurance due to hurricane activity) and/or are driven by external factors (e.g. increased electricity costs for air conditioning). Ultimately such costs must be passed on to the consumer, absorbed by the enterprise, or subsidized by the public purse.

Table 7.1 below provides a matrix of ongoing adaptations to weather and climate related impacts within various components of the tourism industry in Antigua and Barbuda.

Table 7.1 Existing Tourism Sector AdaptationTo Present Day Climate Stresses

	Warm temperatures	Coastal erosion, high seas, and storm surge	Hurricanes and tropical storms	Drought	Heavy rainfall events/flooding[117]
Hotels and guest house	Increased use of air conditioning. Building design. Use of shade trees. Advice to guests.	Beach setbacks. Construction of groynes and other protective devices (Jolly Harbour, Dickenson Bay, Falmouth). Insurance. Construction of swimming pools. Beach nourishment. Advice to guests.	Insurance mechanisms. Building design and construction. Emergency response mechanisms including relocation of guests. Closure of properties during peak hurricane season. Advice to guests.	Installation of desalination plants. Purchase of water from private sources. Efficient water devices including recycling of waste-water. Water collection and storage. Use of drought resistant plants.	Guest advice. Building and landscape design.
	Warm temperatures	**Coastal erosion, high seas, and storm surge**	**Hurricanes and tropical storms**	**Drought**	**Heavy rainfall events/flooding**
Cruise	Increased use of air conditioning. Advice to guests. Promotion of on-board activities as high temperatures encourage some	Shift in destination for major events. Promotion of land based attractions vis-à-vis coastal attractions during high sea events.	Shift in voyage to neighbouring island destination. Heightened weather monitoring capability.	Purchase of water from other destinations.	No direct impact on cruise. Adversely affects visitor expenditure.

[117]Primarily associated with tropical storm/hurricane activity.

	guests to remain on board ship.				
	Warm temperatures	**Coastal erosion, high seas, and storm surge**	**Hurricanes and tropical storms**	**Drought**	**Heavy rainfall events/flooding**
Yachting	Not a major factor to date. Increased use of air conditioning on luxury yachts.	Remaining in sheltered locations where possible. Securing of vessels. Change in yachting activities.	Insurance. Relocation of vessels to safe anchorages[118].	No major impact. Installation of reverse osmosis plants on some yachts. Water conservation. Water conservation measures.	No direct impact.

The table above suggests that the hotel/guest-house sub-sector of the tourism industry is the most vulnerable of the three sub-sectors to existing climate stresses and has had to adopt a number of adaptation measures to ensure its competitiveness and sustainability. Shore based cruise and yacht facilities are also vulnerable particularly to hurricane and coastal surge activity. The principal assets of the cruise and yachting sub-sectors are generally more mobile assets that are able to shift temporary locations to minimize the most adverse impacts of short term extreme weather events. Cruise ships in particular are usually able to avoid extreme weather events and their aftermath by changes in the cruise itinerary.

Measures successfully implemented over the years within the tourism sector for adapting to current extreme weather events provide baselines for the types of policies and measures that are likely to be required for adapting to climate change, at least in the short term.

[118] The yachting season of November to April is mainly outside of the hurricane season.

7.4 FUTURE SCENARIOS FOR TOURISM DEVELOPMENT

Defining possible future socio-economic conditions is important to understanding future vulnerability to climate change and assessing adaptive capacity in the face of new risks. At the same time there are obvious difficulties in attempting any forecast of future socio-economic and other conditions. Not least these difficulties arise from the uncertainties relating to the complex interplay of global, regional and national political and economic forces. This is particularly so for an industry as sensitive as tourism where a wide variety of external factors, ranging from terrorism to costs of air travel, can be expected to have significant impacts on the performance of the sector.

The aim of indicating future socio-economic and environmental conditions is the identification of variables that can be expected to substantially affect vulnerability to climate change. Some broad conclusions of likely or possible future pathways for Antigua and Barbuda are provided as an aide to understanding the likely impacts of future climate change.

Climate change will take place against the background of other changes occurring in Antigua and Barbuda's economy and society and in fact against a background of other socio-economic, environmental, technological and political changes at the global level. Among the variables likely to be influential in terms of impacts on the tourism sector are those relating to government policy, environmental sustainability, economic growth, social stability, and technological development.

In terms of official policy, the Government of Antigua and Barbuda clearly envisages a continuing dominant role for the tourism industry within the wider framework of sustainable social and economic development. The 2008 Throne Speech, the major pronouncement of government of its development plans for the upcoming year, recognizes tourism as "the mainstay of the economy" and identifies a number of strategic goals aimed at strengthening the sector and its contribution to national development[119]. These measures include:

- Upgrading of existing room stock to international standards and establishing a critical mass of new rooms led by 5 Star properties;
- Positioning Antigua and Barbuda as the meetings, sports, conventions, and wedding capital of the eastern Caribbean;
- Upgrade selected sites and attractions and develop various facets of the product;
- Increase airlift to both islands; and

[119]Government of Antigua and Barbuda.Speech from the Throne. Her Excellency Governor-General, Dame Louise-Tack GCMG DStJ. November 2007.

- Upgrading the room and physical capacity of small hotels below 25 rooms.

The bullet points indicated below provide some of the likely directions for socio-economic and environmental conditions that are likely to affect the tourism industry in Antigua and Barbuda. They are based on existing trends and policies as well as on forecasts from various international and other agencies. Among future socio-economic and environmental scenarios for the tourism industry in Antigua and Barbuda for the period to 2015 can be expected to be;

- Continued official focus on tourism as the lead economic sector. Projections target 360,000 stay-over arrivals and 1348,000 cruise passenger arrivals for 2015.
- Construction of hotels focusing on high end visitors. Decline in the overall rate of hotel and tourism growth.
- Continued emphasis on beach and marine attractions and pressure for coastal locations as prime tourism investment sites.
- Continued coastal erosion and degradation on all coastlines and particularly along north western and south western coasts. Slower rates of erosion at other sites and in Barbuda.
- Expansion of tourism plant in Barbuda catering primarily to high end, low impact resort development.
- Greater emphasis on expanding yacht visitor arrivals based on expanded facilities and strengthened management/institutional framework.
- Rising energy, food, transportation and labor costs adversely affecting demand for Caribbean tourism.
- Increased concerns for visitor safety and security.
- Greater awareness among travelers of environmental issues relating to concerns of carbon footprint and the need for sustainable development.
- Continuing pressure within tourism industry to maintain competitiveness in the face of escalating regional and global competition.

Environmental pressures over the short term can be expected to be influenced by local anthropogenic impacts as well as by ongoing climate/weather related impacts. The latter are likely to be particularly severe where anthropogenic influences have already degraded the natural environment. Measures are underway to improve environmental stewardship in the tourism industry through greater use of environmental impact assessment, with the Ministry of Tourism adopting a programme for sustainable tourism within the ministry. However, these measures can provide only limited short term benefits given the extent of coastal resource degradation, and the extent of impacts from existing coastal processes.

7.5 POSSIBLE CLIMATE CHANGE IMPACTS ON TOURISM

This section examines the possible effects of some of the main expected impacts of climate change. As noted earlier, impacts will be both direct and indirect. The tourism industry in Antigua and Barbuda is intricately interlinked with other sectors such as water resources, coastal zone, and human health, and is also dependent on outputs and products from various sources. For example, climate change effects on fresh water availability and quality, coastal water quality, and hurricane formation can be expected to directly affect the tourism product. Other more complex social and economic factors emerging from climate change such as social instability may also impact the tourism industry.

The assessment below looks primarily at first order levels of impacts and examines the effect that four parameters of climate change – increased air temperatures, sea-level rise, hurricane/tropical storm activity, and rainfall variability – may have on the tourism industry in Antigua and Barbuda.

7.5.1. (A)INCREASES IN AIR TEMPERATURES

IPCC projections envisage an increase of air temperatures in the Caribbean region of 0.48 to 1.06 degrees centigrade between 2010 and 2039 relative to the 1960-1991 base-line period[120]. The outputs from the PRECIS climate models project an increase of 0.6 – 0.8 degree Celsius for Antigua and Barbuda by the 2030s.This will have a number of effects of relevance to the tourism industry.

For the hotel and guest house sub-sector, the main employer and source of foreign exchange within the industry, the first of these effects will be to increase considerably the demands for space cooling. While most hotel guest rooms in Antigua and Barbuda are now air conditioned, all hotel properties in Antigua and Barbuda presently utilize large open air common areas such as restaurants and bars, reception areas, and passageways. An increase of temperatures of 0.6 degrees celsius will likely require that many if not most of these areas receive some form of cooling. This could have significant implications in terms of retrofitting and alterations as well as operational costs for cooling. Air cooling costs presently comprise an estimated 30% of electricity costs at some hotels in Antigua and Barbuda. An increase in demand for space cooling will therefore be a significant cost for the ultra-competitive tourism industry.

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[120] The AR4 points out that since the GCMs were able to model only sea surfaces, that it is likely that there is an underestimation of the

Other tourism related properties, such as restaurants, not presently air conditioned will probably be forced to use space cooling in order to provide comfortable surroundings for customers/clients. A continuing pattern of higher night-time temperatures will mean that demand for cooling will not decline considerably during night-time hours but may increase as warmer nights prompt needs for air conditioning[121].

Higher temperatures can be expected to increase demand for potable water within hotels/guest houses and the wider hospitality industry. Water costs either resulting from purchase from the utility, from private haulers, or through desalinization represents an important operating cost. Costs per gallon of water vary according to whether or not desalinization is involved but represent a higher cost compared to most other Caribbean destinations.

Higher air temperatures also have potential for impacting on the tourism industry through a variety of indirect pathways at macro and national levels. Higher temperatures will increase moisture stress in plants and vegetation leading to reduction in aesthetic quality of the landscape of sites such as Fig Tree Drive. It is likely that vegetation types in such areas will be altered towards flora better suited to drier, hotter conditions. Along with drought conditions, there will also be increased likelihood of wildfires which in themselves present health and aesthetic concerns. Warmer temperatures also increase risks associated with food-borne diseases.

It is unlikely that warmer temperatures of the type projected for 2030will of themselves negatively impact tourism demand. Experience from present day island destinations such as Cyprus, Singapore, the Seychelles, Bali and Mauritius suggests that temperatures within the projected PRECIS and IPCC ranges do not of themselves reduce tourism demand[122]. At the same time the experience of many of these destinations indicate the absolute requirement for space cooling and for strong and diversified tourism attractions.

On the other hand, as noted above, warmer temperatures in source market countries of Europe and North America can be expected to reduce the demand for travel to warm weather destinations and lead to increased tourist interest in

121It is believed that only a small number of hotel restaurants presently utilize air conditioning, with most relying on natural cooling.

122 Other hot weather destinations with major tourism industries include Las Vegas, Egypt, Spain, and Israel.

vacations at higher latitudes and altitudes – neither of which will benefit Antigua and Barbuda[123].

7.5.2. (B) SEA – LEVEL RISE

The IPCC TAR indicates an estimated annual sea level rise for the Caribbean of 1mm/year during the twentieth century. The IPCC indicates that global projections point to accelerated rates of sea-level rise during the twenty-first century as compared to the latter half of the twentieth century. Expert opinion suggests a n annual rate of sea-level rise in the eastern Caribbean of approximately 1 – 3mm annually. Outputs from regional climate models also indicate that significant sea level rise can be expected for the region, although there is likely to be considerable variation within the region based on factors such as tectonic movement and land subsidence[124]. Based on these projections, sea level rise, and particularly storm surge under scenarios of sea-level rise, will present significant challenges for tourism related properties located in coastal areas including yacht harbours and cruise ship ports.

Sea level rise can be expected to pose one of the gravest threats to tourism in Antigua and Barbuda. The potential risks for Antigua and Barbuda are particularly severe given that beaches constitute Antigua and Barbuda's principal tourist attraction, the ecological fragility of the resource, and the existing stresses to which these resources are already being subjected. Additionally most of the country's principal hotels lie within 100yds of the high water mark at elevations of less than 30ft above the high water mark. Sea-level rise will exacerbate the level of risks and the vulnerability of coastal properties already associated with natural hazards.

Among the factors that will affect the level of risk for specific tourism properties in Antigua and Barbuda will be:

- Hydrology of drainage basins in which coastal properties and uses reside
- Size of coastal watersheds or drainage basins in relation to size of coastal valleys; a high watershed to valley ratio tends to increase flood risk
- Hydrology of nearshore wetlands
- Hydraulics of streams or ghauts
- Elevation of land above sea level

[123] The WTO report suggests that areas such as western Canada could become more attractive as destinations as temperatures in these arease increase.

[124] Sections of the west coast of Barbados for example is currently undergoing a period of slow gradual uplift: personal communications with officials from the Coastal Zone Management Unit.

- Geology, soils
- Geomorphology

The size of a watershed in relation to a coastal valley (a typical location for tourism facilities) determines to a large extent the level of flood risk. As indicated before, alteration of a wetland in a coastal environment increases the vulnerability to floods. Wetland alteration may also destabilize beaches and coastlines in such an environment, accelerating hydrological changes and impacts associated with sea level rise as has been seen at Dickenson Bay. Where a coastal swamp is no longer available to retain and slowly release flood waters, sediments transported from the upland watersheds will gradually degrade water quality and even reduce the depth of the nearshore area (bay), e.g., Jolly Harbour. Where such conditions exist, natural shoreline retreat and equilibrium in response to sea level rise will be compromised.

Jackson notes that areas often considered as having good potential for coastal tourism in Antigua/Barbuda share characteristics that make them susceptible to hazard risk and to human practices that increase vulnerability to hazard events associated with climate change[125]. These characteristics include:

Watersheds or drainage basins which provide alluvial sediment deposits that create flat lands, coastal swamps and ponds. Typical examples are Runaway and Dickenson Bays, Jolly Beach, Carlisle Bay, Cades Bay and other areas particularly on Antigua's west and south coasts. Failure to acknowledge processes that create coastal lands and systems increases the potential for ecological and economic damage;

Limited, moderate or extensive natural protection offered by offshore reefs and small islands. Where reefs are damaged by natural events or human practices, coastal protection is undermined and damage to coastal beaches and properties is exacerbated;

Topographical and hydrological conditions that lead to the blocking or alternatively the flushing of coastal ponds and wetlands as part of recurring natural cycles. Such natural occurrences may temporarily alter the profile and visual value of beaches. Also, where hydrological characteristics of wetlands are altered by humans, as in the case of McKinnon's Pond, flood risks are significantly increased. Sea-level rise could alter the hydrological functions of the Pond and adversely affect its capacity to trap and filter sediments and other pollutants. This would have potentially damaging

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[125] "Impact of Climate Change on Tourism in Antigua and Barbuda". Ivor Jackson. June 2003. Paper prepared for Government of Antigua and Barbuda UNFCCC Initial National Communications Project.

consequences for the hotels, restaurants and other tourism related properties in that area ;

Formation of mangrove forests in lagoons or along coastlines. The mangrove is a dominant natural feature of numerous coastal areas in Antigua and much of Barbuda. Mangroves function with reefs and seagrass to provide physical and ecological stability to coastal and nearshore areas, often of value to tourism. They also help to reduce impacts to land and property from storm surge and waves and to filter sediment and pollutants carried by flood waters. Such functions can be impeded by natural events or human practices at great economic and social cost to tourism and the society.

Disruptions can be expected to occur to these natural systems from rising sea-levels. A qualitative summary of a number of hazards associated with rising sea-level from climate change is presented at Table 7.7 below.

Table76.2 : Qualitative Summary of Hazard Risks Associated with Selected Tourism Areas

Resort Area	***Hazard Risk***				
	Storm surge	***Waves***	***Flooding***	***Erosion***	***Sea level***
Northwest Coast (NWC) Dickenson/Runaway Bay/Fort James	*	***	***	***	*
Jolly Harbour/Jolly Beach	**	*	**	**	*
Royal Antigua/Pillar Rock	*	*			*
South coast beaches (Crab Hill to Pigeon Point)	*	*	**	**	*
East coast (St. James to Mill Reef)	*	*		*	*
North coast (Long Bay to Weatherills)	*	*		*	*
West coast (Deep Bay to Darkwood)	**	**	**	**	*
Barbuda	**	*	**	*	* *

Jackson 2003

(* = moderate risk. ** = severe risk. *** = Extreme risk)

Jackson points out that property-owners will need to cope with sea level rise impacts on two fronts. One is "event" driven effects associated with wave, storm surge and wind related damage and their direct and indirect damages and cost. The other is from the erosion, land loss and inundation which are likely to be gradual and sustained. A major concern will be how this impacts on property value and income over time. Beach resorts and other facilities will be faced with challenges affecting property, the viability of businesses and earnings. These include:

- Loss of recreational value and carrying capacity of beaches;
- Loss of property value resulting from declining amenity value;
- Loss of land and reductions in land values;
- Deterioration of landscape and visual appreciation;
- Cost for beach and property protection;
- Loss of business".

Sea level rise will also exacerbate issues relating to land ownership on eroded coastal areas. Land loss and cyclical changes to the profile of beaches often result in the shifting of the boundaries between public and private lands at the shoreline. Where land is lost from erosion, the seabed is assumed automatically to revert back to public ownership. The right of the private owner to reclaim lands back to his/her original boundary is unclear. This is an issue that will require legal interpretation for eroding coastal beaches, such as Runaway Bay. Resolution of ownership issues could become quite complicated where private investment is made in beach restoration.

Sea-level rise will require some adjustments to the height of piers, so that coastal and harbour planners will need to undertake coastal resource studies to determine the state of sea level rise and its effects on storm surge and wave heights.

Jackson indicates that the rise in sea level will have mixed results and impacts for boaters. Effects will be gradual but nevertheless should become integral concerns for coastal planning and for the continued development of yachting and marine recreational activities. Changes in bathymetry and depth in relation to nearshore reefs will be critical. Some effect may be beneficial, such as the deepening of channels, anchorages and cruising areas not currently deep enough to accommodate deeper draught yachts.

7.5.3. (C) HURRICANES AND TROPICAL STORMS

Considerable uncertainty still surrounds the impact that climate change will have on the formation of tropical storms and hurricanes. The IPCC's AR4 notes that "although there is not yet convincing evidence in the observed record of changes in tropical cyclone behavior it is likely that the maximum tropical cyclone wind intensities could increase 5 to 10 percent by around 2050". This scenario would also see a 25% increase in the precipitation intensity that could be expected during a storm or hurricane. The AR4 points out that research indicates a trend in hurricane development towards an increase in both the frequency and strength of tropical storms since the 1970s, including longer storm times and intensities.

An increase in hurricane/tropical storm activity can be expected to have a significant effect on the tourism industry from at least two perspectives:

- Direct physical impacts on tourism plant, attractions, and support services.
- Impact on visitor perceptions of the attractiveness of the destination.

As noted earlier in this report, hurricanes during the 1995 – 1999 period impacted adversely on the tourism sector, most severely in 1995 when destruction from Hurricane Luis severely affected the tourism industry and by extension the national economy. Stay over tourist arrivals were reduced following the active hurricane season and did not regain 1994 figures until 2003.
Cruise arrivals were not affected in this manner and maintained steady growth reflecting the lesser vulnerability of the cruise sector to hurricane events.

Table 7.8 above indicates that tourist arrivals dipped in 1995/96 due to the devastation caused by Hurricane Luis and other storms in the third quarter of 1995. At the same time the country's stock of hotel rooms also declined due to damage to properties from Luis and remained stagnant for some time after this. Subsequent storms did not have the same effect as Hurricane Luis on the natural environment or physical infrastructure of tourism. Table 7.10 below indicates the impact of Hurricane Luis on the contribution of the hotel and restaurant sector to gross domestic product (GDP).

Table 7.3 GDP Hotel and Restaurant Contribution to GDP @ Factor Cost in Current Prices

1994	1995	1996	1997	1998	1999	2000
178.74	149.41	165.93	175.41	171.49	107.64	178.61

source: Eastern Caribbean Central Bank

Hurricane impacts on the tourism sector are therefore wide ranging and encompass both direct and indirect effects. All sectors of the industry are affected in some way.

The principal direct impacts are the impacts on property and also possibly on human life including tourists. The vulnerability of much of the tourism infrastructure to coastal processes has already been noted. However damage from the effects of winds and water are also likely to cause extensive destruction. In Antigua and Barbuda damage to hotel properties from Hurricane Luis included sand deposition and removal, damage to roofs and rooms, loss and destruction of drainage, storm surge and destruction of piers and jetties.

Documentation prepared under the Caribbean Disaster Mitigation Project (CDMP) for the hotel industry[126] indicates that an assessment of damage to most buildings from recent hurricanes in the Caribbean showed that roof failure was the primary cause of problems, generally due to inappropriate roofing material and practices. The report notes that the intention of hoteliers to resume business as quickly as possible has often meant that reconstruction has proceeded "based on the same design concepts and the same materials which led to the failures under the hurricane conditions".

In terms of the tourism sector, impacts from climate change also include damage to critical infrastructure such as ports, airports, roads, water, telecommunications and electricity. Disruption of these services will determine the country's ability to receive and provide essential services to visitors.

The extent of vulnerability was underlined by the westward moving Hurricane Lenny of 1999, which caused serious damage to coastal facilities in eastern Caribbean islands since the storm surge was felt along the usually protected west coast where hotel properties and other tourist infrastructure, as in Antigua and Barbuda, are predominantly located.

Critical concerns will be the effect of climate change on the frequency and strength of hurricanes. The chart below provides an indication of the potential effects of hurricanes on buildings and shorelines. Any increase in the number of hurricanes and/or their intensity will affect insurance premiums as well as negatively affecting visitor perceptions of the country and region as a destination.

[126]Caribbean Disiater Mitigation Project Hurricane Procedures Manual. See http://www.oas.org/cdmp/document/chaman/chasect4.html

Table 7.4 : The Saffir-Simpson Scale and Potential for Shoreline and Property Damage

Category	Winds	Pressure (mb)	Possible Effects
1	74-95 mph	>980	Coastal flooding, minor damage to piers and damage to landscape
2	96-110	980-965	Damage to roofs, windows, piers, small craft, vegetation; coastal flooding
3	111-130	964-945	Structural damage to buildings, roads; terrain <5ft ASL (above sea level) may be flooded up to 8 miles inland
4	131-155	944-920	Extensive structural damage, major beach erosion; terrain <10 ft ASL may be flooded up to 6 miles inland and evacuation needed
5	> 155	<920	Massive damage; major damage to floors of structures in terrain <15 ft ASL and within 500 yards of shoreline; evacuation of areas in low ground up to 10 miles may be required in places like Belize and Guyana.

(Source: D. Smith, ECLAC Unpublished Document) Extracted from Jackson. 2003.

For the yachting sub-sector a number of hurricane impacts can be expected. The first and most significant of these is damage and destruction to boats and equipment. During Hurricane Luis widespread damage occurred to yachts in Antigua although no estimate of actual costs were available. Yachts seek various forms of protection during storm events dependent on the forecast strength of the event.

Another adverse impact would be sediment deposition and re-deposition associated with hurricanes. This may occur from shifts in offshore sand due to wave movements during the storms, as well as to restricted channels such as at Jolly Harbour. This reduces the depths of channels and anchorages. More frequent and intense storms would increase both the inconvenience and associated costs for dredging, and undertaking bathymetric surveys or updating of navigation charts.

Of the three major tourism segments, the cruise tourism sub-sector has been, and is likely to remain, the least affected by hurricanes. Cruise tourism facilities in the country are mainly berthing piers and the dedicated shopping complexes at Heritage Quay and Redcliffe Quay. Jackson estimates that even if additional infrastructure is constructed, unless the country becomes a home port for cruise ships, the risk to cruise tourism facilities would remain relatively small compared to hotels and yachting facilities. Cruise ship piers are generally believed to be relatively well equipped structurally to withstand the impacts of storm surge and wave damage.

Data above indicates the recent steady growth of the cruise sector even during 1995 – 1999 when Antigua and Barbuda, and the Caribbean in general, experienced a sustained period of hurricane and storm activity.

Maintenance dredging of deepwater basins for cruise ships is already a recommended practice of harbour/port management. However more frequent and intense hurricanes could increase the frequency, and costs, required. Maintenance dredging cost can be significant and will be dependent on the volume of sediment that must be removed. Realistic prediction of costs is therefore not possible.

Cruise line strategy is to avoid rather than confront a storm. This means that the sector remains vulnerable to short term shifts by the cruise lines, particularly given the contribution of the sector, including at the informal level – hair-braiders, beach vendors, etc. Economic losses are likely to result from damages to attractions used by cruise passengers and the most severe impacts would likely to be taxi drivers, tour operators and vendors. Loss of business could also occur where shops and other businesses depending on cruise passenger patronage are damaged. This will have important negative multiplier effects throughout the economy.

Experience in the region indicates that hurricanes cause temporary interruptions to cruise ship schedules, with loss of income to governments and service providers. Such interruptions are usually not long lasting unless major structural damages occur to berthing infrastructure. However the extent of financial benefits at the destination that accrues from the visit will be dependent on the extent of recovery of onshore facilities and attractions such as beaches, shops, roads etc.

More intense storm activity, as projected under some scenarios of climate change would however lead to increased damage to port berths and negatively impact the ports ability to receive cruise ships.

7.5.4. (D) INCREASED RAINFALL VARIABILITY

The annual rainfall figures at Appendix I indicate that rainfall totals for Antigua and Barbuda vary significantly on a seasonal and annual basis. The projections from IPCC and the PRECIS Caribbean project demonstrate that Antigua and Barbuda can expect to see even greater levels of rainfall variability in the future.

It is difficult to assess what the likely consequences of greater rainfall variability will be on the tourism sector. With a general trend towards drying this is likely to force continued dependence on water from costly sources such as desalinization. Drier conditions do however satisfy the tourist's expectation for sunny vacation days. As noted earlier, various adaptation technologies have historically been used in Antigua and Barbuda to cope with water scarcity. Many of the principal impacts for tourism from a trend towards drying can be expected to be the increased costs associated with providing assured water supplies during periods of shortage or stress, As well as the indirect impacts arising from the effects of climate change in such areas as sanitation and aesthetic quality. Ongoing efforts for adaptation to existing rainfall variability will need to be extended to cope with more intense drought conditions arising from climate change.

Periods of intense rainfall are less common in Antigua and Barbuda. However IPCC projections point towards more intense rainfall events and there is some empirical evidence that there may have already been a shift in rainfall patterns in this regards. As noted above many of the sites where tourism developments are located occur within high risk areas for flooding. Properties at Runaway Bay, Dickenson Bay, Jolly Harbour and Old Road are already at risk to flooding and are likely to experience increased vulnerability with a trend to heavy rainfall events. Impacts would include flooding of low-lying areas with consequent damage to property and risks to human health and welfare.

7.5.5. (E) HIGHER SEA SURFACE TEMPERATURES

The IPCC's AR4 report reaffirms the projections of its 2001 TAR that points to gradual warming of sea surface temperatures in all small island regions and seasons. As pointed out elsewhere in this report, warming of the ocean can be expected to have adverse effects on coastal areas and resources. This includes damage and destruction of the coral reefs which constitute the base resource for Antigua and Barbuda's beaches. Many of the islands important tourism and recreational beaches are protected by coral reefs. Destruction of these assets will greatly increase the rate of erosion at beaches such as Long Bay and Half Moon Bay. As Antigua and Barbuda remains essentially a beach destination, this could have profound implications for the country's tourism industry.

Bleaching resulting in loss of corals will negatively impact the dive operations which are heavily focused towards this feature, by reducing and eventually destroying the resource upon which the dive is based.

Episodes of coral bleaching have been reported for Antigua and Barbuda and in general the country's reef systems are already stressed from a number of anthropogenic sources.

7.5.6. (F) SUMMARY OF IMPACTS

The broad range of direct impacts likely to affect the Antigua and Barbuda tourism industry suggests that the sector is highly vulnerable to climate change. In many instances climate change will exacerbate already stressed and vulnerable resources such as beaches.

Given the sector's central role in the national economy, any adverse effects of climate change on tourism can be expected to negatively impact the wider economy and have implications for poverty reduction and other indicators of socio-economic stability. Tourism stakeholders have devised a number of responses for adapting to existing climate stresses. The scale and magnitude of the changes expected from global climate change can however be expected to provide challenges for existing practices.

The section below attempts to provide some proposals for enabling adaptation to climate change by the tourism sector in Antigua and Barbuda.

7.6. ADAPTATION POLICIES AND MEASURES

7.6.1. INTRODUCTION

The WTO report notes that, globally, comparatively little attention has been paid to issues of adaptation in the tourism sector as compared to sectors such as agriculture. Notwithstanding such relative lack of attention in the past[127], it is clear that climate change adaptation in the tourism industry in Antigua and Barbuda will require a series of policies and measures that address the varied sources of climate related stresses that can be expected to adversely affect the sector. Given uncertainties as to the exact nature of future climate change impacts on the sector, adaptation policies and measures should seek to address existing vulnerabilities as a part of the process towards addressing likely future risks.

Tourism presents special challenges for climate change adaptation since the attraction remains the country itself as a destination, with beach tourism constituting the principal feature of that attraction. While the emphasis here is on adaptation responses specific to the tourism sector, the tourism industry is interlinked with many other sectors (agriculture, banking and real estate, retail and manufacturing, construction, government services etc) so that adaptation in the tourism industry will require effective cross sectoral integration of adaptation policies and measures.

Because tourism is an economic sector and not a geographic area, many of the response measures that tourism sector enterprises will need to adopt for economic reasons within the context of a changing climate will require attention to energy efficiency and other "green" issues: adaptation in the tourism sector is likely to reflect a close linkage between climate change mitigation and climate change adaptation.

Early adaptation within the tourism sector is important for a number of reasons:

- Climate change is already happening and the tourism sector is on the front-line of stresses from existing climate variability and extreme weather events, particularly in the coastal environment;
- Early "soft" actions are likely to be least costly environmentally and financially;
- Many tourism investments (hotels, marinas, air and sea ports) are long term capital investments so that it is important to factor in projected changes in climate into new investments;
- Changes in the global travel industry are already forcing changes in the *modus operandi* of tourism enterprises towards various forms of adaptation.

[127] The tourism sector was not treated as a discrete sector in Antigua and Barbuda's Initial National Communication to the UNFCCC. Similar situation prevails for major tourism destinations such as Barbados and Jamaica.

Adaptation measures cannot proceed in a policy vacuum and need to be consistent with wider development goals and objectives. For Antigua and Barbuda's tourism sector the following goals and objectives are presented as representing the country's adaptive priorities in relation to global climate change[128]:

- Maintaining a viable tourism sector capable of making a substantial contribution to employment, foreign exchange, and sectoral linkages;
- Expansion of the three principal sub-sectors (hotel, guest house, cruise, and yacht) through improved facilities and services;
- Promoting efficiency in the sector so as to retain competitiveness at a time of global economic uncertainty;
- Ensuring environmental sustainability;
- Greater diversification of tourism product offerings towards less dependence on traditional seasonal attractions; and
- Increasing per capita tourist expenditure within the three principal sub-sectors.

The following sections will identify sectoral and cross-sectoral measures that should form critical elements of the tourism sectors adaptive response.

7.6.2. SECTORAL ADAPTATION REQUIREMENTS

Adaptation will involve efforts at reducing vulnerability since it is not possible to avoid the effects of climate change. The table below, adapted from the World Tourism Organization, provides some of the principal adaptations to existing changes in climatic conditions that are already being used by tourism stakeholders at various destinations globally and which are of relevance for climate change adaptation in the tourism sector in Antigua and Barbuda. These are not exclusive or comprehensive and focus primarily on enterprise level adaptation responses. In many instances adaptations in the sector, such as a switch to energy efficient lighting) are likely to be autonomous i.e. they will occur due to stakeholder awareness of the need for action without any external prompting.

The table below points to the critical roles that various stakeholders will be required to play in measures for enhancing the sectors resilience to climate change. Awareness raising and capacity building are important underlying themes in all of these adaptation responses.

[128] The adaptive priorities are also consistent with the aims of the draft CTO Regional Sustainable Tourism Framework which include national capacity for sustainability of the sector, strengthened marketing, and maintaining the integrity of the regions cultural and natural environment.

Table 7.5 Portfolio of Climate Adaptations Utilized by Tourism Stakeholders

	Tourism Operators (hotels, restaurants, attractions)	**Tourism Sector Associations**	**Communities and Government**	**Financial Sector**
Technical	Rainwater collection and management. Hurricane resistant building design and structure.	Early warning systems. Development of web-sites for dissemination of information relevant to climate adaptation.	Management of surface and ground water resources. Support for desalinization technologies.	Require advanced building design and materials. Provide information to customers.
Managerial	Water conservation planning. Low season closures. Product and market diversification. Regional diversification in business operations. Redirecting clients to other destinations.	Training programmes on sustainable tourism and climate adaptation. Encourage "green" programmes/ competitions etc. Use of short term seasonal forecasts for planning (e.g. drought information).	Development and implementation of impact management plans (e.g. for beaches). Event interruption insurance. Business subsidies and supports e.g. insurance and energy.	Adjust premiums. Restriction of lending and insurance cover to high risk operations.
Policy	Hurricane interruption guarantees. Compliance with environmental regulatory requirements	Lobbying for adaptation mainstreaming. Accessing funds for adaptation projects.	Coastal management plans and set-backs. Regulation of building design standards.	Consideration of climate change concerns in credit risk and project finance assessments.

	and best practices.			
Education and Awareness	Water conservation education for employees and guests. Energy awareness and conservation programmes.	Public education campaigns relating to water, electricity conservation practices and incentives, and on environmental management.	Water and energy conservation awareness and management programmes including through pricing mechanisms.	Educate and inform customers on climate adaptation measures.
Behavioural	Water and energy conservation and management programmes. GHG emission offset programmes.	Water and energy conservation measures. GHG offset programmes.	Extreme event recovery marketing.	Adoption of industry best practices for assessing credit risk and physical vulnerability.

Adapted from WTO Climate Change and Tourism

In the Antigua and Barbuda context certain institutions can be seen as emerging from the table as critical players for advancing the goals of climate adaptation. At the government level these include the Ministry of Tourism, the Environment Division, the Development Control Authority, and the National Office of Disaster Services. At the private sector level, the Antigua Hotel and Tourism Association, acting in cooperation with other specialized groups such as tour representatives, taxi drivers, and other groups will be required to play a leadership and coordinating role.

Given the pervasive significance of climate change to the tourism sector, it is recommended as a first step towards adaptation that a climate change sub-committee of the AHTA be established charged specifically with a mandate for promoting sectoral understanding of, and adaptation to, climate change. This should be a cooperative venture to be implemented with technical support from the Ministry of Tourism and Environment. The aim in this initiative is to provide a proactive response for assessing the significance of ongoing changes in climate affecting the sector, to support capacity for responding to climate change, and to

Box 7.1 Draft Terms of Reference for
AHTA Climate Change Sub-Committee

The World Tourism Organization recognizes the Caribbean as a tourism hot-spot, likley to be negatively affected by global climate change. A changing climate can be expected to have adverse consequences for tourism development in Antigua and Barbuda. AHTA members recognize the need to have a better understanding of this process so as to allow them to adapt their operations to changing climatic conditions.

The AHTA Climate Change Subcommittee will:

1. *Identify adverse impacts of currently changing climate, and of anticipated future changes, on AHTA affilaited tourism entities and facilities in Antigua and Barbuda;*
2. *Make recommendations to the AHTA on specific actions that can be taken to encourage AHTA members to reduce their vulnerability to the negative effects of climate change;*
3. *Work with other stakeholders in public and private sectors to promote inter-sectoral response to climate change impacts affecting tourism in antigua and barbuda; and*
4. *Recommend and develop climate change miigation and adaptation projects for funding.*

The Sub-Committee will present bi-annual reports to the AHTA.
Membership of the Sub-committee will comprise three persosn selected by the AHTA executive with technical support from the Environment Division and the National Office of Disaster Services.

make recommendations for adaptation at various levels. Possible terms of reference for the committee are provided in Box 6.1 below.

5.6.1

7.6.3. PRIORITY CROSS-SECTORAL POLICIES AND MEASURES FOR ADAPTATION

In addition to tourism sector specific requirements, certain overarching policy initiatives will also be required if the tourism sector is to meet the multiple challenges associated with global climate change. These are strengthened land use planning, improved management of coastal areas, diversification of tourism product offerings, and enhancing energy efficiency in the tourism sector. These are outlined below.

7.6.3.1. Strengthened Land Use Planning

Land use planning in Antigua and Barbuda remains disjointed and lacking in a focus on sustainable development requirements. This is particularly unfortunate for the tourism sector which requires planning and control of the physical assets that constitute elements of the overall national tourism attraction. The result has been a myriad of environmental problems which affect the tourism sector such as reduced aesthetic quality of the destination, urban sprawl, inadequate drainage, alienation of agricultural lands, and loss of valuable wetland areas.

Significantly despite its long-standing position as a tourism dependent country, there has not been a Physical Master Plan for tourism sector development in Antigua and Barbuda. Additionally despite technical assistance in preparation of a draft national Physical Development Plan, no coordinated physical development plan for tourism yet exists to promote and protect tourism interests. One result of this has been user conflicts and inappropriate development in tourism areas such as McKinnons and Jolly Beach. As noted in other chapters of this assessment, the absence of a strong physical development planning framework is also a serious concern for non-climate change related developments in sectors such as health, agriculture, and human settlements.

Many of the impacts noted as likely to result from climate change have clear linkages to the development planning and approval process. This is particularly so for beach set-backs and for building standards – principal adaptation responses for coastal erosion/sea-level rise and for hurricane preparedness.

- Barriers to strengthening of land use planning mechanisms and agencies for responding to climate change include:

- Absence of methods for integrating climate change concerns into development control;
- Limited technical capacity of the Development Control Authority;
- Political indifference to development planning and control; and
- Lack of mechanisms for incorporating climate change concerns into existing development control functions.

The following activities are recommended:

- Preparation of a National Physical Development Plan for Antigua and Barbuda. This should incorporate concerns and methods relevant to climate change.
- Strengthening of the Development Control Authority strengthened regulatory authority, greater use of information technologies, enhanced technical capacity, and preparation of an appropriate facility for the agency.
- A review of physical planning laws and regulations to incorporate climate change adaptation and mitigation concerns.
- In the case of Barbuda, as recommended in the Draft Tourism Master Plan, the establishment of a system of Parks and Protected Areas. This would allow optimization of use of heritage resources for environmentally sensitive tourism that builds resilience to climate change impacts through enhanced natural resource management.

7.6.3.2. Improved Management of Coastal Areas

Antigua and Barbuda's reputation as primarily a "beach destination" where the principal emphasis is on beach related activities and attractions, means that efforts must be focused on protecting the country's beach resources. Antigua and Barbuda's small beaches and the existing pressures from human and natural stresses highlight the need for effective management of coastal areas.

A critical need is therefore for development and implementation of an integrated coastal zone management framework that incorporates climate change concerns into the development planning process and which recognizes the need for protection of beaches and other coastal features as a central element of the tourism enhancement process.

In addition to the lack of an overall sustainable physical planning framework, as noted above, other factors also serve to impede effective management of coastal resources. This includes the multiplicity of agencies involved in management of the coastal environment and the lack of a documented national coastal area Management Plan able to reconcile and integrate disparate stakeholder interests including tourism. A particular concern relates to the problem of set-backs for buildings in coastal areas.

The following recommendations for strengthening coastal area management are proposed as measures for enhancing the capability of the tourism sector to reduce vulnerability of the sector to some of the anticipated impacts of climate change:

- Implementation of set-backs for buildings in coastal areas. These set-backs should be developed on a site specific basis using established tools for assessing the extent of the set-back and incorporating available information on sea-level rise and climate change.
- Establishment and management of marine reserves and protected areas for important critical habitats, as well as protection of existing popular tourism sites from unsustainable practices and degradation. Programmes in this regard have already begun at some sites including Jabberwock Beach and Ffryes Bay. As an immediate priority attention should be paid to the north-west coastal area in view of its importance as a tourism area and the extent of existing stresses already being experienced.
- Continuation and expansion of beach monitoring programmes so as to assess the extent of beach loss and to assist in identifying possible protection responses. Emphasis should be given to beaches where tourism facilities are already sited and/or planned. This should be conducted with a view towards development and implementation of a beach assessment, enhancement, and management programme for selected priority beaches and coastal areas.

7.6.3.3. Tourism Product Diversification

Antigua and Barbuda, like most other Caribbean destinations remains primarily a natural area destination i.e. the principal attractions are based on features associated with the natural environment – beaches, tropical maritime temperatures, and tropical foliage.

The stresses on the natural environment likely to arise from warmer temperatures, intensified hurricane and tropical storm activity, and enhanced sea-level rise will cause significant alterations to existing natural features. Among the likely impacts will be the disappearance of many beaches due to sea-level rise and greater coastal erosion, as has already happened at the northern section of Runaway Bay; heat/moisture stress from rainfall variability and warmer temperatures further adversely affecting the aesthetics of hill-side vistas as well as forested areas in the south of the islands used as rainforest tours; while storm activity and warmer seas will negatively impact coral reefs that constitute the main attraction for the small dive sub-sector and yachting day-tours, as well as providing the basis for the country's beaches.

Impacts of this type mean that the principal tourism attractions of Antigua and Barbuda will be threatened by climate change. Alongside measures to reduce vulnerability to climate risks, there is therefore the need to diversify away from these traditional attractions towards a broader range of man-made attractions that are less dependent on climate. The initiative towards a more diversified tourism product offering is already ongoing as reflected in on-going promotion of cultural, heritage, entertainment, literary, educational, gaming, shopping and other niche segments of the tourism market. Attention will now need to include possible consequences associated with a changing climate and seek to develop "climate resistant" attractions that highlight cultural, sporting and other activities less directly related to traditional natural resource based attractions.

Such product diversification will be required at enterprise level as well as at the macro policy level. This means that hotels and restaurants may need to increase entertainment offerings, construct swimming pools, and provide other services and features (e.g. spas) that are less dependent on "outside" weather conditions and variables. Policy level interventions at the macro level will be required to support product diversification. This will include continued government support for events such as carnival and the recent Romantic Rhythms music festival, advancing duty-free shopping for tourists, and generally providing an enabling framework for development of non-traditional attractions.

This matter should also form a part of the consultative mandate of the joint AHTA/government climate change sub-committee noted above.

7.6.3.4. Energy Efficiency

Existing adaptations in the tourism sector to heat related stresses are use of fans and air conditioning as well as design and use of open air spaces that allow for natural ventilation and cooling. Both approaches are successful and are generally used in combination. While all properties seek to maintain their guests in comfort, air conditioning already represents an important, and rapidly escalating, cost for tourism properties.

Warmer temperatures as forecast in IPCC and other projections will intensify the need for cooling technologies. A principal factor will be costs. The principal adjustments here will be to find mechanisms for cooling at the most economic rates. Apart from costs associated with cooling, high and rising fuel and electricity costs, mean that tourism facilities, particularly within the accommodations sub-sector will need to find mechanisms for reducing energy costs if they are to remain competitive with other Caribbean and global destinations.

Hotels and other large energy users within the tourism sector will need to be given the fullest possible scope for reducing energy costs. Public policy interventions are required to remove obstacles to efficiency. At present hotels are constrained in choice of electricity supply by the public monopoly of the Antigua Public Utilities Authority although some properties do have authorization for self-generation. Alternatives for energy generation such as solar remain costly, invariably require back-up conventional power sources, and have only limited access to technical capabilities for servicing and maintenance.

The Draft Tourism Master Plan estimates a growth of approximately 3% annually in tourism demand for electricity. This is based solely on projected growth in the sector and does not factor in any non-linear increases that may arise from warmer temperatures as a result of climate change. High energy costs could effectively cripple the viability of the tourism industry. The Plan also notes proposals by APUA for a decentralized system of power generation as well as general plans for electricity generation expansion to meet future demand including in the tourism sector.

In addition to price, a critical issue for the tourism sector is reliability of energy services. This is particularly of interest in a context of increased hurricane/tropical storm activity and the need to provide reliable sources of emergency energy and other services to guests.

Two major strategies for adaptation to climate change can be identified:

- Improving energy efficiency and reducing energy use; and
- Increased use of renewable energy technologies.

The following recommendations are made in relation to "adaptations" in energy use in the tourism sector as a response to climate change:

- Establishment of an energy audit programme for tourism facilities. While larger hotels generally have systematic engineering programmes and capacities for addressing energy efficiency objectives, this is not so for many smaller properties and establishments. A collaborative programme should be developed through AHTA and APUA utilizing technical personnel from both agencies to conduct energy audits on a continuous basis in AHTA members. The aim would be to identify opportunities for reducing consumption and increasing efficiency on a cost effective basis and identifying opportunities for joint purchase, training, and other forms of collaboration on energy efficiency among AHTA member companies and entities.

- Preparation and implementation of a project proposal for assessing renewable energy options within the tourism sector. The aim would be to identify cost effective renewable energy technologies that could be used in the tourism sector. Financing should be sought from regional and/or international agencies including the GEF.

- Agreement by AHTA to move within a specified time frame to adoption of an internationally recognized set of environmental standards. Examples of these standards are the ISO14001 standard and Green Globe 21 (used by Dominica). These standards assist in identifying, monitoring and reducing environmental impacts. Importantly, the standards also serve as marketing tools, identifying the destination as having certain “green” credentials, which enables advertising and commercial networking with other certified service providers in the tourism and otherwise.

7.6.3.5. Insurance Initiatives

Within the tourism industry, insurance constitutes a principal instrument in reducing the negative economic impacts of hurricanes and other natural disasters. Adequate coverage allows individual property owners to recover losses from damaged buildings, furnishings and loss of business. While it is reported that some coastal properties are unable to obtain insurance cover because of the risks involved, insurance remains a principal adaptive response for all stakeholders within the hotel and tourism sector in Antigua and Barbuda.

Although insurance claims for the tourism industry in Antigua and Barbuda during the active 1995-1999 hurricane seasons are not available, settlement of insurance claims clearly represented a major source of financing for reconstruction after Hurricane Luis and subsequent storms. Insurance flows also had a positive effect on macro-economic activity and have been critical to the process of economic recovery and reconstruction after hurricanes. Without adequate insurance, hotels would take considerably more time to complete hurricane related repairs and an even longer time to return to normal operations. Without insurance, for any extended period of damages and losses from hurricane and disaster insurance, most hotels would likely be forced out of business.

Nevertheless it is recognized that climate change will have adverse impacts on insurance availability and affordability, potentially slowing the growth of the industry and shifting more of the burden to governments and individuals. It is also recognized that there is a declining ability of the global insurance industry to absorb weather related natural disasters[129]. The effects of these developments for the tourism sector are:

- Reductions in the availability of insurance as a result of high premiums costs;
- Under-insurance of properties resulting from high premiums and deductibles; and
- Removal of insurance coverage from high risk tourism properties especially in coastal areas.

In Antigua and Barbuda insurance companies depend on regional and international insurance and re-insurance companies for settlement of their financial obligations in the event of claims. This makes the sector totally dependent on financial and reinsurance markets outside of the control of policy makers in Antigua and Barbuda.

In addition to their role in providing financial resources for damages resulting from hurricanes and other natural disasters, insurance companies also facilitate adaptation through policies that provide financial incentives in the form of lower premiums where certain structural adaptations (e.g. hurricane shutters) are adopted by policy holders.

An innovative measure for insurance within the public sector has been the establishment of the Caribbean Catastrophe Risk Insurance Facility (CCRIF), a venture involving a tripartite mixture of private sector insurance companies, The World Bank and other international development agencies, and CARICOM governments. The facility, the first of its type anywhere in the world, is presently directed towards support for government risks in relation to earthquakes and hurricanes.

The central role of tourism to the Antigua and Barbuda economy, and the critical function that insurance plays in facilitating recovery of the sector to climate related

[129] See "Insurance in a climate of change". Evan Mills et al. In Science 309, 1040 (2005). Available at http://ncsp.va-network.org/UserFiles/File/PDFs/Resource%20Center/Adaptation/Insurance_in_Climate_Change.pdf

stresses that are likely to intensify with global climate change, requires that policies and measures be sought for ensuring that insurance can continue to play a major role in the sectors development. Obviously there can be no simple Antigua and Barbuda, or even Caribbean, response to what is a complex global issue. In that context the following recommendations can be seen as initial adaptation actions for strengthening the instrumentality of insurance as a climate change adaptation tool:

- Initiating discussions through the AHTA and the Caribbean Tourism Organization (CTO) with national, regional and international insurance companies for extending and strengthening insurance coverage for tourism properties in Antigua and Barbuda and the region. The CCRIF provides a possible model for such collaborative efforts; and
- Government collaboration with the CCRIF to ensure that critical tourism infrastructure is adequately covered by insurance. This should include air and sea ports, hospital facilities, and electricity and telecommunications infrastructure.

Given the scale of the issue, as far as possible a coordinated CARICOM or even CTO response to insurance will be the most practical approach, so that efforts should be pursued in this regards by the AHTA and by government.

7.7. CONCLUSION

The tourism industry has dominated the economy of Antigua and Barbuda since the 1960s. The growth of the sector has been based largely on the country's natural environment especially its beaches and favorable tropical climate. The sector is already vulnerable to a number of weather and climate related stresses particularly drought, coastal erosion and tropical storms and hurricanes and these vulnerabilities and risks will increase with global climate change. Projections for global climate change will exacerbate existing stresses within an industry already facing unprecedented challenges.

Development and implementation of adaptation measures to address these impacts will require leadership by those actors and agencies with the stakeholder interests and technical capacity for responding to the challenges presented to the sector by climate change. Many of the measures required for risk reduction, such as coastal setbacks will involve changes to current operational practices. Stakeholder and public awareness of the necessity of such measures is therefore critical. Establishment of a focused stakeholder group, mandated to advise the industry on a continuing basis on climate change adaptation and to advise on policies and measures relating to climate change will therefore be an important element for empowering adaptation in this extremely vulnerable sector.

The focus of Antigua and Barbuda's tourism on its beaches and the existing stresses to which these resources are already subjected, suggests that a focused programme for coastal area management especially beach assessment, restoration/enhancement and management is required. In most instances adaptation priorities for climate change, such as product diversification and improving energy efficiency, represent important non-climate change priorities already being advanced in order to ensure the continued development of the industry. The need now exists to incorporate climate change concerns into the policy development and implementation processes of these initiatives.

While uncertainties exist, and will continue to exist, as to the specifics of future climate change, there is an urgent need for adaptation within the tourism sector. This includes the need for individual tourism enterprises to adopt practices that will reduce their vulnerability to climate change risks, as well as macro-level interventions and policies that will create the enabling framework for enabling Antigua and Barbuda's tourism industry to face the considerable challenges that confront it from global climate change.

CHAPTER 8

HUMAN SETTLEMENT

CHAPTER 8: HUMAN SETTLEMENTS

8.1. INTRODUCTION

8.1.1. Background

Human settlements can be defined as units that provide the living and working environment for people. This includes a wide range of settlement types ranging from camps and villages to modern mega-cities as well as the supporting infrastructure that support centres of human population and industry. Despite these differences, whatever their physical size, human settlements face a number of challenges to their sustainability. These include the delivery of adequate health and other social services, provision of adequate infrastructure, coping with existing natural disasters, and the maintenance of law and order.

Climate change can therefore be expected to affect human settlements against the dynamic background of a multiplicity of socio-economic and environmental pressures. While human settlements, as built environments, are generally regarded as better able to adapt to changes in climate than natural or biological systems[130], human settlements also represent an integration of vulnerabilities from other sectors – health, water resources, coastal zone, agriculture – so that vulnerability levels are exacerbated by the cross sectoral nature of the stresses that they face. In general, urban centres are vulnerable to a number of climate related risks emanating from outside of the urban environment which have significant implications for human settlements.

The IPCC points out that human settlements are likely to be affected directly by climate change impacts on human health and public infrastructure, and indirectly through impacts on the physical environment, natural resources and industries such as agriculture and tourism. The risks are likely to be heightened for a number of high risk communities and groups particularly low income groups and the elderly. In many instances the situation is likely to be exacerbated by the physical conditions

[130] See Wilbanks et al. 2007; Industry, Settlement, and Society. Climate Change 2007.Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani,, J.P. Palitukof, PJ Van der Linden, and C.E. Hansen Eds., Cambridge University Press, Cambridge, UK, 357-390.

under which low income communities are to be found such as in low-lying coastal areas and densely settled areas lacking in adequate health and community services[131].

8.1.2. Methodology

The approach adopted in this chapter for analyzing the likely effects of climate change impacts on human settlements in Antigua and Barbuda involves an outline of existing patterns of human settlement, indicating the existing stresses and difficulties facing these areas that are likely to be relevant to climate change, as well as the institutional processes for human settlement development. This is followed by an indication of possible future socio-economic and climatic scenarios for Antigua and Barbuda. An assessment of some of the principal impacts of climate change likely to affect Antigua and Barbuda is then provided and this is followed by an overview of risk reduction and adaptation measures that can be utilized to minimize the principal adverse impacts of climate change.

The assessment incorporates the approach of the United Nations Development Programme (UNDP) Adaptation Policy Framework (APF) that seeks to identify and respond to existing climate related stresses that are likely to be exacerbated by climate change[132].

It is important to recognize that uncertainty forms a critical element of any climate change assessment. In relation to human settlements this uncertainty arises from a number of climatic and non-climatic factors including:

- Uncertainty as to the extent and timing of climate change.
- Uncertainty as to what future public policy and other initiatives may do to affect the extent of climate impacts on the country's natural environment as well as on human settlements.

In that context it is important to recognize that the assessment does not represent a prediction of future climate impacts and the possible adaptations that might arise, but is rather intended as a guide for identifying some of the principal risks and vulnerabilities based on existing knowledge. As with other chapters, and consistent with the use of the UNDP Adaptation Policy Framework approach utilized in this

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[131] See IPCC at 1 above.
[132] See Chapter 1, Section 1.2 above.

assessment, emphasis is on identifying present risks and vulnerabilities as well as on short to medium term adaptation responses.

This recognizes the inherent uncertainties noted above, as well as the importance of addressing existing sustainable development concerns in the sector as an initial response for responding to the type of projections identified by the PRECIS and IPCC projections for future climate change. With its focus on recent climate experience, the UNDP APF approach also seeks to coordinate climate change risk reduction and adaptation with current development policies, priorities and commitments and to integrate adaptation across sectors.

It should also be noted that much of the research on the impacts of climate and climate change on human settlements has focused on large cities in developed and developing countries, and on rural communities in developing countries. This makes the task of assessing impacts on human settlements in small island communities such as Antigua and Barbuda more challenging given the paucity of reference material[133].

8.2. OVERVIEW OF EXISTING HUMAN SETTLEMENTS

8.2.1. Characteristics of Human Settlements

The distribution pattern of human settlements on Antigua and Barbuda reflects both the topographical and physical structure of the land as well as its socio-economic history and circumstances. The islands generally flat topography has facilitated transportation and communications as well as the establishment of industry and housing across the country. Centuries ago, these topographic features enabled the spread of plantation agriculture across Antigua with accompanying settlements serving these sites. The collapse of the agricultural industrycoupled with the development of the tourism sector, based around the islands beaches, has also contributed towards the dispersed nature of the country's settlement patterns.

The result has been a pattern of human settlements that encompasses virtually all areas of Antigua with a major concentration of population and economic activity in St Johns parish. Other principal concentrations are found in the middle of the island

[133] See "UNFCCC Compendium on Methods and Tools to Evaluate Impacts of Vulnerability and Adaptation to Climate Change". At http://unfccc.int/adaptation/nairobi_workprogramme/compendium_on_methods_tools/items/2674.php

in the AllSaints/McPond/Liberta area, the south of the island at English Harbour/Falmouth; and at Bolans/Jolly Harbour in the south-west.

Barbuda represents a special situation in regard to the pattern of human settlements, with a lone principal settlement at Codrington. This unique pattern of spatial development reflects the island's historical experience and cultural mores.

The 2001 Population Census reveals that out of an official population of approximately 79,000 persons, more than 50% of the population resided in St Johns parish, with St Pauls being the next most populous parish and Barbuda the least populous. Population density for St Johns parish was almost 1600 persons per square mile compared to an average of 700 for Antigua and 21 for Barbuda. For urban areas in St Johns, density is likely to exceed 2,000 persons per square mile. A poverty assessment report commissioned by the Caribbean Development Bank and the Government of Antigua and Barbuda notes that "in some of the low income districts, there is severe overcrowding and densification, with three dwellings being constructed on one lot"[134]. Areas described as overcrowded include urban communities in Clare Hall, Point, Potters, and Green Bay.

As in other small island countries, in Antigua and Barbuda a high proportion of the population resides in coastal communities. Coastal areas are generally more vulnerable to hurricane and storm action including storm surge. At the same time, population pressures and tourism based developments have resulted in significant adverse impacts on coastal resources. These include coastal erosion, sand mining, removal of mangroves, and improper waste disposal with impacts resulting in loss and deterioration of coastal and marine resources for recreational, tourism as well as impacting the ability of these resources to perform critical environmental functions. Expansion of housing, tourism facilities, and commercial properties has also taken place onto hillside areas resulting in soil erosion and blocking of watercourses: the latter occurrence has become increasingly common and is regarded as contributing greatly to flooding events during the 2008 hurricane season.

Roads service virtually all areas of Antigua. Traffic congestion poses an ever increasing problem. In Barbuda, a road network links Codrington with some of the principal island locations such as the port, hotels and the scenic Two Foot Bay.

[134] Living Conditions In Antigua; Poverty in a Services Economy in Transition. Vol I Main Report. KairiConcultants. Caribbean Development Bank. Government of Antigua and Barbuda. August 2007. Page 126.

Other important infrastructural assets include an international airport, the VC Bird International Airport in the north of the island, two airstrips in Barbuda, seaports including a commercial deep water port in St Johns, cruise ship berths in St Johns and English Harbour, and ports of entry for yachts at Jolly Harbour and English Harbour. With the exception of a few areas, public utilities of water, electricity, and modern telecommunications services also reach virtually all settlements in Antigua and Barbuda.

There is a clear trend towards urbanization as residential and commercial activity from St Johns has spread into adjacent communities. There is generally little difference in public services and amenities between rural and urban communities, particularly as telecommunications and improved road access enhance linkages between traditional rural communities and the outside world. Other factors contributing to the merger of rural and urban communities include the demise of the agricultural sector and the spread of tourism activity into rural areas. Commercial activity while still predominantly concentrated in St. Johns also extends to other areas particularly around major settlements. As with residential buildings, commercial and industrial properties consist primarily of concrete structures. High rise buildings are not a major feature of either residential or commercial buildings with most buildings being of either single or two floors.

Data from the 2007 Caribbean Development Bank (CDB)/Government of Antigua and Barbuda Poverty Assessment report indicates that approximately 61% of the population owned their own dwelling with or without mortgage, and with 48% of the population claiming full ownership. 93% of households lived in undivided private houses although there is an increasing tendency among all income groups toward apartment style housing: St Johns parish saw the greatest proportion of households occupying apartment type dwellings. Approximately 97% of roofing consisted of galvanize sheeting while approximately 50% of housing consisted of concrete blocks followed by 41% of wood and timber materials. The report points out that access to pipe borne water into dwellings improved with socio-economic status. Overall 89.3% of the population had access to piped public water either in their home or through a public standpipe. Approximately 13% of the population depended on public standpipes for their water supply.

Management of solid and liquid wastes presents various challenges to the health conditions within human settlements in Antigua and Barbuda. Antigua and Barbuda does not have a central sewerage system. The 2007 CDB report indicates s that most households (72.9%) possessed WC linked to septic tank soak-way systems, while approximately 21% of households relied on pit latrines or ventilated pit latrines.

Existing climate related adaptations for human settlements include storage of water for drought conditions, with most buildings having provision for collection of rainwater. The other principal adaptations are in relation to measures adopted for protection of life and property against hurricane and storm damage, primarily from wind damage. This includes storm shutters, use of hip and multiple roofs, steep roof gradients, and hurricane clips. Notwithstanding these adaptations and vigorous efforts to promote awareness of these concerns, human settlements in Antigua and Barbuda remain vulnerable to hurricanes and droughts particularly among low income groups.

8.2.2. Institutional Arrangements for Human Settlements

The effects of rapid tourism and commercial development and a largely unplanned process of urbanization point to the urgent need for improving land use planning and development control. Development control is the responsibility of the Development Control Authority (DCA) established under the Land Development Control Act of 1977. The DCA is a regulatory body with limited capability to effectively enforce its responsibilities. Penalties for contravening the law are generally weak and staffing deficiencies prevent effective surveillance and enforcement.

Among the other agencies directly involved in management of human settlements are the Central Housing and Planning Authority, the Ministry of Agriculture, the Central Board of Health, the National Solid Waste Management Corporation, the National Parks Authority, and the St Johns Development Corporation. At the private sector level important agencies impacting on human settlements are private developers as well as banks and insurance companies.

Among the principal difficulties facing planning and management of human settlements in Antigua and Barbuda are:

- A weak legislative and regulatory framework that inhibits effective enforcement;
- Limited technical and administrative capabilities that restrict the capacity for forward planning, project development, and monitoring;
- A traditionally *laissez faire* approach to housing and settlement development that informs policy and public perceptions of physical development;
- Inadequate public awareness of the importance of physical planning controls to sustainable development;
- Limited coordination at inter-agency levels; and
- Unavailability of data and information for guiding physical development.

Hazard maps have been prepared for Antigua and Barbuda covering drought, hurricane, flooding, and storm surge. The hurricane related maps for storm surge, wind and waves are the most heavily used maps including by the National Office of Disaster Services (NODS), Antigua Public Utilities Authority (APUA), banks, insurance companies, Ministry of Health, Police, and the Public Works department. The maps also provide data for conducting environmental impact assessments. Their primary uses are to identify vulnerable locations and to provide information for warnings for hurricanes. Primary users of the drought maps are the Ministry of Agriculture, APUA, and the Meteorological Office. The flood hazard map is also used by the DCA and the Environment Division.

The focal point for disaster management at the government level in Antigua and Barbuda is the National Office of Disaster Services (NODS). A National Disaster Plan provides a framework for the activities, not only of NODS, but also of other sectors of government as well as the private sector, and offers guidance on disaster preparedness and response.

8.2.3. Existing Vulnerabilities

A 1997 assessment report prepared on behalf of the Government of Antigua and Barbuda with support from the United Nations Environment Programme (UNEP) and the Global Environment Facility (GEF) notes that two primary factors influencing the vulnerability of human settlements in Antigua and Barbuda are location and design[135]. Using various physiographic indices of vulnerability such as location in a flood plain or watershed, exposure to storm surge, and rainfall deficiency, the assessment points out that inland settlements have a lower vulnerability than coastal areas or flood-plain oriented settlements. At the same time some inland settlements are susceptible to strong winds particularly during hurricanes or storms.

The 1997 assessment report indicates that about 70% of major settlements occur within watershed areas. This makes them prone to flooding from heavy rainfall events including from hurricanes and other tropical systems. In relation to coastal vulnerability, most of the coastal settlements are sited upon flood-plains that drain to the sea. The assessment identifies settlements located within costal areas as well

[135] Angela Braithwaite, Ernest Benjamin, Jaceey Sebastian, Kevin Edwards. Ministry of Planning, Government of Antigua and Barbuda/United Nations Environment Programme. Climate Change Impacts and Adaptation: Human Settlements and Tourism Sectors.". November 1997.

as those in floodplains as those that are most vulnerable to existing climate related stresses and indicates that it was these areas that were most affected by the hurricanes and storms of the 1995 hurricane season. In that year coastal infrastructure and resources suffered major damage in the more exposed areas such as along the southern coast and at Dickenson Bay/Runway Bay/Fort James. The assessment notes that "there is also a relationship between wind damage and micro-locational factors such as site elevation and slope exposure. Some of the extreme wind damage that was seen in the aftermath of Hurricane Luis can only be explained by wind acceleration caused by local topography".

Human settlements vulnerability in Antigua and Barbuda is conditioned by the physical exposure of buildings and infrastructure to storm and hurricane hazards. In terms of hurricane hazard, the location of some hotels and other tourism properties and other infrastructure, particularly in beach front locations, increases the vulnerability of the tourism sector, and therefore the island's economy as a whole, to the adverse impacts arising from current climatic conditions.

Squatter settlements, primarily consisting of migrant workers and families from neighbouring islands, have been established in some areas, principally in low lying reclaimed land at Green Bay. These communities are particularly at risk to flooding and storm surge.

The design factor or development standard consists of the increase in vulnerability caused by the application of inappropriate standards, building shortcuts in residential construction, improper grading of road cuts, and use of design parameters inconsistent with hazard susceptibility of the site. While the traditional Caribbean house proved to be highly resistant to hurricanes, the gradual adoption of new building styles and structural systems, may have significantly increased vulnerability to hurricanes in recent decades. Additionally in many low income communities such as Green Bay and Grays Farm, houses often do not have proper foundations and are poorly constructed, greatly increasing their vulnerability to hurricanes and flooding.

The 2001 Census indicates that 14% of housing stock was constructed prior to 1970 and 17% of the building stock as having been built since 1995. This is significant since the impacts from Hurricane Luis and other storms that year resulted in a shift towards greater hurricane resistance in building design and materials.

The capacity to absorb the impact of a climate related hazard is however also related to social factors, such as health and educational levels, the existence of community organisation and other family, community and religious group support systems, as well as the existence of social services provided by government. Although compared to other countries in Latin America and the Caribbean, Antigua and Barbuda has traditionally had high social development indicators there are a number of high risk and vulnerable communities.

In Antigua and Barbuda, environmental degradation in terrestrial and coastal environments has resulted in increased hazard levels. While hurricanes droughts and floods are natural phenomena, hazards are also conditioned by human activity. For example, groundwater extraction in watersheds may intensify drought impacts. Similarly the destruction of mangroves and natural coastal defences is likely to increase hurricane hazard. The destruction of mangrove ecosystems in areas such as Jolly Beach, the McKinnons Salt Pond, and at Deep Bay; erosion caused by infrastructure development and building on hillsides ; beach sand mining; and uncontrolled sewerage disposal are examples of environmental degradation, which have increased the risks associated with climatic hazards such as hurricanes and droughts, as well as for seismic and other hazards facing the country (Caribbean Conservation Association, 1991).

8.3. SOCIO-ECONOMIC AND CLIMATE CHANGE SCENARIOS

8.3.1. Introduction

The intention of this section is to identify some of the future scenarios for human settlements. This involves both climatic and non-climatic scenarios. Prospects for future sustainable development of human settlements in Antigua and Barbuda will be determined by a combination of non-climatic and climatic factors. It is quite possible that non climatic factors could be equally, if not more significant, than climatic factors in determining development pathways for human settlements. Important uncertainties exist in this regard. The critical concern therefore is the need to recognize and begin to identify some of the other factors that may also be occurring at the same time as human induced changes in climate. These factors can be expected to influence the extent of the impacts as well as the type of adaptation and risk reduction responses that are required or even possible.

Possible scenarios for non climate issues and concerns are identified looking at existing trends and official plans and programmes. Climate scenarios presented includes those that have been developed utilizing the regional climate model

(PRECIS) as well as information for future climate scenarios for the Caribbean from the IPCC.

8.3.2. Non-Climate Scenarios

A number of factors can be expected to affect human settlements development in Antigua and Barbuda. These include:

- Population growth
- Migration patterns
- Economic performance

Some of these will be outside of the direct influence of policy makers in Antigua and Barbuda. For example poverty levels will be influenced by global economic conditions, and will themselves influence issues like the extent of rural – urban drift. International economic conditions will also impact the nature and extent of return migration to Antigua and Barbuda and the amount of emigration out of the country.

Antigua and Barbuda's topographic conditions mean that settlements are physically possible in most locations. In the case of Barbuda, legal principles enforce a restriction on private ownership of land and have to date focused settlement in and around Codrington village. Existing plans envisage extension of settlements outside of Codrington in response to population growth and economic development.

For Antigua demands for lands for housing, agriculture, tourism development, commercial space and other uses are likely to continue. To date a physical development plan has not been developed for Antigua and Barbuda although this process now appears to be underway. Existing land use and settlement plans are perceived as favoring tourism and residential development while agricultural lands and environmentally sensitive areas have reduced in size. Trends towards continuedurbanization of settlement characteristics can be expected to continue as agriculture remains limited and as urbanized settlements expand into rural areas. This is likely to meangreater pressures on limitedavailablelands. Existing trends towards concentrations in urban communities around St Johns, development of apartment style buildings, and existence of enclaves of non-nationals in low income communities can be expected to continue, at least in the short term, for as long as there is no national plan for physical development.

Government policy towards decentralization of various social services can also be expected to result in greater spread of communities into rural areas.

However, the uncertainties inherent in forecasting future socio-economic activity is increased in the instance of human settlements which bring together factors from a multiplicity of economic sectors and geographic areas. Table 8.1 below provides a set of indicators for sustainable human settlements in Antigua and Barbuda. These represent targets for sustainable settlements and are among the factors that will be affected by a changing climate.

Table 8.1 Target Indicators for Human Settlements

Demographic indicators	• Sustainable population growth • Improvements in population health • Improved low income urban conditions
Economic indicators	• Sustainable economic growth • Development and maintenance of key economic infrastructure • Balanced role between public and private sectors.
Governance and policy indicators	• Equitable access to decision making and public facilities. • Transparency and legal process in decisions relating to human settlements.
Cultural indicators	• Protection of historic and cultural sites. • Opportunities for sporting, cultural, and educational purposes

8.3.3. Climate Change Scenarios[136]

All aspects of the changing regional climate can be expected to impact upon human settlements in Antigua and Barbuda. In relation to temperature, the global general circulation models (GCMs) project increases of up to 0.5°C by the 2015s, 0.8°C by the 2030's, 1.3°C by the 2050s and between 1°C and 3.5°C by the end of the century.

[136]Based primarily on information extracted from Chapter Two above.

The regional climate models also show a similar rate of increase with an annual temperature change of 2–2.5°C by the 2080s. This range of increase is consistent with IPCC projections for the Caribbean which indicate that annual mean temperatures will increase by 1.4°C to 3.2°C, with a median increase of 2.0°C, by 2100. The increase is however slightly less than the anticipated global average warming.

The GCMs are generally less consistent with regard to projections for future rainfall regimes for Antigua and Barbuda and the Caribbean. Through the 2030's the projected change in mean annual rainfall ranges from +15% to -20% dependent on modeland scenario. There is greater consensus in the sign of the trend from the 2050's through to the end of the century, with most models and scenarios indicating that Antigua and Barbuda will be drier in the mean.

IPCC projections for hurricane activity point towards an intensification in strength of tropical storms and hurricanes as a feature of a changing climate. Warmer ocean temperatures are also likely to fuel an increase in the number of storms[137]. The IPCC reports that there has been a marked increase in both intensity and frequency since the mid 1970s with this increase in the power of hurricanes reflecting warming sea surface temperatures. The maximum surface wind speed of the stronger tropical storms is likely to increase in both northern and southern hemispheres. This points toward an overall increase in the destructive potential of storms and hurricanes.

The Caribbean experienced an average rise in sea-level of 1mm/yr during the twentieth century although this varied greatly from location to location. The IPCC's AR4 report notes that climate models suggest that sea-level rise for the twenty-first century are likely to exceed rates experienced during the latter half of the twentieth century. Whereas it is not presently possible to project sea level rise for Antigua and Barbuda, changes in the Caribbean are expected to be near the global mean with an increase of up to 0.24 m by the middle of the twentieth century.

In summary the following can be projected for the future climate of Antigua and Barbuda:

- There is evidence to suggest that the climate of Antigua and Barbuda is changing. Both maximum and minimum temperatures have increased in the recent past.
- The warming trend is expected to continue. The country is projected to be warmer by up to 1.3°C by the 2050s, and between 1 and 3.5 degrees by the end of the century.

[137] See IPCC Third Asessment Report Vol. II. Chapter 16.Mimura and Nurse.

- Winter months will see marginally larger increases in temperature than summer months.
- The frequency of very hot days will increase, while very cool nights will decrease.
- There is a likelihood that the country will be drier (in the mean) by the end of the century.
- Climate change will likely make the dry periods early in the year and in June/July drier.
- The seasonality of Antigua and Barbuda will be largely unchanged. The cooler (with respect to late season temperatures) dry early months and wet hotter late months will still prevail.
- Hurricane intensity is likely to increase (as indicated by stronger peak winds and more rainfall) but not necessarily hurricane frequency.
- Caribbean sea levels are projected to rise by up to 0.24 m by mid century.
- Sea surface temperatures in the Caribbean are projected to warm, perhaps up to $2^{o}C$ by the end of the century.

8.4. IMPACTS OF CLIMATE CHANGE ON HUMAN SETTLEMENTS

8.4.1. Introduction

The projections of climatic and non-climatic scenarios outlined above will present important challenges for human settlements in Antigua and Barbuda. As noted above human settlements in many ways represent a combination of many of the sectoral vulnerabilities that exist, reflecting impacts from the coastal zone, health, freshwater, and other sectors. Because human settlements are also centres for socio-economic activity, various direct and indirect impacts can be expected. These indirect impacts will include impacts on economic resources and competitiveness, with possible impacts even in areas such as political processes and social structures.

Within the urban settlement setting there are also likely to be a number of vulnerable and high risk groups – the elderly, homeless people, persons with chronic diseases and/or disabilities etc – where poverty and the lack of an adequate social safety net enhances the risk factors from stresses associated with a changing climate.

As with other aspects of climate change science, uncertainty remains a major consideration in any assessment of impacts of climate change. At the current state of knowledge, vulnerabilities of human settlements are easier to identify than impacts because they estimate risks or opportunities rather than estimating consequences which requires more detailed information about future conditions.

The following section will look at certain specific parameters of climate change and some of the risks and vulnerabilities that can be expected. The climate parameters to be reviewed here are increased temperatures, sea-level rise, intensified tropical storms and hurricanes, and rainfall variability. While presented separately for analytical purposes, it is important to recognize that these changes in climatic conditions will not be manifested on the ground as separate events. This is perhaps seen most clearly in relation to hurricanes, which bring together into one event impacts relating to storm surge, wind damage, and rainfall (flooding and water damage). Indeed, Antigua and Barbuda's experience with hurricane impacts from Hurricane Luis, as well as the impact of storms and hurricanes since then, underline the country's vulnerability to projected climate change.

8.4.2. Hurricane and Tropical Storms

The important uncertainties that characterize climate change are apparent in the projections for hurricane activity in Antigua and Barbuda and the rest of the Caribbean. While there is a general view that the intensity or strength of hurricanes is likely to increase, driven by warmer oceanic conditions, there is less consensus as to whether there will also be an increase in the number of hurricanes and other tropical systems.

However there can be little doubt that Antigua and Barbuda are already vulnerable to the impacts of climate change. The country is geographically located in a region at risk to multiple types of natural hazards particularly hurricanes and earthquakes. Of these hazards hurricanes impact most dramatically on the natural environment as well as on human settlements. Over approximately the last half century Antigua and Barbuda has suffered from four major hurricanes. In addition, there have been many less significant storm events which nevertheless caused damage to the natural and built environments with attendant socio-economic disruption.

The historical record indicates that forty-five hurricanes have been documented as making direct strikes on Antigua and Barbuda between 1642 and 1997 amounting to approximately one hurricane every eight years. Particularly severe hurricanes are reported to have occurred in 1681, 1772, 1792, 1804, 1835, 1871 and 1950[138]. Recent major hurricanes to make direct strikes on Antigua include Hurricane Hugo in 1989 and Hurricane Luis in 1995.

During hurricanes and strong tropical storms, human settlements, in Antigua and Barbuda are subject to damage and destruction by wind force, storm surges, landslides and flooding. Public utilities such as overhead power lines, water and gas distribution lines, bridges, culverts and drainage systems are also subject to severe damage. Fallen trees, wind driven rain and flying debris can also cause considerable damage to human life and to property. High-rise buildings are particularly vulnerable to hurricane-force winds, particularly at the higher levels since wind speed tends to increase with height. Hurricanes also produce tornadoes that add to the storm's destructive power.

Hurricanes cause storm surges which affect the country's coastline. In 1995, storm surges of up to 14 feet were registered during Hurricane Luis[139].

In addition to direct strikes from storms and hurricanes, outer bands of rain and other elements of tropical systems cause damage and even loss of life due to flooding and high winds. Intense rainfall is not directly related to the wind speed of tropical cyclones. In fact, some of the greatest rainfall amounts occur from weaker storms that drift slowly or stall over an area. Historically, and throughout the Atlantic hurricane belt, more lives are lost to flooding caused by storm related rainfall than from any other source.

Threats to public health also emerge in the aftermath of hurricane events when conditions such as water contamination or shortages, flooding, and damage to sanitation facilities may favor the spread of disease. Disruptions to medical services resulting from damage to hospital and other medical facilities as well as electricity and communications disruptions also impact adversely on health services and care. In addition to health impacts, hurricanes and tropical storms can also adversely impact economic activity including through damage to public infrastructure and services – electricity, telecommunications, and road transport. Notably, the tourism industry, Antigua and Barbuda's principal economic sector, is vulnerable to hurricane activity resulting from damage to ports, hotels and other facilities, as well as by damage caused to beaches and other natural attractions.

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[138] Extracted from "Disaster Early Warning Systems in Antigua and Barbuda : An Assessment of Early Warning Systems in Antigua and Barbuda and an Action Plan for Enhancing Capabilities". German Agency for Technical Cooperation (GTZ). Andrew Maskrey – Consultant. 1997. This historical data is sketchy and may need to be checked and complemented with other sources.

[139] See Maskrey above at footnote 9.

The most significant hurricane to strike Antigua and Barbuda in recent time was Hurricane Luis in September 1995 which affected the twin island State over a continuous thirty-five hour period. Among the effects of Hurricane Luis were two deaths; over one hundred and fifty injuries; damage to 90% of the country's housing stock including major damage to an estimated 40% of all homes; placement of over two thousand six hundred persons in shelters in Antigua and over five hundred persons on Barbuda; and damage to roads, electricity and public utilities infrastructure, schools and government buildings. Estimates of the economic costs associated with the event vary, with one estimate of approximately EC$ 350m or 30% of the country's GDP[140].

During Hurricane Luis damage to buildings was mainly due to inappropriate design, weak connections of light-weight roofing and siding materials, impact damage from flying objects, inadequate windows and external doors and water damage from the torrential rains. There were also examples of catastrophic collapse of entire buildings due to unsound structural practices. In many instances, including several government owned buildings, the lack of maintenance of building components contributed significantly to the damage. In the cases of structures not associated with buildings (e.g. telecommunication towers and transmission systems) inadequate specification of performance criteria at the procurement and design stages was an important factor in the failures[141].

The 2008 Atlantic Hurricane season provides graphic evidence of the present period of intense hurricane activity in the tropical Atlantic and Gulf of Mexico. The season was one of the most active seasons since comprehensive records began, with a total of sixteen (16) named storms that included eight hurricanes, five of which were major hurricanes at Category 3 strength or higher. The 2008 hurricane season continued the active hurricane phase of the Atlantic hurricane belt that started in 1995, and was the tenth season to produce above-normal activity in a successive 14 year period.

Given the wide ranging and destructive nature of hurricane impacts on human settlements in Antigua and Barbuda, any intensification of these events arising from global climate change is likely to present significant adverse implications for the sustainability of human settlements in the country.

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140 Braithwaite A. et al see above. Massive economic destruction cost was also estimated for Grenada following destruction from Hurricane Ivan in September 2004.

141 See "Case Study of the Effects of Hurricane Luis on the Buildings and Other Structures of the Electricity Division of the Antigua Public Utilities Authority.

8.4.3. Warmer Temperatures

PRECIS and IPCC projections for climate change in the Caribbean are most definitive for temperature projections. These projections point to important increases in daytime and night time temperatures, reducing incidence of cool days and nights, and seeing a greater warming of the traditionally cooler winter months. Chapter Nine on Human Health identifies some of the health consequences of climate change and these will be of direct influence on human settlements. Many of these are likely to be exacerbated by urban conditions.

The IPCC notes that "the impact of climate change on health in human settlements is a complicated mechanism that involves the interaction of physical attributes of settlements and precursors for direct effects of heat stress, vector borne diseases such as malaria, and enteric diseases such as cholera"[142]. Settlements provide disease vectors and organisms with habitats in the form of standing water, garbage, and sheltered spaces. Flooding can flush organisms into water supplies, causing disease outbreaks. Heavy rainfall in normally dry areas leads to rapid increases in rodent populations as do warm conditions.

In Antigua and Barbuda increasing trends towards urbanization are likely to intensify negative impacts from temperature rise associated with climate change, as this process generally tends to result in the establishment of dense, poorly ventilated settlements. Built up areas generally can be expected to attract and retain higher temperatures than forested or other natural landscapes In most instances persons in low-income communities are further at risk by being unable to afford adequate artificial cooling and may also be unable to access information on how best to respond to the impacts from temperature rise associated with climate change. While Antigua and Barbuda's urban and built up areas are too small to create "urban heat island effect", warming along the lines as projected by PRECIS and IPCC estimates could result in an urban micro-climate in St Johns and environs increasingly characterized by warmer temperatures than surrounding areas.

Warming can be expected to increase demand for space cooling in buildings which will have implications for energy demand. This will mean increased use and reliance on fans and air conditioning with implications for energy demand. Demand for cooling during warm spells will put strains on the ability of electric utility suppliers to meet higher than normal peak demands. Provision of space cooling will have

[142] IPCC TAR Vol. II.

financial costs, and higher temperatures also impacts cost of urban business operations by increasing the costs of climate control in buildings. Lower income communities, particularly vulnerable groups such as the elderly, are especially at risk in densely concentrated urban settlements.

The principal impacts of warmer temperatures in urban areas are likely to be reflected in health impacts as well as in cooling costs. As Chapter Nine indicates, trends in Antigua and Barbuda towards higher rates of cardiovascular diseases and of certain other lifestyle diseases as well as an aging population mean that an increasing segment of the population is likely to be at risk to heat stress and other heat related diseases. Higher air temperatures are also generally favorable to a number of bacteriological and epidemiological agents. One likely outcome of higher temperatures is increased spoilage of food with consequent implications for household, institutional and commercial food preparation and storage. These problems can be expected to be more severe for low-income communities and individuals unable to afford adequate cooling facilities.

Urban communities provide ideal habitats for certain disease carrying vectors particularly rodents and mosquitoes. These vectors are able to adapt, and even thrive, in warmer conditions, further increasing the possibility for the spread of various communicable and infectious diseases. Urban communities around St Johns are already recognized as facing significant rodent and mosquito infestation issues and these are likely to intensify under the PRECIS and IPCC projections for the Caribbean climate.

8.4.4. Sea-Level Rise

While sea-level rise is recognized as one of the principal impacts of climate change on small island States, very few detailed assessments have been done of the effects of rising sea-levels on human settlements in the Caribbean. Sea-level rise can be expected to have serious implications for Antigua and Barbuda where considerable sections of the population live in areas likely to be impacted by medium to long term projections for sea-level rise. Rising sea-levels can submerge low lying areas, impede coastal drainage, augment saline intrusion, and increase coastal flooding and storm damage. Additionally ecological and physical environments along the coast will change with sea-level rise prompting the need for relocation of houses and infrastructure further inland.

The 1997 Government of Antigua and Barbuda/UNEP assessment of human settlement impacts indicates that more than 60% of the Antigua and Barbuda population can be considered as living within the coastal zone. Already population increase and tourism development have resulted in major stresses in coastal areas. Additionally, land reclamation, sand mining, and the lack of a comprehensive natural system engineering approach to control development has resulted in flooding and sedimentation has increased the country's vulnerability to erosion, coastal flooding and storm damage.

The 1997 assessment of the impacts of climate change on human settlements concluded that a sea level rise scenario of 0.3 meters (approximately one ft) would have no major effect on human settlements since this represents a small change over a 100 year span. It was determined that areas which are currently submerged at high tide would be most at risk to a 0.3m rise in sea-level. Vulnerable areas include Parham, Falmouth, English Harbour, Crabbe Hill, Old Road, and Dickenson Bay.

In assessing the impact of a one metre rise in sea-level on coastal resources the UNEP/GoAB assessment notes that sea-level rise will lead to an increase in the risks of floods resulting from storm surge as well as significantly reducing the return period for flooding events. Flooding in Antigua is primarily a result of torrential rain and during storms, human settlement encroachment onto low-lying flood-plains, and blockage of natural watercourses and channels due to development and other man-made causes (e.g. improper solid waste disposal). The latter contributes to widespread flooding due to backwater effects as seen in Villa and Greenbay. Flooding along low-lying coastal areas will be exacerbated by sea-level rise as where stream discharge occurs based on gravity.

Of thirty three settlements examined the most vulnerable to sea-level rise were identified as St. Johns (GreenBay and Villa/Point), Codrington, Urlings, Johnsons Point, Crabb Hill, Bolans, Bethesda, Parham, English Harbour, Cobbs Cross, and Falmouth. Settlements in the south west of Antigua were considered most at risk while most of Barbuda will be at risk from a one metre rise in sea-level. The concentration of tourism properties on beaches makes them extremely vulnerable to even moderate sea-level rise with areas such as Dickenson Bay, Jolly Beach, and Long Bay, where tourism development has encroached onto areas of active coastal wave energy, likely to be particularly at risk.

8.4.5. Rainfall Variability/Droughts

As with hurricanes, considerable uncertainties exist as to the nature of the impacts that can be expected with global climate change. PRECIS and IPCC projections indicate a range of possibilities that vary from dramatic reductions in rainfall to small increases. Uncertainties with the likely future impacts of ENSO and hurricane/tropical storm activity also further complicate matters. These variations point to a future likely to be characterized by a greater variability in rainfall than under current weather with greater variability in seasonal and annual distribution. The two effects of this are likely to be flooding in scenarios of intense rainfall and increased water scarcity in scenarios of reduced rainfall.

8.4.5.1. Drought

Freshwater is a scarce resource in Antigua and Barbuda with the islands experiencing periodic episodes of drought. Between 1960 and 2000, there were eight years in which rainfall for Antigua fell below 30.74 inches while during the period 1965 to 2000, annual rainfall fell below 27.79 inches in Barbuda on 10 occasions. A particularly severe drought occurred in 1983-84 with an annual rainfall recorded at the Coolidge Met Office of 22.31 inches in 1983. The country imported water to help meet local demands.

Since then the switch to desalinization has dramatically reduced household vulnerability to drought related impacts. Nevertheless, while vulnerability has been reduced with respect to water supply, settlements in Antigua and Barbuda are still affected by water rationing during droughts. This can be expected to intensify in the future without increased water production from desalination.

At present the country's water demands are met by desalination plants; surface dams, numerous small ponds and well-fields. Individual residences also have cisterns which provide part or all of the household water needs: the amount of water collected through this method is not known.

There are no perennial water sources in the country. The Antigua Public Utilities Authority’s water development plans emphasize desalinization of sea water to eliminate the risks associated with drought and inadequate surface storage and groundwater facilities. The relatively higher cost of producing desalinated water compared to ground and surface water is a major constraint to providing water that would not be affected by variable rainfall. High cost notwithstanding, a commitment to increasing desalinated water production may be required to reduce the vulnerability of settlements as water demands increase in the future.

Despite a widespread recognition of the value of the water resources significant obstacles remain to sustainable use of water resources. In Antigua, water loss from evaporation and seepage at surface reservoirs is an issue without a cost-effective solution. Despite the need to ration water in droughts, water is frequently lost due to leaks from supply mains. In Barbuda, the major ground water aquifer has been affected by sand mining activity. Desalinization has now been introduced to enable the supply of potable water to residents of Barbuda. Land and resource use will need to be managed in the future to ensure that Barbuda's important underground water resource are not further compromised. Although most building supply stores carry water saving toilets, showerheads and faucets, there has been no national water conservation campaign that targets households.

Impacts of drought on human settlements are likely to be manifest in a wide variety of health related consequences. These include diarrhoea as well as other diseases associated with inadequate hygiene. Storage of water can also encourage breeding of mosquitoes including the *aedesaegptyi* mosquito associated with dengue fever143.

IPCC and PRECIS projections point towards long term drying trends for Antigua and Barbuda and other Caribbean islands. This is likely to see an increase in drought related conditions and this will enhance many of the vulnerabilities that already exist. Combined with other conditions likely to affect human settlements from climatic and non-climatic factors – population growth, urbanization, economic vulnerability – increasing water scarcity can be expected to be an additional strain confronting municipal planners,

8.4.5.2. Flooding

Many of the impacts of flooding will be similar to those experienced from hurricane or other rain events. This includes possible loss of life from flood waters, significant health risks including dengue and food borne illnesses, and damage to property and infrastructure. At the same time it is important to recognize that flooding events result from other non-hurricane weather systems. Increase in La Nina phase activity of the ENSO for example, could result in greater incidence of heavy rainfall. There is also some evidence of a shift in rainfall patterns towards heavier rainfall events and with a larger proportion of rain falling during those events. This increases the risk of flooding as natural and man-made drainage systems are unable to cope with the large volumes of water during a short period of time.

Flooding in Antigua results primarily from the flooding of its floodplains. Damage due to flooding has increased owing to the pursued pattern of development where housing projects are being undertaken without the accompanying development control or flood mitigation measures. The flooding has been exacerbated by inadequate and poorly constructed hydraulic structures and inadequate maintenance of the structures and channel sections.

[143] A fuller analysis of health impacts associated with drought are at Chapter 9 "Human Health" below.

In Antigua areas prone to flooding have been identified as those with gentle slopes, poor drainage, large ratios of watershed area to flood plain, rapid run-off to flood plain with high run-off potential. Flooding occurs primarily in the areas located upstream of swamps and mangroves. High flooding vulnerability zones exist around North Sound Bridge and north of the Bendals Bridge. An area of high vulnerability can be found in the central western area of the island in the floodplain of the Cooks Creek. This encompasses a number of low income urban communities including Nut Grove, Golden Grove, and Brownes Avenue.

High flood potential also exists in the northern areas of the island in the Skerrits Pasture, Paynters, and Pigotts areas as well as along the Sir George Walter Highway and Old Parham Road, both of which are major road transport arteries linking the airport with other areas. The areas around Jolly Beach particularly in the Palm Beach area are also at risk to flooding.

For Barbuda reports by the US Army Corps of Engineers and by the Organization of American States identify the area of highest risk to flooding as being the Codrington Village area, which includes the principal human settlement and key infrastructure such as the hospital and the airport. Two moderate flood hazard areas exist in the south of the island.

The present high levels of vulnerability to flooding of a number of communities in Antigua and Barbuda means that PRECIS and IPCC projections for rainfall variability including floods would have significant adverse socio-economic impacts.

8.5. ADAPTATION TO CLIMATE CHANGE

8.5.1. Introduction

Adaptation to climate change represents the broad range of actions and initiatives that are undertaken to promote sustainable development within the context of anthropogenic climate change. At least two types of adaptation can be identified – proactive and reactive – as well as a continuum of options within that framework.

For Caribbean islands like Antigua and Barbuda the imperative for proactive measures arises from the islands existing high levels of vulnerability. Levels that can be expected to increase as a result of climate change. In line with the objectives of the UNDP Adaptation Policy Framework any proposed adaptation policies and measure should be relevant to existing development concerns and be consistent with wider sustainable development objectives.

In relation to human settlements it is important that adaptation policies and measures take place in a manner that is integrated with other development policies and programmes. This is particularly acute due to the cross-sectoral nature of human settlements issues and concerns.

8.5.2. Adaptation Frameworks for Risk Reduction in Human Settlements

Various efforts at identification of risk reduction and adaptation policies and measures have been completed for human settlements at the global level. The Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat has identified the following broad elements of adaptation and risk reduction.

Table 8.2 Human Settlements Technologies for Adaptation to Climate Change

Hard Technologies	Soft Technologies
a. Building sector	
• Lay out cities to improve efficiency of combined heat and power systems and optimize use of solar energy. • Minimize paved surfaces and plant trees to moderate urban heat and to reduce energy required for air conditioning.	• Limit development on flood plains and land-slide prone areas. • Establish appropriate building codes and standards. • Provide low-income groups with access to property.
b. Transportation	
• Cluster homes, jobs and stores • Control vehicles ownership through fiscal measures such as import duties and road taxes, as well as through quotas for vehicles and electronic road pricing. • Develop urban road systems.	• Promote mass public transportation. • Use a comprehensive and integrated system of planning. • Link urban transport to land-use patterns.
c. Industrial sector	
• Use physical barriers to protect industrial installations from flooding.	• Reduce industrial dependence on scarce resources • Site industrial systems away from vulnerable areas.

Source: UNFCCC Secretariat

A framework of adaptation policies and measures has also been developed for Antigua and Barbuda under the Caribbean Planning for Adaptation to Climate Change (CPACC) project and is presented below as Table 8.4.

Table 8.3 Adaptation Framework for Human Settlements for Antigua and Barbuda

Climate Element	***Likely Impact/Issue***	***Possible Intervention Option (Planning or Management)***
Increased temperature	Increased water use and needs. Increased demand for cooling. Psychological stress.	Improved site planning. Protection and Relocation of Vulnerable Settlements.
Change in seasonal temperature	Changes in patterns of human behavior	Possible adaptations (changes in human behavior).
Increased hurricane intensity and frequency	Loss of life and property. Increased stress for all life forms.	Comprehensive disaster planning and management.
Increased rain/flooding	Physical damage to property. Inadequate and poor drainage. Loss of life and property. Economic displacement.	Improved drainage and infrastructure. Disaster management. Development planning and control.
Seasonal changes	Impacts on seasonal crops affecting food security.	Development of alternative crops. Product diversification.

CPACC/P.James/Fisheries Division[144]

The UNFCCC and CPACC adaptation priorities point to the wide range of interventions necessary for effectively managing the adverse impacts of climate

[144]From Government of Antigua and Barbuda/GEF/World Bank/Organization of American States CPACC project. See http://www.caricom.org/jsp/projects/macc%20project/cpacc.jsp .

change on human settlements. This includes a number of social policy interventions which are required if vulnerabilities are to be minimized, and reflect the importance of social partnerships in reducing the risks to socially disadvantaged groups. The wide range of initiatives required means that there is need for some measure of prioritization and focus.

Importantly, the multi-sectoral and cross-sectoral nature of the adaptations required means that many of the adaptations to occur will be in sectors such as health, coastal area management, agriculture, and energy supply. These adaptations will themselves occur against a background of dynamic change in socio-economic and technological processes. Notwithstanding the diversity of needs, three central factors relevant to successful adaptation in human settlements will be:

- Public Awareness
- Natural Disaster Mitigation and Response, and
- Development Planning and Control.

8.5.3. Public awareness

Awareness of climate change related risks should be raised among key sectors and mass media, including by using current events such as economic, weather, and health crises, as a basis to promote adaptation measure with co-benefits. Improving public awareness and developing communications strategies makes climate change science accessible to the citizenry and enables them to reduce their level of vulnerability. Besides awareness building at local levels it is also important to involve high level policy makers to ensure integration of climate change considerations into national development policies.

8.5.4. Development Planning and Control

However the overall lack of an integrated national plan which brings together sectoral and environmental issues and concerns means that there has been no method for effectively regulating the types of adverse impacts that currently affect human settlements in Antigua and Barbuda and which are likely to be exacerbated by climate change. Of particular concern are likely to be the need for protecting coastal communities and habitats from the effects of intensified storm surge and rising sea level scenarios, and measures to reduce vulnerability arising from existing climate stresses such as droughts and hurricanes.

A primary recommendation for protection of human settlements from future adverse effects of climate change is therefore for the establishment of a national

Physical Development and/or Land Use Plan, based on extensive stakeholder involvement, and aimed at enabling physical planners and other resource managers to more effectively regulate structural development within the context of agreed national priorities.

Recent pronouncements by senior government officials point to the adoption of a national land use plan for Antigua in the near future. However the Plan should strengthen the capacity of planners to intervene in addressing critical areas of risk reduction for future development – something that is likely to be crucial for minimizing vulnerabilities in the context of a changing climate.

The development planning process typically does not usually include measures to reduce hazards, and as a consequence, climate related natural disasters such as floods, hurricanes, and droughts, cause needless human suffering and economic losses. With anthropogenic climate change planners should now include climate related events in their project planning, assess climatic natural hazards as they prepare investment projects, and promote ways of avoiding or mitigating damage caused by climate related events.

Antigua and Barbuda are not only in the regular path of severe hurricanes. It is also located in the most hazardous area of seismic activity in the Caribbean archipelago. The interrelationship of (and differences between) wind-resistant and earthquake-resistant design must not be lost sight of in the reconstruction process.

8.5.5. Natural Disaster Management and Response

Climate change is expected to increase the severity and frequency of weather-related natural hazards such as storms, high rainfall, floods, and droughts. Coupled with sea level rise these are likely to lead to more disasters. Of particular concern is that disasters have been increasing over recent decades, mainly owing to increased populations in hazard-prone locations, unplanned settlements and environmental degradation. However there is also mounting evidence that climate change is also a factor resulting for example in more intense hurricanes, higher rainfall intensities and heat-waves. Disaster mitigation must therefore be made an essential component of development planning and capital works projects. Consideration must now be given to incorporating climate and natural hazard impact assessments in the planning of certain categories of projects.

Climate change is impacting the nature of disaster risk, through increasing weather related risks, sea-level and temperature rise as well as through increases in societal vulnerabilities from greater stress on water availability, agriculture and ecosystem health.

Intensification of conditions associated with disaster risk as a result of climate change means that there will be a corresponding need to strengthen the country's capability for disaster response and management. Actions will be required for building capacity at all levels. There is the need for policy level commitment to ensure that efforts are directed towards development of an emergency management organization able to satisfy its mandate for disaster management in the context of a changing climate. At the community level there will also need to be institutional structures as well as the physical structures needed for managing pre and post disaster scenarios. Finally at the individual level, issues such as adequacy of training, motivation and reward will be important considerations for implementation of a strengthened disaster management capability.

Disaster management in Antigua and Barbuda is the responsibility of the National Office of Disaster Services (NODS). This organization coordinates the various aspects of the disaster management process including disaster relief and shelter management. The agency works in close cooperation with other agencies and departments such as health, public works, law enforcement, and the military as well as serving as focal point for international and regional disaster management agencies. The agency has acquired significant experience in disaster response and also provides logistical support to other regional disaster response management.

At the same time it is important to recognize the inherent limitations which NODS faces. These include

- Limited manpower
- Weak legislative and regulatory framework
- Inadequacies in information database
- Limited technical and financial resources, and
- Low levels of community participation in community management activities.

The challenges presented by a changing climate are already evident globally. In Antigua and Barbuda and most other small island States degradation of environmental conditions has increased vulnerability to climate related disasters. Efforts to meaningfully address natural disaster response to climate change will require that the national agency responsible for coordinating and managing response be adequately empowered in these areas.

8.6. CONCLUSION

In Antigua and Barbuda the vulnerabilities of human settlements to existing climate related events are in many instances enhanced by unsustainable land use practices, coastal degradation, and weak development controls.
As the focus for most human activity, the need for sustaining the viability of human settlements against the adverse impacts associated with global climate change is a critical concern in efforts to adapt to climate change.

These areas are likely to be particularly at risk to many of the projected adverse impacts of climate change particularly sea level rise, intensified storm activity, rainfall variability, and increasing temperatures. These components of climate change will affect human settlements in diverse ways including health and economic impacts. The present concentration of settlements in coastal areas and the weaknesses in the implementation of the country's physical planning and development control infrastructure means that development in a number of communities are already at high levels of risk to extreme weather events. These conditions are likely to worsen based on PRECIS and IPCC projections for climate change.

A diverse range of adaptation options will be required. These reflect the cross-sectoral nature of human settlements which encompass vulnerabilities from other sectors such as coastal zone, health, and freshwater resources. In this context the aim of adaptation measures must also be cross-sectoral and targeted at addressing core problems. Various frameworks for adaptation have been identified that include public awareness, legislative reform, and institutional strengthening. These will be critical and will need to be complemented by commitment to implementation of a national development plan and for strengthening of capacity for disaster response. The scale of potential economic damage also points to the need for strengthening of insurance as a potential mode for risk reduction and spread.

Adaptation and risk reduction within the human settlements sector must be integrated with those being implemented in other sectors and areas. Regional and international cooperation and implementation will be essential given the limited capabilities that exist in a small island State like Antigua and Barbuda. A central element of such multinational action must also be to support and encourage action for reducing global emissions as this is essential for sustainable development.

CHAPTER NINE
WATER RESOURCES

CHAPTER 9. Water Resources

9.1. INTRODUCTION

9.1.1. Background

The global impacts of climate change on freshwater systems are clear and present. Such impacts are primarily due to observed and projected increases in temperature, precipitation variability, and sea-level rise.

To better adapt to the effects of climate change and anthropogenic forces will require an awareness of stressors and factoring them into future integrated water management plans, programs and policies.

9.1.2. Methodology/Approach

The purpose of this assessment is to provide an indication of possible impacts of projected changes in climate on the freshwater resources of Antigua and Barbuda, and to identify possible policies and measures for enabling adaptation, or minimizing vulnerability of these resources to climate change. The assessment identifies existing climate related vulnerabilities and risks as an essential response for addressing longer term risks and threats. This is consistent with the UNDP Adaptation Policy Framework which recognizes the importance of sustainable development action in responding to climate change related vulnerability.

Methodological tools utilized for this assessment include:

- Deducing the average annual water production flow for groundwater, surface water and desalination water utilizing ten (10) years (1996 – 2007) of data from the APUA,
- Estimating the amount of water provided by rainwater harvesting and private dams and adding these quantities to the total average yearly water production during the period 1994 to 2007.
- Examining records from the APUA and averaging the annual water supplied to the domestic, agricultural, commercial & hotel sectors of AB.
- Allowing the total average annual water supply to correspond with the total yearly water produced by augmenting deficits with physical and commercial losses in the system (Table 8.5).

- Establishing a baseline year of 2000 and projecting water demand until 2030 utilizing four (4) input parameters:
  - Population increasing at 1.2% per year
  - Domestic water consumption at 0.99m^3/day
  - Agriculture water demand increasing at 2% per year
  - Hotel & commercial demand increasing at 1% per year
- Deducing the unit cost and revenue of water and applying these amounts to the projected water production and supply.
- Projecting water demand and supply in decadal intervals between 2000 and 2030 utilizing two (2) scenarios:
  - Scenario 1: Meeting the projected water demand by increasing only the desalination water component.
  - Scenario 2: Meeting the projected water demand by holding desalination steady while increasing the supply of groundwater, surface water and rainwater harvesting.

9.2. DESCRIPTION OF WATER RESOURCES IN ANTIGUA AND BARBUDA

9.2.1. Surface Storage

The reservoirs and ponds in AB have an existing storage capacity of approximately 7.4 million cubic meters (Mm^3) with the potential to further increase the storage volume by another 8.75 Mm^3 (Table 8.1); this could possibly be achieved by building new dams at a number of locations around Antigua.

Table 9.1 Surface Storage Capacities in Antigua and Barbuda

Surface Storage	ac-ft.	Mm^3	% of Total
Existing storage capacity	6,000	7.40	45.8
Potential added storage capacity	7,090	8.75	54.2
Total storage capacity	**13,090**	**16.15**	100.0

9.2.2. Yield

Although surface water yields approximately 54% (Table 8.2) annually, a large portion of this yield is accounted for as precipitation runoff from watershed areas as well as seepage and evaporation losses, hence, much of this yield is not used as supply to the national water grid. In contrast, desalination, which accounts for 37%

of annual water yield, contributes around 62% (Table 8.4) to annual water production.

Table 9. 2 Water Yield in Antigua and Barbuda

Water Source	(ac-ft.)/yr.	(Mm^3)/yr.	% of Total
Surface Water (10% precip in watersheds)	7,350	9.07	53.5
Groundwater	1,260	1.55	9.2
Desalination	5,130	6.33	37.3
Total Annual Water Yield	**13,740**	**16.95**	100

9.2.3. Production

Table 8.3 outlines the annual water produced by the APUA from 1994 until 2007. As noted from the table, there are three (3) essential sources of water produced by the authority:

1. Groundwater (GW)
2. Surface Water (SW)
3. Desalination Water (DW)

Based on the data provided, it is noted that DWs average annual production is 4.5Mm^3 per year as compared to smaller inputs from GW (1.145Mm^3) and SW (1.308Mm^3) as shown in Table 8.3 (refer Table 8.11, Appendix 8.9.1 for the APUAs Water Production Data).

Table 9.3 Annual Water Production in Antigua and Barbuda (1994 – 2007)

	Groundwater		Surface water		Desalination	
YEARS	(MG)	(m^3)	(MG)	(m^3)	(MG)	(m^3)
1994	186.653	848541.71	201.01	913809.95	735.654	3344350.76
1995	136.767	621755.36	143.744	653473.45	825.360	3752162.49
1996	*119.011*	541034.96	*305.069*	1386871.74	*927.499*	4216495.78
1997	*237.180*	1078242.10	*152.64*	693915.48	*798.18*	3628599.71
1998	*212.722*	967053.78	*109.228*	496560.54	*797.887*	3627267.71
1999	*207.031*	941181.97	*246.893*	1122398.29	*950.47*	4320924.06
2001	*249.105*	1132454.25	*121.799*	553709.46	*962.604*	4376086.34
2003	*215.59*	980091.97	*54.055*	245739.00	*1312.00*	5964472.70
2004	*266.91*	1213397.42	*440.66*	2003280.90	*878.747*	3994864.71
2005	*333.656*	1516830.87	*472.994*	2150274.24	*971.474*	4416410.18
2006	*364.92*	1658959.89	*640.252*	2910644.50	*756.657*	3439832.33
2007	*312.051*	1418612.55	*350.561*	1593682.56	*1295.617*	5889994.08

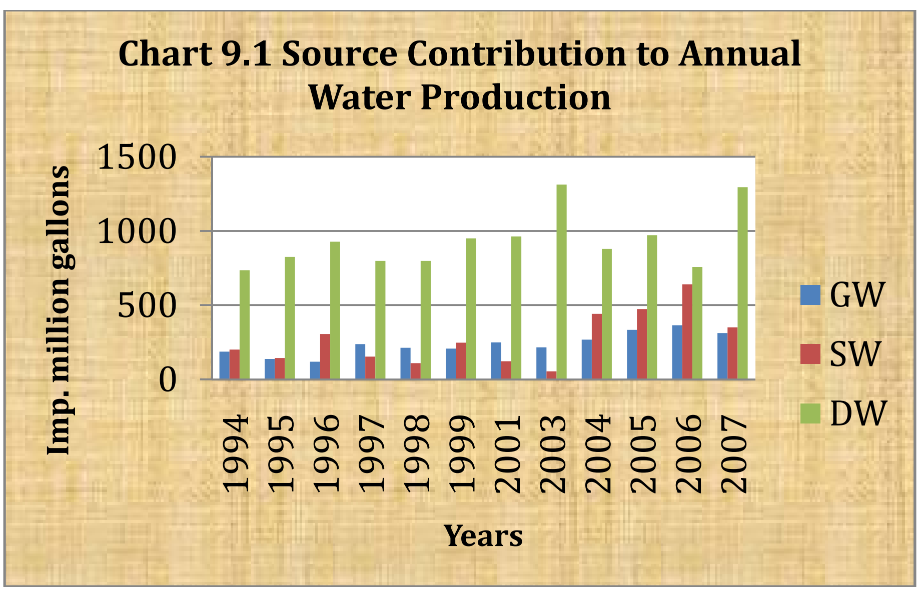
Average annual production (1996 - 2007)					
1996-2007	(Mm^3)/yr.	(Mm^3)/mo.	(MG/yr.)	(MG/mo.)	(MG/day)
Ground	1.145	0.095	251.8176	20.9848	0.690
Surface	1.308	0.109	289.4151	24.117925	0.793
Desalination	4.504	0.375	965.1135	80.426125	2.644
Total	**6.956**	**0.580**	**1506.3462**	**125.52885**	**4.127**

Table 8.4 shows that the production of DW accounts for the largest contribution (62%) to the national water grid while GW and SW contribute around 16% and 18% respectively. The actual production depends on the amount and intensity of the rainfall events throughout the year. For example, during a very intense rainfall event (10 cm within 24 hour period), there is likely to be appreciable runoff which has the effect of filling surface reservoirs and ponds; the runoff is a function of a number of hydraulic parameters including antecedent moisture conditions and land use changes. In such instances, once the sediments settle in these reservoirs, the APUA will begin using a large portion of the SW storage to meet daily demands; this water source is less costly to produce when compared to desalination. In addition, due to high evaporation and seepage losses in surface reservoirs, it is also more advantageous to use this water as soon as it becomes available.

Table 9.4 Average Water Production by source (1994 -2007)

Water Source	(MG)/mo	(Mm^3)/yr.	% of Total
Groundwater (APUA)	21	1.15	16
Surface Water (APUA)	24	1.32	18
Rainwater Harvest (private) (estimated)	3	0.14	2
Surface Water (private dams) (estimated)	2	0.09	2
Desalinated Water (APUA)	80	4.39	62
Total Water Production average	**130**	**7.09**	100

Chart 9.1 below shows the sizable contribution of DW (olive column) to the national water grid as compared to GW and SW. During the hurricane years that produced appreciable runoff rains, most of the supply was furnished by DW (hurricane Louis in 1995; hurricane Lenny in 1999); this is due to the fact that excessive sedimentation requires a period of settling and the infrastructure needs repair work. During the years 2001, 2001 and 2003 Antigua experienced annual rainfalls of 67cm, 87cm and 75cm respectively (VC Bird Met office). These annual rainfalls were well below ABs annual average (100cm) and resulted in surface reservoirs at extremely low stages; this accounted for the minor contribution of SW in those years.



9.2.4. Distribution

The main sectors in AB that receive water from the APUA supply are shown in Table 8.5. The domestic sector accounts for the largest volume of water (2.29 Mm^3/yr.), with the commercial and hotel sectors being supplied with 1.39 Mm^3/yr. it is estimated that rainwater harvesting contributes approximately 0.16 Mm^3/yr to the private sector while a similar amount is also provided to food producers by agricultural reservoirs and ponds. The total water supply to the sectors of AB averages around 7.09 Mm^3 per year.

Table 9.5 Average Water Supplies to Sectors

Sector	(MG)/mo	(Mm^3)/yr.
Domestic (APUA)	42	2.29
Private (rainwater harvesting)	3	0.16
Commercial & Hotels (APUA)	25.5	1.39
Government (APUA)	8	0.44
Agriculture (APUA)	3.5	0.19
Agriculture (private dams & ponds)	3	0.16
APUA	2.25	0.12
Unaccounted for Water physical + commercial (APUA)	42.75	2.33
Total Water Supply	**130**	**7.09**

10 year average (1990 – 2000); APUA

9.2.5. Barbuda's Water Supply

The relatively flat nature of Barbuda with its small geographic size and permeable soils make surface runoff minimal and surface catchments impractical. The population (1300) relies predominantly on private shallow wells and desalination water supplied by the APUA to meet their domestic demands. At present, the APUA has two (2) desalination plants installed on Barbuda each with a capacity of around 30,000 US gallons per day. The plants, which supply water to some four hundred (400) households, are currently been subsidized by the Central Government.

9.3. WATER COST AND REVENUE

9.3.1. Present Cost

The present costs of producing a cubic meter of GW and SW water in AB are US$2.5 and US$3 respectively. The cost to produce a cubic meter of DW, however, is around US$4.7/$m^3$ as shown in Table 9.6. Based on the difference in total production cost and total revenue generated from the sale of water it is evident that water supply is heavily subsidized. Given this fixed price of water, this subsidy increases as more of the DW is added each year to the national grid. (this assessment does not take into consideration the full cost of taking water from watersheds).

AB, at present, relies heavily on imported of oil and gas to meet its energy needs. The large percentage of DW added to the national grid each day, which requires large energy input as well as high levels of maintenance and operational costs, accounts for the high cost of producing water. Typical production costs (APUA) for the three main water sources are shown in Table 9.6 below.

Table 9.6 Present Water Production Costs in Antigua and Barbuda

Water Source	US$/m^3	US$/1000gal.	EC$/1000gal.
Ground	2.5	11.38	30.71
Surface	3	13.65	36.86
Desalinated	4.7	21.39	57.74

Based on general assessment by G. Fernandez in 2000
Estimates of Production Cost include cost of energy, chemicals, maintenance and labor.

9.3.2. Present Revenue

The domestic, hotel and commercial sectors are dominant as far as income generation from the sale of water (Table 9.7) is concerned. Some income (0.66 US million per year) is also generated from the sale of electricity that is generated from the desalination process.

Table 9.7 Present Water Revenues in Antigua and Barbuda

Year			2000
Unit cost	**US$ per KWh**	**US$ per m^3**	**US Mill per yr.**
Revenue Stream			
Domestic/Gov./Institution		2.00	5.22
Agriculture		2.40	0.96
Commercial & Hotel		4.90	8.33
Unaccounted Water		0.00	0.00
Sale of elect. Form DW	0.06		0.66
Total water Revenue			15.17

2000 Estimate: G. Fernandez working with the APUA data

9.3.3. Projected Water Resources (2000 – 2030)

The domestic, hotel and commercial sectors will continue to be the dominant sectors as far as water demand and revenue are concerned in AB.

Table 9.8 Projected Water Revenue (Antigua and Barbuda)

Year			2000	2010	2020	2030
Unit cost	**US$ per KWh**	**US$ per m^3**	**US Mill per yr.**	**US Mill per yr.**	**US Mill per yr.**	**US Mill per yr.**
Revenue Stream						
Domestic/Gov./Institution		2.00	5.22	5.86	6.46	7.74
Agriculture		2.40	0.96	1.18	1.42	1.75
Commercial & Hotel		4.90	8.33	9.21	10.14	11.22
Unaccounted Water		0.00	0.00	0.00	0.00	0.00
Sale of elect. Form DW	0.06		0.66	0.72	0.81	0.88
Total water Revenues			15.17	16.97	18.83	21.59

If AB continues to rely on DW to meet future demands this will require an additional 6 million US dollars each year by 2030 (water projection comparison for Scenario's 1& 2, Appendices 8.9.2 and 8.9.3).

The unit water production cost and unit water revenue generated are assumed constant throughout the water resource projections. Some of the basic parameters used in the future projection analysis are shown in Table 9.9. For example, the population is projected to increase annually at 1.2%.

Table 9.9 Basic Assumptions for Future Projections

Years	2000	2010	2020	2030
PARAMETERS				
Population	75000	84500	95200	107300
Domestic water	.099	.099	.099	.099
Agriculture(APUA)	increasing 2% per year from year 2000			
Hotels & Comm.	increasing 2% per year from year 2000			

Some additional assumptions applied to the study include:

- Domestic water consumption estimated at 22 imperial gallons per person per day;
- Agricultural, hotel and commercial sectors expected to grow at 2% per year.
- The water study based on current unit cost, while the investment component has not been factored into the study.

Two Scenarios (1&2), applicable to water resource projections, were developed in this presentation.

Scenario 1 (S1)

This projection assumes that groundwater and surface water remains constant throughout future years (2010 to 2030) while the demand shortfall is made up by increasing the production of desalination water.

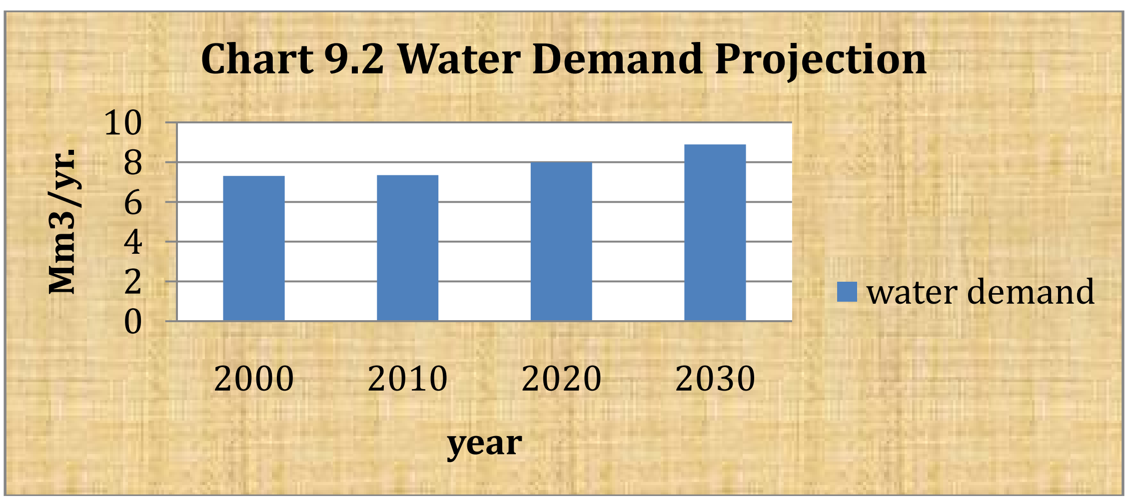
Scenario 2 (S2)

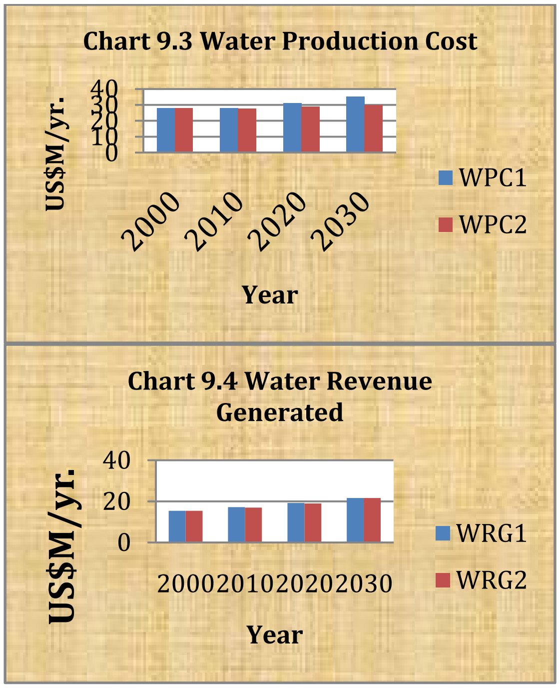
This projection assumes that the contribution of desalination water remains constant throughout years 2010 to 2030 while the demand shortfall is attained by increasing production through a combination of other sources (i.e. GW, SW, Rainwater Harvesting (RH), and private dams).The numerical basis for the water demand and supply projections, shown in Charts 9.2 to 9.5, is supported by Appendices 8.9.2 and 8.9.3.

9.3.4. Findings

The water resource projections for Scenario 1 (i.e. DW increased to meet demand) are shown in Chart 9.2 below. Based on the water resource projections from the years 2000 until 2030, it is noted that:

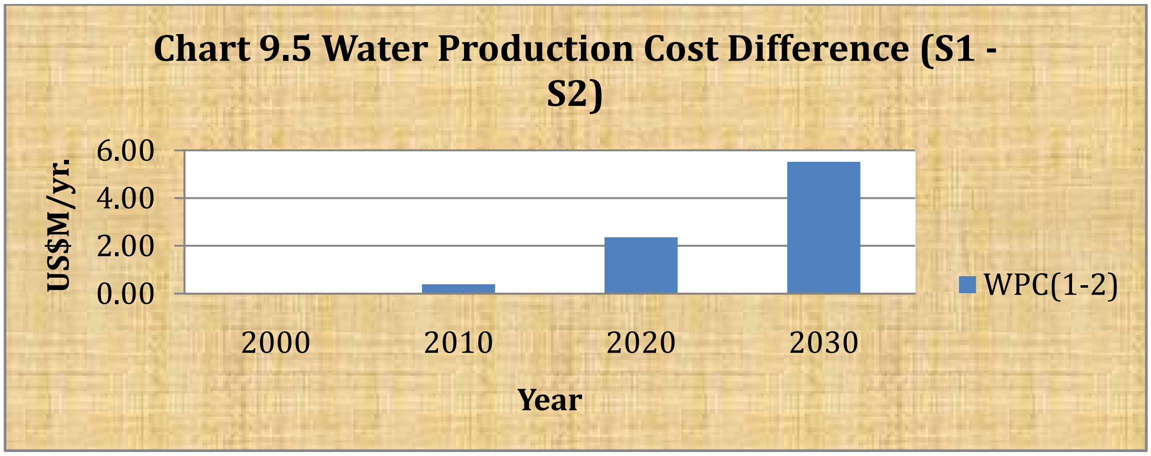
- Water demand is expected to increase from 7.31 Mm^3/year in 2000 to 7.99 Mm^3/year in 2020 and 8.89 Mm^3/year in 2030 (Chart 8.2).





- DW, the only supply parameter that is adjusted in S1 to meet future demand, increases from 4.5 Mm^3/year in 2000 to 6.08 Mm^3/year in 2030 (refer Scenario 1, Appendix 8.9.2).
- The water production cost (Chart 9.3) for:
    - S1 is projected to approach US$35.38 million for the year 2030; and
    - S2 is projected to approach US$29.86 million for the year in 2030.

  The difference in cost between scenarios is due primarily to the high energy cost of producing DW (US$4.70 US/$m^3$) as compared to producing GW, SW and RH.
- With the pricing of water held constant, irrespective of the contribution of source water (DW, GW, SW), there is no difference in revenues projected between Scenario 1 and Scenario2 (Chart 9.4).



- Scenario 2, which considers increasing supplies from GW, SW, RH to meet added demands from population and economic development, provides a savings of US$5.52 million in year 2030 as compared to Scenario 1 (Chart 9.5).
- Assumptions for these two scenarios have to be adjusted in accordance with actual plans for more desalination capacity and/or anticipated surface and groundwater development. The water resource situation is already dominated by the supply of desalinated water, and unless substantial investment is made for new reservoir and treatment capacity, both GW and SW resources would continue to be small compared to DW in the future.

Based on the findings from the analysis of Scenario1 and 2, it is important that consideration be given to increasing the number of dams and/or rainwater catchments around the island. In addition, sustainable alternative sources of energy should be promoted in order to help reduce the high cost of fuel input which accounts for high outflows of scarce foreign reserves.

The difference between water production costs and water revenues (Appendices 8.9.2 and 8.9.3) shows that piped water is already a subsidized commodity. A pertinent question to be pondered is, "whether this situation will prevail, or if consumers will have to pay the real cost in the future?" It is assumed that the existing differentiated tariff structure will be maintained, which means that certain consumer groups will continue to pay a higher price.

9.4. LEGAL & INSTITUTIONAL ARRANGEMENTS FOR WR IN AB

9.4.1. Public Utilities Act

The APUA is governed by the Public Utilities Act (Cap. 359 of 1973; amended 1993 and 2004). This Act provides the APUA with the exclusive right to sell, distribute and maintain water and perform services within Antigua & Barbuda. The Authority also has powers to control, manage, maintain, operate and supervise all watercourses, and waterworks in Antigua and Barbuda, and provide, as far as practicable, an adequate supply of water for the use of the public in general.

The Authority with the approval of the public utilities Minister, where in their opinion the drainage of water from any area flows or is conveyed to a watercourse or waterworks, may declare that area or any part of that area to be a watershed. This is an important section of the Act as it gives the Authority some leverage to regulate and control the runoff water from affected areas. It should be noted, however, that the Act does not explicitly define what constitutes a watershed and also does not provide details as to what actions will be taken in such circumstances. In spite of the fact that the Public Utilities Act was amended in 1993 and 2004, there has been no further elucidation made to the watershed issue.

9.4.2. Physical Planning Act

The Physical Planning Act (2003) offers some cover to the Public Utilities Act as it states (where in the Act. hat the Town & Country Planner may and if so directed by the Minister shall cause a survey to be made of any part of the country with a view to determining whether any area of the country ought to be declared an "Environmental Protection Area." The Planner may prepare or cause to prepare an environmental protection management plan for the protection area. This plan will set policies and plans to include such issues as:

- The preservation of marine flora and fauna including regulation for hunting and fishing;
- The protection of water supplies, water catchment areas and mineral resources;
- The prevention of erosion, landslides and flooding;
- The control of fires; and
- The control of pollution.

Any person who contravenes any provision commits an offense and is liable on summary conviction to a fine not exceeding EC$20,000.

9.4.3. Forestry Act

The present Forestry Act (Cap.178, 1989) gives the Minister of Agriculture the mandate to declare any suitable land as:

- A “Forest Estate” for the purpose of Reforestation; and
- “Forestry Reserves” (section 10) mainly for the prevention of deforestation.

The Forestry Unit is mandated to protect and conserve the upper-watershed areas in Antigua and, hence, the unit serves a critical role in ensuring the quantity and quality of surface water and groundwater are maintained.

There is need, however, for the present Forestry Act to be updated to include the protection and conservation of biological resources. This would allow for the establishment of Protected Areas such as Forestry Reserves and Conservation Areas. Conservation areas should also include the use of private lands that are in need of special conservation requirements.

9.4.4. Barbuda Land Act

The Barbuda Land Act (No. 23, 2007) confirms that all land in Barbuda is owned in common by the people of Barbuda to provide for the administration and development control of land in Barbuda, to provide for the confirmation or otherwise of certain lease of land in Barbuda, and for incidental and connected purposes.

Section (9) –Restriction on Land Use states in subsection (1) that a person shall not:

(a) Cut or fell any growing timber;
(b) Burn charcoal;
(c) Destroy any mangrove; or
(d) Mine sand

- The Barbuda Council (BC) is the local authority that manages the internal affairs of the island of Barbuda.

9.4.5. Institutional Arrangements

Although a number of agencies (e.g. Forestry, Soil & Water, Water Division, Extension Division, Environment Division, and National Parks Authority.) are involved with the management of specific ecosystems within the watersheds of AB, there is no specific integrated management structure currently in place to effectively manage watershed functions and services. For example, the actual cleaning of water storages (i.e. ponds and reservoirs) and intermittent stream ways are minimal at best, due in part to unclear and/or overlapping spheres of responsibilities by natural resource agencies of government.

9.5. CLIMATE CHANGE

9.5.1. Drivers

Climate change according to the IPCC refers to any change in climate over time, whether due to natural variability or as a result of human activity. This definition differs somewhat from that of the Framework Convention on Climate Change, where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

It becomes challenging when one tries to distinctly separate actual climate drivers from non-climate drivers since they both affect systems. Some climate drivers examined in this presentation include temperature, precipitation, and sea-level rise while some of the non-climate divers include land-use changes, land degradation, invasive species and pollution.

The Millennium Ecosystem Assessment (MA, 2005), which documented the condition and recent trends of ecosystems have shown that since 1960, withdrawals from rivers and lakes have doubled, flows of available nitrogen in terrestrial ecosystems have doubled, and flows of phosphorus have tripled.
The MA (2005) has identified two different categories of drivers of change:

1. Direct drivers of ecosystem change (e.g. land cover and land use change, climate change and species introductions); and
2. Indirect drivers (e.g. socio-political changes and economic changes) that affect ecosystems in a more diffuse way, generally by affecting one or more direct drivers.

Both the direct and indirect drivers have been changing at an appreciable rate over the past few decades. For example, direct drivers such as food production and water use have greatly increased. Among the indirect drivers, global population has doubled since the 1960s to reach 6 billion people.

The global impacts projected for changes in climate have indicated that decreasing water availability and increasing drought will be experienced in mid-latitudes and semi-arid and low latitudes (results from global circulation models, e.g. B1, B2, A1B, A2, etc.).

Predictions from global climate models also suggest that the magnitude and frequency of atmospheric natural hazard events will increase. The question remains, however, whether climate change has occurred or is occurring and can we measure this phenomenon? Changing trends over short historical records (i.e. few decades) could be evidence of climate change but it could also be natural variability of a particular hazard. For example, the air temperature changes have been recorded over multi-century scales. It is difficult to separate human-induced change from the natural variability of the hazard without knowledge of the long term hazard.

9.5.2. Future Impacts and Vulnerabilities

9.5.2.1. Floods and Drought

Given the increase in global temperatures, one can expect an acceleration of the hydrological cycle with an increase in frequency and intensity of flood and drought events. Floods in Antigua are caused by long lasting and/or intense precipitation events, dam or spillway failures and/or reduced conveyance caused by erosion and sedimentation. The extent of the flood will depend on antecedent moisture conditions, rainfall intensity and duration as well as the characteristics of the runoff basins.

Recent housing developments in Antigua have been undertaken without much consideration given to the location of the development and its impact on downstream areas of the watershed. Flood conditions are usually exacerbated if the project development team of the post development phase does not take effective and efficient drainage design into account. The pre-development drainage characteristics of the development should be maintained during the post development and operational phases. In this regard, it is recommended that an Environmental Impact Assessment (EIA) be undertaken by a reputable agency to ensure hydrological characteristics are maintained at pre-development conditions during the construction and operational phases of the project.

The increase in frequency and intensity of floods in mid-latitudes would increase the risk of flash flooding. Storm drainage systems that were designed some years ago to accommodate specific flows may now prove to be inadequate to receive the climate change induced rainfall intensity flows. Consideration should be given to designing storm drains on new developments with a 20% margin of safety, based on the actual runoff calculated, for a given sub-watershed so as to accommodate increasing flows due to forced climate change.

The term drought may be referred to as:

- A meteorological drought (precipitation below a specified average);
- A hydrological drought (water levels in reservoirs and groundwater tables);
- An agricultural drought (moisture level in the soil profile); and
- An environmental drought (combination of the above).

Using results derived from the Rooys Drought Index that relies on precipitation as the sole input parameter, and based on average annual rainfall of 1040 mm for ABs 35 year mean, a simplistic scenario was developed for AB (Table 9.10 below).

Table 9.10 Drought scenario for Antigua and Barbuda

Year	Type of Drought	Annual Rainfall Total (mm)
1995	average year	1040
2006	Slight	≤ 988
2016	Mild	≤ 937
2030	Moderate	≤ 833
2055	Severe	≤ 729
2080	Extreme	≤ 622

Source: Climatological scenarios in AB (MET Office Study Team, 1999)

The drought scenario for AB indicates that there would be an incremental increase in drought of some 5% per decade. The demands for freshwater is also expected to increase in order to meet a projected growing population and anticipated economic expansion. The challenge for water resource planners and technicians would be to create an environment that will promote a sustained quantity and quality water supply to meet these future demands on a cost-effective basis.

In the past, the Public Utilities Authority has increased water production by relying heavily on high-cost desalination plants. This paper projects water demand to the year 2030; such projections are based on an increase in population of 1.2% per annum. To meet future water demand, two scenarios are presented:

1. Increasing desalination water while holding surface storage and well supply constant; and
2. Increasing surface storage, groundwater supplies, and rainwater harvesting while holding desalination constant.

In order to bridge the gap between water availability and future demand, commercial and private enterprises should be encouraged, through innovative incentives and knowledge of long-term savings, to adopt water conservation technologies (e.g. recycling wastewater, rainwater harvesting, low-flow faucets, etc.).

Changes in land use and land cover as well as an increase in water use due to population increase and economic development can exacerbate drought impacts. Projection for 2090, using the HadCM3 GCM and the SRES A2 scenario, show the proportion of global land surface in extreme drought to increase by a factor of 10 to 30. The number of extreme drought events per 100 years is projected to increase by a factor of two and the mean drought duration to increase by a factor of six by the 2090s (Burke et al., 2006).

As temperatures rise, there is likely to be a drying effect on the soil layers thereby exacerbating drought conditions and adversely affecting agriculture and groundwater reserves. In addition, higher temperatures are causing glaciers to melt at an alarming rate which causes a forcing of sea levels to increase in elevation thereby creating flood conditions and salt water intrusion in coastal areas. Antigua and Barbuda are small island states in which a vast proportion of the population lives within coastal areas where the topography is generally flat and the land lies a few meters above sea level. One can expect infrastructure to be affected by sea-level rise and also the quality of coastal aquifers to become more saline as sea water moves inland.

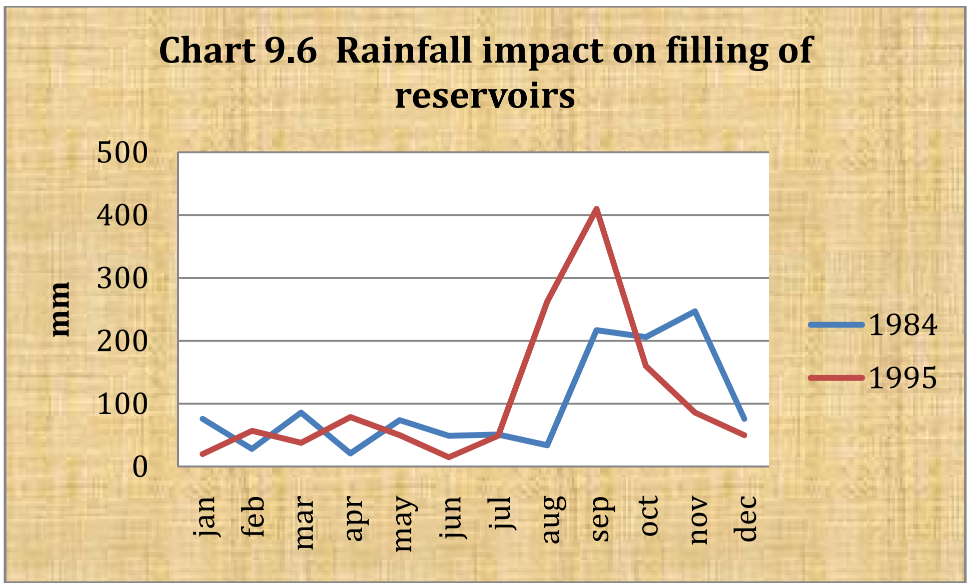
Consideration may be given to:

- Increasing setback distance from coastal areas for future development;
- Redesigning and/or retrofitting coastal infrastructure to accommodate the effects of intense floods and rising sea-level; and
- Relocating near shore communities to higher elevations to avoid the impacts of storm surges and tidal waves.

9.5.2.2. Surface Water

A general conclusion from catchment flow studies (Evans and Schrieder, 2002) is that flow seasonality exhibits marked variations, with higher flows during the hurricane season and lower flows during the extended dry periods.

The freshwater resources of AB are under stress due to population and economic growth coupled with climate variability. The extremes in inter-annual precipitation in Antigua can be seen by analyzing and comparing rainfall patterns from different years. For example, recordings of weather data from the Met Office at VC Bird International Airport (VCB Airport) shows that while 1165mm of rainfall fell during 1984, only a minor portion of these rains contributed to runoff, hence, the major reservoirs (Potworks, Collings, Body Ponds) were not significantly replenished. In contrast, the rainfall recorded for 1995 at the met office at VCB Airport was 1277mm, in spite of the small difference in annual rainfall between these two years, it was noted that the all the major reservoirs were filled to capacity at the end of 1995. What caused reservoirs to fill in 1995 and not 1984? The primary reason was the inter-annual variability.



During 1984 the rains were fairly uniform over the entire year, whereas in 1995 some 65% of the rains (refer Chart 9.6 above) fell in a three month period (August to October). This clearly illustrates the importance of the effect of precipitation events (duration and intensity) to the filling of major storages in AB. On average, the current reservoir's capacity can provide approximately 1.3Mm^3/yr. of water; hence it is critical that the reservoir be filled by runoff rains at least once each year.

From a previous water balance assessment (Water Resource Sector Study of AB 1999; G. Fernandez), it was revealed that losses due to evaporation and seepage, from the Potworks Reservoir, were three (3) times as high as the average outlet supply. With increasing temperatures due to climate change, one can expect the gap between evaporation and reservoir outlet supply to widen and, hence, impact more negatively on surface storage capacity. Consideration may have to be given to pumping water from reservoirs when full into neighboring aquifers to nullify the effect of evaporation loses; the transfer should be subject to an analysis of the reservoir water for the presence of harmful chemicals.

During high storm runoff periods, the reservoirs and ponds in Antigua will face increasing problems from sedimentation and pollution. The sedimentation, if left to accumulate over a few years, will significantly reduce the potential storage capacity of these storages thereby placing extreme pressures on spillways and dams-walls, leading to dam and overflow failure. Government must consider an ongoing program of cleaning reservoirs and ponds during the dry season in anticipation of collecting runoff waters.

9.5.2.3. Groundwater

With a general increase in precipitation variability and warmer temperatures, one could envisage a declining surface water availability which would make the groundwater supply more critical to the nation’s water grid.

Although there has been very little research on the impact of climate change on groundwater and its relation to surface water, it is likely that climate change will adversely impact groundwater recharge rates and levels. Population pressure and land development may alter land cover which may also affect infiltration and thus recharge rates. In AB, heavy rain, accompanied by flooding, is a major source of groundwater recharge. Government must establish a meaningful National Physical Development Plan and enforce building codes that lend support to such a plan.

Under the A1B scenario, expected sea level is projected to rise between 0.17 m and 0.24 m by 2050 (IPCC 2007); this would indicate sea-level rise of the order of 4 mm to 6 mm per year. The continual annual increase in the height of sea-level will also increase the storm surge intensities and wave heights thereby making coastal water resource infrastructure more vulnerable. This will be a major concern for coastal inhabitants of AB since both islands are generally flat in nature. Any decrease in groundwater recharge will increase the movement of the rising sea-level inland which will lead to further salt intrusion into coastal aquifers. Government will have to re-evaluate the existing placement of water infrastructure and, where necessary, replace or relocate pipes pumps and other accessories. Also, well fields will have to be closely monitored to minimize over pumping as this could shift the balance in favor of salt intrusion into nearshore aquifers.

Barbuda is an extremely flat island (highest point around 70 meters above sea level) with no significant surface storages and, hence, relies exclusively on shallow aquifers and desalination water to meet domestic and commercial demands. Most of the coastal wells at present are, however, under threat from salt-water intrusion due to excessive drawdown and more frequent and intense storm surge and wave action. At the moment there are two desalination plants, with a combined capacity of 80,000 gallons, which supply some 400 households. It is becoming more apparent that Barbudans are relying more and more on desalination to meet their daily water demands.

9.5.2.4. Water Quality

The higher water temperatures linked with extremes in rainfall intensity and frequency are likely to produce adverse changes in water quality thereby affecting human and ecosystem health, and water availability. More intense rainfall will lead to an increase in suspended solids (turbidity) and pollutants in reservoirs, streamways and coastal waters (wetlands, nearshore).

Higher surface water temperatures will promote algal blooms which may lead to a bad taste and toxins in chlorinated drinking water. In addition, higher runoff coupled with unplanned development will increase nutrients and pollutants (e.g. pesticides, heavy metals, organic matter, etc.) entering the water bodies. Water borne diseases (diarrhea, cholera and typhoid) will likely be amplified during drought periods signaling the deterioration in water quality. To effectively manage algal blooms, nutrient and pollutant runoff, the water utility will have to invest in appropriate technology (e.g. increase phases of filtration) which would, unfortunately, add to the cost of producing water.

Water quality modifications in the treatment and drainage systems may be needed in the future due to:

- Disturbances in drainage and sewage disposal in coastal areas;
- Water withdrawals from low-quality sources;
- Greater pollutant loads from higher precipitation;
- Water infrastructure malfunctioning during flood events; and
- Overload capacity of wastewater treatment plants during extreme rainfall.

These modifications will increase the overall cost of water production. It is important that “wise water management” techniques (e.g. rainwater harvesting, recycling and reuse, and conservation) be adopted by private and commercial entities. In addition, in order to reduce vulnerabilities and promote adaptation strategies there is an urgent need to:

- Provide access to reliable and relevant information;

- Promote coordination and collaboration at the intra and inter institutional levels; and
- Mobilize and pool resources.

9.5.2.5. Erosion and sediment transport

Antigua and Barbuda are tropical coastal islands that experience variable extremes in weather; drought periods followed by flood events. Due to population and development pressures, food producers have been developing lands on hillside areas. During the dry months (May to August) these lands are usually cleared and prepared for the onset of the rainy season (September to December). However, if the rain suddenly falls in torrential downpours, most of the exposed soil surfaces could be lost due to the erosive force of the raindrops as well as the momentum of water moving down-slope. Such soil loss has the potential to:

- Block waterways and impede downstream water flow;
- Reduce the health of the topsoil from which earth has eroded;
- Settle in reservoirs, ponds and streamways thereby reducing their carrying capacity and increasing the potential for flooding;
- Increase the nutrient load on water storages (reservoirs, ponds, and aquifers) and coastal areas (wetlands, bays, harbors, etc.).

Given the impact of climate change on erosion potential:

- Food producers will have to adopt improved conservation practices (e.g. minimum tillage, terraces, etc.);
- Foresters will have to protect and conserve the critical upper watersheds from degradation; and
- Land developers will have to maintain pre-development storm runoff conditions.

9.6. ADAPTATION PROPOSALS AND COSTS

9.6.1. Costs

Although impacts of climate change will involve social and economic costs (e.g. adaptation) and benefits (e.g. improved water quality and availability) they will, however, prove difficult to accurately determine. When considering the impacts of climate change on the future water resources one will have to also consider socio-economic factors as well. Costs may include relocation of households due to flooding as well as loss to ecosystem habitat and species. Efforts to quantify economic impacts of climate related changes to water resources in AB are made more difficult due to a lack of data and varying assumptions as to how changes in water availability will be re-allocated across various water uses (e.g. agriculture, domestic, etc.).

The impacts of floods and droughts will likely increase costs due to:

- Added/improved infrastructure;
- Changes in land use and water management; and
- Rising conflicts among different interest groups.

Hydrological changes will create both positive and negative impacts. For example, increasing rainfall intensities may induce greater runoff which will assist in the filling of reservoirs and ponds but, on the other hand, may also induce flooding, pollution and sedimentation.

9.6.2. Water Demand & Availability

The demand for water will increase across all sectors and will require augmented production from desalination water, surface water, groundwater and/or rainwater harvesting. If DW is solely targeted to meet this increased demand then one can expect an annual increase in energy costs; based on results from Scenario 1, the increase in energy cost will account for an annual increase in water production to around US$M 5.5 by 2030 (refer Chart 9.5). The advantage of using DW, however, is that more of the runoff water in the watershed areas would be able to be dedicated to aquatic ecosystems, recreation and irrigation.

The downside of increasing the production of DW includes the:

- High energy, maintenance and operational costs; and
- Likely adverse impacts of brine backflow on nearshore ecosystems (mangrove, coral, sea water) and aquatic species.

Climate change may force sectors to adjust their water demands and adapt accordingly; adaptation may include:

- Technical changes to improve water use efficiency;
- Demand management (e.g. pricing and metering); and
- Institutional changes (e.g. establish “Water Council” to manage water allocation).

The increased variability of precipitation and higher temperatures would generally lead to an increased irrigation demand. The wise use of water and general irrigation efficiency must be adopted in order to maintain yields with reduced water supplies.

Based on a simple crop model applied to climate change effects on irrigated agriculture for AB, it was observed (Fernandez et al.; 2000) that there is a likelihood of a possible shift in the optimal growing season that could basically affect planting dates.

9.6.3. Water Availability

According to the Millennium Ecosystem Assessment, 2005b, the freshwater ecosystem will have the highest proportion of species threatened with extinction due to climate change; for example bird breeding could be disrupted around given water bodies. Changed freshwater inflows into the ocean will affect turbidity, salinity, and nutrient availability which impact coastal ecosystems (wetlands, coral, etc.).

Climate change is also likely to affect steam discharge, resulting in impacts on water availability and quality. Changes in water levels may require additional costs in water infrastructure and land development.

Water stress is not only a function of population and climate change but also depends on non-climatic drivers such as water use efficiency, income, and industrial production. The effect of water stress in the future on populations will depend greatly on the rate of increase of emissions.

9.7. ADAPTATION

As a first step to apply sound adaptation measures one must consider collecting and analyzing hydrological and environmental data as well as sharing competent information pertaining to social, cultural and economic needs. The effect of variable precipitation patterns, which are drastically changing intensities of flood and drought events, water quality problems as well as water demand, are creating an urgent need for infrastructural investment and institutional changes in AB.

One of the critical mechanisms in managing the effects of climate change on water resources in AB is the adoption of an Integrated Water Management (IWM) approach. The IWM approach, though in its infancy, includes:

- Planning and implementing natural resource management initiatives, which includes water resources, on a watershed basis;
- Reshaping the planning process to include stakeholders in water management decisions;

- Recognizing the interdependence of water quantity and quality as well as surface and groundwater deposits;
- Protecting human health and natural ecosystems and their organisms; and
- Improving the flow of sound information to stakeholders and technicians.

An integrated approach will help to resolve conflicts in competing water use and downstream pollution. For example, by involving interest groups from a particular watershed area will help resolve conflicts arising from competing water use.

As Barbudan's continue to rely more heavily on desalination water, their energy costs is likely to increase. The island is known for its strong wind currents on the northern coast and its abundant sunshine. In this regard, consideration should be given to exploring the possibility of installing wind turbines and/or solar panels to lower the long term energy costs as well as reduce fossil fuel emissions.

It must be noted that one of Barbuda's main sources of revenue and food is the marine environment and, hence, it must be protected and conserved. In this regard, it is recommended that an Environmental Impact Assessment should be undertaken to assess the impact of the installation and operation of desalination plants on the coastal ecosystem. Two areas of concern are the quality and temperature of the brine return flow to the sea. The study should articulate what appropriate measures should be adopted to mitigate the adverse impacts discovered.

9.7.1. Supply-side

Some of the supply-side adaptation options to be considered in AB include:

- Building more reservoirs to increase surface capacity;
- Exploring the possibility of exploiting deep wells for addition of GW to the national grid;
- Increasing desalination of sea-water;
- Providing incentives to encourage home-owners and business operators to trap and store rain-water; and
- Maintaining indigenous riparian vegetation around streamways.

The addition of deep wells would increase pumping and treatment costs while the addition of DW plants would boost energy costs and incur possible adverse impacts on coastal environments. Consideration should be given to undertaking environmental impact assessments pertaining to the operation of desalination plants and their effects on the marine environment.

9.7.2. Demand-side

Some of the demand-side adaptation options to be considered include:

- Encouraging food producers to use water efficiently (applying drip irrigation and mulch techniques, recycling grey water where appropriate, and installing terraces);
- Providing incentives for businesses to recycle grey water;
- Establishing an institution to be responsible for the allocation of water to all sectors; this body should be independent of the body mandated to produce and distribute water;
- Providing incentives through metering and pricing to encourage water conservation.

To better manage climate change, water managers may consider designing flood drains to accommodate around 20% more runoff. In addition, contingency planning should be developed for possible drought conditions (e.g. restricting or reallocating water use).

9.8. CONCLUSIONS

Based on the analysis of water projections and the water management capacity in AB, it is showing positive signs that the water supply system is capable of adapting to changes in climate and population. The adaptation, however, would require some costly adoption of new technologies (i.e. added treatment and desalination plants, new and relocated infrastructure, etc.).

The ability to protect against flooding would depend on enforcing setbacks and other regulations pertaining to drainage and building codes. For example, it is critical that engineers design post-runoff storm drains to equal the natural conditions at pre-development in a given watershed area. In addition, effective safe-guards (e.g. treatment systems, effective collection tanks) must be in place to avoid pollution to downstream areas in the watershed.

The volumes of existing water demand and supply are by and large based on data from APUA complemented with estimates of additional household rain harvesting and private dams for irrigated agriculture. The future domestic water demand is assumed to increase in proportion to the population growth. It is also assumed that

that domestic per capita water consumption remains constant over the next 20-25 years, although it should normally increase with an improved standard of living. This assumption, however, takes into account that the potential per capita increase will be compensated by the expected positive effects of water saving measures and awareness campaigns. When it comes to the projections of future demands for agriculture and tourism it is assumed that these will increase in proportion to anticipated economic growth for these sectors, using the medium economic growth scenario for each of the sectors as a basis.

Antigua and Barbuda are dry islands that must continue to seek innovative and efficient water distribution systems. It is recommended, given the extreme day-light hours and strong winds, that solar panels and wind turbines be installed and electricity so generated be added to the nation's electric grid. This will better position the country to meet the increasing future energy demands of the water sector.

9.9. APPENDICES

9.9.1. Water Produced by the APUA (1994 – 2007)

Table 9.11 Water Production (APUA; 1994 – 2007)

YEARS	Groundwater (IMG)	Groundwater (m^3)	Surface water (IMG)	Surface water (m^3)	Desalination (IMG)	Desalination (m^3)	convers 0.00454
1994	186.653	848541.71	201.01	913809.9529	735.654	3344350.764	0.00454
1995	136.767	621755.36	143.744	653473.4484	825.360	3752162.493	0.00454
1996	119.011	541034.96	305.069	1386871.74	927.499	4216495.784	0.00454
1997	237.180	1078242.1	152.64	693915.4829	798.18	3628599.713	0.00454
1998	212.722	967053.78	109.228	496560.537	797.887	3627267.708	0.00454
1999	207.031	941181.97	246.893	1122398.292	950.47	4320924.063	0.00454
2000	174.57	793611.28	336.041	1527673.302	31500.73	143205216.6	0.00454
2001	249.105	1132454.2	121.799	553709.4595	962.604	4376086.344	0.00454
2003	215.59	980091.97	54.055	245739.0031	1312.00	5964472.704	0.00454
2004	266.91	1213397.4	440.66	2003280.901	878.747	3994864.707	0.00454
2005	333.656	1516830.9	472.994	2150274.239	971.474	4416410.18	0.00454
2006	364.92	1658959.9	640.252	2910644.495	756.657	3439832.334	0.00454
2007	312.051	1418612.6	350.561	1593682.558	1295.617	5889994.079	0.00454

YEARS	Groundwater (IMG)	Surface water (IMG)	Desalination (IMG)	Total (IMG)	Total (m^3)
1994	186.653	201.01	735.654	1123.317	49936618.24
1995	136.767	143.744	825.360	1105.871	49161063.13
1996	119.011	305.069	927.499	1351.579	60083916.25
1997	237.180	152.64	798.18	1188	52812075.73
1998	212.722	109.228	797.887	1119.837	49781916.2
1999	207.031	246.893	950.47	1404.394	62431786.43
2000	174.57	336.041	31500.73	32011.341	1423051654
2001	249.105	121.799	962.604	1333.508	59280577.01
2002					
2003	215.59	54.055	1312.00	1581.645	70311410.37
2004	266.91	440.66	878.747	1586.317	70519102.3
2005	333.656	472.994	971.474	1778.124	79045807.53
2006	364.92	640.252	756.657	1761.829	78321419.67
2007	312.051	350.561	1295.617	1958.229	87052304.92

YEARS	Groundwater (IMG)	Surface water (IMG)	Desalination (IMG)	Total (IMG)	GW (%) of Total	SW (%) of Total	DW (%) of Total
1994	186.653	201.01	735.654	1123.317	16.6	17.9	65.5
1995	136.767	143.744	825.360	1105.871	12.4	13.0	74.6
1996	119.011	305.069	927.499	1351.579	8.8	22.6	68.6
1997	237.180	152.64	798.18	1188.000	20.0	12.8	67.2
1998	212.722	109.228	797.887	1119.837	19.0	9.8	71.3
1999	207.031	246.893	950.47	1404.394	14.7	17.6	67.7
2000	174.57	336.041	31500.73	32011.341	0.5	1.0	98.4
2001	249.105	121.799	962.604	1333.508	18.7	9.1	72.2
2002							
2003	215.59	54.055	1312.00	1581.645	13.6	3.4	83.0
2004	266.91	440.66	878.747	1586.317	16.8	27.8	55.4
2005	333.656	472.994	971.474	1778.124	18.8	26.6	54.6
2006	364.92	640.252	756.657	1761.829	20.7	36.3	42.9
2007	312.051	350.561	1295.617	1958.229	15.9	17.9	66.2

9.9.2. Water Resource Projection (Scenario 1)

sole variable for increased supply is DESALINATION				
	2000	**2010**	**2020**	**2030**
Population (increasing 1.2% per year)	75000	84500	95200	107300
Domestic Water (m^3/day)	0.099	0.099	0.099	0.099
Agriculture: water demad	increasing 2 % per year from yr 2000			
Hotels & Commercial: water demand	increasing 1 % per year from yr 2000			
WATER DEMAND PROJECTION (Mm^3/yr.)	**2000**	**2010**	**2020**	**2030**
Domestic, Govt. Institutions	2.71	3.05	3.44	3.88
Ariculture (APUA)	0.40	0.49	0.59	0.73
Ariculture (private dams)	0.60	0.73	0.89	1.09
Commercial & Hotels	1.70	1.88	2.07	2.29
Unaccounted Water - Commercial loses	0.90	0.7	0.6	0.5
Unaccounted Water - Physical loses	1.00	0.5	0.4	0.4
Total Water Demand	**7.31**	**7.35**	**7.99**	**8.89**
WATER SUPPLY PROJECTION (Mm3/yr.)	**2000**	**2010**	**2020**	**2030**
Groundwater	1.15	1.15	1.15	1.15
Surface Water	1.31	1.31	1.31	1.31
Rainwater Harvest (estimated)	0.17	0.17	0.17	0.17
Agriculture (private dams)	0.18	0.18	0.18	0.18
Desalination Water	4.5	4.54	5.18	6.08
Total Water Supply	**7.31**	**7.35**	**7.99**	**8.89**
WATER PRODUCTION COST (US $Million/y	**2000**	**2010**	**2020**	**2030**
Groundwater ($2.5 US/$m^3$)	2.88	2.88	2.88	2.88
Surface Water ($3.0 US/$m^3$)	3.93	3.93	3.93	3.93
Rainwater Harvest	0.00	0.00	0.00	0.00
Agriculture (private dams)	0.00	0.00	0.00	0.00
Desalination Water ($4.7 US/$m^3$)	21.15	21.34	24.35	28.58
Total Production Cost	**27.96**	**28.14**	**31.15**	**35.38**
Average Production Cost ($ US/m3)	5.59	5.63	6.23	7.08
WATER REVENUES (US $Million/yr.)	**2000**	**2010**	**2020**	**2030**
Domestic, Govt., & Institutions ($2 US/$m^3$)	5.42	6.11	6.88	7.75
Agriculture ($2.4 US/$m^3$)	0.96	1.18	1.42	1.75
Commercial and Hotels ($4.9 US/$m^3$)	8.33	9.21	10.14	11.22
Unaccounted Water	0.00	0.00	0.00	0.00
Sale of electricity from gen. plant ($0.05 US/k	0.66	0.72	0.81	0.88
Total Water Revenues	**15.37**	**17.22**	**19.25**	**21.60**
WATER REVENUE - PRODUCTION COST	**-12.59**	**-10.93**	**-11.90**	**-13.78**

9.9.3. Water Resource projection (Scenario 2)

variables for increased supply is GW and SW				
	2000	**2010**	**2020**	**2030**
Population (increasing 1.2% per year)	72300	81000	91600	107200
Domestic Water	0.099	0.099	0.099	0.099
Agriculture	increasing 2 % per year from yr 2000			
Hotels & Commercial	increasing 1 % per year from yr 2000			
WATER DEMAND PROJECTION (Mm³/yr.)	**2000**	**2010**	**2020**	**2030**
Domestic, Govt. Institutions	2.61	2.93	3.31	3.87
Ariculture (APUA)	0.40	0.49	0.59	0.73
Ariculture (private dams)	0.60	0.73	0.89	1.09
Commercial & Hotels	1.70	1.88	2.07	2.29
Unaccounted Water - Commercial loses	1.00	0.7	0.6	0.5
Unaccounted Water - Physical loses	1.00	0.5	0.4	0.4
Total Water Demand	**7.31**	**7.23**	**7.86**	**8.88**
WATER SUPPLY PROJECTION (Mm3/yr.)	**2000**	**2010**	**2020**	**2030**
Groundwater (APUA)	1.15	1.15	1.28	1.42
Surface Water (APUA)	1.31	1.24	1.48	1.72
Rainwater Harvest (estimated)	0.17	0.17	0.28	0.55
Agriculture (private dams)	0.18	0.17	0.32	0.69
Desalination Water	4.5	4.50	4.5	4.5
Total Water Supply	**7.31**	**7.23**	**7.86**	**8.88**
WATER PRODUCTION COST (US $Million/yr.)	**2000**	**2010**	**2020**	**2030**
Groundwater ($2.5 US/m³)	2.88	2.88	3.20	3.55
Surface Water ($3.0 US/m³)	3.93	3.72	4.44	5.16
Rainwater Harvest	0.00	0.00	0.00	0.00
Agriculture (private dams)	0.00	0.00	0.00	0.00
Desalination Water ($4.7 US/m³)	21.15	21.15	21.15	21.15
Total Production Cost	**27.96**	**27.75**	**28.79**	**29.86**
Average Production Cost ($ US/m3)	5.59	5.55	5.76	5.97
WATER REVENUES (US $Million/yr.)	**2000**	**2010**	**2020**	**2030**
Domestic, Govt., & Institutions ($2 US/m³)	5.23	5.85	6.62	7.75
Agriculture ($2.4 US/m³)	0.96	1.18	1.42	1.75
Commercial and Hotels ($4.9 US/m³)	8.33	9.21	10.14	11.22
Unaccounted Water	0.00	0.00	0.00	0.00
Sale of electricity from gen. plant ($0.05 US/kWh)	0.66	0.72	0.81	0.88
Total Water Revenues	**15.17**	**16.96**	**18.99**	**21.60**
WATER REVENUE - PRODUCTION COST	**-12.78**	**-10.78**	**-9.80**	**-8.26**

Chapter Ten

Human Health

CHAPTER 10: HUMAN HEALTH

10.1INTRODUCTION

Health has been defined by the World Health Organization (WHO) of the United Nations as “a state of complete physical, mental and social well being, and not merely the absence of disease or infirmity” (WHO, 1946). This diverse nature of human health is especially significant for an examination of the linkages with climate change as it points to the wide range of impacts that changes in climate can be expected to have on the various factors relating to human health. An assessment of human health impacts is therefore in many ways an analysis of the impacts of climate change on the various geographical areas and socio-economic sectors that constitute the scope of the assessment, as many of the adverse effects of climate change resulting from hurricane and storm activity, warmer temperatures, and sea-level rise can be expected to be manifested in impacts on human health.

In its Fourth Assessment Report (AR4) the IPCC indicates with a high level of confidence that climate change already currently contributes to the global burden of disease and premature death. The report notes that evidence of these changes includes alterations in seasonal distribution of some allergenic pollen species, altered distribution of disease vectors, and increases in heat-wave related deaths[145].

At the global level, important health related problems that can be expected to arise with climate change are an increased incidence of certain types of communicable diseases, increases in cases of heat related mortality and morbidity, and increased damage to health facilities from extreme weather events.

A number of factors pertaining to individual as well as population vulnerabilities influence human health vulnerability to existing climate variability. At the level of the individual, factors directly relevant to health vulnerability include age, disability, gender, educational level and financial resources. At the population, or macro, leveldeterminants of vulnerability to climate change include population dynamics (for example growth rates, population structure, gender), socio-economic conditions (poverty, urbanization, education etc.), and technological capabilities such as sewage systems, water supply, and coastal protection (Bertellini and Menne, 2000). These are also likely to influence responses human health responses to a changing global climate.

[145] See IPCC, Fourth Assessment Repot. Chapter 8 “Human Health”.Confaloniere and Menne (lead authors). 391-431.

Various complexities therefore exist in attempting to isolate climatic from other influences on human health. An additional obstacle to identifying linkages between climate change and human health is that in many instances the availability of data that would allow for study of climate-health linkages are not available. This is so in Antigua and Barbuda where limitations in health and meteorological data exist. The IPCC AR4 also notes that most of the research done on the health impacts of climate change has been conducted in developed countries, with important gaps remaining in information on middle and low income countries.

Among the elements of climate change that can be expected to influence human health, both directly and indirectly, in Antigua and Barbuda are increased temperatures, changes in the frequency and intensity of hurricanes and tropical storms, and changes in precipitation patterns. Direct impacts of relevance to health are likely to include an increase in heat related morbidity and mortality, greater risks of vector borne diseases, and damage to health infrastructure. Indirect impacts can be expected to include impacts on nutrition and food security, increased costs for health care services, and impacts arising from economic and social disruptions.

The following section will attempt to provide an overview of the main characteristics of human health in Antigua and Barbuda, particularly those elements that can be expected to be either impacted by, or to affect, human health under scenarios of future climate change.

10.2 HEALTH CHARACTERISTICS AND TRENDS

10.2.1 Mortality and Morbidity Indicators

The UNDP Human Development Report 2007/2008 indicates that with a ranking of 57 in the global table of countries, an average life expectancy of 73.9 years for 2005, high levels of accessibility to public sanitation and water, and access to immunization and other health services, that Antigua and Barbuda enjoys generally high standards of health indicators and health services. The 2007 Caribbean Development Bank (CDB) report on living conditions in Antigua and Barbuda indicates that approximately 86% of the population was satisfied with health services made available to them[146].

Table 10.1 below indicates the leading communicable diseases affecting the country between 1995 and 2006, and points to the significance of a number of climate sensitive diseases such as acute respiratory infections and gastroenteritis. The data indicates a fairly consistent rate of infections over the eleven year span with no

[146] See "Living Conditions in Antigua and Barbuda; Poverty in a Services Economy in Transition. Volume .Main Report. August 2007. Prepared by Kairi Consultants Ltd in association with the National Assessment Team of Antigua and Barbuda. Caribbean Development Bank.

significant deviations during years of major weather events such as years of hurricane activity or El Nino periods.

Table 10.1 Leading Communicable Diseases 1995 – 2006

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
DISEASES	**No.**	**No.**	**No.**	**No.**	**No.**	**No.**	**No.**	**No.**	**No.**	**No.**	**No.**	**No.**
Acute Respiratory Infection	NA	8397	8067	7869	9120	6291	9081	5888	6024	6264	7652	5483
Gastroenteritis	NA	1616	4754	2728	2959	1643	1771	1743	1527	1763	1363	1781
Influenza	NA	505	522	306	596	94	308	120	291	271	444	252
Impetigo	78	92	164	185	149	109	103	71	86	196	284	120
Food borne Illness	195	109	75	156	174	218	195	209	226	244	210	240
Ciguatera Poisoning	310	237	260	330	209	393	295	276	244	255	192	171
Chicken Pox	198	146	110	172	402	173	239	222	108	202	116	110
Gonococcal Infection	17	35	34	56	41	36	27	40	53	21	10	17
Syphilis	41	51	27	40	92	107	81	72	41	21	16	53

In Antigua and Barbuda, and other CARICOM countries, non-communicable diseases have displaced communicable diseases as the main causes of mortality. Nutrition related chronic diseases such as obesity, diabetes and hypertension, are major contributors to illness, disability and death. Of concern is the fact that while prevalence and mortality are most prevalent in the elderly population, that these are not restricted to any one age group. Table 9.5 provides the main causes of mortality in Antigua and Barbuda and indicates the dominance of malignant neoplasms, heart disease, and diabetes as the consistently three principal causes of death.

Table 10.2 Major Causes of Mortality 2002-2004

	2002	**2003**	**2004**
Cause of Death	**Number/rank**	**Number/rank**	**Number/rank**
Malignant Neoplasms	**77/1**	**73/2**	**103/1**
Heart Diseases	**68/2**	**106/1**	**89/2**
Diabetes Mellitus	**52/3**	**62/3**	**59/3**
Hypertensive Diseases	**38/4**	**35/4**	**34/5**
Cerebrovascular Diseases	**37/5**	**34/5**	**54/4**
Accidental & Intentional Injuries	**25/6**	**18/7**	**30/6**
Diseases of the Digestive System	**24/7**	**12/8**	**16/8**
Diseases of the Respiratory System	**22/8**		
Conditions Originating in Perinatal Period	**18/9**	**12/8**	**18/7**
HIV/AIDS	**9/10**		
Septicemia	**9/10**		
Pneumonia		**20/6**	
Other Endocrine Metabolic Diseases		**12/8**	**11/9**

Source: Health Information Department, Ministry of Health

In Antigua and Barbuda and elsewhere the prevalence of asthma has increased dramatically over the years with this being a phenomenon affecting both developed and developing countries. While uncertainties remain as to the cause of this increase in asthma prevalence, drivers are likely to include environmental/

10.2.2 Existing Health Care Concerns

Existing health sector concerns can be viewed within two principal categories: medical issues and problems; and secondly institutional constraints and problems.

Virtually all of the health issues and concerns facing Antigua and Barbuda are also being confronted by other Caribbean small island States and territories particularly those within the CARICOM group. The Caribbean Cooperation in Health[147] (CCH) programme, developed under the CARICOM framework, provides an indication of the priority health concerns facing Antigua and Barbuda and other Caribbean countries. Priorities identified in the CCH are environmental health, strengthening health systems, chronic non-communicable diseases, mental health including substance abuse, family health, prevention and control of communicable diseases, food and nutrition, and human resource development. Collectively these components represent an integrated and comprehensive framework for health management. Significantly, virtually all of these elements can be expected to be adversely impacted by climate change.

Of particular concern in Antigua and Barbuda and other Caribbean countries are the high rates of non-communicable diseases throughout the region[148], the high rate of HIV/AIDS infection as well as other sexually transmitted diseases, injuries from accidents and crime, and problems associated with environmental health. Particular concerns exist as to the high rates of lifestyle related non-communicable diseases. It is increasingly recognized that the epidemic of non-communicable diseases places severe strains on the health care system in Antigua and Barbuda and the region. In particular, the rising epidemic of obesity is recognized as being of particular concern, increasing risks of cardiovascular disease and diabetes, two of the principal causes of morbidity and mortality. These concerns have prompted health and consumer education by the Medical Benefits corporation, other health agencies, and civic groups.

As noted above, environmental health management presents considerable challenges. Improper disposal of solid wastes and the rapid increase in waste volumes have

[147] Caribbean Cooperation in Health represents an agreed framework for priority action in health cooperation among CARICOM countries. The initiative was first formalized at the CARICOM level in 1986 and targets priority areas of health concern within the CARICOM group. Identification of priorities is a dynamic process involving new areas s these become required. See http://www.caricom.org/jsp/community/regional_issues/health_initiative.jsp?menu=community

[148] In September 2007, CARICOM countries held a special summit of Heads of Government to examine and advance work on non-communicable diseases in the region.

contributed to a situation where waste management represents one of the most immediate and pressing tasks of health managers. This is of particular concern from a climate change perspective given the close linkage between many of the principal climate sensitive diseases and environmental conditions.

The first and most obvious of the institutional set of health care problems relates to financing of health care. Delivery of the range of services provided within such a small population means that per capita health costs are necessarily high. Health sector financing in Antigua and Barbuda consistently exceeds 10% of budgetary expenditures, with PAHO reporting expenditures of up to 14% of budget resources during the latter 1990s[149]. This high percentage of expenditures on health reflects the costs associated with many of the principal causes of morbidity and mortality, demand for services resulting from an aging population, and a growing population including a large immigrant community.

These levels of expenditure represent a considerable strain for any country, and come in a context of high per capita costs in other sectors such as public works and education. Notwithstanding the achievements in provision of health services at primary and tertiary levels, financial constraints means that provision of many health services remains often severely constrained in the delivery of day to day services.

Compounding the problems associated with increasing health care costs is the issue of the aging of the population. It has been noted that the English-speaking Caribbean will have one of the highest rates of aging in the hemisphere. This is complicated by migration patterns as young adults have traditionally emigrated for better economic opportunities while at the same time, older adults return after years of working abroad to retire in their home countries, adding to pressures on local social and health services[150].

Related to the problems of financing, but also reflective of constraints associated with small size, are problems of limited technical capability in many areas. Most acute has been the problems associated with the loss of nurses and other health care professionals through migration particularly to North America and the UK. The recruitment of nurses from Cuba and from other Caribbean countries has been used to ease the critical shortage of nurses in the public health system. Nevertheless, recruitment and retention of nurses and other health care professionals remains a critical problem facing health managers in Antigua and Barbuda.

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[149] See "Health in the Americas: 2002" @ paho.org.
[150] See Matt Loewy "Aging in the Americas" @ http://www.news-medical.net/?id=4432

10.2.3 Conclusion

Despite its small size and limited resources Antigua and Barbuda has been relatively successful in putting into place a relatively comprehensive system of heath care delivery. The extent of the achievement is reflected in the island's high ranking in the UN Human Development Index, a measure of national capability to meet the requirements for sustainable human development in which health concerns play a dominant role. Nevertheless significant challenges remain towards reaching desirable levels of health care in certain areas.

The wide ranging nature of the impacts that can be expected on health from climate change means that many of the achievements in health care could be stressed by climate change. The next section will look at some of the principal impacts that can be expected on human health in Antigua and Barbuda from climate change.

10.3 HEALTH IMPACTS OF CLIMATE CHANGE

10.3.1 Scenarios for Human Health

An assessment of possible future impacts of climate change on the human health condition in Antigua and Barbuda will need to reflect what wider socio-economic parameters relevant to health are likely to be. While it is impossible to predict what future socio-economic and health conditions in Antigua and Barbuda (or elsewhere) will be by the year 2030, official policy statements as well as trends in population growth, environmental alteration, and trends at the wider global level provide indicators as to some of the likely features relevant to the health sector. These include:

- Continued growth in population reflecting both natural increases and increases from migration into Antigua and Barbuda.
- An ageing of the population;
- Continuing difficulties in financing for public health;
- Continuing preponderance of lifestyle associated diseases as major causes of morbidity and mortality;
- Cosmopolitan population reflecting differing cultural and health practices;
- Problems associated with improper solid waste management; and
- Shortages of health care professionals including nurses and technicians.

The following section will examine some of the features of a changing climate that can be expected in Antigua and Barbuda and the potential impacts that these could have on human health.

10.3.2 Warmer Temperatures

The PRECIS and IPCC scenarios for temperature for the Caribbean by 2030 and 2050 envisage increases between approximately 1.5 – 2.0 degrees centigrade in mean temperature. While heat stress is not presently identified as a major source of morbidity or mortality in Antigua and Barbuda, this situation could be altered with average temperatures in the mid to high 90 degrees Fahrenheit (30-33 degrees centigrade) ranges. This would be particularly so for certain high risk groups that would include the elderly, persons with cardiac and respiratory problems, persons working outdoors engaged in strenuous activity, and persons living and/or working in poorly ventilated areas. Given the significance of cardiac problems within the existing health profile, temperature increase could constitute a major climate change related problem. Additionally the aging of the population could compound this as the present youthful demographic picture gives way to one with a greater balance between young and old.

An article on the WebMD web-site points to some of the medical complications relating to elevated temperatures and their interplay with social factors to aggravate the adverse health effects of higher air temperatures in the USA. In addition to physiological effects such as heat stroke, cramps and exhaustion, the article notes that extreme heat also tends to negatively affect human behavior[151] resulting in increased household and workplace accidents as well as incidents of road rage.

In Antigua and Barbuda increasing trends towards urbanization are likely to intensify negative impacts from temperature rise associated with climate change, as this process generally tends to result in the establishment of dense, poorly ventilated settlements in low to middle income communities. In most instances persons in low-income communities are further at risk by being unable to afford adequate artificial cooling and are also unable to access information on how best to respond to the impacts from temperature rise associated with climate change.

Higher air temperatures are also generally favorable to a number of bacteriological and epidemiological agents. One likely outcome of higher temperatures is increased spoilage of food with consequent implications for household, institutional and commercial food preparation and storage. Again these problems can be expected to be more severe for low-income communities and individuals unable to afford adequate cooling facilities. Certain vectors particularly rodents and mosquitoes are also able to adapt to, and even thrive in, warmer conditions, further increasing the possibility for the spread of various communicable and infectious diseases.

[151] Martin Downs "Surviving Summer Scorchers". At **http://my.webmd.com/content/article/1738.55027**. Originally published July 15, 2002.

Pathogens are often found in coastal waters particularly where there is inadequate disposal of sewage and other wastes. Higher ocean temperatures encourage the proliferation of micro-organisms in coastal waters. This would have implications for Antigua and Barbuda where disposal of wastes into the marine environment continues can present problems for coastal water quality in some areas particularly after periods of heavy rainfall. Additionally certain bacteria that occur naturally in sea-water are believed to be more often transmitted to humans in conditions of warmer sea surface temperatures (IPCC TAR).

In Antigua and Barbuda the problem of ciguatera poisoning is an important health concern relating to the consumption of fish caught in surrounding waters. CAREC reports that Antigua and Barbuda accounted for 41% of the 331 reported cases of ciguatera poisoning in CAREC member countries[152]. This is of concern sine the presence of even small amounts of ciguatera can result in severe illness including neurological damage and even death. Findings from Pacific island countries during ENSO periods indicate a distinct correlation between ciguatera and warmer sea temperatures: additional research will be required to determine whether such links also exist for Antigua and Barbuda and other Caribbean countries. Table 9.6 below indicates the cases of ciguatera poisoning in Antigua and Barbuda for the 1995 to 2006 period, indicating no obvious correlation between and any pattern of weather events.

The most significant of the vector borne diseases to affect Antigua and Barbuda is dengue fever which is endemic to the Caribbean, including since the early 1980s the dengue haemmorhagic fever which may lead to death. Dengue fever is caused by the domesticated *Aedesaegypti* mosquito which thrives in urban environments and breeds in artificial containers that hold water. Temperature affects the rate at which the virus develops inside the mosquito and increases in incidence are often associated with warmer more humid temperatures. Four dengue viruses produce disease in humans and the incidence is largely seasonal. The social determinants of dengue risk include high human population densities and unplanned urbanization. Houses that are not screened, blocked drains and uncovered water storage containers create habitats for the mosquito.

[152] See CAREC Annual Report 2007

Table 10.3 Ciguatera Poisoning Cases 1995 – 2006

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	No	No	No	No	No	No	No	No	No	No	No	No
Ciguatera Poisoning	310	237	260	330	209	393	295	276	244	255	192	171

Chen *et al* point a link between periods of high incidence of dengue fever and El Nino climate episodes. The findings indicate that 'during the El Nino years in the Caribbean, drier than normal conditions occur, with increases in air temperatures in the latter half of the year, leading to the need for domestic water storage" and thereby providing enhanced conditions for breeding of the mosquito. Chen indicates that "although socio-economic conditions factors must also be considered, the sharp rise in the incidence of DF (dengue fever) from 1991 onwards may be related to increases in minimum temperatures". This would suggest that warmer temperatures under a future climate will provide enhanced opportunities for breeding of the AedesAegypti with consequences for dengue transmission.

10.3.3 Hurricanes and Extreme Weather

Globally, disaster occurrence and loss associated with climatic events has increased dramatically in recent years and particularly since the mid 1990s[153]. This trend is consistent with IPCC projections for changes in extreme weather.

Antigua and Barbuda is already particularly prone to hurricanes and risks arising from hurricane and storm activity are likely to represent one of the most significant health impacts of climate change. These will comprise a varietyof impacts such as physical damage to property and persons, enhanced opportunities for breeding of mosquitoes andothervectors,as well as damage to health facilities. Other health effects arise from secondary economic and social impacts.

[153] While the number of reported disasters associated with geophysical events such as volcanic eruptions and earthquakes has remained relatively constant, those associated with hydro-meteorological events such as floods, drought, forest fires and storms have demonstrated a curve of exponential growth. A. Lavell (editor) Report of UNDP Expert Group Meeting on Integrating Disaster Reduction with Adaptation to Climate Change. Havana. June 19-21, 2002.

In Antigua and Barbuda Hurricane Hugo in September 1989 destroyed or damaged over two thousand houses, resulted in the death of two people, injured four hundred persons and caused an estimated EC$36 million damage. In 1995 Hurricane Luis destroyed or damaged an estimated 6144 homes, killed two (2) people and caused an estimated EC$275 million dollars damage (Maskrey, 1997). Damage from hurricanes Georges in 1998, and Jose and Lenny in 1999 also resulted in various health related effects and impacts including deaths and injury.

One major impact of hurricanes is in relation to damage to health facilities and infrastructure. The Holberton Hospital was damaged in 1995 by Hurricane Luis reportedly reducing the number of beds available from 200 to 135 after the storm. While the facilities have remained functional, the buildings are old with increasing risk of damage fromstorms and hurricanes. Most of the country's health centres have generally been able to resume operations relatively rapidly following storms, with most receiving only limited structural damage. However, the risks posed to medical facilities from hurricanes was shown in the impact of Hurricane Ivan in 2004 on Grenada, with the Category 4 storm causing extensive damage to that island's main hospital, and exacerbating the problems of health care delivery after the hurricane.

The health impacts of hurricanes include:

- Physical injury (including from pre and post disaster activities).
- Decreases in nutritional status especially in children following the storm.
- Increases in respiratory and diarrheal diseases resulting from crowding of survivors, often with limited shelter and access to portable water.
- Impacts on mental health.
- Increased risk of water related diseases as a result of disruption of water supply or sewage systems.
- Release and dissemination of dangerous chemicals from storage sites and waste disposal sites into floodwaters.
- Increased risk of diseases from contact with rodents and other disease vectors.

Most deaths, injuries and damages arise from water related incidents. Flooding associated with hurricane and storm activity has immediate and medium term health effects. Immediate effects include deaths and injuries caused by drowning and by being swept against hard objects. Medium term effects include increases in communicable diseases such as those caused by ingestion of contaminated water (e.g. cholera, hepatitis A), contact with contaminated water (e.g. leptospirosis), and respiratory diseases resulting from overcrowding in shelters. Where there is inadequate response many of these problems can become long term.

Hurricanes generally result in increases in vector borne diseases for a number of reasons. In terms of rodents, destruction of property and damage to the environment tends to create conditions ideal for foraging as well as disrupting their habitat, increasing the possibility for the spread of disease. One potentially significant problem in this regard is leptospirosis a potentially fatal disease spread from the urine of infected rodents. This emerged as a significant health concern in areas of Central America in 1998 following the devastation caused by Hurricane Mitch. Enhanced storm activity associated with climate change will make conditions favourable for the spread of the disease both in those areas where it is already endemic and in new areas such as Antigua and Barbuda through travel from endemic areas and by propagating conditions for its spread. The increased incidence of rodents in St Johns and its environs has already been noted above, increasing the risks of spread of disease from this source.

In the case of mosquitoes, increased rainfall associated with storm activity can enhance the potential for breeding including malaria and dengue bearing insects. For dengue, an assessment of epidemic potential conducted for Antigua revealed no historical linkage with hurricane/tropical storm activity. The analysis did however indicate that dengue transmission was affected bytemperature and rainfall patterns in Antigua, and consequently could be expected to be adversely impacted by climate change (O'Marde and Michael, 1997).

Findings from studies conducted in Trinidad and Tobago based on data collected for ENSO years and the years immediately following an ENSO between 1986-2000 have also revealed a link between rainfall and upsurge in dengue fever. The strongest effect was observed for 1998, the year following the ENSO event. It was suggested that improper water storage during ENSO years enhanced breeding of the vector. High rainfall periods subsequent to the ENSO years provided conditions for larval development of the mosquito vector. Temperature was also seen as a factor because of the influence on the breeding cycle of the mosquito vector (Rawlins,2002[154]). This would appear to be consistent with findings from island communities in the Pacific where positive relationships between ENSO and dengue have also been observed.

Eradication programmes for malaria over the years have been successful in eliminating this disease from Antigua and Barbuda and these efforts are likely to be continued. However there is likely to be increasing possibility of importation of the disease as warmer temperatures in Europe and North America allows the disease to spread into areas not previously at risk.

[154] Rawlins S. "How Climate Impacts on the Occurrence of Dengue Fever: A Fifteen Year Retrospective Study of Correlation of Dengue Fever and Rainfall in Trinidad and Tobago".

10.3.4 Drought

Globally the principal health impacts of drought occur via impacts on food production. Additionally, in times of shortage water is used for cooking rather than personal hygiene with the consequent risks of diarrheal infections and hygiene related diseases such as scabies.

Drought has historically been a principal feature of the climate of Antigua and Barbuda. This situation spurred the installation of a desalinization facility in the 1980s that has now become the cornerstone of the country's water supply system. It is likely that intensified drought conditions as a result of changes in climate will amplify existing problems associated with water scarcity. As noted above diarrheal diseases already account for significant recorded levels of morbidity and these would likely increase under scenarios of reductions in water supply.

The drought of 1983 - 85 adversely affected the agricultural and tourism sectors, resulting in the need to import water from Dominica and ultimately leading to the establishment of a desalinization plant on Antigua. More recent impacts of drought on the national economy are difficult to ascertain given the existence of the desalinization plant. However many areas, particularly Barbuda, continue to be adversely affected by disruptions in water supply resulting from drought. Desalinization has of course increased the costs of water production.

One response associated with drought conditions is the increased storage of water due to scarcity of supply. This has potential for the creation of conditions conducive to the breeding of mosquitoes where the water is not properly stored. Dengue fever, for example, is carried by the domesticated mosquito *Aedesaegypti.* This mosquito thrives in urban environments and breeds in artificial containers that hold water.

The data on communicable diseases at Table 9.1 above indicates a high proportion of diseases that can be exacerbated by drought conditions under scenarios of climate change. This is of particular concern for certain vulnerable groups such as the elderly, infants, and persons with a number of pre-existing medical conditions.

Drought conditions can also intensify the prevalence of wind borne contaminants. Health implications of drier conditions include asthma, allergic rhinitis, sinusitis and other ailments of the respiratory system. In the case of asthma, recent years have seen an increase in the incidence of this condition in Antigua and Barbuda and the Caribbean and any intensification of this condition due to climate change is likely to affect a significant number of persons and place additional stresses on available health care services. Respiratory conditions already represent one of the principal causes of illness across all age groups and the intensification of drought conditions as projected by IPCC and PRECIS models point towards climatic conditions that would increase the likelihood of respiratory illnesses.

10.3.5 Sea Level Rise

Sea-level rise is not expected to have any significant direct impacts on human health in Antigua and Barbuda. There will however likely be significant impacts in terms of damage to residences and buildings, resulting in displacement of persons and subsequent health impacts associated with emergency shelter conditions, as well as more long term impacts associated with population resettlement. In Barbuda low lyingtopographic conditions means that a range of health related services and facilities could be affected by sea level rise and storm surge scenarios.

10.3.6 Nutrition and Well-Being

Possibly as significant for human health under the available scenarios for climate change for Antigua and Barbuda will be changes in health conditions arising from impacts felt in areas such as water supply, agriculture, and human settlements. At the same time, reflecting the complexity of the climate-health linkage, these impacts are likely to be even more difficult to quantify at this stage. Nevertheless it is important that these be identified and that some measure of adaptation be introduced.

Given the country’s dependence on imported foods, the state of global agriculture is likely to be as significant for the state of nutrition and health in Antigua and Barbuda as is the impact on local agriculture. The IPCC’s TAR and AR4 reports indicate that food production of certain crops is likely to increase in mid to high latitudes and then to decline. For lower latitudes, agriculture is likely to be generally adversely affected by global climate change.

While uncertainties necessarily exist as to the extent and nature of such changes, firstly globally and then more specifically for Antigua and Barbuda, there is general expert consensus that issues of food insecurity are likely to be exacerbated by climate change. The IPCC AR4 notes that “due to the very large number of people that may be affected, malnutrition linked to extreme climate events may be one of the most significant consequences of climate change”. For Antigua and Barbuda this could mean a situation where shortfalls in production due to extreme weather events major food producing countries and regions is adversely affected by extreme weather events, causing supply disruptions to Antigua and Barbuda and other markets. Such disruptions to international trade in food could be expected to have adverse consequences for Antigua and Barbuda with consequent health effects for nutrition and well being.

10.3.7 Global Environmental Change

Climate change is proceeding at a global level, producing a range of impacts that have health impacts at national, regional and global levels. For example the IPCC AR4 report notes that exposure to ultra-violet radiation is likely to be affected by climate change. Among the impacts of this could be effects on the human immune system. Altered and disrupted ecosystems as a result of a changing climate are projected to affect migration of birds with possible implications for the movement of disease.

At the global level, expanding desertification and drought conditions in Africa associated with climate change are likely to be already influencing human and ecosystem health in the Caribbean. West African sand storms are transported by winds over the Altantic Ocean to the Caribbean particularly between the summer months, although clouds of African dust can be seen outside this period.

Studies conducted in Barbados and the US Virgin Islands indicate the presence of microbes and spores in the transcontinental movement of African dust into the eastern Caribbean[155]. The one year Barbados study also pointed to a correlation between the presence of spores in the African dust and asthma cases in Barbados. Similar findings of the impacts of the dust on asthma have been reported for Trinidad where tests have also revealed the presence of harmful pesticides in the dust particles[156].

Projections for climate change in Africa point to a continuation, if not intensification, of the ongoing processes of desertification. This is likely to mean continuing, and possibly accelerated, adverse impacts on human health and natural ecosystems in Antigua and Barbuda and the Caribbean. Notably cardiovascular and respiratory diseases, and which are likely to be affected by the African dust, already comprise major sources of mortality and morbidity, thereby adding to the health burden of climate sensitive diseases under the IPCC and PRECIS scenarios for climate change in Antigua and Barbuda.

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[155] See C. Kellogg. Characterization of Microbial Communities Associated with African Desert Dust and Their Implications for Global Human and Ecosystem Health. PAHO 2002. Also see E. Blades "The Transport of Soil Dust and Microbes from Africa and Their Relationship to Asthma in Barbados". PAHO 2002.

[156] See Trinidad Express newspaper May 12th 2008.

10.3.8 Conclusion

The potential impacts of climate change on health identified above will represent additional stresses on already stretched financial and human resources available to the health sector as well as causing increased misery and distress at the individual and family level.

For Antigua and Barbuda the range of health related impacts is wide and includes both direct impacts from changes in temperature, rainfall, and tropical storm/hurricane activity, as well as indirect impacts emanating from stresses in other sectors that may give rise to health problems. Of concern is that many of the existing primary health care problems are likely to be adversely affected by projected changes in weather patterns.

The next section seeks to identify some of the key measures that may be taken to minimize, and possibly avoid, some of these anticipated impacts.

10.4 ADAPTATION IN HEALTH

10.4.1 Overview of Health Adaptation

The World Health Organization (WHO) has identified two overarching and integrated themes for human health adaptation to global climate change. These are:

- Putting health at the heart of the climate agenda, and
- Strengthening public health systems.

In relation to the first thematic area, the WHO report notes that "protection from climate change is part of a basic, preventive approach to public health, not a separate or competing demand". The report points out that actions required for addressing many existing health concerns, such as disease vector eradication and the provision of sanitation services, are likely to have positive effects in reducing overall vulnerability to climate change.
The table below identifies a number of adaptation measures for health.

Table 10.4 Health Sector Adaptation Responses

Health issues	Legislative options	Technical options	Educational and Advisory	Cultural and behavioral
Extreme weather events	New planning laws New building guidelines	Urban planning Air conditioning	Early warning systems	Appropriate clothing Storm shelters
Air quality	Emissions controls	Improved public transport	Pollution warnings	Car-pooling

	Traffic restrictions	Tall chimneys Catalytic converters		
Vector borne diseases	Environmental health regulation and enforcement	Vector control Vaccination Impregnated bed-nets	Health education	Greater care with water storage
Waterborne diseases	Watershed protection Water quality regulation	Genetic/molecular screening of pathogens Improved water treatment and sanitation	Boiling of water campaigns	Washing hands and other hygiene measures.

UNFCCC (2006) Technologies for Adaptation to Climate Change

Table 10.7 above indicates the wide ranging nature of adaptations required if health impacts of climate change are to be minimized. This is not surprising as health impacts are reflective of the impacts of climate change in other areas and sectors. If these individual measures for adaptation are to be successful there will be the need for a focus within the health sector aimed at providing an overall policy framework conducive to advancing health sector adaptation to climate change. The following three inter-related areas of focus are priority areas for attention.

10.4.2 Enhanced Technical and Public Awareness

Perhaps the most basic adaptation need is for enhancing awareness of the changing climate among health sector personnel, as well as among the wider public. In terms of the general public, health information is already effectively transmitted on a number of priority health concerns using various forms of media. There will now be a need for including health-weather linkages into the information content going to the public.

All adaptive measures are dependent on the existence of adequate levels of awareness among stakeholders that will enable them to understand the linkages between health and medical concerns and the linkage to weather and climatic parameters. For medical personnel, awareness and sensitization needs will range from in-depth exposure to technical concerns such as modelling of vector behavior in a warmer world, to a greater understanding of climate-health linkages and a greater appreciation for atmospheric conditions as a focus of health care.

10.2.3 Strengthened Environmental Health Capability

Many of the health impacts of climate change will be affected by, and will themselves affect, environmental health and public sanitation conditions. For example, the risks associated with enhanced conditions for vector borne diseases arising from changes in rainfall and temperature patterns will manifest themselves at the community level, where the primary responsibility for enforcing health and sanitation is with public health inspectors. In some instances the risks associated with health and climate change are likely to be able to be mitigated through existing health control and planning measures. In other instances enhanced capabilities may be required to cope with the conditions arising from changes in climate.

As noted above, environmental health already presents significant challenges for health managers, particularly problems associated with improper and inadequate solid waste disposal, which itself has implications for the spread of vector borne diseases, blocking of drainage and flooding during heavy rainfall events: all problems that will be exacerbated by projections for a warmer and less stable atmosphere. Similarly, issues associated with liquid waste disposal will be exacerbated by projections for a long term trend towards drier conditions, as well as warmer temperatures. This will affect various aspects of the environmental health portfolio including existing concerns ranging from food-safety to various sanitation related diseases. Enhancing awareness among environmental health inspectors will be crucial since many of the possible adverse health impacts of climate change will manifest at that level, and with environmental health workers being at the front line of health management response in those areas.

Environmental health also has significant implications, for and linkages with, the issues of development control. This has at least two perspectives. Firstly, the use of development guidelines will be required to ensure that buildings and other infrastructure are designed to meet health standards and appropriate best practices that may be necessitated by a changing climate. There may for example be changes in requirements for liquid waste management in coastal areas, such as for hotels, in the context of rising sea-levels and more intense storm surge activity associated with changes in hurricane frequency and intensity. Secondly, there is the need for increased use of development control as a planning tool to ensure, for example, that physical developments do not exacerbate problems of flooding, heating and other health related risks associated with climate change.

These increasing responsibilities for environmental health managers point to the need for strengthening the national capability to manage this function. Such strengthening will require:

- Increased numbers of health inspectors and sanitation workers.
- More specialized sensitization and training for technical public health officials in aspects of environmental monitoring and in weather-disease linkages.
- Review and strengthening of environmental health regulations to provide for greater inspection, monitoring and enforcement capabilities.

- Greater capability for scientific testing and analysis.

Environmental health workers already play a central role in management of many of the critical public health parameters. Climate change, with its adverse impacts on many aspects of the natural environment, is likely to add stress to already burdened ecosystems and public health systems. Environmental health workers will have a critical role in advancing public health adaptation to climate change as a proactive measure for ameliorating many of the potential elements that would increase vulnerability to adverse health consequences of climate change.

10.5 SURVEILLANCE AND MONITORING

Table 10.4 below provides a summary of data needed to monitor some of the impacts of climate change.

Table 10.4 Climate Change Data Needs for Health

Health Impact	Data Needs
Changed seasonal patterns of diseases	Primary health care morbidity data, hospital admissions, emergency room attendance
Marine ecosystems	Phytoplankton and pathogen sampling; epidemeology of cholera, shellfish poisoning
Emerging diseases	Population based time series; identification of "new" diseases
Heat stress	Daily morbidity and mortality, cardiorespiratory diseases. Clinical data. Air pollution data
Malnutrition/food supply	Population nutritional status; agricultural pest and disease resistance
Vector borne disease	Primary health care data, local field surveys, communicable diseases surveillance centres
Diseases/sickness related to weather extremes	Mortality, morbidity, surveillance data; data on impacts of disasters

Adapted from Bertollini and Menne (2000)

10.5.1 Reducing Vulnerability of Health Infrastructure

It is almost always the case that, when struck by large-scale natural disasters, hospital services are interrupted temporarily or permanently, mainly due to damage to their infrastructure. The operational loss of these facilities signifies more than the loss of the capital investments. Equally importantly, it has a major negative impact on the wellbeing and the socioeconomic development of the population and the country. Projections for global climate change suggest that increased frequency and intensity of hurricanes may become a prominent feature of the Caribbean regional climate.

Table 10.5 below provides information on hurricane damage to hospitals and health facilities in the region during the destructive 1998 Atlantic hurricane season.

Table 10.5 Hurricane Damage to Hospitals and Health Centres

Location and event	**Nature of the Phenomenon**	**Overall effects**
Jamaica, Hurricane Gilbert	Category 5	Twenty-four hospitals and health centres damaged or destroyed. Over five thousand (5085) beds lost.
Costa Rica and Nicaragua Hurricane Joan	Category 4	Four hospitals and health centres damaged or destroyed.
Dominican Republic, Hurricane Georges	Category 3	hospitals and health centres damaged or destroyed.
St. Kitts and Nevis Hurricane Georges	Category 3	hospitals and health centres damaged or destroyed.
Honduras Hurricane Mitch	Category 5	hospitals and health centres damaged or destroyed.
Nicaragua, Hurricane Mitch	Category 5	hospitals and health centres damaged or destroyed.

In Antigua and Barbuda impacts arising from the passage of hurricanes and tropical storms are likely to represent one of the principal risks to provision of health services given the destructiveness of these events. As noted above damage to Holberton Hospital from Hurricane Luis caused extensive damage to that facility. The Pan American Health Organization (PAHO) notes that public health infrastructure which has been specifically designed to reduce vulnerability to climate variability will play an important role in enhancing adaptive capacity to climate change.

At the international level increasing attention is being focused on the issue of protection of hospital facilities from natural disasters. The UN's International Strategy for Disaster Reduction (ISDR) has adopted hospital safety from disasters as the theme for the 2008-2009 World Disaster Reduction Campaign. Organized within the context of the ISDR's Hyogo Framework for Action this campaign will take up one of the Hyogo frameworks priority areas of integrating disaster risk reduction planning into the health sector and promoting safe hospitals[157].

For Antigua and Barbuda meeting the goal of having hospitals safe from disasters – an ambitious, long-term undertaking involving structural modifications and human resource development – will require political commitment and financial resources. Improving resilience implies improving the structural resilience of health facilities (new or existing); reducing the risks to non-structural elements (such as water heaters, storage tanks, mechanical equipment, shelving, cabinets etc.) so as to facilitate the delivery of services and ensuring that the health workforce is well prepared to respond to the challenges generated by the disaster. To achieve overall resilience, multiple stakeholders and disciplines must be involved: from managers to engineers and architects; from emergency room physicians to the primary health care providers.

10.5.2 Regional and International Cooperation in Health.

As identified above, a critical element of adaptation for human health in Antigua and Barbuda will involve regional and international cooperation. Antigua and Barbuda does not have the technical and financial resources for adequately addressing many of the scientific elements of strengthening health capabilities for adaptation to climate change. Furthermore a number of regional and international agencies – notably the University of the West Indies, CAREC, PAHO, and CEHI – already exist, which can and do provide technical and specialist services in areas related to the impacts of climate change. Regional health cooperation will also be essential for facilitating information exchange on diseases and other health impacts associated with climate change, again highlighting the need for adequate systems of national health monitoring and reporting[158].

A potentially significant role would seem to exist for CAREC given its three main technical areas of laboratory services, epidemiology, and public health programmes – all elements of health care that will require increasing attention as a result of global climate change. Already CAREC's focus is on a number of the areas that are identified as likely to be most affected by climate change such as vector control, and certain non-communicable and communicable and food borne diseases. Similarly other technical agencies such as regional universities and the Caribbean Environmental Health Institute (CEHI) should be urged and encouraged to support research and capacity building relevant to reducing risks associated with climate

[157]PAHO/WHO has developed guidelines and approaches for reducing vulnerability of health institutions to natural disastersand a number of countries have been able to implement policies for reducing the vulnerability of theses structures.

[158] The 2007 Annual Report indicates the low level of on time reporting to CAREC of most Caribbean countries, including Antigua and Barbuda.
See www.carec.org/pdf/2007-Annual-Report/ANNUAL_REPORT_2007.PDF

change and health in Antigua and Barbuda and the Caribbean. This is particularly important given the limited scientific and medical research done to date of health impacts of climate change in tropical island settings.

10.6 CONCLUSION

Various social, technological, demographic, cultural and environmental factors directly and indirectly influence human health. Climatic influences are important determinants of health the effects of which are integrated with other wider influences. What is critical is the need to recognize that climate change is likely to be a dominant force affecting future social and economic development.

Small island States like Antigua and Barbuda are recognized as among the most vulnerable communities to climate change. Expected increased temperatures, more intense storm activity, and droughts will have wide ranging health impacts. Existing patterns of morbidity and mortality along with the country's demographic profile present risks for intensification of various chronic and other diseases. Problems of environmental management, particularly solid waste, present existing challenges some of which are likely to intensify with climate change.

High priority must now be paid to incorporating climate change concerns more firmly into national health policy. Among the measures required in this regard are increasing technical and public awareness of health-weather linkages, strengthening environmental health management, and enhancing health information capabilities. Critical to the success of these measures is regional and international cooperation.

Chapter ELEVEN

Priority actions

CHAPTER 11: PRIORITY ACTIONS

11.1CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

The foregoing sectoral assessments point to the significant adverse impacts which scientific projections for global climate change would have on Antigua and Barbuda. With an official population of less than 90,000 persons and an economy dependent on tourism and services, the country is vulnerable to the vagaries of the international economy as well as to a range of natural disasters both climatic and non-climatic.

While having achieved significant positive milestones in areas such as health, education, and access to basic services, as a small island developing State, Antigua and Barbuda remains highly vulnerable to international economic forces beyond its influence or control. Antigua and Barbuda also already presents high risks to droughts and hurricanes. While substantial adaptations have been developed over time to cope with these climate stresses, there is concern that the type of impacts associated with future climate change will severely stress existing capacity.

Although climate change can be expected to result in a multitude of impacts on Antigua and Barbuda there are many uncertainties involved in projecting the magnitude and specific nature of these impacts. These uncertainties arise from uncertainties surrounding the rate and effect of greenhouse gas emissions, as well as by the level of climate sensitivity of the affected area. Specific predictions are therefore not possible and this presents problems for decision makers and policy makers faced with existing stresses and requirements, while at the same time ensuring sustainable management of limited natural resources.

11.2IMPACTS AND ADAPTATIONS

A review of the potential impacts of climate change reveals that a number of the existing vulnerabilities to current climatic conditions experienced by Antigua and Barbuda are likely to be exacerbated by many of the projected changes in regional and global climate. Across all sectors, a number of adverse impacts are likely to be felt, influenced by such critical climatic parameters as temperature, rainfall, and extreme events.

All of these principal features of a changing climate for Antigua and Barbuda can be expected to impact adversely on the country's coastal and terrestrial resources and ecosystems, and equally significantly on its economic performance. For example, coastal erosion, linked to storm activity but also independent of it, currently impacts negatively on beaches as well as the built structures – homes, tourist establishments, roads, public infrastructure, and commercial establishments – that are to be found in these areas. In many instances current practices and actions increase vulnerability to present and projected climate change.

All of these factors will present challenges for Antigua and Barbuda achieving sustainable levels of development. The wide ranging nature of the impacts requires a strategic approach to risk reduction and adaptation that focuses on building capacity at all levels to be able to respond to climate change[159]. It is important to realize that it may not be possible to fully adapt to certain elements of changing climatic conditions. In that context, emphasis should be on risk reduction i.e. reducing the level of exposure of the sector or area to current and projected climate.

In many cases autonomous adaptations will take place requiring very little intervention by governments. However there are also likely to be many instances where autonomous action will not occur. Reasons for this include limited understanding of climate change effects, cultural and other constraints, and inadequate technical and financial resources for effecting risk reduction and adaptation measures. Against this background, governments will have a critical role in:

- Providing information to decision makers at all levels.
- Providing technical and financial resources for adaptation and risk reduction efforts.
- Ensuring that adaptation and risk reduction policies and measure are consistent with wider social, economic and environmental goals, and
- Actions to protect government investments in infrastructure, buildings etc.

Limited technical and financial resources and common problems means that Antigua and Barbuda should attempt to cooperate with neighboring States in responding to challenges presented by climate change[160]. This might include measures such as cooperation in research and the sharing of technical personnel. In any event Antigua and Barbuda must also lobby consistently at international and regional forums for strong international action to mitigate and adapt to climate change. Ultimately, action to attempt risk reduction and adaptation in Antigua and Barbuda will be

[159]The UNDP Adaptation Policy Framework provides methodological guidance for developing strategies for climate change risk reduction and adaptation.
[160]The Caribbean Community Climate Change Centre based in Belize provides the institutional base for cooperation on climate change at the Caricom level. The Centre has developed various tools for suporting risk management and vulnerability to climate change in the Caribbean.

meaningless unless there is a global commitment to meaningfully reduce the global atmospheric pollution that causes climate change.

11.3 PRIORITIES FOR ADAPTATION AND RISK REDUCTION

The pervasive nature of the likely impacts of climate change means that the optimal adaptation approaches are likely to be those that are anticipatory and facilitate inclusion of adaptation. In this regard three strategies can be identified to enable integration of climate change adaptation concerns into development activities[161];

I. Incorporating climate change concerns into new development proposals;
II. Developing proposals that are specifically aimed at climate change risk reduction and adaptation.
III. Developing proposals for strengthening institutional and technical capacity for climate change response.

Incorporating climate change considerations into development activity is critical for a number of important reasons. Firstly, there will be continuing pressure for development activity. Development decisions taken now need to incorporate climate change considerations if the projects are to be sustainable. This is particularly so for projects involving significant transformations to the physical environment. The extent of land transformation that has already occurred in Antigua has compromised the vulnerability of coastal and terrestrial areas to certain types of climate risks.

There are three types of proposals that can be considered in terms of climate change risk reduction and adaptation. The first type involves primarily development projects such as infrastructure, housing, tourism, and agriculture. The second type of project involves initiatives developed specifically for climate change. These include coastal protection, development of drought tolerant crops and animals, and reforestation projects. The third type of project involves policies and measures for strengthening national capacity for responding to the various effects of climate change. This should involve institutional development, climate science monitoring and training, technical awareness and training, and public awareness.

Public awareness will be the critical factor in determining the success or otherwise of risk reduction efforts. This must be seen as an ongoing process, much of which will be autonomous of official efforts. Stakeholder involvement and participation in risk reduction and adaptation response will also be critical. Ultimately, meaningful adaptation to the projected impacts of climate change will require that policy

[161] Extracted from "Climate Change Adaptation; Incorporating Climate Change Adaptation into Development Activities in Pacific Island Countries". SPREPP. Western Samoa.

makers in private and public sectors, as well as the general populace, are attuned to the sustainability concerns that will arise as a result of a changing climate.

Chapter TWELVE

IDENTIFICATION OF REASEARCH GAPS AND CONCLUSIONS

CHAPTER 12: IDENTIFICATION OF RESEARCH GAPS AND CONCLUSIONS

12.1. INTRODUCTION

The Caribbean is identified as one of the regions of the world that would receive the full brunt of the effects of climate change. Most of the countries are micro Island states with economies dependent on one or two main industries, fully vulnerable to the effects of climate change. Inspite of this, none of the governments have begun to focus on the full reality of the likely impacts of climate change. As a consequence very little work has been done in identifying gaps in knowledge on the impact of climate change on the region or on individual countries and adaptation options that are critical in minimising any harmful effect.

Most island States have been carrying out their own research work , seeking to navigate the complex international research financing community, addressing their own individual island interest and priorities. Since climate change projections are generally similar for most of the islands in the Caribbean there has been some duplication and fragmentation of research effort compounded by difficulties of information and data sharing.

12.2. STRATEGIC REGIONAL RESEARCH AGENDA

The first most important issue which therefore needs to be tackled and resolved is a strategic regional research agenda to fill the gaps in knowledge on the impact of climate change and best adaptation measures. Clearly the technical and financial resource limitations of the countries in the region, the absence of critical mass and economies of scale in national research efforts, make a regional strategic research agenda vitally important in quickly filling the gaps in knowledge of climate change impact on the region...

The development of a regional strategic research agenda and rationalization of research across the islands and territories in the Caribbean has seen the initiation of regional efforts, first in the establishment of the Caribbean Center for Climate Change base in Belize and the establishment of the UWI MONA Jamaica climate change group and the establishment of three teams of scientists appointed to carry out extensive research on climate change scenarios and modelling coastal, marine and terrestrial biodiversity in the region.

In March 2007 The Caribbean Natural Resources Institute (CANARI) launched the Climate Change and Biodiversity in the Caribbean (CCBIC) Project, which is funded by the John D. and Catherine T. MacArthur Foundation. The project focuses on increasing understanding and consensus on what is known, and perhaps more importantly what is not known, about the predicted climate change trends and their impact on biodiversity in Caribbean small island developing states. The goal is to develop a regional research agenda and capacity needs assessment to address identified gaps and to consider how protected area management, biodiversity protection, and conservation policy might address climate change in the region. Three working groups, focusing on coastal and marine biodiversity; terrestrial biodiversity; and the development of climate change scenarios and models, were convened to undertake the research required to assess the state of knowledge of the expected impacts of global climate change on Caribbean biodiversity, and to identify the gaps in our knowledge and the research required to fill these gaps. The findings derived from this research effort of the climate change and scenario working groups have given much of the region and country specific data on the effects and impacts of climate change...

This strategic regional research agenda must reflect a focus on the economic, social and biodiversity underpinning of these countries. In April 2008 regional scientists meeting in Kingston Jamaica identified gaps in existing capacity in the region to deal with the effects of climate change and outlined a program of work to correct those deficiencies.

The preliminary agenda urges action on the following:

- Facilitating community involvement in the research process
- Fostering linkages between biodiversity conservation and traditional use
- Researching how to establish a regional system of protected areas that facilitate effective biodiversity conservation and sustainable livelihoods under climate change and variability, -Research that moves from generating climate scenarios to projected impact on ecosystem services including socio economic valuations.
- Developing protocols and agreements for data sharing and access,
- Developing a Caribbean climate atlas investigating how key species will respond to change in temperature.
- Research on how to strengthen the resilience of regional ecosystem to adapt to climate change.

This research agenda was communicated to the Caricom Climate Change Center located in Belize as part of a critical input into initiating a discussion among Caricom governments to develop a regional policy on climate change and an action agenda:

Panos Institute of Caribbean online at http://www.panoscaribbean.org

This proposed regional gap research agenda provides an appropriate framework in identifying and organizing critical gaps in local climate change knowledge. Utilizing a common regional framework to identify individual Caribbean island information gaps, facilitates an efficient aggregation of common study initiatives and regional networking and development of joint and or common regional gaps bridging work that could benefit from economies of scale and rationalization of funding, human resource and research infrastructure.

12.3. NATIONAL RESEARCH AGENDA

The major gaps identified in Antigua and Barbuda existing knowledge of climate change and its impacts and national capacity to deal with its effects, can be detailed under the following elements of the proposed regional agenda framework with another element added.

1. Research that moves from generating climate scenarios to projecting impact on ecosystem services including socio economic valuations

2. Investigating how key species will respond to changes in temperature

3. Researching how to establish a system of protected areas that facilitate effective biodiversity conservation and sustainable livelihood under climate change and variability
4. Researching how to strengthen the resilience of eco systems to adapt to climate change

5. Fostering linkages between biodiversity conservation and traditional use

6. Mainstreaming climate change work into economic and social planning

12.4. MAINSTREAMING OF CLIMATE CHANGE WORK:

Mainstreaming of climate change adaptations requires organization of gap research work in the context of current economic and social planning sectoral work. Specifically there are significant gap research work required to support the sustainability of the tourismsector, human settlement and fisheries sector.

12.4.1. Tourism:

Antigua Barbuda heavy dependence on its natural resource base makes the effects of climate change on coastal and marine environment, on water resources ,human settlement and tourism the most critical areas where information gaps need to be filled as a matter of urgent priority, to facilitate adequate adaptation and the sustainability of the development process

Tourism is responsible for over 60% of current economic activity and is projected to continue to be the main economic sector in the foreseeable future. The sustainability of the development process would depend heavily on the sustainability of the tourism sector which in turn depends heavily on the sectors successful adaptation to climate change.

In most destinations, and certainly in Antigua and Barbuda and the Caribbean, the natural environment provides the basis of the tourism resource. Climate affects a wide variety of the environmental resources that are critical attractions for tourism such as coastal and marine habitats and biodiversity. The WTO report on this subject points out that these can be expected to include coastal erosion, reduced landscape aesthetics, changes in coastal water quality, biodiversity loss, increased natural hazards, damage to infrastructure, and increasing vector borne diseases. Mountain, island and coastal destinations are regarded as particularly sensitive to the indirect impacts of climate change.

The WTO report identifies the Caribbean as a climate change and tourism "hotspot" with future conditions likely to be characterized by a wide range of potential direct and indirect climate change impacts including warmer summers, increase in the number of extreme events, water scarcity, marine biodiversity loss, sea-level rise, disease outbreaks, and travel cost increases. The report indicates that evidence from available studies that have explored the potential impacts of global climate conditions for tourist destinations, suggests that anticipated impacts include a gradual shift to higher latitudes and to higher altitudes in mountainous areas. Tourists from temperate countries that presently dominate international travel are expected to take more holidays in their home country or nearby. More tourists may travel north in winter and less to warmer destinations such as the Caribbean.

For example, climate change effects on fresh water availability and quality, coastal water quality, and hurricane formation can be expected to directly affect the tourism product.The IPCC TAR indicates an estimated annual sea level rise for the Caribbean of 1mm/year during the twentieth century. The IPCC indicates that global projections point to accelerated rates of sea-level rise during the twenty-first century as compared to the latter half of the twentieth century. Expert opinion suggests an annual rate of sea-level rise in the eastern Caribbean of approximately 1 – 3mm annually. Outputs from regional climate models also indicate that significant sea level rise can be expected for the region, although there is likely to be considerable variation within the region based on factors such as tectonic movement and land subsidence[162]. Based on these projections, sea level rise, and particularly storm surge under scenarios of sea-level rise, will present significant challenges for tourism related properties located in coastal areas including yacht harbours and cruise ship ports.

[162]Sections of the west coast of Barbados for example is currently undergoing a period of slow gradual uplift: personal communications with officials from the Coastal Zone Management Unit.

Sea level rise can be expected to pose one of the gravest threats to tourism in Antigua and Barbuda. The potential risks for Antigua and Barbuda are particularly severe given that beaches constitute Antigua and Barbuda's principal tourist attraction, the ecological fragility of the resource, and the existing stresses to which these resources are already being subjected. Additionally most of the country's principal hotels lie within 100yds of the high water mark.

A program of monitoring these projected climate changes and their impact on critical ecosystems and projecting their impact on ecosystem services including socio economic valuations of these impacts together with identification of suitable and effective adaptation measures should be first priority in supporting the sustainability of the development process in the face of climate change and climate variability.

Specifically a monitoring program should be establish to monitor the impact of climate change on coastal erosion, reduced landscape aesthetics, changes in coastal water quality, biodiversity loss, increased natural hazards, damage to infrastructure, and increasing vector borne diseases.

12.4.2 Human settlement

The 1997 assessment report indicates that about 70% of major settlements occur within watershed areas. This makes them prone to flooding from heavy rainfall events including from hurricanes and other tropical systems. In relation to coastal vulnerability, most of the coastal settlements are sited upon flood-plains that drain to the sea. The assessment identifies settlements located within coastal areas as well as those in floodplains as those that are most vulnerable to existing climate related stresses and indicates that it was these areas that were most affected by the hurricanes and storms of the 1995 hurricane season. In that year coastal infrastructure and resources suffered major damage in the more exposed areas such as along the southern coast and at Dickenson Bay/Runway Bay/Fort James.

The assessment notes that "there is also a relationship between wind damage and micro-locational factors such as site elevation and slope exposure. Some of the extreme wind damage that was seen in the aftermath of Hurricane Luis can only be explained by wind acceleration caused by local topography".

Human settlements vulnerability in Antigua and Barbuda is conditioned by Disaster mitigation which must therefore be made an essential component of development planning and capital works projects. Consideration must now be given to incorporating climate and natural hazard impact assessments in the planning of certain categories of projects.

At the current state of knowledge, vulnerabilities of human settlements are easier to identify than impacts because they estimate risks or opportunities rather than estimating consequences which requires more detailed information about future conditions. Gap bridging work needs to be continued in providing the information base to identifying impacts.
While sea-level rise is recognized as one of the principal impacts of climate change on small island States, very few detailed assessments have been done of the effects of rising sea-levels on human settlements in the Caribbean. Sea-level rise can be expected to have serious implications for Antigua and Barbuda where considerable sections of the population live in areas likely to be impacted by medium to long term projections for sea-level rise. Rising sea-levels can submerge low lying areas, impede coastal drainage, augment saline intrusion, and increase coastal flooding and storm damage. Additionally ecological and physical environments along the coast will change with sea-level rise prompting the need for relocation of houses and infrastructure further inland.

The 1997 Government of Antigua and Barbuda/UNEP assessment of human settlement impacts indicates that more than 60% of the Antigua and Barbuda population can be considered as living within the coastal zone. Already the 1997 assessment of the impacts of climate change on human settlements concluded that a sea level rise scenario of 0.3 meters (approximately one ft) would have no major effect on human settlements since this represents a small change over a 100 year span. It was determined that areas which are currently submerged at high tide would be most at risk to a 0.3m rise in sea-level. Vulnerable areas include Parham, Falmouth, English Harbour, Crabbe Hill, Old Road, and Dickenson Bay.

In assessing the impact of a one metre rise in sea-level on coastal resources the UNEP/GoAB assessment notes that sea-level rise will lead to an increase in the risks of floods resulting from storm surge as well as significantly reducing the return period for flooding events. Flooding in Antigua is primarily a result of torrential rain and during storms, human settlement encroachment onto low-lying flood-plains, and blockage of natural watercourses and channels due to development and other man-made causes (e.g. improper solid waste disposal). The latter contributes to widespread flooding due to backwater effects as seen in Villa and Greenbay. Flooding along low-lying coastal areas will be exacerbated by sea-level rise as where stream discharge occur based on gravity. Of the thirty three settlements examined the most vulnerable to sea-level rise were identified as St. Johns (GreenBay and Villa/Point), Codrington, Urlings, Johnsons Point, Crabb Hill, Bolans, Bethesda, Parham, English Harbour, Cobbs Cross, and Falmouth. Settlements in the south west of Antigua were considered most at risk while most of Barbuda will be at risk from a one metre rise in sea-level. The concentration of tourism properties on beaches makes them extremely vulnerable to even moderate sea-level rise with areas such as Dickenson Bay, Jolly Beach, and Long Bay, where tourism development has encroached onto areas of active coastal wave energy, likely to be particularly at risk.

A detailed assessment of the impact of sea level rise with socio economic valuations on human settlement is a second major area of mainstreaming climate change work.

12.4.3. Fisheries:

Research has shown the effects of climate change on marine ecosystems cannot be easily mitigated by engineering measures. The better the quantity and quality of important coastal habitats, the less likely it will be that climate change will affect them and the fisheries that depend upon them. Other effects of climate change include declines in fish production due to ocean acidification, changes in production and availability of fished species and potential mismatch between prey (plankton) and predator (fished species) and declines in production as a result of warming of the upper ocean layers and reduced production of coastal marine and freshwater systems and related fisheries (Allison, et al., 2009). In relation to potential outcomes for fish stocks, Allison also noted that there will be changes in timing and levels of productivity across marine and freshwater systems and reduced production of target species in marine and fresh water systems because of higher water temperatures.

Considering that there is not much research on the impacts of climate and climate change on fisheries for the Caribbean, assessing impacts on fisheries in small island communities such as Antigua and Barbuda is more challenging given the paucity of reference material163.

As in other Caribbean countries, the consequences of climate change on fisheries in Antigua and Barbuda are expected to be mostly negative (Nurse, 2008). Adverse impacts on fisheries are likely to manifest themselves through habitat alteration and loss, reduced species abundance and diversity, possible shifts in distribution induced by changes in ocean currents, reduced number of fishing days and possible loss of livelihoods or shift to alternative livelihoods.

Appropriate adaptation options may be adopted for each fishery. These will vary from simple practical cases to more theoretical mainstreaming of climate change into the fisheries sector.

The vulnerability of any sector to climate change is a function of the degree of exposure to the threat, the sector's sensitivity to the risk and the capacity of the sector to cope with or adapt to the threat (FAO, 2005; IPCC, 2001; IPCC, 2007). Any objective assessment of fisheries in Antigua and Barbuda would conclude that exposure and sensitivity to climate change threats are high, while adaptive capacity is relatively low.

[163] Personal observation
s and research, at UWI, 2007/2008.

There is a need for future research focusing on key ecosystem and other linkages. This is necessary to further understand and wisely manage the fisheries. Fisheries–related areas and possible relationships with long term changes and natural climate variability that have been identified can be studied further. Possible areas for further research including socio economic valuation of impacts can include but not limited to:

- Seasonal variation of current; current movement; Influence of currents on fishing
- Influence of local habitat on different fish species/ how different fish species adapt to different temperature and depth regimes
- Migratory patterns of fish species; Climate change impact on fish migration
- Climate change and marine invasive species, e.g. jellyfish
- Sea Level Rise and Fisheries.

12.5 BUILDING RESILIENCE AND CAPACITY OF ECO SYSTEMS TO ADAPT TO CLIMATE CHANGE:

12.5.1. Coral Reefs:

Coral reefs are particularly important to Antigua and Barbuda because of their high value to fisheries, tourism and coastal protection. They are also particularly vulnerable to the effects of climate change and therefore research is needed to determine the best strategies for building their resilience and capacity for adaptation (James P. A., 2008).

Increased temperatures, especially sea surface temperatures can cause major changes in the natural coastal environment. Evidence of impacts of climate change on reefs include coral bleaching, reduced calcification potential leading to a slowdown or reversal of reef building and loss of reef in the future, diseases of corals and other organisms164, widespread losses of major reef-building corals (staghorn and elkhorn) due to white band disease, the current widespread occurrence of aspergillosis, a fungal disease that attacks some species of gorgonians (sea fans), numerous outbreaks of white plague and possible migration (both vertical and horizontal) of fish and other marine life.

Elevated sea surface temperatures are a primary cause of coral bleaching. The most severe episodes in the past have coincided with years when the El Niño signal was strongest, for instance in 1983, 1985, 1997/98, 2005/2006. In the 1997/98 event, approximately 25-30% of coral reefs in the Caribbean were affected (Nurse, 2008)

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[164] Caribbean-wide die-off of the long-spined black sea urchin *Diademaantillarum*

Research has also shown that the world's oceans have become approximately 30% more acidic since 1750 - the start of the Industrial Revolution, associated with increasing anthropogenic emissions of CO_2 (IPCC, 1990; IPCC, 2001; IPCC, 2007b; Nurse, 2008). This can result in the reduction of calcium available to marine animals (including corals) for the formation of their skeletons and shells. This can have serious repercussions for the provision of seafood and various ecosystem services especially to coastal communities.

There is urgent need for gap research bridging work on Coral Reefs to

Investigating how key species will respond to changes in temperature

Researching how to establish a system of protected areas that facilitate effective biodiversity conservation and sustainable livelihood under climate change and variability

Researching how to strengthen the resilience of reef eco system to adapt to climate change

Fostering linkages between biodiversity conservation and traditional use e.g. reef fishery management and harvesting protocols.

12.5.2. Coastal habitats

In recognition of the importance of coastal habitats, including coral reefs, sea grass beds, beaches and wetlands to Antigua and Barbuda and the implications of climate change impacts on these resources, it is critical that wise use practices within coastal areas of Antigua and Barbuda be developed and promoted. Monitoring programmes within government agencies, NGOs and key stakeholders within the coastal zone should focus on understanding coastal changes and develop appropriate solutions to adapt to or mitigate negative impacts.

To date, there is no comprehensive assessment of the impact of poor agricultural and developmental practices in inland areas on the coastal environment. The same is true for residential and other developments that may negatively impact the coast of Antigua and Barbuda, through connections within and between watersheds. Specific studies are necessary to verify perceived effects. Additional gap bridging work on coastal habitats should also include

- Vulnerability and impact assessment of the coastal zone with socioeconomic valuations
- The development of coastal hazard maps
- The development of stricter building codes and land use plans and policies within the coastal zone.
- The establishment of marine protected areas (MPAs)
- The development and utilisation of alternative fresh water sources.

Support from the international community for this program of Gap bridging research work would provide the knowledge basis to allow Antigua and Barbuda and many other Caribbean Islands and micro Islands generally adapt to the most harmful impacts of Climate Change.

12.6 CONCLUSION

Climate change is increasingly recognized as one of the major challenges facing humanity as it progresses into the twenty-first century[165]. Successful adaptation to the threats emanating from global climate change is likely to require levels of international and regional cooperation of unprecedented scope. At the national level, reduction of risk will need to increasingly factor into the development policy and planning process, and will require adherence to principles of equity and socio-economic and Scientific investigation if sustainable development is to be attained.

An important consideration is to recognize the urgency for immediate action. Climate change is not a future scenario but a current event with almost daily scientific reassessments of the immediacy of the risks presented. Adaptation policies and measure must therefore be viewed as a priority and therefore integrated into decision-making at virtually all levels.

[165]See United Nations. "Mobilizing Political Momentum for Copenhagen: Note from the Secretary-General to Heads of States and Governments Regarding the Summit on Climate Change" at http://www.un.org/wcm/webdav/site/climatechange/shared/Documents/Background_Paper.pdf

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