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AN ASSESSMENT OF THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE COASTAL AND HUMAN SETTLEMENTS, TOURISM AND TRANSPORT SECTORS IN BARBADOS

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EXECUTIVE SUMMARY

This report analyses the coastal and human settlements, tourism and transport sectors in Barbados to assess the potential economic impact of climate change on the sectors. The fundamental aim of this report is to assist with the development of strategies to deal with the potential impact of climate change on Barbados. Some of the key anticipated manifestations of climate change for the Caribbean include elevated air and sea-surface temperatures, sea-level rise, possible changes in extreme events and a reduction in freshwater resources.

The economic impact of climate change on the three sectors was estimated for the A2 and B2 IPCC scenarios until 2050 (tourism and transport sectors) and 2100 (coastal and human settlements sector). An exploration of various adaptation strategies was also undertaken for each sector using standard evaluation techniques.

The analysis has shown that based upon exposed assets and population, SLR can be classified as having the potential to create potential catastrophe in Barbados. The main contributing factor is the concentration of socioeconomic infrastructure along the coastline in vulnerable areas. The A2 and B2 projections have indicated that the number of catastrophes that can be classified as great is likely to be increased for the country. This is based upon the possible effects of the projected unscheduled impacts to the economy both in terms of loss of life and economic infrastructure. These results arise from the A2 and B2 projections, thereby indicating that growth in numbers and losses are largely due to socioeconomic changes over the projection period and hence the need for increased adaptation strategies. A key adaptation measure recommended is for the government of Barbados to begin reducing the infrastructure deficit by continuously investing in protective infrastructure to decrease the country’s vulnerability to changes in the climate.

With regard to the tourism sector, it was found that by combining the impacts due to a reduction in tourist arrivals, coral reef loss and SLR, estimated total economic impact of climate change is US $7,648 million (A2 scenario) and US $5,127 million (B2 scenario). An economic analysis of the benefits and costs of several adaptation options was undertaken to determine the cost effectiveness of each one and it was found that four (4) out of nine (9) options had high cost-benefit ratios. It is therefore recommended that the strategies that were most attractive in terms of the cost-benefit ratios be pursued first and these were: (1) enhanced reef monitoring systems to provide early warning alerts of bleaching events; (2) artificial reefs or fish-aggregating devices; (3) development of national adaptation plans (levee, sea wall and boardwalk); (4) revision of policies related to financing carbon neutral tourism; and (5) increasing recommended design wind speeds for new tourism-related structures.

The total cost of climate change on international transportation in Barbados aggregated the impacts of changes in temperature and precipitation, new climate policies and SLR. The impact for air transportation ranges from US$10,727 million (B2 scenario) to US$12,279 million (A2 scenario) and for maritime transportation impact estimates range from US$1,992 million (B2 scenario) to US$2,606 million (A2 scenario). For international transportation as a whole, the impact of climate change varies from US$12,719 million under the B2 scenario to US$14,885 million under the A2 scenario. Barbados has the institutions set up to implement adaptive strategies to strengthen the resilience of the existing international transportation system to climate change impacts. Air and sea terminals and facilities can be made more robust, raised, or even relocated as need be, and where critical to safety and mobility, expanded redundant systems may be considered.

1. INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report (IPCC, 2007) provided conclusive scientific evidence that human activity in the form of greenhouse gas (GHG) emissions is responsible for many observed climate changes, but noted that use of this knowledge to support decision making, manage risks and engage stakeholders is inadequate.

The nations of the Caribbean Community (CARICOM)[1] contribute less than 1% GHG emissions (approximately 0.33%[2]; World Resources Institute, 2008), yet these countries are expected to be among the earliest and most severely impacted by climate change in the coming decades, and are least able to adapt to the impacts (Nurse et al., 2009). A global scale analysis of the vulnerability of developing nations to sea level rise (SLR) by the World Bank in 2007 (Dasgupta et al., 2007) found that Caribbean nations were among the most impacted nations from climate change in terms of land area lost, and the percentage of population and Gross Domestic Product (GDP) affected.

In the Caribbean more than half of the population lives within 1.5 km of the shoreline (Mimura et al., 2007). Barbados is no exception, with the majority of its 281,000 inhabitants residing along southern and western coasts. The greater part of the island's infrastructure, government, health and commercial facilities also lie along various portions of the 97 km coastline.

Climate change is impacting on a wide range of sectors and assets of the Caribbean including its' biodiversity (corals and fisheries), tourism, transportation and agriculture sectors, water resources, human health and disaster management planning (IPCC, 2007; Dulal et al., 2009; Simpson et al., 2009). This report attempts to assess the economic impact of climate change on the coastal and human settlements, tourism and transportation sectors in Barbados as these were deemed most vulnerable to climate change and key contributors to the country's GDP.

2. BRIEF REVIEW OF THE SECTORS

A. COASTAL AND HUMAN SETTLEMENTS

The main economic activities located within the low elevation coastal zones (LECZ)[3] of Barbados are shipping, manufacturing and tourism. The clustering of infrastructure has significant economic benefit to the national economy, but it also presents a disadvantage in that it increases the vulnerability of the economy to the impact of climate change. The infrastructure at risk are churches, cemeteries, government buildings, post offices, petroleum storage facilities, police stations, power stations, the Pier, recreation sites, schools, the Transport Centre, the University of the West Indies (UWI) and the Wharf. Over 90% of all hotels in Barbados are located on, or proximal to, the beaches and are therefore highly vulnerable to climate change induced SLR. The vulnerable[4] road network was estimated to be 288 km.

Climate change is expected to increase the risk of coastal human settlements to sustain damage from the onset of high tides combined with storm surges and/or severe weather changes such as precipitation and drought. The poor within the economy are those who are the most vulnerable and are also the least able to finance adaptation to climate change. The United Nations[5] estimates that there exist 7,000 households or 35,000 persons with per capita annual income less than US$2,751, and as such are deemed to be living below the poverty line. The latter translates into approximately 14% of the population and 9% of households.

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1 Antigua and Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, Saint Lucia, St. Kitts and Nevis, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago.

2 The Caribbean Islands contribute about 6% of the total emissions from the Latin America and Caribbean Region grouping and the Latin America and Caribbean Region is estimated to generate 5.5% of global CO_2 emissions in 2001 (UNEP, 2002).

3 Land area with a vertical height of 10 metres above median/peak tide level.

4 An equal distribution of road is assumed.

5 unstats.un.org/unsd/methods/poverty/RioWS-Barbados.pdf

Along the coastline and in the nearshore marine environment, coral reefs function as natural breakwaters and represent one of the most important natural sea defenses available for Barbados. These coastal ecosystems are increasingly being threatened by SLR, increases in sea surface temperature and increases in extreme weather events. Vulnerability to SLR includes induced land loss, which is most evident in the parishes of Christ Church and Saint James.

B. TOURISM

Tourism has been the mainstay of the Barbados economy, contributing on average from 10-12.5% of total GDP.[6] In 2009, the island of Barbados was ranked by the World Economic Forum's Travel and Tourism Competitiveness report as the number one destination for affinity for travel and tourism among the Caribbean and Latin American countries (World Economic Forum, 2009).

Through strategic marketing of programmes appealing to a wide variety of travellers, coupled with increased direct airlift, Barbados has managed to increase its tourism niche in 2010 despite global economic challenges to the travel industry (PRNewswire, 2008). Much of the success in the growth of the industry can be attributed to aggressive advertising, placing particular emphasis on marketing the island's beaches and other coastal resources. As such the majority of tourism-related infrastructure has been placed along the coastline.

C. TRANSPORTATION

1). Air Transportation

Air transportation in Barbados is organized around catering to the demands of both extra and intra regional tourists as well as other visitors, with tourist arrivals numbering just under 520 thousand in 2009. Barbados has one airport, the Grantley Adams International (GAIA), which lies 12.9 km from the centre of the capital city Bridgetown, in an area officially known as Seawell. The Government of Barbados had recently completed a major US$100 million upgrade and expansion airport programme, which has doubled peak period capacity. The airport's current infrastructure is designed to meet the needs of Barbados until at least 2015. The GAIA has direct service to destinations in Canada, Central America, South America and Europe and operates as a major gateway to the Eastern Caribbean.

2). Sea Transportation

In 2008, the total value of trade in goods in Barbados amounted to US$2.1 billion or 60.5 % of GDP. Total tonnage handled at the Bridgetown Port terminal typically relates to import, export and transshipment cargo (containerized and breakbulk) for both the Deep Water and the Shallow Draught Harbours. According to the 2007 Annual Report of the Barbados Port, a total of 1,314,716 tonnes of goods was handled in 2007, up slightly by 0.5 % from 2006. While tourism in Barbados is predominantly driven by higher spending air arrivals, the cruise market has been strong and growing. According to the Caribbean Tourism Organisation (CTO[7]) in 2007 more than 485 cruise ship calls were made to Barbados with cruise ship passenger arrivals amounting to almost 648 thousand persons. Barbados is seeking to develop its potential as a hub connecting air and cruise traffic. It has invested in upgrading facilities to accommodate cruise ships.

3. FUTURE CLIMATE SCENARIOS

The IPCC has confirmed that global warming during the twentieth century has resulted from rising concentrations of anthropogenic GHG emissions with a 90% level of confidence. The increase in average air and ocean temperatures, the melting of ice caps and snow fields and the rise in average sea levels are unequivocal evidence of climate system warming (IPCC, 2007).

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[6] See IMF Country Report (available at: http://www.imf.org/external/pubs/cat/longres.aspx?sk=24503.0)
[7] Statistics available at: http://www.onecaribbean.org/statistics/tourismstats/),

ECLAC, in consultation with other key members of the Caribbean community, recommended the use of the IPCC emissions scenarios A2 and B2 for the assessment of the economic impact of climate change on Caribbean economies since these scenarios were deemed to be the most consistent with the type of development observed in the region. The general consensus of the global scientific committee, and a significant conclusion of the February 2007 report issued by the IPCC (2007), is that global temperatures are increasing and this increase is driving a number of phenomena. The Caribbean thus faces inevitable climate change during the 21st century, which may have long-term effects on the sustainable growth of the island states (table 1).

Table 1: Predicted climate scenarios for the Caribbean region by 2099

Parameter	**Predicted Change**
Air and sea surface temperature	Rise of 1.4 to 3.2°C
Sea Level Rise	Rise of 0.18 to 0.59* m
Ocean acidity	Reduction in pH of 0.14 – 0.35 units making the oceans more acid
Tropical Storms and Hurricanes	Likely (>66% certainty) increase in hurricane intensity with larger peak wind speeds and heavier precipitation
Precipitation	No clear predictions for the region, although most models predict a decrease in summer (June, July, August) precipitation in the Greater Antilles
Extreme weather events	Number of flood events expected to increase Picture for droughts is unclear regionally
*The prediction does not include the full effect of changes in the ice sheets in Antarctica and Greenland, therefore the upper values could increase.	

Source: Inter-Governmental Panel on Climate Change (2007)

4. METHODOLOGIES

While a largely similar approach was undertaken to analyse each sector on the whole (economic impact analysis, forecasting cost until 2050 and costing adaptation strategies), the unique characteristics and data availability for each sector necessitated the use of different methodologies with regard to the economic impact analysis.

1). Coastal and Human Settlements: The nature of this sector required a different analytical approach to costing the economic impact of climate change. The analytical approach employed for costing the economic impact of climate change in this sector comprises consecutive analytical steps that allow for the identification of populations and physical and natural resources at risk, and of the costs and feasibility of possible responses to adverse impacts. The following resources were identified for analysis:

a. People affected: The people living in the hazard zone affected by sea-level rise;
b. People at risk: The average annual number of people flooded by storm surge;
c. Housing value at loss: The market value of houses which could be lost due to sea-level rise;
d. Land at loss: The area of land that would be lost due to sea-level rise;
e. Wetland at loss: The area of wetland that would be lost due to sea-level rise;

Using standard evaluation techniques, including net cost-benefit analysis, multicriteria analysis or a combination of these strategies, costing of the adaptation strategies in each of the sectors was undertaken.

2). Tourism: Four layers of economic impact analysis were employed to evaluate the tourism sector. The first focused on tourist arrivals, where climate (represented by temperature, relative humidity, precipitation, wind speed and duration of sunshine) and economic data were modeled using multiple regression analysis. The second addressed tourism mobility deriving from climate policy in source countries, the third examined climate related impacts on coral reef-related tourism, and the fourth analyses SLR and related impacts, such as coastal erosion.

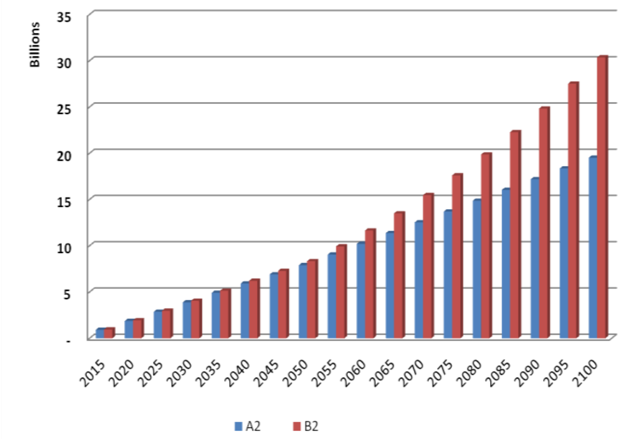
3). Transportation: Evaluation of the transportation sector also used a layering technique employing three layers. The first layer applied regression analysis methodology and modeled the demand for transportation (air and sea) using climate (temperature and precipitation) and economic variables. The two other core impacts considered in the assessment were international travel mobility and the impact of SLR on the international transport infrastructure.

5. ECONOMIC IMPACT ASSESSMENT OF CLIMATE CHANGE ON THE COASTAL AND HUMAN SETTLEMENTS, TOURISM AND TRANSPORT SECTORS

A. COASTAL AND HUMAN SETTLEMENTS

Schumann (2010) estimates that the implicit price of beach-width is $28.67 per metre per person per night in Barbados and this estimate was used to calculate the value of beach width in Barbados. The Caribbean Tourism Organisation estimates that there were 532,180 stopover visitors for the year 2010[8], with 7.4 or 7 nights on average per stopover visitor entering Barbados. It follows that the estimated aggregate value of the lost beach width is US$106.8 million per metre. The accumulated value of land loss estimated under the A2 and B2 population projections and the results are presented in figure 1.

Figure 1: Value of Accumulated Land Loss

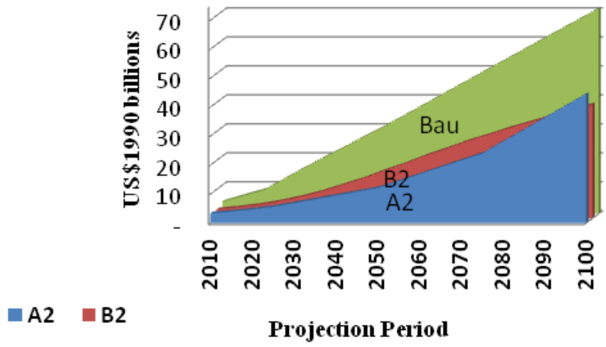


Source: ECLAC, 2011

The B2 scenario resulted in a greater exposed asset than the A2 scenario. Figure 2 indicates that exposed asset value reached an estimated US$ 4.7 billion in 2020 for the A2 scenario while peaking in excess of US$ 44 billion with a US$ 39.4 billion in the year 2100 for the B2 scenario. In excess of 50% of the exposed assets are located in St. Michael and Christ Church for both the A2 and B2 scenarios.

[8]Caribbean tourism Organisation (2011) "Table 3: Tourist Arrivals by Main Market – 2010, *Latest Statistics 2010"*. http://www.onecaribbean.org/content/files/Feb152011Lattab10.pdf (Feb 25, 2011)

Figure 2: Vulnerability Trends

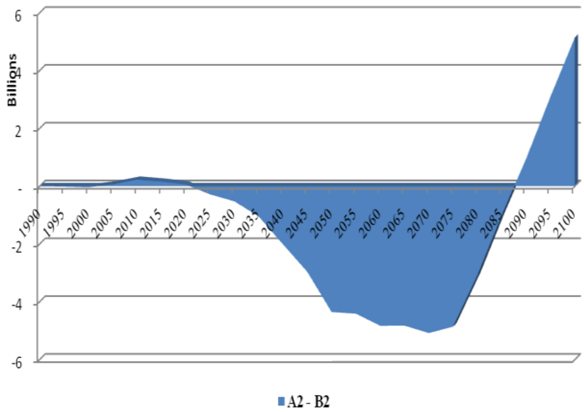


Source: ECLAC, 2011

Of the exposed population, it is estimated that 20% and 33% are from Christ Church and St. Michael respectively. This ratio applies for the entire projection period from 2020 to 2100[9]. For the B2 scenario, exposed assets reached the US$ 4 billion mark between the years 2015 and 2020. The latter is also consistent for the B2 scenario. The 10 billion dollar mark was however reached between the years 2040 and 2045 and this mark surpassed between the years 2030 and 2035 for the B2 scenario (figure 2).

There is an overall increase in exposed assets as the distribution of exposed assets by parish remains the same, with St. Michael (34%) and Christ Church (20%) accounting for the bulk of the exposed population. Asset exposure under the A2 and B2 scenarios tend to be equal for the years 2025 and 2085 (figure 3). For the years 2025 to 2085, the projected exposed assets for the B2 scenario is on average US$ 3 billion greater than that of the A2 scenario. The annual rate of asset exposure for the period 2050 to 2100 for the A2 scenario was greater than that of the B2 scenario.

Figure 3: Scenario Difference in Exposed Assets



Source: ECLAC, 2011

B. TOURISM

Three distinct scenarios[10] were considered in the context of tourist arrivals, namely the A2, B2 and BAU[11]. The observed annual tourist arrivals and forecasts for each of the three scenarios are shown in figure 4. The B2 or low emissions scenario suggests that annual arrivals will continue to increase until 2017, after which they will decrease due to the adverse effect of climate change on the Tourism Climatic Index[12] values. By comparison, the A2 scenario produces substantially greater changes to the climate variables, thereby

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[9] A outcome directly related to population distribution being constrained to be equal to that of current day Barbados

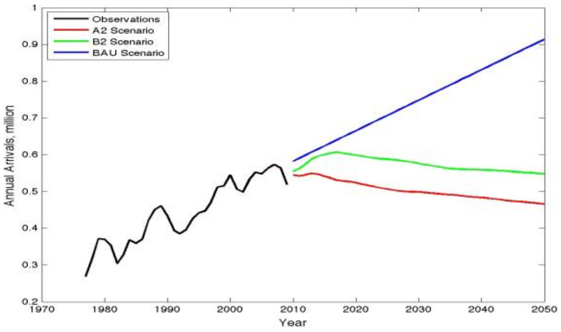
[10] For an explanation of the IPCC climate scenarios see: http://sedac.ciesin.columbia.edu/ddc/sres

[11] The BAU scenario is a linear extrapolation of the time series of tourist arrivals.

[12] The TCI uses a standardized rating system, with each sub-index ranging from 5 (optimal) to –3 (extremely unfavourable), to provide a common basis of measurement for the climate variables (temperature, humidity, sunshine, rain and wind and other climate features) that constitute the index.

reducing the number of tourist arrivals from 2013 onwards. The downward trend for the A2 scenario is similar to that for the B2 scenario but it is expected to start by 2013 and has a large impact in terms of the resulting decrease in tourist arrivals.

Figure 4: Annual arrivals and forecasts for each of the three scenarios (A2, B1 and BAU)



Source: ECLAC, 2011a

The corresponding tourism expenditure (cumulative) in US$ million for each decade under each of the three scenarios are provided in table 2. The difference between the cumulative expenditures of each scenario and that of the BAU scenario by 2050 was US$ 18,309 million (A2 scenario) and US$ 13,224 million (B2). Taken relative to the BAU scenario, this implies losses of US$ 3,814 million (or 96% of GDP[13]; A2 scenario) and US$ 2,754 million (or 69% of GDP; B2 scenario) when converted to present value.

Table 2: Cumulative tourist expenditure in US$ millions for specific years for the three scenarios (A2, B2 and BAU)

Year \ Scenario	A2 Scenario	B2 Scenario	BAU Scenario
2020	8,704	9,565	10,114
2030	16,980	19,144	21,741
2040	25,826	29,318	36,080
2050	35,265	40,350	53,574

Source: ECLAC, 2011a

The international community and various national governments are experimenting with carbon taxes and alternative climate policies that may impact on the willingness of tourists to purchase flights to destinations such as Barbados. In the United Kingdom, there has already been a new policy that has resulted in the imposition of an Aviation Passenger Duty (APD) tax of £240 for flights for a family of four people travelling to Barbados. This would imply a decrease in tourist arrivals by as much as 25.2% by 2050. The loss in tourism expenditure due to this policy for the intermediate climate policy scenario is given in table 3. The potential economic loss for the B2 scenario of US$ 1,117 million (28% of GDP) is greater than that for the A2 scenario of US$ 964 million (24% of GDP). The losses for the BAU scenario are assumed to be equal to zero in this scenario since it is assumed that there are no impacts of climate change and therefore no losses.

Table 3: Tourism mobility impacts as measured by implied losses to tourism expenditure

Year \ Scenario	A2 Scenario	%GDP	B2 Scenario	%GDP	BAU Scenario
Loss by 2050, US$ million	4,626	116%	5,361	135%	0
Present Value, US$ million	964	24%	1,117	28%	0

Source: ECLAC, 2011a

[13] The 2010 estimate for GDP (US$3.963 billion) cited in this document has been used for this and other calculations of losses as a percentage of GDP.

Estimated tourist expenditure associated with visitors travelling to Barbados to enjoy activities associated with coral reefs is US$ 206.25 million. This figure is based on 25% of the estimated tourism expenditure in 2009 of US$ 825 million and follows the World Resource Institute approach of valuation[14], and assumes that Barbados' tourism has approximately the same focus on coral reef tourism as that of Saint Lucia. The economic losses suffered due to climate change, expressed as a percentage of the value of the coral reef, is taken as 80% for the A2 scenario and 40% for the B2 scenario. Table 4 shows the relevant calculations and indicates that the present value of coral reef loss as a result of climate change is estimated at US$ 1,333 million (33% of GDP; A2 scenario) and US$ 667 million (17% of GDP; B2 scenario).

Table 4: Estimated value of coral reef loss

Value\ Scenario	A2 Scenario	B2 Scenario	BAU Scenario
Loss by 2050, US$ million	6,400	3,200	0
Present Value, US$ million	1,333	667	0

Source: ECLAC, 2011a

SLR will have a three-fold impact on the tourism sector resulting in loss of land and tourist expenditure and rebuilding costs. Estimates of the potential SLR from regional climate simulations range from 0.1 m under the B2 scenario to 0.3 m under the A2 scenario. Following Nicholls and Tol (2006), the potential land loss as a result of climate change ranges from 1% under the B2 scenario to 2% under the A2 scenario. The value of the land is assumed to be US$ 100 million/km^2. Table 5 gives details of the calculations and shows that the present value of land lost is estimated at US$ 179 million (4.5% of GDP; A2 scenario) and US$ 90 million (2.3% of GDP; B2 scenario).

The annual loss of tourist expenditure due to SLR is estimated to increase linearly to US$ 35 million (0.88% of GDP; B2 scenario) and to US$ 154 million (3.89% of GDP; A2 scenario) by 2050. Annual tourism expenditure loss is estimated by assuming a loss of amenity factor where SLR causes beach loss and hence reduced the attractiveness of the country to tourism.

Table 5: Estimated value of land lost due to sea level rise (US$ million)

Value\ Scenario	A2 Scenario	B2 Scenario	BAU Scenario
Total Land Area (km^2)	430	430	430
Land Loss (km^2)	8.6	4.3	0
2050 Value of Land Loss	860	430	0
Present Value of Land Loss	179	90	0
Present Value of Tourism Loss	658	149	0
Present Value of Rebuild Costs US$ million	700	350	0
Present Value of Total Loss due to Sea Level Rise	1,537	589	0

Source: ECLAC, 2011a

The total rebuilding cost resulting from damage due to SLR is US$ 4.2 billion. This calculation is supported by work conducted by the World Bank (Haites et al., 2002; Fish et al., 2008; Simpson et al., 2010). It is assumed that 80% of this value pertains to the A2 scenario and 40% for the B2 scenario as the losses that will be generated by 2050. The present value of the total loss due to SLR is US$ 1,537 million (38.8% of GDP) under the A2 scenario and US$ 589 million (14.9% of GDP) under the B2 scenario.

The total cost of climate change to the tourism sector in Barbados was calculated by combining the impacts of reduced tourist arrivals (both changes in weather patterns and new climate policies that may reduce tourist mobility), loss of coral reefs and adverse impacts due to SLR. In each case, the present value

[14] Economic Valuation Methodology and Tool available at: http://www.wri.org/project/valuation-caribbean-reefs/tools

of the loss is used. Table 6 gives the breakdown of these costs and demonstrates that the impact could range from US$ 5.127 billion (129% of GDP; B2 scenario) to US$ 7.648 billion (193% of GDP; A2 scenario).

Table 6: Total impacts of climate change on tourism (US$ million)

Losses\ Scenario	**A2 Scenario**	**%GDP**	**B2 Scenario**	**%GDP**	**BAU scenario**
Tourism Loss due to climate	3,814	96.2%	2,754	69.5%	0
Tourism mobility loss	964	24.3%	1,117	28.2%	0
Coral reef	1,333	33.6%	667	16.8%	0
Sea level rise	1,537	38.8%	589	14.9%	0
Total	**7,648**	**193%**	**5,127**	**129%**	**0**

Source: ECLAC, 2011a

C. TRANSPORTATION

The forecasted expenditure data are used to cost the effects of temperature and precipitation on the international transportation sector in Barbados under the A2 and B2 climate scenarios until 2050. Table 7 shows the impact of temperature and precipitation on cumulative international transport expenditure for Barbados under the BAU, A2 and B2 climate change scenarios.

Table 7: Impact of Temperature & Precipitation on Cumulative International Transport Expenditure for Barbados under A2 and B2 Scenarios *(2008 US$ millions)*

	Air Transportation			**Maritime Transportation**			**International Transportation**		
Year	**BAU**	**A2**	**B2**	**BAU**	**A2**	**B2**	**BAU**	**A2**	**B2**
2020	2,371	1,660	1,897	356	249	285	2,727	1,909	2,182
2030	5,730	4,011	4,584	860	602	688	6,590	4,613	5,272
2040	10,796	7,557	8,636	1,619	1,134	1,295	12,415	8,691	9,931
2050	18,946	13,262	15,157	2,842	1,989	2,274	21,788	15,251	17,431

Source: ECLAC, 2011b

In comparison to the BAU scenario, the A2 scenario is expected to be the worse-case scenario for emissions, and has a heavy impact on the climate and on international transport expenditure. Cumulative air transportation expenditures (in 2008 dollars) in the A2 scenario are projected at US$ 13,262 million by 2050, an implied loss of some US$ 5,684 million relative to the BAU scenario over the forty-year period. Air transportation expenditures under the B2 scenario, will reach a cumulative US$ 15,157 million by 2050 indicating an implied loss of US$ 3,789 million relative to the BAU scenario over the forecast period.

A similar trend, albeit at a much lower expenditure level (in 2008 dollars), is observed for maritime transportation. Sea transportation expenditures in the A2 scenario are projected to reach a cumulative US$ 1,989 million by 2050, an implied loss of US$ 853 million when compared to the BAU scenario of US$ 3,380 million over the forty-year period. Sea transportation expenditures under the B2 scenario will reach a cumulative US$ 2,274 million by 2050, generating an implied loss of US$568 million.

For the combined international transportation sector, the total cumulative expenditure (in 2008 dollars) amounts to a considerable US$ 15,251 million under the A2 scenario and US$ 17,431 million under the B2 scenario. Relative to the BAU scenario, the implied costs to the international transportation sector under the A2 scenario amount to US$ 6,537 million by 2050, while that for the B2 scenario will reach US$ 4,357 million by 2050.

Simpson (2010) estimates that the imposition of the APD is likely, on a intermediate scenario basis, to reduce tourist arrivals to Barbados by 6.3% in 2020 and by as much as 25.2% by 2050. Based on these estimates, table 8 gives the cumulative loss in international transport expenditure in Barbados due to the impact of climate change policies in advanced countries on international travel mobility. The potential cumulative economic loss for air transportation under the A2 scenario is US$ 3,342 million and under the B2 scenario is US$ 3,820 million. The potential cumulative economic cost for maritime transportation under the A2 scenario is US$ 501 million and under the B2 scenario is US$ 573 million. The cumulative economic loss for the international transport sector in Barbados arising from climate change policies in advanced countries is US$ 3,843 million by 2050 under the A2 scenario and US$ 4,393 million under the B2 scenario over the forecast period.

Table 8: Impact of Climate Change Policies in Advanced Countries on International Travel Mobility in Barbados under A2 & B2 Scenarios *(2008 US$ millions)*

	Air Transportation		**Maritime Transportation**		**International Transportation**	
Year	**A2**	**B2**	**A2**	**B2**	**A2**	**B2**
2020	105	120	16	18	121	138
2030	441	504	66	43	507	547
2040	1,511	1,727	227	259	1,738	1,986
2050	3,342	3,820	501	573	3,843	4,393

Source: ECLAC, 2011b

The total cost of climate change on international transportation in Barbados was calculated by combining the impact of changes in temperature and precipitation, new climate policies and SLR. Table 9 provides the breakdown of these costs and shows that the impact for air transportation could range from US$ 10,727 million (B2 scenario) to US$ 12,279 million (A2 scenario) and for maritime transportation impact estimates range from US$ 1,992 million (B2 scenario) to US$ 2,606 million (A2 scenario). For international transportation as a whole, the impact of climate change varies from US$ 12,719 million under the B2 scenario to US$ 14,885 million under the A2 scenario.

Table 9: Total Impact of Climate Change on International Transport Expenditure in Barbados under A2 and B2 Scenarios to 2050 *(2008 US$ millions)*

	Air Transportation		**Maritime Transportation**		**International Transportation**	
	A2	**B2**	**A2**	**B2**	**A2**	**B2**
Changes in Temperature & Precipitation	5,684	3,789	853	568	6,537	4,357
International Transport Mobility	3,342	3,820	501	573	3,843	4,393
Sea Level Rise	3,253	3,118	1,252	851	4,505	3,969
Total Impact	**12,279**	**10,727**	**2,606**	**1,992**	**14,885**	**12,719**

Source: ECLAC, 2011b

6. ADAPTATION STRATEGIES

A. APPROACHES TO ADAPTATION IN BARBADOS

The Ministry of Transport in Barbados is addressing climate change impacts by re-designing its road network to facilitate better drainage as a result of recent heavy rainfall events. Some of these changes, such as curbs, will assist with drainage in heavier downpours, such as may be associated with climate change. Although not the only reason for its construction, the Adams-Barrow-Cummins Highway (ABC), which was constructed as an inland highway, has successfully mitigated against the vulnerability of the coastal highways to SLR.

The Folkestone Marine Park in Barbados is the only legislated marine protected area on the island. It is a 2.2 sq km no-take, zoned marine reserve lying in one of the most heavily used areas of marine space in Holetown, Barbados. Every five years, the government's Coastal Zone Management Unit monitors the health of the coral reefs around the island for bleaching and diseases. While data have been collected on corals, fish and water quality, there are large areas and periods of time for which no information exists. The Barbados Permanent Mooring Project aims to make Barbados "anchor free" through the installation of the Manta Anchoring System (Burke et al., 2004).

The Barbados Water Authority, Environmental Protection Department and Ministry of Tourism are collaborating to implement a Water Conservation and Management Project in the Tourism and Hotel Sector. Since 1997, the Government has mandated, as part of the process for planned development that all houses with over 1,500 sq. ft floor space must have a system of collecting rain water to supplement non-potable water use requirement. Since 2000, a desalination plant in St. Michael has been producing 30,000 m^3 of water per day which supplies potable water to 44,000 people which is approximately one-sixth of the island's population.

B. COSTING ADAPTATION STRATEGIES IN THE COASTAL AND HUMAN SETTLEMENT SECTORS

From interviews with in-country government experts, it is plausible to assume that there are no single consolidated accounts of adaptation costs but only direct project costs associated with a particular adaptation strategy. For the adaptation infrastructure, fifty years of anticipation needs to SLR is considered in the BAU scenario. The costs of the major projects undertaken as Barbados climate change adaptation strategy are:

- Rockley to Drill Hall– Waterfront Improvement (US$ 7.9 million)
- Woman's Bay (Silver Sands) – Headland Protection – US$ 1.2 million
- Crane Beach, St. Phillips – Restoration and Enhancement (US$ 2.5 million)
- Holetown Beach improvement (US$ 700,000)
- Welches Beach Improvement (US$ 2.5 million)
- Walkers Savannah – Dune Restoration (US$ 0.5 million)
- Capital cost for hard structures to adapt to CC under the BAU in Barbados is estimated at US$ 15.3 million dollars.

From the analysis, it was shown that the benefit of adaptation far exceeds the cost of adaptation. One of the main adaptation measures is to reduce the infrastructure deficit by increasingly investing in protective infrastructure. This process is a gradual one. The lack of provision or inadequacies in provision for protective infrastructure does add to the vulnerability to climate change. However, the analysis is consistent with the literature as it has shown that the benefits from adaptation outweigh the costs.

C. COSTING ADAPTATION STRATEGIES IN THE TOURISM SECTOR

A cost-benefit analysis of nine adaptation options was undertaken for the tourism sector in Barbados (table 10). The analysis indicated that out of the nine options considered, five had cost-benefit ratios above 1 for the 20-year period. The most feasible proposals were options 4, 5 and 6, which had the largest cost-benefit ratios. Options 1 and 9 also had cost-benefit ratios above 1 and demonstrated payback over periods of 13 and 2 years respectively. The application of option 1 is recommended as a retrofit adaptation for only hotels as a first stage. Legislation and the building code should require a wind speed design component for all new tourism plants (hotels, villas, cottages and guesthouses). If strong opposition results, this legislation may be written with more strict requirements for tourism plants within a specified range of the coast and areas with high exposure to winds and relaxed for those tourism plants located in more sheltered/safe locations. Consideration of hazards within a specified radius should also be included (trees with a diameter greater than 0.5 m).

Table 10: Cost-benefit Analysis

US$ Mil	Description	Cumulative Net Present Value of Benefits ($)	Cumulative Net Present Value of Costs ($)	Benefit Cost Ratio	Net Benefits/(Costs) ($)	Payback Period (years)
Option 1	Design wind speeds	987.08	569.87	1.7	417.21	13
Option 2	Water tanks	578,408.43	887,853,593.54	0.0	(887,275,185.10)	-
Option 3	Water recycling	10,199,724.71	96,203,454.44	0.1	(86,003,729.73)	-
Option 4	Reef monitoring	382,521,872.64	38,481,381.77	9.9	344,040,490.86	1
Option 5	Artificial reefs	382,521,872.64	46,177,658.13	8.3	336,344,214.51	1
Option 6	National plans	4,664,842,404.32	554,005,413.01	8.4	4,110,836,991.31	2
Option 7	Alternative attractions	22,175,821.28	38,481,381.77	0.6	(16,305,560.50)	-
Option 8	Re-training	95,039,234.04	106,359,988.76	0.9	(11,320,754.72)	-
Option 9	Revise policies	332,637,319.15	169,719,478.12	2.0	162,917,841.03	2

Source: ECLAC, 2011a

D. COSTING ADAPTATION STRATEGIES IN THE TRANSPORT SECTOR

A multi-criteria analysis (MCA) was used to prioritise adaptation options in the transportation sector in Barbados (table 11). The adaptation options are grouped into four categories: (1) design issues, where changes in the design of the international transport network are proposed; (2) operational issues, where changes in the operation of the international transport network are proposed; (3) research issues, where further applied studies are required; and (4) policy issues, where recommendations would affect current policies.

Firstly, and from a financial perspective there are a number of “no-regrets” options that would probably be desirable even if SLR was not a risk for Barbados and the implementation of which would be cost effective. These options are closely aligned to conventional sustainable development and include an early warning system for storms, the prevention of additional coastal land reclamation, improved quality housing and transport routes and conservation of estuarine vegetation and dune buffers. No-regrets options represent an appropriate point of departure for SLR adaptation.

The ultimate institutional approach involves the implementation of a coastal buffer zone that is void of settlement. In some instances this will involve planned relocation of population with appropriate compensation. Finally, biological options can be highly cost effective, but are difficult to implement well.

Table 11: MCA of the Effects of Climate Change on International Transport Infrastructure

Aspect of the Effect	Adaptation Reference (Ar)			
	Ar1	**Ar2**	**Ar3**	**Ar4**
Adaptation	Assess the adequacy of international transport asset protection structures under existing conditions within the context of this report	Map air and sea infrastructure assets and coastal margins at 1m scale with at least 0.2 m precision in elevation across tidal reach	Model combined effects of inundation risk (SLR,storm surge and wave run up) at GAIA and Port	Monitor coastal hazard risk (sea levels and waves)
Type	Research	Research	Research	Policy
Ownership	Barbados – Ministry of Works, GAIA, Bridgetown Port	Barbados – Ministry of Works	Barbados – Ministry of Works	GAIA, Bridgetown Port and coastal property owners
Recommended Timeframe /1	Short	Short	Short	Short and ongoing
Cost/VFM	Good VFM	Good VFM	Good VFM	Good VFM
Scale /2	Localized in low-lying areas	Prioritize air and sea assets that are at risk under existing conditions	Prioritize areas and surrounding communities that are at risk under existing conditions	National
Co-benefits/Unintended Consequences	Economic: will prioritize which air and sea transportation assets are inadequate under current conditions	Economic: will enable climate change modeling to incorporate local topography	-	Will improve the accuracy of information available for decision makers
Priority	No regrets	No regrets	No regrets	No regrets

Source: ECLAC, 2011b

Table 11 (continued)

Aspect of the Effect	Adaptation Reference (Ar)			
	Ar5	**Ar6**	**Ar7**	**Ar8**
Adaptation	Redesign/retrofit air and sea terminals and facilities with appropriate protection, or relocate. Dependent on A1, A2, A3 and A4.	Incorporate existing and predicted climate change conditions in new design of air and sea transport assets. Dependent on A3 and A4.	Incorporate predicted climate change conditions on existing air and sea transport assets where they require rehabilitation or improvement. Dependent on A3 and A4.	Incorporate predicted change in new and existing international transport assets when population growth is facilitated through land use changes in coastal areas.
Type	Operation	Design	Operation	Policy
Ownership	Barbados – Ministry of Works, GAIA, Bridgetown Port	Barbados – Ministry of Works, GAIA, Bridgetown Port	Barbados – Ministry of Works, GAIA, Bridgetown Port	GAIA, Bridgetown Port and local authorities
Recommended Timeframe /1	Medium to long	Short and ongoing	Short and ongoing	Short and ongoing
Cost/VFM	Good VFM	Good VFM	Good VFM	Good VFM
Scale /2	Localized in low-lying areas.	Localized in low-lying areas.	Localized in low-lying areas.	National
Co-benefits/Unintended Consequences /3	Economic: will prioritize which air and sea transportation assets are inadequate for current conditions	Minimizes risk of over-engineering.	Minimizes risk of over-engineering.	Social: minimizes the risk of disruption to communities.
Priority	Low regrets	Low regrets	Low regrets: preventative action.	Low regrets

Notes: /1 Short = to 2011; medium = by 2040s; long by 2090s
/2 e.g. low cost and high return = priority
/3 e.g. social, economic or environmental consequences; alignment with policies.
Source: ECLAC, 2011b

7. CONCLUSIONS AND POLICY RECOMMENDATIONS

Barbados is at great risk from the economic impact of climate change on its tourism, international transportation and coastal and human settlements sectors. The analysis on the coastal and human settlements sector has shown that based upon exposed assets and population, SLR can be classified as having the potential to create potential catastrophe in Barbados. The main contributing factor is the concentration of socioeconomic infrastructure along the coastline in vulnerable areas. The A2 and B2 projections have indicated that the number of catastrophes can be classified as great and is likely to increase. This is based upon the possible effects of the projected unscheduled impacts to the economy both in terms of loss of life and economic infrastructure. These results arise from the A2 and B2 projections, thereby indicating that growth in numbers and losses are largely due to socioeconomic changes over the projection period and hence the need for increased adaptation strategies. A key adaptation measure recommended is for the government of Barbados to begin reducing the infrastructure deficit by continuously investing in protective infrastructure to decrease the country's vulnerability to changes in the climate.

With regard to the tourism sector, it was found that by combining the impacts due to a reduction in tourist arrivals, coral reef loss and SLR, estimated total economic impact of climate change will be US 7,648 million (A2 scenario) and US $5,127 million (B2 scenario). Of the adaptation options examined, it was found that four (4) out of nine (9) options had high cost-benefit ratios and are therefore cost effective. It is therefore recommended that these strategies be pursued first: (1) enhanced reef monitoring systems to provide early warning alerts of bleaching events; (2) artificial reefs or fish-aggregating devices; (3) development of national adaptation plans (levee, sea wall and boardwalk); (4) revision of policies related to financing carbon neutral tourism; and (5) increasing recommended design wind speeds for new tourism-related structures.

The total cost of climate change on international transportation combined the impact of changes in temperature and precipitation, new climate policies and SLR. The impact for air transportation ranges from US$ 10,727 million (B2 scenario) to US$ 12,279 million (A2 scenario) and for maritime transportation impact estimates range from US$ 1,992 million (B2 scenario) to US$ 2,606 million (A2 scenario). For international transportation as a whole, the impact of climate change varies from US$ 12,719 million under the B2 scenario to US$ 14,885 million under the A2 scenario. Barbados has the institutions set up to implement adaptive strategies to strengthen the resilience of the existing international transportation system to climate change impacts. Air and sea terminals and facilities can be made more robust, elevated, or even relocated.

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