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**AN ASSESSMENT OF THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE
HEALTH, TOURISM AND TRANSPORT SECTORS IN MONTSERRAT**

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EXECUTIVE SUMMARY

This report analyses the health, tourism and transport sectors in Montserrat to assess the potential economic impacts 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 Montserrat. 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, using discount rates of 1%, 2% and 4%. An exploration of various adaptation strategies was also undertaken for each sector using standard evaluation techniques.

The assessment of the health sector demonstrates the potential for climate change to add a substantial burden to the future health systems on Montserrat. Monetary valuation was based on a transfer value of statistical life approach with a modification for morbidity. The results show mean annual costs (morbidity and mortality) ranges from \$1 million (in the A2 scenario, discounted at 1% annually) to \$0.61 million (in the B2 scenario, discounted at 4% annually) for Montserrat. These costs are compared to adaptation cost scenarios involving increased direct spending on per capita health care. This comparison reveals a high benefit-cost ratio suggesting that moderate costs will deliver significant benefit in terms of avoided health burdens in the period 2010-2050. The methodology and results suggest that a focus on coordinated data collection and improved monitoring represents a potentially important 'no regrets' adaptation strategy for Montserrat. It is also recommended that the adaptation option be part of a coordinated regional response that avoids duplication in spending.

With reference to the tourism sector, the results suggest that under both scenarios, the island's key tourism climatic features will likely decline and therefore negatively impact on the destination experience of visitors. It was found that the total cost of climate change for the tourism industry was projected to be 9.6 times 2009 GDP if no action is taken to adapt to likely effects of climate change. Given the potential for significant damage to the industry a large number of possible adaptation measures were considered. From these a short-list consisting of nine potential options were selected using ten evaluation criteria. Using benefit-cost analyses three options were put forward: (1) increase recommended design speeds for new tourism-related structures; (2) enhanced reef monitoring systems to provide early warning alerts of bleaching events, and; (3) deployment of artificial reefs and fish-aggregating devices. While these options had positive benefit cost ratios, other options were also recommended based on their non-tangible benefits: irrigation network that allows for the recycling of waste water, development of national evacuation and rescue plans, providing retraining for displaced tourism workers and the revision of policies related to financing national tourism offices to accommodate the new climatic realities.

The total cost of climate change on international transportation in Montserrat was calculated by combining the impacts of changes in temperature and precipitation, new climate change policies in advanced countries, sea level rise and a possible eruption of the Soufriere Hills volcano. The impact for air transport could range from US\$742 million (A2 scenario) to US\$630 million (B2 scenario) and for maritime transport impact estimates range from US\$347 million (A2 scenario) to US\$209 million (B2 scenario). For international transport as a whole, the impact of climate change varies from US\$1,089 million under the A2 scenario to US\$839 million under the B2 scenario. Montserrat 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 hardened, raised, or even relocated. The adaptive strategies that are eventually employed depends on the associated costs, and the relative effectiveness of those strategies will have to be determined on a case-by-case basis, based on studies of individual facilities and system-wide considerations.

Despite revealing a number of areas worthy of further research, the results of this study are important because the framework utilized and the analyses undertaken have generated examples of data that are not only specifically geared for inclusion in a formal decision-making context, but are also intended to contribute to the overall process of adapting Montserrat to the future risks associated with climate change.

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% to global 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.

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). The effects of climate change are already being felt in Montserrat. Between 1970 and 2009, there was a rise in the number of relatively hot days experienced on the island, a decline in mean precipitation over the period and the threat of wind speeds. Since the early 20th century, the number of hurricanes passing through the Caribbean has risen from about 5-6 per year to more than 25 in some years of the 21st century. In Montserrat, the estimated damage from 4 windstorms (including hurricanes) affecting the island was US\$260 million or almost 5 times 2009 GDP. Climate change is also likely to significantly affect coral reefs. Hoegh-Guldberg (2007) estimates that should current concentrations of carbon dioxide in the Earth's atmosphere rise from 380ppm to 560ppm, decreases in coral calcification and growth by 40 percent are likely.

This report attempts to assess the economic impact of climate change on the health, tourism and transportation sectors in Montserrat as these were deemed most vulnerable to climate change and are key direct or indirect contributors to the country's GDP

2. BRIEF REVIEW OF THE SECTORS

A. HEALTH

The Soufrière Hills volcano eruptions have affected every aspect of Montserrat's economy, politics, development, and overall living conditions. Accurate population figures are extremely difficult to track the result of the emergency, as many residents left to spend varying periods abroad. The best population estimates show a drop from 10,402 in 1994 to 5,600 in 1997. By January 1998, the population had decreased to 3,483. There were 150 live births in 1994, 126 in 1995, and 128 in 1996. Age and sex breakdowns are not available for the period under review.

The island's Sustainable Development Plan (2008-2020) targets a population of 9000 by 2020. Under this scenario, health exposures are likely to be more important than at present. Montserrat provides good vaccine coverage and is considered a middle-income country, though the health sector receives substantial donor support, and suffers from a shortage of trained staff (PAHO, 2010).

¹ Antigua and Barbuda, The Bahamas, Montserrat, 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 CO₂ emissions in 2001 (UNEP, 2002).

B. TOURISM

The tourism product in Montserrat is based around the sea. The island's beaches reflect the impact of past volcanic eruptions and therefore tend to be grey. Diving and snorkelling are also becoming popular tourist activities, as the pyroclastic flows into the sea surrounding the island have added new substrates for reefs and protected the marine ecosystem from human activities. As most of the island lies in the Exclusion Zone, a number of hiking trails have developed so that visitors can explore the entire island. Of course, volcano viewing has also emerged as a popular tourist attraction.

Like most other Caribbean countries, Montserrat has been significantly affected by the global recession. In 2009, 7875 tourists visited the island, down from 10,159 in 2008 and 10,450 in 2007 (ECCB, 2009). It is estimated that these tourists spent almost US\$5.2 million in 2009 (almost 23 percent of GDP), down from US\$7.1 million one-year prior and US\$9.1 million in 2005. As an indicator of the importance of the tourism industry, foreign-exchange earnings from tourism on the island were almost five times more than that from merchandise exports. The majority of tourists visiting the island are stay-over arrivals, with most of the remainder being excursionists.

C. TRANSPORTATION

1). Air Transportation

Air transportation in Montserrat is critical to the island's economic regeneration and to re-establishing external links with the rest of the world. Montserrat is accessible to the rest of the world via Antigua and Barbuda. The completion of Gerald's Airport (renamed John A. Osborne Airport in 2005) allowed for the resumption of regular but still limited commercial airline service to Montserrat for the first time since 1997, when W. H. Bramble Airport, which had been the island's only aviation gateway, was completely destroyed by an eruption of the nearby Soufriere Hills volcano. Between 1997 and 2005, Montserrat had been only accessible by helicopters or boat.

The shift from ferry to air service also had quite an impact on tourism island-wide. The current arrival rates are less than half the 1995 figures when arrivals approached 20,000³. According to the 2010 Budget Statement, as of November 2009, visitor arrivals to Montserrat were 14 percent lower than the corresponding 11-month period for 2008.

2). Transportation

In 2009, the total value of trade in goods in Montserrat amounted to US\$30 million or 65 percent of GDP. Most of this trade relates to imports whereas domestic exports declined by 31.5 percent in 2009 following the closure of three of the mining plants in the Trants Bay Area in October 2009. In terms of imports, the United States of America is by far the most important trading partner for Montserrat accounting for about one-fifth of total imports. Other major trading partners are Trinidad and Tobago, Japan and Canada. Outside of Trinidad and Tobago, Montserrat has little merchandise import trade with other CARICOM countries. For exports, the situation is different. Most of the merchandise exports of Montserrat go to Antigua. Outside of the Caribbean region, the United States of America account for the lion's share of Montserrat' total merchandise exports. According to the 2010 Budget Statement⁴, the long awaited port development project with an anticipated total cost of about US\$28 million (or more than 60 percent of 2009 GDP) is now in the design phase.

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).

³ Statistics available at: <http://www.onecaribbean.org/statistics/tourismstats/>

⁴ Available at: http://www.gov.ms/?page_id=4933

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). Health. The nature of this sector required a different analytical approach to costing the economic impact of climate change. As a result the research implemented a dose response-based rapid integrative assessment approach to project and value the excess disease burden caused by climate change. An outline of the methodology is shown below:

- 1) Estimating climate variables under climate change
- 2) Identifying the time line for the study
- 3) Identifying potential areas of impact
- 4) Identifying areas of impact that can be quantified
- 5) Quantifying those impacts
- 6) Comparing those impacts to a baseline representing a world without climate change
- 7) Valuing this excess disease burden

These steps are divided into stages relating to preliminary assumptions, baseline projections, climate change scenario projections and endpoint valuation.

2). Tourism. Three layers of economic impact analysis were employed to evaluate the tourism sector. The first focused on tourist arrivals, where climate (represented by temperature, humidity, precipitation, wind speed and duration of sunshine) and economic data were modeled using regression analysis. The second

addressed climate related impacts on coral reef-related tourism and the third assessed the impact of SLR and related impacts, such as land and infrastructure loss.

3). Transportation. Evaluation of the transportation sector also used a layering technique employing four 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 three other core impacts considered in the assessment were international travel mobility, the impact of SLR on the international transport infrastructure and the influence of an eruption of the Soufriere Hills volcano.

Given the long-run nature of climate change impact assessments, it is common to calculate the present value of the impacts calculated over the 50- or 100-year horizon. This study uses three social discount rates – 1%, 2%, and 4% – to better gauge the sensitivity of the economic impact estimates of climate change on the sectors under review, but recognizes the need to regularly review the appropriateness of this range of interest rates in light of changing economic and capital market circumstances, both domestic and international.

Costing of the adaptation strategies in each of the sectors was undertaken by using net cost-benefit analysis or multicriteria analysis.

5. ECONOMIC IMPACT ASSESSMENT OF CLIMATE CHANGE ON THE HEALTH, TOURISM AND TRANSPORT SECTORS

A. HEALTH

Evaluation of the impact of climate change on the health sector in this study employs an approach which assigns monetary values to cases of morbidity and mortality under the climate scenarios. Table 2 shows the maximum range of the mean extra Value of a Statistical Life (VSL) burden generated by climate change under two climate change scenarios. The overall VSL impacts are smaller under scenario B2 than A2.

Table 2: VSL anomaly burden range 2010-2050 (US\$)

Mean Cumulative VSL Anomaly Burden 2010-2050	A2			B2		
	Morbidity	Mortality	Total	Morbidity	Mortality	Total
Range Type	4% DR	4% DR	4% DR	4% DR	4% DR	4% DR
	–	–	–	–	–	–
Cumulative PV Range	1% DR	1% DR	1% DR	1% DR	1% DR	1% DR
	336,957	26,889,115	27,226,072	300,182	24,872,598	25,172,780
Mean Annual Range	–	–	–	–	–	–
	464,724	42,277,446	42,742,170	350,974	36,196,082	36,547,056
Mean Annual Range	8,218	655,832	664,051	7,322	606,649	613,970
	–	–	–	–	–	–
Mean Annual Range per Capita	11,335	1,031,157	1,042,492	8,560	882,831	891,392
	1	97	98	1	91	92
Mean Annual Range per Capita	–	–	–	–	–	–
	2	153	154	1	132	133

Notes: The top number in each cell shows the lower bound calculated for that particular category of impact. Each lower bound was calculated using the 4% discount rate. The bottom number in each cell shows the upper bound, which was calculated using the 1% discount rate. Source: ECLAC, 2011

The PPP-adjusted US\$ values shown in table 2, reveal a nontrivial impact, especially considering that the statistical life costs represent only the value of the indirect, nonmarket costs of human life which

represents part of the total economic costs that will be incurred by each of these fatalities or incidence of disease.

B. TOURISM

Three distinct scenarios⁵ were considered in the context of tourist arrivals, namely the A2, B2 and BAU⁶. The cumulative forecasted arrivals under the A2 and B2 scenarios are 718325 and 735647 tourists, respectively, compared to 726986 in the BAU scenario (table 3). The projected earnings of the industry over the 40-year horizon under the BAU scenario are US\$834.65 million. Under the A2 scenario, however, the earnings from the industry fall to US\$750.09 million.

Table 3: Cumulative Forecasted Arrivals and Expenditure in US\$ millions for specific years for the three scenarios (A2, B2 and BAU)

Arrivals	A2	B2	BAU
2008-2020	118116	120946	127753
2021-2030	146921	150516	161818
2031-2040	194872	199530	217470
2041-2050	258416	264655	292262
Total	718325	735647	799303
Earnings(US\$ million)	A2	B2	BAU
2008-2020	123.34	126.29	133.40
2021-2030	153.42	157.17	168.97
2031-2040	203.49	208.35	227.09
2041-2050	269.84	276.36	305.19
Total	750.09	768.18	834.65

Source: ECLAC, 2011a

Coral reefs are one of the most important components of the regional tourism product. However, Hoegh-Guldberg et al. (2007) notes that climate change could have potentially large and important effects on coral reefs in the region. The results for the effect of climate change on coral reefs under the A2, B2 and BAU scenarios are provided in table 4.

Table 4: Value of Coral Reef Affected

	Value (US\$ mil)		
	A2	B2	BAU
Value of Reef Affected	600	300	75

Source: ECLAC, 2011a

The coastline in tourism destinations is a major part of the product. Beachfront properties, often sell for more than those further inland. In addition, most major aspects of the economy also tend to be located along the coastline (e.g. government offices, electricity generation plants). The impact of a 2m (A2) and 1m (B2) rise in sea levels are provided in table 5. For Montserrat about 1 percent of the land area is lost under both scenarios. Therefore, Simpson et al. (2010) forecasts that the impact on major tourism resorts was minimal. In all three scenarios, however, all the major ports are affected, both in the 1m and 2m sea level rise scenarios. Due to limited information, no annual cost estimates are available; only capital costs. In the mid-range sea level rise scenario, the capital cost was estimated at US\$20 million (38 percent of GDP), and US\$37 million (70 percent of GDP) in the high range scenario.

⁵ For an explanation of the IPCC climate scenarios see: <http://sedac.ciesin.columbia.edu/ddc/sres>

⁶ The BAU scenario is a linear extrapolation of the time series of tourist arrivals.

Table 5: Annual and Capital Costs of Sea Level Rise

	GDP (US \$mil)	Annual Costs (US\$ mil)				Capital Costs (US\$ mil)								
		Tourism	Agriculture	Industry	Total Annual Costs (US\$ mil)	Airports	Ports	Roads	Power	Property	Tourist Resorts	Dry land	Wetland	Total
Mid range sea level rise	111	n.a.	0	0	0	n.a.	17	0	-	0	n.a.	3	-	20
High range sea level rise	125	n.a.	0	0	0	n.a.	30	0	-	1	n.a.	5	-	37

Source: Simpson et al. (2010)

Note: n.a. indicates 'not available'.

Source: ECLAC, 2011a

The estimated value of land loss in Montserrat is provided in table 6. The nominal value of the land loss was US\$37million under the A2 scenario and US\$20 million for the B2 scenario.

Table 6: Estimated Value of Land Loss Due to Sea Level Rise

	A2	B2
Land Area (km)	102	102
Expected Land Loss (km)	1.02	1.02
Nominal Value of Land Loss (US\$ mil)	37.0	20.0

Source: ECLAC, 2011a

Given the above estimates, the total cost of climate change to the tourism product in Montserrat (using a discount rate of 1 percent) was estimated at US\$504.6 million under the A2, or 9.6 times the value of 2009 GDP and US\$208 million for the B2 scenario, or 5.2 times the value of 2009 GDP (table 7).

Table 7: Total Estimated Impact of Climate Change on Tourism (US\$ Mil)

Estimated Damage	1% discount rate		2% discount rate		4% discount rate	
	A2	B2	A2	B2	A2	B2
Tourism	(76.55)	(60.18)	(69.37)	(54.53)	(57.12)	(44.91)
Coral Reefs	(403.21)	(201.60)	(271.88)	(135.94)	(125.04)	(62.52)
Land	(24.85)	(13.43)	(16.76)	(9.06)	(7.71)	(4.17)
Total	(504.61)	(275.21)	(358.00)	(199.53)	(189.87)	(111.59)

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 Montserrat under the A2 and B2 climate scenarios until 2050. Table 8 shows the impact of temperature and precipitation on cumulative international transport expenditure for Montserrat under the BAU, A2 and B2 climate change scenarios.

Table 8: Impact of Temperature & Precipitation on Cumulative International Transport Expenditure for Montserrat under A2 and B2 Scenarios (2008 US\$ millions)

Year	Air Transportation			Maritime Transportation			International Transportation		
	BAU	A2	B2	BAU	A2	B2	BAU	A2	B2
2020	65	45	52	38	27	31	103	72	83
2030	226	158	181	79	55	63	305	213	244
2040	614	430	491	127	89	101	741	519	592
2050	1,507	1,055	1,205	192	134	153	1,699	1,189	1,358

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\$1,055 million by 2050, an implied loss of some US\$452 million relative to the BAU scenario over the forty-year period. Air transportation expenditures under the B2 scenario, will reach a cumulative US\$1,205 million by 2050 indicating an implied loss of US\$302 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 expenditure in the A2 scenario is projected to reach a cumulative US\$134 million by 2050, an implied loss of US\$58 million when compared to the BAU scenario of US\$192 million over the forty-year period. Sea transportation expenditure under the B2 scenario reaches a cumulative US\$153 million by 2050, generating an implied loss of US\$39 million.

For the combined international transportation sector, the total cumulative expenditure (in 2008 dollars) amounts to US\$1,189 million under the A2 scenario and US\$1,358 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\$510 million by 2050, while that for the B2 scenario reach US\$341 million by 2050.

Simpson (2010) estimates that the imposition of the Aviation Passenger Duty (APD) is likely, on a intermediate scenario basis, to reduce tourist arrivals to Montserrat by 6.3% in 2020 and by as much as 25.2% by 2050. Based on these estimates, table 9 gives the cumulative loss in international transport expenditure in Montserrat 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\$266 million and under the B2 scenario is US\$316 million. The potential cumulative economic cost for maritime transportation under the A2 scenario is US\$34 million and under the B2 scenario is US\$39 million. The cumulative economic loss for the international transport sector in Montserrat arising from the climate change policies in advanced countries is US\$300 million by 2050 under the A2 scenario and US\$355 million under the B2 scenario over the forecast period.

Table 9: Impact of Climate Change Policies in Advanced Countries on International Travel Mobility in Montserrat under A2 and B2 Scenarios (2008 US\$ millions)

Year	Air Transportation		Maritime Transportation		International Transportation	
	A2	B2	A2	B2	A2	B2
2020	3	3	2	2	5	5
2030	17	20	6	7	23	27
2040	88	98	18	20	106	118
2050	266	316	34	39	300	355

Source: ECLAC, 2011b

The total rebuilding cost for Montserrat resulting from damage due to SLR is conservatively assumed as follows. The cost of the upgrade and expansion program at Little Bay Port – US\$9 million – is

projected over the period 2010 to 2050 using an annual inflation rate of 5%. About 80 percent of this value for the A2 scenario and 40 percent for the B2 scenario are assumed as the losses that will be generated by 2050 (table 10).

Table 10: Impact of Sea Level Rise on International Transport Infrastructure in Montserrat under A2 and B2 Climate Change Scenarios by 2050 (2008 US\$ millions)

	Air Transportation		Maritime Transportation		International Transportation	
	A2	B2	A2	B2	A2	B2
Total Land Area, km ²	34	34	68	68	68	68
Land Loss, km ²	0	0	1.4	0.7	1.4	0.7
2050 Value of Land Loss	0	0	140	70	140	70
2050 Value of International Transport Loss	0	0	6	7	6	7
2050 Value of Rebuilding Costs	0	0	61	30	61	30
Total Loss Due to Sea Level Rise	0	0	207	107	207	107

Source: ECLAC, 2011b

Montserrat is a volcanic island with evidence suggesting at least five major eruptions in the last 30,000 years. Estimating the economic costs associated with volcanic eruptions is very difficult, because there are numerous distinct but interconnected hazards, each of which is threatening to different aspects of human activities. For any one volcano, not all of these hazards may be significant, and individual eruptions also differ in the extent and importance of the different hazards. The next eruption of any volcano may be quite unlike those of the past. Indeed, 12 of the 16 biggest eruptions of the past 200 years have occurred at volcanoes which have not erupted in recorded history (McGuire, 2003). Thus, in assessing the potential risks associated with an eruption of the Soufriere Hills volcano, a well-informed scientific opinion is needed and a precautionary approach should be adopted, including all potential hazards whether they have occurred in its recorded history or not.

In this regard, a conservative approach was adapted and a catastrophic eruption of the Soufriere Hills volcano at the end of the forecast period in 2050 with the economic costs similar to that of the eruption in 1997 was assumed. The 1997 cost of US\$10 million using an annual inflation rate of 5 percent over the forecast period is projected and about 80 percent of this value for the A2 scenario and 40 percent for the B2 scenario are assumed as the losses that will be generated by 2050. Table 11 shows that the impact of an eruption of the Soufriere Hills volcano on international transportation in Montserrat amounts to US\$72 million under the A2 scenario and US\$36 million under the B2 scenario by 2050.

Table 11: Impact of Eruption of Soufriere Hills Volcano on International Transportation in Montserrat under A2 & B2 Scenarios by 2050 (2008 US\$ millions)

Year	Air Transportation		Maritime Transportation		International Transportation	
	A2	B2	A2	B2	A2	B2
2050	24	12	48	24	72	36

Source: ECLAC, 2011b

The total cost of climate change on international transportation in Montserrat was calculated by combining the impacts of changes in temperature and precipitation, new climate change policies in advanced countries, sea level rise and an eruption of the Soufriere Hills volcano. Table 12 presents the net present value of the total impact of climate change (in 2008 dollars) on the air and sea transportation industry in Montserrat for 2050. The net present value of the total impact under the A2 scenario amount ranges from US\$570 million (4% discount rate) to US\$1,013 million (1% discount rate). The net present value under the

B2 scenario varies from US\$428 million using a 4% discount rate to US\$758 million under a 1% discount rate.

Table 12: Net Present Value of Total Impact of Climate Change on International Transportation in Montserrat to 2050 under Scenarios A2 and B2 (2008 US\$ million)

Discount Rate (%)	Air Transportation		Maritime Transportation		International Transportation	
	A2	B2	A2	B2	A2	B2
1	748	599	265	159	1,013	758
2	639	512	226	136	865	648
4	421	338	149	90	570	428

Source: ECLAC, 2011b

6. ADAPTATION STRATEGIES

A. APPROACHES TO ADAPTATION IN MONTSERRAT

Montserrat has already begun to look seriously at potential adaptation options. As an overseas territory of the United Kingdom, however, the island is not party to either the United Nations Framework Convention on Climate Change or the Kyoto Protocol. Nevertheless, since 2005 the Department of the Environment, along with the Montserrat Tourist Board, Montserrat National Trust, Royal Botanic Gardens Kew, Durrell Wildlife and the Royal Society for the Protection of Birds have implemented a Darwin project to conserve the Centre Hills area. This process involved biological and socioeconomic assessments (management plans, outreach, increased local capacity for environmental management and the preparation of new environmental legislation to enable the Centre Hills to be designated a national park.

In addition, the government of Montserrat is also coordinating a project to establish the Organisation of Eastern Caribbean States (OECS) Climate Change Centre at the summit of the Silver Hills in the northern section of the island. The main goal of the Centre would be to identify and recommend potential adaptation to climate change options for the OECS and the wider Caribbean region.

B. COSTING ADAPTATION STRATEGIES IN THE HEALTH SECTOR

Mitigation in the health sector is concerned with the cost of treating health impacts as they occur. This implies treatment of impacts rather than cure - the latter is associated with a more targeted program of adaptations to obviate the health impacts occurring. If treatment of cases takes place in the A2 and B2 scenarios, the costs that are likely to be incurred are shown in table 13.

Table 13: Estimated present value treatment cost for A2 and B2 relative to baseline \$US present value 2010-2050

Discount Rate	A2				B2			
	Cardio and respiratory impacts	Malaria	Dengue	Gastro.	Cardio and respiratory impacts	Malaria	Dengue	Gastro
1%	42,167	441	33,601	228,930	19,417	437	9,495	204,471
2%	1,821	351	28,051	192,367	16,677	346	9,591	176,048
4%	13,281	233	20,140	140,893	12,542	226	8,889	132,913

Source: ECLAC, 2011

For the health sector, it is suggested that an adaptation strategy based on monitoring and public

information, i.e. relatively low cost “no regrets” interventions. In the absence of more detailed baseline spending and unmet adaptation needs, a comprehensive program should be developed based on a modest increase in per capita healthcare spending - \$220 in 2007 (PAHO, 2010)).

C. COSTING ADAPTATION STRATEGIES IN THE TOURISM SECTOR

Table 14 provides a summary of the benefit-cost analyses conducted for the study. Of the 9 options considered, 3 had benefit-cost ratios above 1 over a 20-year horizon: option 1, option 4 and option 5. While some of the other options may have ratios below 1, once non-tangible benefits are included in the analysis it is quite likely that these ratios might easily rise above 1. For example, while retraining workers might not be cost effective, in terms of the well being of the country’s citizens, the option might still be considered viable.

Table 14: Benefit-cost analysis of selected options

	Details	1% discount rate		2% discount rate		4% discount rate	
		Benefit Cost Ratio	Payback Period (years)	Benefit Cost Ratio	Payback Period (years)	Benefit Cost Ratio	Payback Period (years)
Option 1	Increase recommended design wind speeds for new tourism-related structures	1.5	14	1.4	14	1.3	15
Option 2	Construction of water storage tanks	0.4	-	0.4	-	0.4	-
Option 3	Irrigation network that allows for the recycling of waste water	0.3	-	0.3	-	0.3	-
Option 4	Enhanced reef monitoring systems to provide early warning alerts of bleaching events	4.5	3	4.4	3	4.0	3
Option 5	Artificial reefs or fish-aggregating devices	1.9	6	1.8	7	1.7	7
Option 6	Develop national evacuation and rescue plans	0.9	-	0.9	-	0.8	-
Option 7	Introduction of alternative attractions	0.0	-	0.0	-	0.0	-
Option 8	Provide re-training for displaced tourism workers	0.4	-	0.4	-	0.4	-
Option 9	Revise policies related to financing national tourism offices to accommodate the new climatic realities	0.1	-	0.1	-	0.1	-

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 Montserrat (table 15). 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.

Table 15: MCA of the Effects of Climate Change on International Transport Infrastructure in Montserrat

Aspect of the Effect	Adaptation Reference (Ar)			
	Ar1	Ar2	Ar3	Ar4
Adaptation	Review the findings of this study on vulnerable sections of the air and sea transport network, and assess the adequacy of international transport asset protection structures under existing conditions	Map air and sea infrastructure assets and coastal margins at 1m scale or better, with at least 0.2 m precision in elevation across tidal reach	Model combined effects of inundation risk (sea level rise plus storm surge plus wave run up) at John A. Osborne Airport and Little Bay Port	Monitor coastal hazard risk (sea levels and waves)
Type	Research	Research	Research	Policy
Ownership	Montserrat – Ministry of Works, John A. Osborne Airport and Little Bay Port	Montserrat – Ministry of Works	Montserrat – Ministry of Works	John A. Osborne Airport and Little Bay 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 those air and sea assets that are at risk under existing conditions	Prioritize those 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 15 (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	Montserrat – Ministry of Works, John A. Osborne Airport and Little Bay Port	Montserrat – Ministry of Works, John A. Osborne Airport and Little Bay Port	Montserrat – Ministry of Works, John A. Osborne Airport and Little Bay Port	John A. Osborne Airport and Little Bay 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

Montserrat is at great risk from the economic impact of climate change on its tourism, international transportation and health sectors. In this connection, Montserrat has already begun to look seriously at potential adaptation options. The government of Montserrat is also coordinating a project to establish the Organisation of Eastern Caribbean States (OECS) Climate Change Centre at the summit of the Silver Hills in the northern section of the island. The main goal of the Centre would be to identify and recommend potential adaptation to climate change options for the OECS and the wider Caribbean region.

The assessment of the health sector demonstrates the potential for climate change to add a substantial burden to the future health systems on Montserrat. Monetary valuation was based on a transfer value of statistical life approach with a modification for morbidity. The results show mean annual costs (morbidity and mortality) ranges from \$1 million (in the A2 scenario, discounted at 1% annually) to \$0.61

million (in the B2 scenario, discounted at 4% annually) for Montserrat. These costs are compared to adaptation cost scenarios involving increased direct spending on per capita health care. This comparison reveals a high benefit-cost ratio suggesting that moderate costs will deliver significant benefit in terms of avoided health burdens in the period 2010-2050. The methodology and results suggest that a focus on coordinated data collection and improved monitoring represents a potentially important 'no regrets' adaptation strategy for Montserrat. It is also recommended that the adaptation option be part of a coordinated regional response that avoids duplication in spending.

It was found that the total cost of climate change for the tourism industry was projected to be 9.6 times 2009 GDP if nothing is done to adapt to likely effects of climate change. Given the potential for significant damage to the industry a large number of potential adaptation measures were considered. From these a short-list consisting of 9 potential options were selected using 10 evaluation criteria. Using benefit-cost analyses 3 options were put forward: (1) increase recommended design speeds for new tourism-related structures; (2) enhanced reef monitoring systems to provide early warning alerts of bleaching events, and; (3) deployment of artificial reefs and fish-aggregating devices. While these options had positive benefit cost ratios, other options were also recommended based on their non-tangible benefits: irrigation network that allows for the recycling of waste water, development of national evacuation and rescue plans, providing retraining for displaced tourism workers and the revision of policies related to financing national tourism offices to accommodate the new climatic realities.

The total cost of climate change on international transportation in Montserrat was calculated by combining the impacts of changes in temperature and precipitation, new climate change policies in advanced countries, sea level rise and an eruption of the Soufriere Hills volcano. The impact for air transport could range from US\$630 million (B2 scenario) to US\$742 million (A2 scenario) and for maritime transport impact estimates range from US\$209 million (B2 scenario) to US\$347 million (A2 scenario). For international transport as a whole, the impact of climate change varies from US\$839 million under the B2 scenario to US\$1,089 million under the A2 scenario. Montserrat has established the institutions 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 hardened, raised, or even relocated. The adaptive strategies that are eventually employed depends on the associated costs, and the relative effectiveness of those strategies will have to be determined on a case-by-case basis, based on studies of individual facilities and system-wide considerations.

The results of this study are important because the framework utilized and the analyses undertaken have generated examples of data that are not only specifically geared for inclusion in a formal decision-making context, but are also intended to contribute to the overall process of adapting Montserrat to the future risks associated with climate change.

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