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AN ASSESSMENT OF THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE WATER SECTOR IN THE TURKS AND CAICOS ISLANDS

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Acknowledgement

The Economic Commission for Latin America and the Caribbean (ECLAC) Subregional Headquarters for the Caribbean wishes to acknowledge the assistance of Juan Llanes, Consultant, in the preparation of this report.

Notes and explanations of symbols:

The following symbols have been used in this study:
A full stop (.) is used to indicate decimals
n.a. is used to indicate that data are not available
The use of a hyphen (-) between years, for example, 2010-2019, signifies an annual average for the calendar years involved, including the beginning and ending years, unless otherwise specified.
The word “dollar” refers to United States dollars, unless otherwise specified.
The term “billion” refers to a thousand million.

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Executive Summary

The best description of water resources for Grand Turk was offered by Pérez Monteagudo (2000) who suggested that rain water was insufficient to ensure a regular water supply although water catchment was being practised and water catchment possibilities had been analysed. Limestone islands, mostly flat and low lying, have few possibilities for large scale surface storage, and groundwater lenses exist in very delicate equilibrium with saline seawater, and are highly likely to collapse due to sea level rise, improper extraction, drought, tidal waves or other extreme event.

A study on the impact of climate change on water resources in the Turks and Caicos Islands is a challenging task, due to the fact that the territory of the Islands covers different environmental resources and conditions, and accurate data are lacking. The present report is based on collected data wherever possible, including grey data from several sources such as the Intergovernmental Panel on Climate Change (IPCC) and Cuban meteorological service data sets. Other data were also used, including the author's own estimates and modelling results. Although challenging, this was perhaps the best approach towards analysing the situation.

Furthermore, IPCC A2 and B2 scenarios were used in the present study in an effort to reduce uncertainty. The main conclusion from the scenario approach is that the trend observed in precipitation during the period 1961 - 1990 is decreasing. Similar behaviour was observed in the Caribbean region. This trend is associated with meteorological causes, particularly with the influence of the North Atlantic Anticyclone. The annual decrease in precipitation is estimated to be between 30-40% with uncertain impacts on marine resources.

After an assessment of fresh water resources in Turks and Caicos Islands, the next step was to estimate residential water demand based on a high fertility rate scenario for the Islands (one selected from four scenarios and compared to countries having similar characteristics). The selected scenario presents higher projections on consumption growth, enabling better preparation for growing water demand.

Water demand by tourists (stopover and excursionists, mainly cruise passengers) was also obtained, based on international daily consumption estimates. Tourism demand forecasts for Turks and Caicos Islands encompass the forty years between 2011 and 2050 and were obtained by means of an Artificial Neural Networks approach. for the A2 and B2 scenarios, resulting in the relation BAU>B2>A2 in terms of tourist arrivals and water demand levels from tourism.

Adaptation options and policies were analysed. Resolving the issue of the best technology to be used for Turks and Caicos Islands is not directly related to climate change. Total estimated water storage capacity is about 1, 270, 800 m^3/ year with 80% capacity load for three plants. However, almost 11 desalination plants have been detected on Turks and Caicos Islands. Without more data, it is not possible to estimate long term investment to match possible water demand and more complex adaptation options. One climate change adaptation option would be the construction of elevated (30 metres or higher) storm resistant water reservoirs. The unit cost of the storage capacity is the sum of capital costs and operational and maintenance costs. Electricity costs to pump water are optional as water should, and could, be stored for several months.

The costs arising for water storage are in the range of US$ 0.22 cents/m^3 without electricity costs. Pérez Monteagudo (2000) estimated water prices at around US$ 2.64/m^3 in stand points, US$ 7.92 /m^3 for government offices, and US$ 13.2 /$m^3$for cistern truck vehicles. These data need to be updated.

As Turks and Caicos Islands continues to depend on tourism and Reverse Osmosis (RO) for obtaining fresh water, an unavoidable condition to maintaining and increasing gross domestic product

(GDP) and population welfare, dependence on fossil fuels and vulnerability to increasingly volatile prices will constitute an important restriction. In this sense, mitigation supposes a synergy with adaptation.

Energy demand and emissions of carbon dioxide ($CO_{2)}$ were also estimated using an emissions factor of 2. 6 tCO_2/ tonne of oil equivalent (toe). Assuming a population of 33,000 inhabitants, primary energy demand was estimated for Turks and Caicos Islands at 110,000 toe with electricity demand of around 110 GWh.

The business as usual (BAU), as well as the mitigation scenarios were estimated. The BAU scenario suggests that energy use should be supported by imported fossil fuels with important improvements in energy efficiency. The mitigation scenario explores the use of photovoltaic and concentrating solar power, and wind energy. As this is a preliminary study, the local potential and locations need to be identified to provide more relevant estimates. Macroeconomic assumptions are the same for both scenarios. By 2050, Turks and Caicos Islands could demand 60 m toe less than for the BAU scenario.

I. INTRODUCTION

Turks and Caicos Islands is a paradise under the sun discovered almost 500 years ago by Spanish explorers and rediscovered by tourists almost 20 years ago. Tourism, water and fossil fuels comprise the key assets of the economy of Turks and Caicos Islands which have facilitated the tremendous expansion recorded in the last 10 years. Native populations learned to live there, and adapted to the environmental conditions of the Islands, but the expansion of the economy towards a tourism-based economy demanded larger quantities of water for various purposes that could only be obtained by artificial means. Authorities therefore chose to employ Reverse Osmosis (RO) technology as the best option.

The best description of water resources for Grand Turk was offered by Pérez Monteagudo (2000) who suggested that rainwater was insufficient to provide a regular water supply, although water catchment was being practised and water catchment possibilities had been analysed. A study on the impact of climate change on water resources for Turks and Caicos Islands is a challenging task, due to the variations in environmental resource conditions, the inaccurate and, in some cases, controversial data, and poor systems of data collection and recording.

When considering adaptation to climate change, the first goal of the Turks and Caicos Islands authorities should be the implementation of a sound information and data collection system for environmental conditions and resources, as a strategy for improving adaptive capacity towards climate change impacts. However, implementation ultimately depends on the available human, financial and institutional capacities.

This draft report is based on data collected globally, including grey data from several sources, the Intergovernmental Panel on Climate Change (IPCC) and the Cuban meteorological service data sets. Other data were also used, including the author's own estimates and modelling results. Although challenging, this was perhaps the best approach towards analysing the situation. Furthermore, various scenarios were used in an effort to reduce uncertainty. This report focuses on drivers and environmental resources and conditions strongly related to water resources, supply sources, demand and withdrawal, so as to allow for conclusions about adaptation and mitigation policies for Turks and Caicos Islands.

Assessment of the economic impact of climate change on the water sector in Turks and Caicos Islands involved, firstly, the use of hydro-meteorological variables and IPCC scenarios, and proxies to estimate future climate variables and water potential from precipitation. Secondly, it required the estimation of tourist arrivals and population growth towards 2050 under several conditions and scenarios. This estimation utilized a model which employs an Artificial Neural Networks approach to project the impact of climate change on the water sector to 2050. United Nations population data estimates were used.

Thirdly, estimation of water demand for both population and tourism consumption was conducted. Other uses are covered under the high growth scenario of per capita water consumption by the population. This exercise is useful because it creates awareness about water supply in the future. Although there seems to be no limit to desalination, the study may also help to reconsider the situation, considering the fact that less future precipitation and higher salinity may affect desalination effectiveness and marine ecosystems. In this regard, it should also be remembered that, in small island developing States (SIDS), fresh water is a complementary commodity the consumption of which may not be reduced below certain levels, and water supply improvement should be carefully weighed. Standard methodological approaches may not work, but consumer surplus may provide a guide for economic valuation.

Fourthly, adaptation and mitigation options are addressed through the introduction of solar energy to reduce vulnerability to volatile oil supply and prices. Adaptation strategies for water resources have been mainly developed for countries where water is obtained from precipitation and other sources of runoff, such as rivers or water from the cryosphere, and not for small islands like Turks and Caicos Islands that obtain fresh water through desalination, and where limits to salt water extraction are yet undetermined.

In this regard, only one special adaptation option was explored, because many of the other water policies are not exclusively linked to climate change. This option involves the construction of elevated, extreme event-resistant, gravity-fed reservoirs for the supply of water under adverse conditions. There are quite good experiences in the Caribbean and in Cuba with this kind of solution.

Finally, the study does not focus on extreme events, as it has not been proven that such events are linked to climate change, especially tropical hurricanes (see Box 1, a special report on "The Detection and Attribution Anthropogenic Climate Change in the Atmosphere from a Global Perspective", IPCC). Such an exercise (the link to extreme events) may distract from the real challenge which the Turks and Caicos Islands has to face in the future. It can be said that climate change will exacerbate the impact of extreme events, and countries like Turks and Caicos Islands should be prepared to confront this. Sea level rise (SLR) is an especial threat to Turks and Caicos Islands. However, its likely impact appear to relate more to the tourism industry, rather than to the desalination plants that are currently located at safe elevations or that may be removed from their present locations, if necessary.

II. CLIMATE CHANGE AND WATER RESOURCES

Box 1

Detection and Attribution of Anthropogenic Climate Change in the Atmosphere from a Global Perspective

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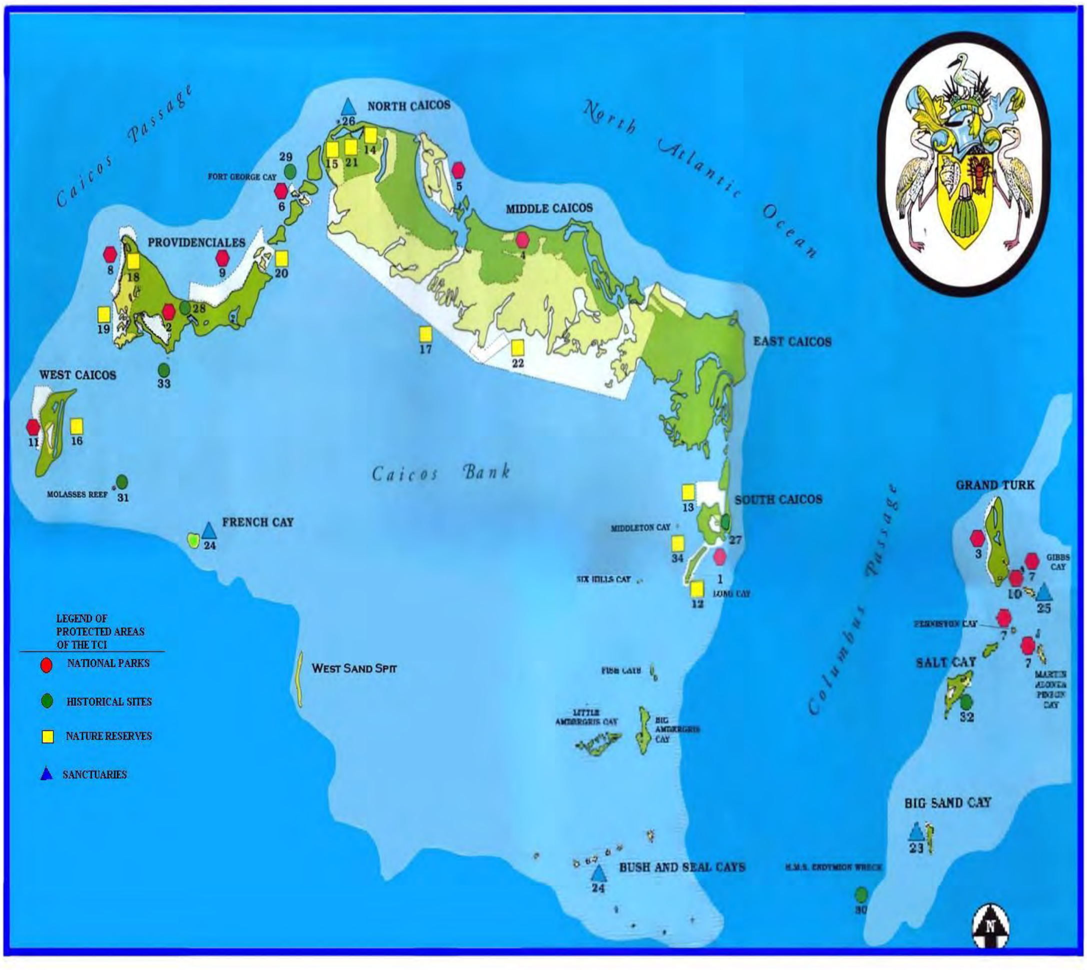
Theoretical understanding of how the hydrological cycle is expected to respond to anthropogenic warming is broadly consistent with the projections of climate models and the changes observed to date. It is expected that the there should be a roughly exponential increase with temperature and specific humidity and anthropogenic influence has been detected in surface humidity and in lower tropospheric moisture content consistent with theoretical expectations. Global precipitation is expected to be constrained by the global energy budget and an anticipated consequence of moisture flux and transport changes is that wet regions should become wetter and dry regions drier. An analysis of observed and modeled trends averaged over latitudinal bands has shown that anthropogenic forcing has had a detectable influence on observed changes in mean precipitation (Zhang and others, 2007). While these changes cannot be explained by internal climate variability or natural forcing, the magnitude of change in the observations is greater than simulated. This could indicate that climate models underestimate the real world's hydrological cycle sensitivity to global warming, although further analyses are required to determine whether this is the case.

From: IPCC Expert Meeting on Detection and Attribution Related to Anthropogenic Climate Change
The World Meteorological Organization Geneva, Switzerland
14-16 September 2009, Meeting Report

III. BACKGROUND AND DATA FOR TURKS AND CAICOS ISLANDS

Figure 1: Turks and Caicos Islands



Source: Data compiled by author

Table 1: Population[1] and size of Turks and Caicos Islands

Name	Abbr.	Km^2	1980	1990	2001	2006
Grand Turk	GTU	30	3 098	3 691	3 976	5 718
Middle Caicos	MCC	136	296	272	301	307
North Caicos	NCC	116	1278	1275	1347	1537
Parrot Cay	PAR	1	-	-	58	60
Providenciales & West Caicos	PRO	133	977	4821	13021	24348
Salt Cay	SCY	7	284	208	120	114
South & East Caicos	SCC	75	1 380	1 198	1 063	1 118
Turk & Caicos Island	TCA	497	7 413	11 465	20 014	33 207

Source: http://www.citypopulation.de/TurksCaicos.html, 2011

Table 2: Turks and Caicos Islands, real GDP (constant 2000 prices; US$ '000)

	Year					
	2000	**2002**	**2004**	**2006**	**2008**	**2009**
Agriculture & Fishing	4 620	3 871	5 147	5 542	4 100	4 230
Manufacturing	10 844	8 265	9 322	9 720	9 191	8 206
Hotel & Restaurants	98 931	100 043	113 564	161 267	228 755	228 253
Transport, Storage & Communication	33 758	36 337	42 846	50 350	68 185	68 171
Financial Intermediation	26 858	29 082	40 079	61 704	76 038	72 487
Real Estate, Renting & Business Activities	37 948	40 590	42 386	47 921	51 863	511 188
GDP, constant 2000 prices	284 375	304 298	368 724	485 349	606 190	547 830
GDP per capita, constant 2000 prices ($)	17 276	16 551	15 324	17 112	18 199	14 965*
GDP, current prices	319 443	345 923	421 349	568 138	679 626	604 222

Source: Data compiled by author

The tourism sector, the principal driver of economic activity (see table 2), is the main employer on the Islands and tourism is responsible for directly creating more than 50% of total jobs across the islands.[2] Since 2005, Turks and Caicos Islands has become a major cruise ship destination. Arrivals prior to 2006 were on average 20,000 visitors a year, increasing dramatically to

[1] Some additional information suggests that the population increased to 34,862 in 2007, and that 73% of total population lives in Providenciales. 2007 population data obtained from: http://www.depstc.org/reports/29b%20Labor%20&%20Employment%20Situationer%202007%20-%20Tables.pdf

[2] The Department of Economic, Planning and Statistics, 2005 data.

295,000 in 2006 and 532,245 in 2007 (table 3). The tourism sector contributes approximately 34.1% to GDP.

Table 3: Tourist arrivals to Turks and Caicos Islands

	2000	2003	2005	2008	2011 (projection)
Non-residents (stopovers)	151 372	164 100	176 130	352 271	362 945
Growth rate (%)	25.2	5.9	1.8	33.0	1.0

Source: The Department of Economic, Planning and Statistics (DEPS), February 2011 and author's projections

The range of merchandise exports from the Turks and Caicos Islands is very limited, yielding a total of US$ 24.8 million in revenue for 2008. The main exporting sector is fisheries (lobster, conch, and scale fish), which contributes 17.3% to total exports. Fishing resources rank as the third most important export industry after tourism and the financial services sector.[3] The United States of America continues to be the main export market, accounting for 99.5% of total Turks and Caicos Islands exports in 2008.

Turks and Caicos Islands is heavily dependent on imports for both consumption and production. Trade is mostly with the United States of America. According to the Department of Economic Planning and Statistics (DEPS), total imports were valued at US$ 591.3 million, while merchandise imports were valued at US$ 359.3 million or 60.8% of total imports into the Turks and Caicos Islands in 2008. Among the top imports were food and beverages, which accounted for 13.6% of total imports, and oil and derivate products (11.8%).

IV. CLIMATE AND HYDROMETEOROLOGICAL CHARACTERISTICS

During the decade of the 1970s, significant changes in regional climate behaviour have been observed in the tropical American Region. These changes are clearly reflected in the hydrological cycle, and were preceded by an important increment of inter annual variability (Planos and others, 1998; Gutiérrez and others, 1999; Planos, 2001). Atmospheric circulation in the last decade has been dominated by complex manifestations in natural climate variability, with cycles from two to ten years. The most relevant regulator of regional climate for the American Region is the El Nino-Southern Oscillation (ENSO). Although these observations have some level of uncertainty, the regional atmospheric circulation has responded to the changes observed recently in global circulation and it is very likely that a narrow link exists in the American Tropics between the variations of the North Atlantic Anticyclone, the thickness of

[3] This section benefits from the ECLAC report, "Turks and Caicos Islands: Macro Socio-Economic Assessment of the damage and losses caused by Tropical Storm Hanna and Hurricane Ike", ECLAC, 2008.

the low layer atmosphere, and observed fluctuations in precipitation. It is also possible that changes in the frequency and intensity of drought could be linked to these processes.

Among the changes in meteorological variables observed during the 1970s are a significant intensification in precipitation in the winter months, and a decrease in the duration of the rainy season. In addition, a significant increase relative to the period 1931-1960 in moderate and severe drought processes has been detected in the period 1961-2011.

The unquestionable influence of the North Atlantic Anticyclone (NAA) on regional atmospheric characteristics is confirmed by the finding that "the influence of the growing lineal tendency observed in the atmospheric pressure at mean and high levels during the last decades on precipitation is an indication of an intensification of the North Atlantic Anticyclone" (Naranjo and others, 1999). Fonseca (2001) reports that the relationship between the position and the intensity of the North Atlantic Anticyclone is expected to result in significant periods of rainfall deficit.

The following are some meteorological facts that corroborate the atmospheric anomalies:

- Throughout the period 1948 – 2000, a sustained modification of the atmospheric circulation characteristics was observed in all tropospheric levels of the Caribbean, producing an increase in vertical downward movements.
- The variation in the North Atlantic Oscillation (NAO) Index during winter is inversely related to average annual precipitation. Conversely, wet periods match times of low NAO.
- The strong presence of ENSO events is associated with dry, warm summers in the Caribbean as well as periods of no tropical storm formation. Strong ENSO periods have been shown to reduce the number and intensity of hurricanes in the Atlantic.
- Over the past 30 years, maximum summer sea surface temperature has increased by 0.7 °C.
- Reduction in annual precipitation, increase in drought and air temperature.
- Since the 1970s, a change in the anomalies of sea surface temperature has been observed.

V. WATER RESOURCES IN TURKS AND CAICOS ISLANDS

Pérez Monteagudo (2000) explained that the size, geology, topography and climatic conditions of Turks and Caicos Islands dictate that there will be problems related to the availability of fresh water. Limestone islands such as Grand Turk, which are mostly flat and low lying, have few possibilities for large scale surface storage. In addition, groundwater may be present in thin lens-shaped bodies. These lenses coexist in a very delicate equilibrium with saline seawater and can be destroyed by improper extraction, drought, tidal wave or other extreme events. With little opportunity for surface storage and very limited groundwater reserves, small islands suffer much more from the effects of drought than larger countries. These vulnerabilities are the major limitations to climate change adaptation in the water and other sectors in Turks and Caicos Islands. Pérez Monteagudo (2000) further reports that water availability in Turks and Caicos Islands remains a problem and, from a climate change perspective, is a great challenge because of the following:

- Surface water is excluded as a possible and secure source of water supply.
- The water distribution system consists of storage tanks and related catchment areas, reverse osmosis plants and a main pipe linking all the tanks.
- The main sources of water in Grand Turk are rainwater, reverse osmosis, desalination plants, non-potable water resources such as saline, brackish and "gray" water, and groundwater.
- Groundwater is not used for a fresh water supply in Grand Turk. Previous studies discarded the possibility of this source in Grand Turk and other islands off the Caicos.

Thus, in considering the impact of climate change on the water sector in the Turks and Caicos Islands, attention should be paid to the precipitation regime and sea level rise.

A. HYDROMETEOROLOGICAL BALANCE 1961 - 1990

Hydro-meteorological data for Turks and Caicos Islands are not available and, for this reason, precipitation and air temperature data obtained from the FRIEND project of the UNESCO International Hydrological Programme (IHP) for Latin-American and the Caribbean were used.[4] With this information a climate/water balance was developed using the universal equation of balance:

$$Q = P - E,$$

where Q: runoff (mm), P: is precipitation (mm) and E: evaporation (mm).

Since the variable Q represents the annual total of the precipitate water that potentially can be harvested for different consumption types, the intermediate physical variables need to be

[4] The precipitation and air temperature data used came from the IHP-UNESCO FRIEND project. See http://www.insmet.cu/sequia/amigo.htm

estimated. In this case, the simplest and most well-known methodology is the one proposed by Budyko for which estimates were based on the following considerations:

Determination of annual radiation balance:

- $R_o = 3.65 * T$ (Ro in Kcal / cm^2 – year and T in ^{o}C);

Determination of Index of aridity:

- $B = 10 * R_o / L * P$, where P: precipitation (mm) and L=0.59 (condensation latent heat of the water vapour, Kcal/g)

Determination of potential evaporation:

- $E_0 = 10 * R_o / L$, (mm)

Well-known E_o and B, the evaporation E is determined by:

$$E = P * \sqrt{B * [1 - \cosh(B) + \sinh(B)] \tanh(1/B)}$$

Using this methodology, the water balance for the period 1961 - 1990 was calculated. This result is not the exact quantity of available fresh water in the Islands, but it can be considered as the potential availability of water from precipitation. Table 4 shows the Turks and Caicos Islands general water balance for the period 1961-1990.

Table 4: Turks and Caicos Islands water balance for 1961-1990

T	***R_o***	***B***	***P***	***E_o***	***E***	***Q***
28,0	102.2	1.27		1732	1105	255

Source: Data compiled by author

Where T: temperature (^{o}C); R_o: annual radiation balance (Kcal / cm2 – year); B: Index of aridity; P: precipitation (mm); E_o: potential evaporation (mm); E: evaporation (mm), Q: runoff (mm)

B. PRECIPITATION

The main natural source of water in Turks and Caicos Islands is precipitation. The average annual precipitation obtained for the period 1961-90 is 1,361 mm, distributed monthly as shown in table 5.[5]

[5] Pérez Monteagudo suggests that good records were kept from 1908 to 1973, allowing the average rainfall in Grand Turk to be estimated at 685 mm per year. Other sources estimate average precipitation to be around 710 mm/ year

Table 5: Monthly distribution of precipitation in Turks and Caicos Islands: 1961 - 1990

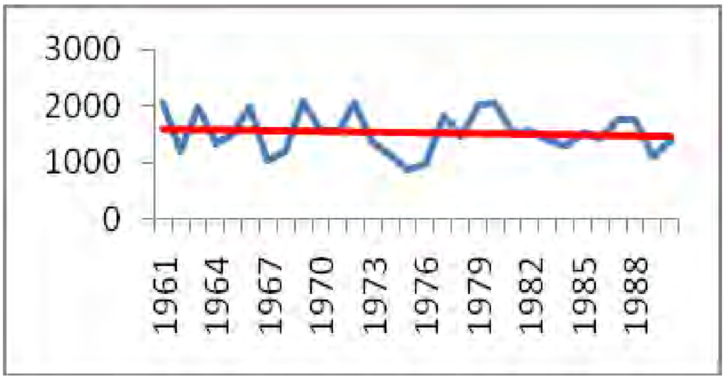
Period	Precipitation (mm)	% of annual precipitation
January	33.8	2.5
February	62.5	4.6
March	67.8	5.0
April	82.8	6.1
May	142.3	10.5
Jun	182,8	13.4
July	120.1	8.8
August	135.6	10.0
September	159.5	11.7
October	155.4	11.4
November	126.8	9.3
December	91.3	6.7
Total	1361	100

Source: The Department of Economic, Planning and Statistics (DEPS), February 2011 and author's projections

The trend observed in precipitation during the period 1961 - 1990 is a decreasing one. Similar behaviour was observed in the Caribbean subregion; and this trend is associated with the meteorological causes described previously, particularly to the influence of the North Atlantic Anticyclone (see figures 2, 3, 4 and 5).

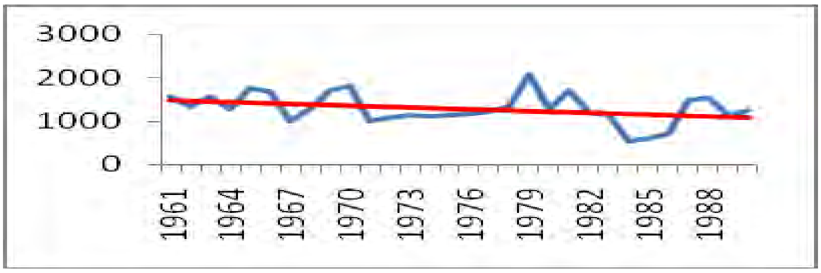
for Turks and Caicos Islands. These data highlight the possibility that large differences in precipitation patterns may exist for different islands.

Figure 2: Trend of annual precipitation period 1961 -1990: Coordinates 72.75, 19.75



Source: The Department of Economic, Planning and Statistics (DEPS), February 2011 and author's projections

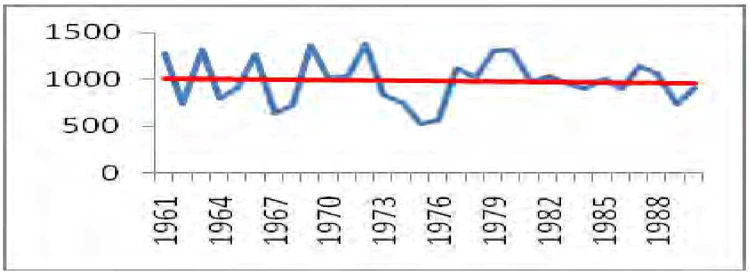
Figure 3: Trend of annual precipitation period 1961 -1990: Coordinates 72.25, 18.25



Source: The Department of Economic, Planning and Statistics (DEPS), February 2011 and author's projections

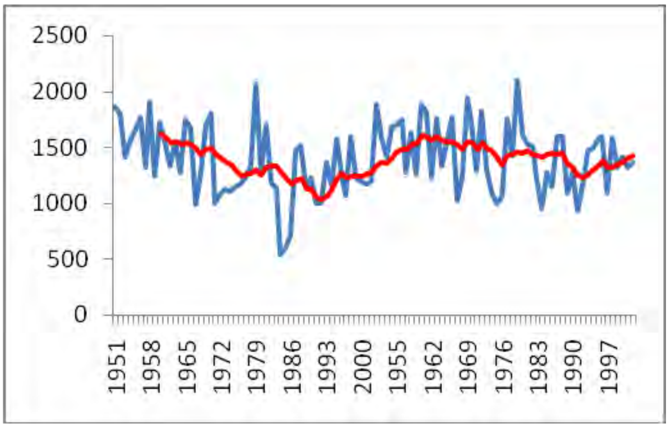
The downward tendency of annual precipitation extends into the first decades of the twenty-first century (see figures 4 and 5). Considering that precipitation is one of the main natural sources of fresh water for Turks and Caicos Islands, this indicates that the main source of water is in decline compared to data of previous decades.

Figure 4: Trend of annual precipitation period 1961 -1990: Coordinates 73.25, 19.75



Source: The Department of Economic, Planning and Statistics (DEPS), February 2011 and author's projections

Figure 5: Trend of annual precipitation period 1951 -2002: Coordinates 72.25, 18.25



Source: The Department of Economic, Planning and Statistics (DEPS), February 2011 and author's projections

C. HYDROMETEOROLOGICAL SCENARIO FOR 2050

To estimate water availability to 2050, the regional Providing Regional Climate Impact Studies (PRECIS) model (www.metoffice.gov.uk/precis) was used. The scenarios available on this Web page were generated by simulations developed with PRECIS for two time periods, 1961-1990 and 2071-2100. Calculations were made for the period 2071-2100 using the A2 greenhouse (GHG) emissions scenario. Once the results were obtained, the differences in outputs were calculated between the control period (1961-1990) and the simulated period (2071-2100).

Results refer only to the A2 scenario and, for the periods 2010-2070 and 2071-2100, climate change signals were estimated for the B2 emissions scenario. It was not possible to calculate these directly using the Regional Climate Model because of the substantial computer resources required.

To obtain projections for other periods and scenarios, the signals were "scaled" using factors from the Global Climate Model. This procedure is described in the PRECIS Manual, including the scaling factors used in estimations. Essentially, the application of scaling factors is quite simple. The original output fields of variables of the PRECIS[6] run for 2071-2100 were divided by the value of global warming of the HadCM3 and were multiplied by the blue values in the table. The fields were calculated in this way for the previous period and for the B2 scenario.

Two factors influenced the decision to estimate the signals for the B2 scenario. Firstly, B2 is a scenario with less global warming and its use can permit the consideration of an extreme level of projection. Secondly, the projections for B2 will soon be available. Thus, it would not be inconsistent to present indirect estimations. Although B2 was requested, the high level of uncertainty associated with the precipitation data for this scenario makes a big difference in the results.

VI. IPCC SCENARIOS

The IPCC scenarios considered for the present report were the A2 and B2 scenarios (see table 6 and figure 6). The A2 storyline represents a differentiated world which is consolidated into a series of economic regions. Self-reliance in terms of resources and less emphasis on economic, social, and cultural interaction between regions are characteristic of this future. Economic growth is uneven and the income gap between now-industrialized and developing parts of the world does not narrow. The A2 world has less international cooperation than the A1 or B1 worlds. People, ideas, and capital are less mobile so that technology diffuses more slowly than in the other scenario families. International disparities in productivity, and hence in income per capita, are largely maintained or increased in absolute terms.

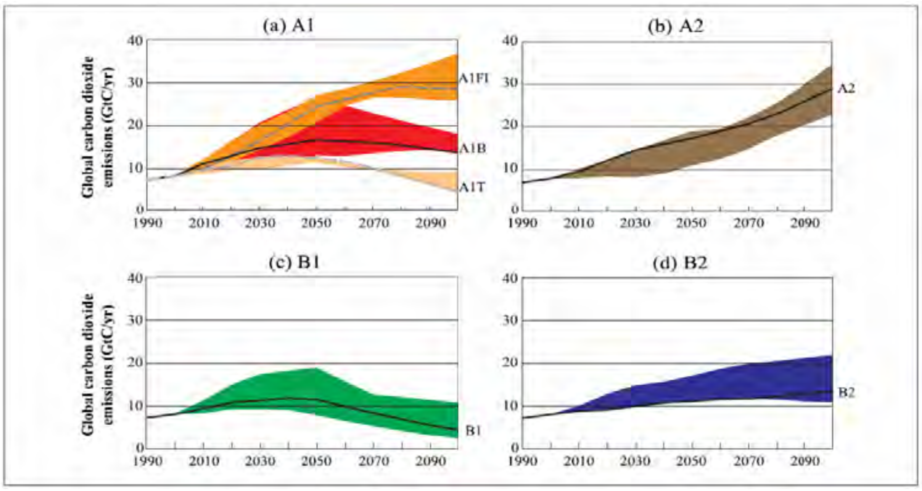
The B2 scenario represents a more divided world, but one that is more ecologically friendly. B2 scenarios are characterized by populations that are continuously increasing but at a slower rate than in A2, and where the emphasis is on local rather than global solutions to economic, social and environmental stability; intermediate levels of economic development; and less rapid, and more fragmented, technological change than in the A1 and B1 scenarios.

Table 6: A2 and B2 emission scenarios

Storyline	Description
A2	Self reliance, preservation of local identity, continuously increasing population, economic growth on regional scales
B2	Local solution to sustainability, continuously increasing population at a lower rate than A2

Source: Table A.2, page 107 of the UKCIP02 Climate Scenarios Technical Report.

Figure 6: Schematic of IPCC scenarios



Source: IPCC, 2007

A. THE PROBABLE FUTURE

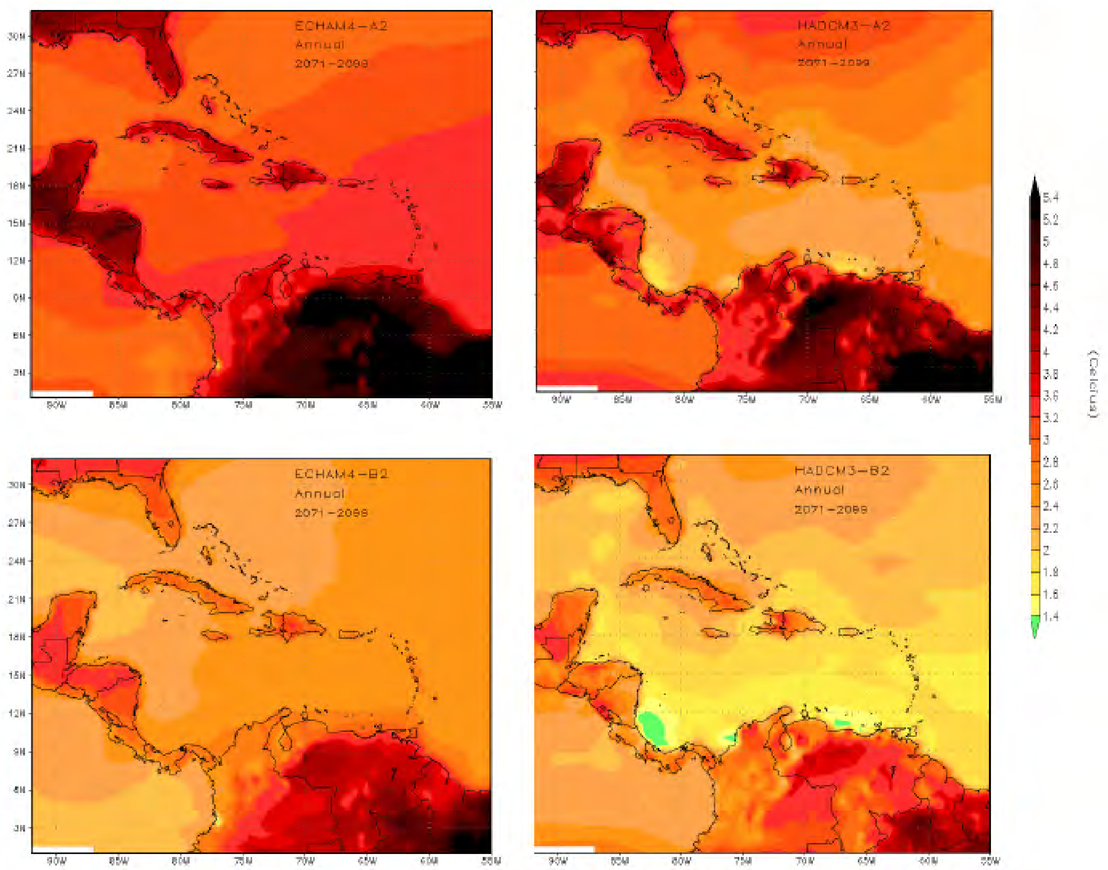
Figure 7 shows the pattern of change of the annual temperature for the period 2071-2099, according to the A2 and B2 emission scenarios. In this figure, a substantial warming of the entire Greater Caribbean Region is observed with major temperature increases in terrestrial areas. The warming observed in terrestrial areas is approximately 4.5 °C for the A2 scenario, and 2.8 °C for the B2.

The patterns of change of precipitation suggest a drier future in several areas of the Great Caribbean Region (see figure 8), with a significant reduction (between 10% and 50%) in the rainy period (see figure 9). The areas of precipitation reduction appear more extensive both in dimension and magnitude.

The results obtained with the PRECIS model for the A2 scenario up to 2050 reflect a temperature increase of up to 1.11 ^{o}C and a decrease in annual precipitation from 1,361 mm to 840 mm. For the B2 scenario projected to 2050, the annual temperature will increase by 0.86 ^{o}C while the annual precipitation will decrease to 968 mm.

The results obtained represent a complex scenario for the water sector in Turks and Caicos Islands, not only because of the Islands' dependence on precipitation, but because any policy focused on developing, or improving, strategies based on water catchment and storage and the development of water systems needs to face this scenario. This situation recalls the necessity to increase both the osmosis process alongside increased economic and tourism activities, and the number of reservoirs to store water obtained from rainfall and by osmosis.

Figure 7: Mean changes in the annual mean surface temperature for 2071-2099 with respect to 1961-1989, as simulated by PRECIS_ECH and PRECIS_Had for SRES A2 and SRES B2



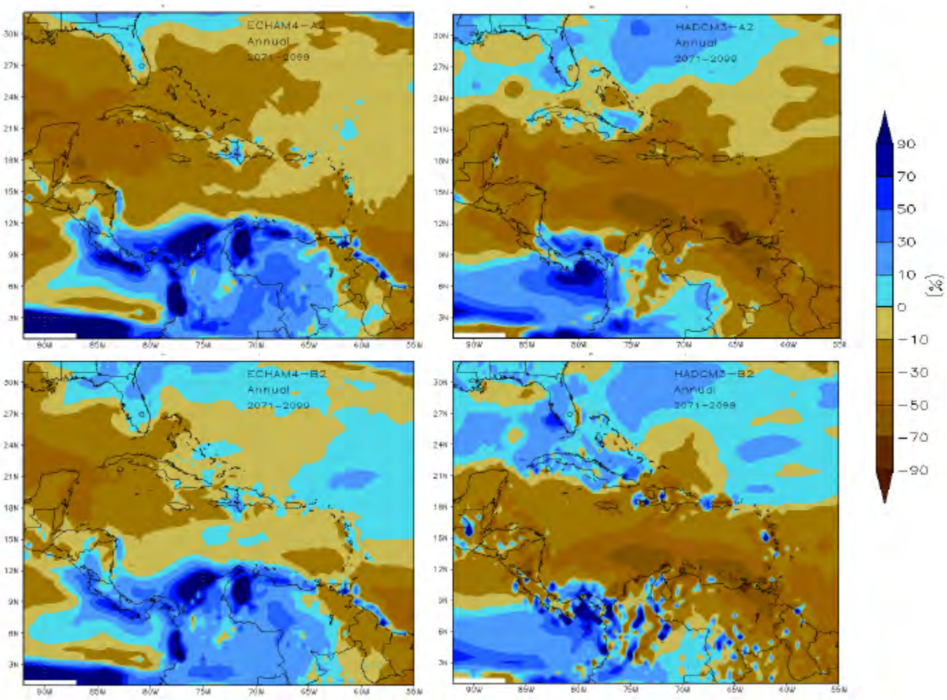
Source: Centella, 2010

B. ESTIMATES OF WATER AVAILABILITY FOR TURKS AND CAICOS ISLANDS[7]

Although water obtained from precipitation can be used in certain conditions and is an important source mainly by catchment for dispersed populations, water is also needed for species other than humans. A decrease in precipitation can stress these populations, increase salinity in coastal zones and produce adverse conditions for reverse osmosis plants (table 7).

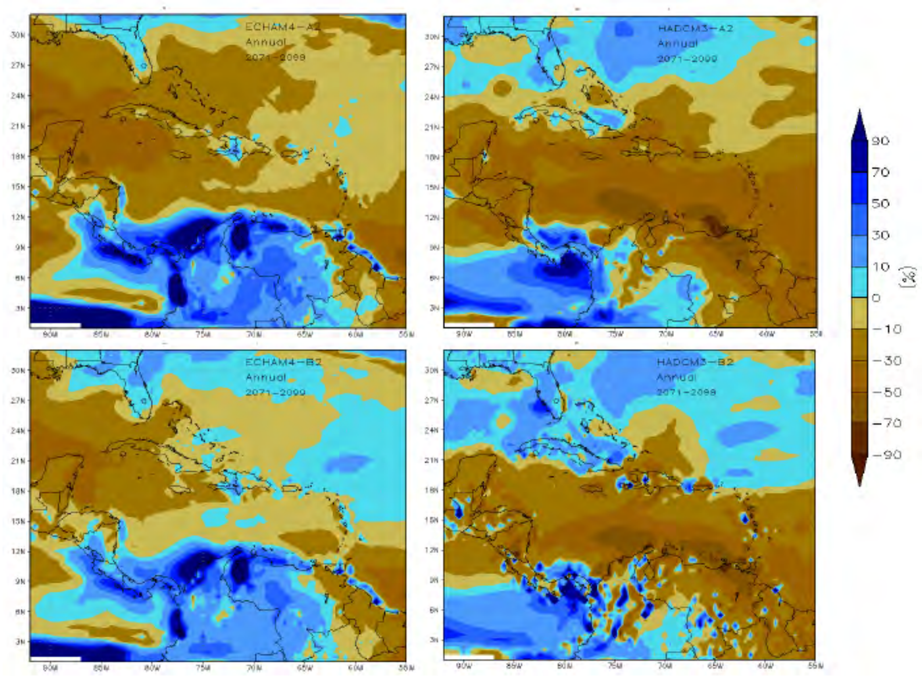
[7] Based on runoff as presented in table 1.

Figure 8. Annual mean changes in precipitation (%) for 2071-2099 as simulated by PRECIS_ECH and PRECIS_Had for A2 and B2 emission scenarios.



Source: Centella, 2010

Figure 9: Wet Season mean changes in precipitation (%) for 2071-2099 as simulated by PRECIS_ECH and PRECIS_Had for A2 and B2 emission scenarios.



Source: Centella, 2010

Table 7: Water availability for potential human consumption in Turks and Caicos Islands

	1316 MM	20%	840 MM	20%
	TOTAL ($KM^{3)}$	TOTAL ($KM^{3)}$	TOTAL KM^3	TOTAL($KM^{3)}$
GRAND TURK				
TOTAL	4.11	-	2.61	
POTENTIAL	0.795	0.159	0.50	0.1
PROVIDENCIALES				
TOTAL	11.85	-	7.56	
POTENTIAL	2.29	0.46	1.47	0.29

Note: Potential is precipitation considered as possible runoff, 20% of which may be considered as available for human use. Source: Author's estimates.

C. WATER DEMAND ESTIMATES

After an assessment of fresh water resources in Turks and Caicos Islands, and the conclusions that the mostly flat and low-lying limestone islands have few possibilities for large scale surface storage, and that groundwater lenses are found in a very delicate equilibrium with saline seawater with high possibilities of collapse due to sea level rise and by improper extraction, drought, tidal waves and other extreme events, the next step is to estimate water demand.

The absence of available data and general information about the water sector in the Turks and Caicos Islands is a critical constraint. To calculate the prospective water demand, the contribution of the different sectors to GDP was examined for the period 2003 - 2007, the only time span for which data were available. Table 8 shows their relative weights.

Table 8: Contribution of economic sectors to GDP in Turks and Caicos Islands

	2003	**2004**	**2005**	**2006**	**2007**
Water (% GDP)	0.8	0.9	0.9	0.8	0.8
Hotels & Restaurants (%)	30.0	28.0	27.0	27.0	27.0
Construction (%)	8.0	10.0	11.0	14.0	15.0
Financial Intermediation (%)	7.0	9.0	10.0	11.0	11.0

Source: Department of Economy, Planning and Statistics, Turks and Caicos Islands

Clearly, the water sector makes a lower contribution to GDP, whereas the tourism, construction and financial sectors are the main contributors. In view of the scarcity of data, projections of water demand will be carried out only for domestic and tourism consumption, although other sectors such as construction are likely to be important consumers as well.

1. Domestic water demand

In order to estimate future water demand from the residential sector (domestic consumption), projections on population growth were taken from the United Nations statistical division (www.data.un.org) for Turks and Caicos Islands, which yield four scenarios of population numbers for every five-year period up to 2050. The first is a constant-fertility scenario, while the other three are differing population growth scenarios (high, medium and low). Due to the lack of data to estimate water demand in several other sectors, domestic water demand was calculated using the most extreme scenarios as a proxy for demand from other sectors (table 9).

In the present study, the high population growth scenario has been selected, because it offers higher projections on consumption growth, thus making a better estimation of the growth in water demand possible. Data for daily water consumption were obtained from comparator countries since data for Turks and Caicos Islands were not available. Table 10 summarizes water consumption data for selected countries and some international organizations.

Considering the large differences in daily water consumption among countries and the need for a range of choices, values were considered under three population growth scenarios (high, medium and low) and obtained from comparator islands, the World Health Organization (WHO) minimum (80 litres/day) and the Natura optimum (250 litres/day). A higher maximum rate of daily consumption was used so as to achieve more robust consumption forecasts (see tables 10 and 11). Water demand was calculated in the high growth scenario using these rates (see table 12).

Table 9: Population forecasts for Turks and Caicos Islands, 2015 – 2050

Year	Constant-fertility scenario	High population growth scenario	Medium population growth scenario	Low population growth scenario
2015	35 043	35 237	34 917	34 598
2020	36 768	37 210	36 416	35 627
2025	38 351	39 087	37 696	36 312
2030	39 897	40 910	38 858	36 815
2035	41 327	42 648	39 817	37 043
2040	42 492	44 177	40 432	36 854
2045	43 330	45 431	40 637	36 193
2050	43 892	46 472	40 491	35 122

Source: Author’s estimates

Table 10: Daily water consumption

Selected countries	Year	M^3/per year	Daily (litres)
Antigua and Barbuda	1990	75	205
Barbados	1996	312	855
Belize	1993	396	1085
Dominica	1996	239	655
Jamaica	1993	348	953
St. Lucia	1997	89	244
St. Vincent and the Grenadines	1995	88	241
Trinidad and Tobago	1997	221	605
World Health Organization	2007		80
Natura-Medioambiental[8]	2011		250

Source: Falkland & Brunel (2009);

Table 11: Daily domestic water consumption in Turks and Caicos Islands

	Litres daily		
	High variant	Medium variant	Low variant
2015-2050	300	225	150

Source: Author's estimates

2. Tourist arrivals forecast

Forecasting the relationship between tourist arrivals and climate change is a necessary prerequisite to calculating future total water demand. Tourist arrivals to Turks and Caicos Islands have grown at a mean annual rate of 11.3 % in the last 15 years (see figure 10).

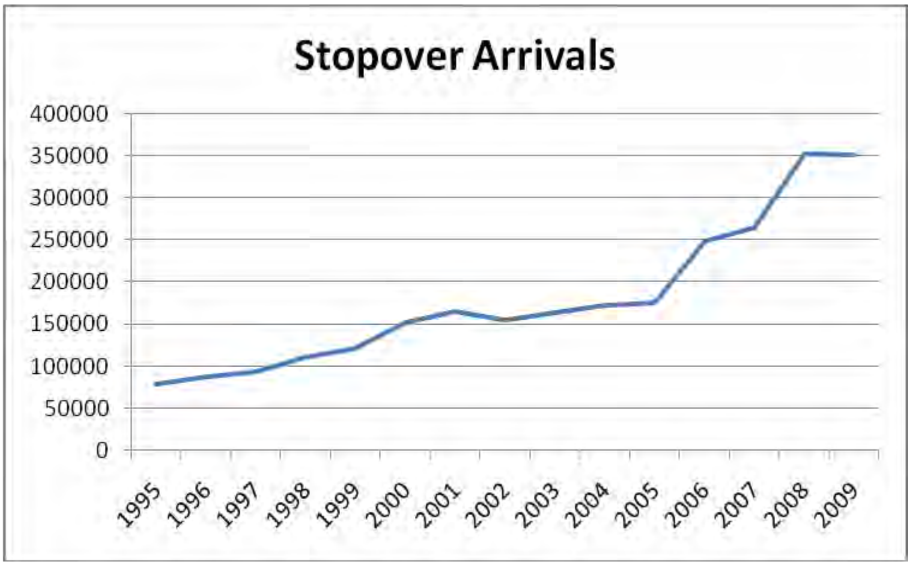
[8] http://www.natura-medioambiental.com

Table 12: Yearly domestic water consumption in the high population growth scenario (cubic metres)

Year	High population growth scenario	Medium population growth scenario	Low population growth scenario
	0.3 m^3 daily	0.225 m^3 daily	0.15 m^3 daily
2015	3 858 452	2 893 839	1 929 226
2020	4 074 495	3 055 871	2 037 248
2025	4 280 027	3 210 020	2 140 013
2030	4 479 645	3 359 734	2 239 823
2035	4 669 956	3 502 467	2 334 978
2040	4 837 382	3 628 036	2 418 691
2045	4 974 695	3 731 021	2 487 347
2050	5 088 684	3 816 513	2 544 342

Source: Author's estimates

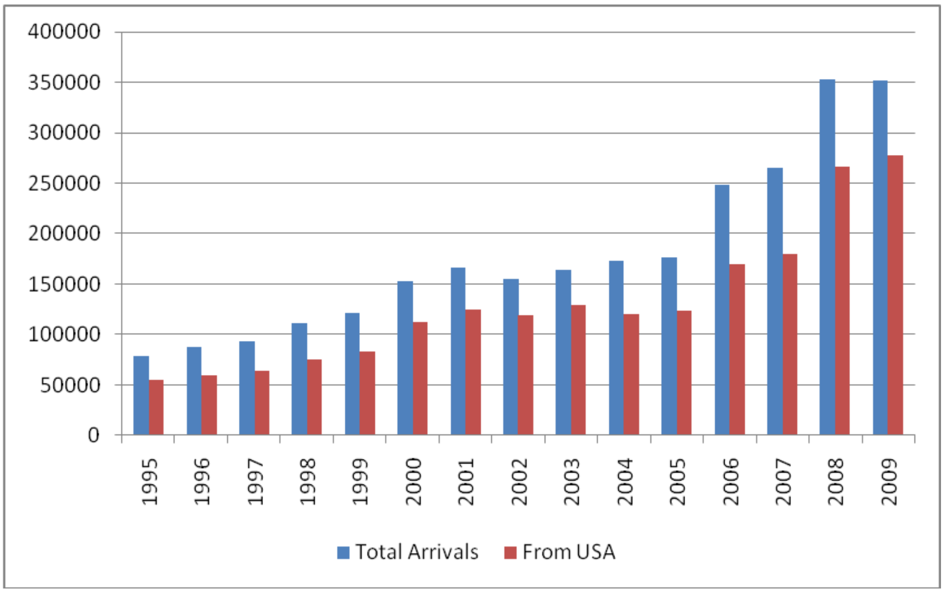
Figure 10: Tourist arrivals at Turks and Caicos Islands



Source: Department of Economy, Planning and Statistics, Turks and Caicos Islands

Figure 11 shows that the largest share of tourist arrivals originates from the United States of America.

Figure 11: Stopover arrivals from USA and total arrivals to Turks and Caicos Islands



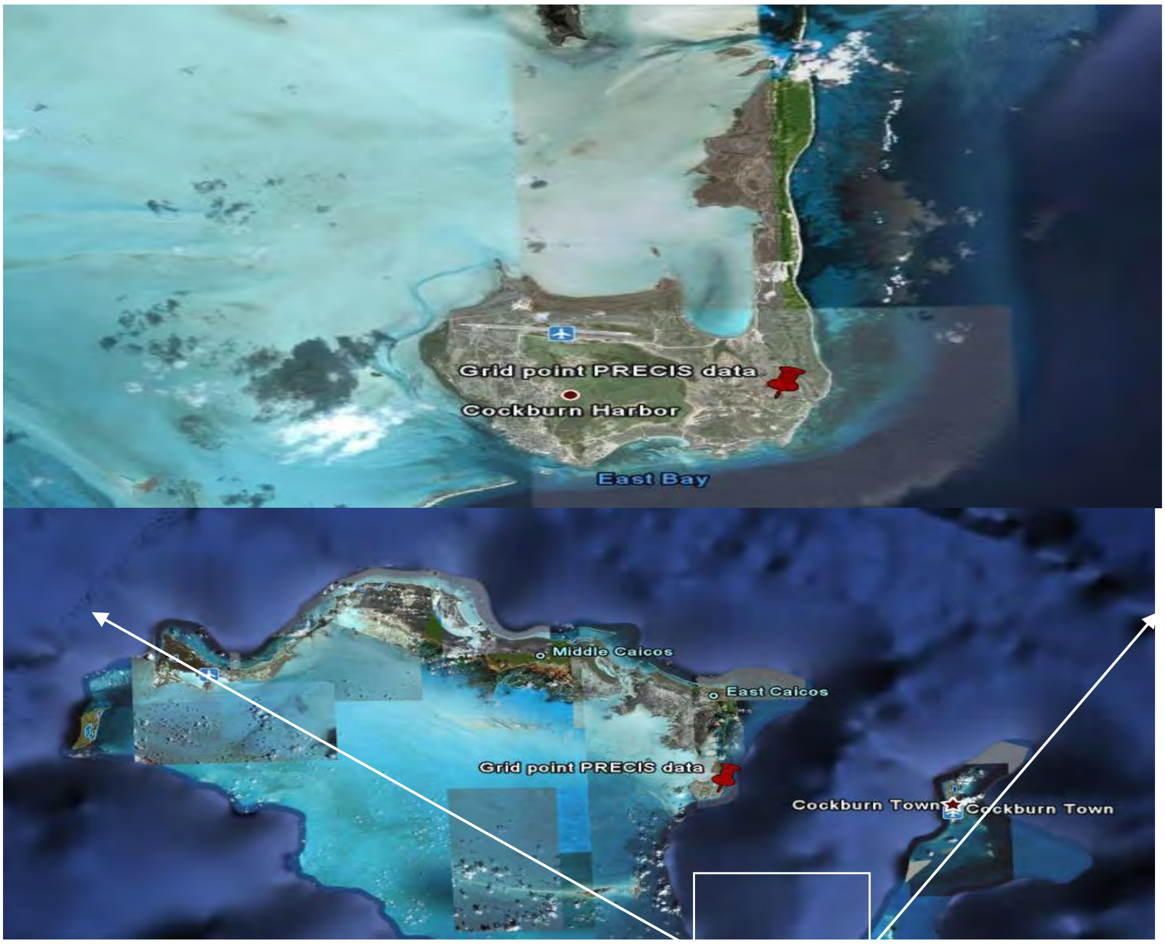
Source: Department of Economy, Planning and Statistics, Turks and Caicos Islands

Total visitors are classified into tourists (stopovers) and excursionists (mainly cruise passengers). Tourism development in Turks and Caicos Islands dates from the time the salt trade started to play a less important role in the Islands' economy. In fact, cruise ships started to visit Grand Turk only after 2006. The number of cruise passenger arrivals was assumed constant at the current cruise terminal capacity of 550,000 arrivals per year for the projected time span (2012-2050). Given this assumption, it was then possible to forecast the number of tourist arrivals under changing climatic conditions.

VII. MODELLING CLIMATE CHANGE EFFECTS ON TOURISM DEMAND

The main climate variables included in the model are maximum temperature, precipitation, relative humidity and wind speed. Historical values (1995 – 2009) and projections were taken from the dataset from PRECIS RCM (INSMET – CUBA), in Latitude 21.5º N and Longitude 71.5º W, at a point near Cockburn Harbour, on the island of South Caicos (see figure 12). It was the only point on the land surface with available forecast data, because the grid is 25 km wide. This represents an issue to be aware of in forecasting climate variables because of the differences in sea surface and land surface temperature.

Figure 12: Grid point used for economic assessment



PRECIS RCM brings a complete dataset of climate variables on A2 and B2 scenarios. Modelling results for ECHAM in both scenarios were used. Source: Centella, 2010.

A. TOURISM DEMAND AND SUPPLY VARIABLES

The IPCC (2007) stated two important assumptions related to assessment of the economic impact of climate change, namely, that regional and local impacts are heterogeneous, and that they have non-linear relationships that increase over time, particularly in the twenty-first century. These two aspects inform the use of scenarios instead of accurate forecasts. Nevertheless, within the scenarios, it is necessary to forecast variables and calculate some ranges in order to observe their likely behaviour, taking into consideration the uncertainty of complex relationships and the extensive range of long term projections considered in climate change studies.

There exists a quantity of literature demonstrating that there is no unique methodology for achieving appropriate results. However, the real transmission channels between dependent variables and the explanatory variable need to be identified. In the case of climate change and tourism, a consensual methodology to express the non-linear interactions between these variables does not yet exist. Also, the scenarios, the model to be used and the characteristics of these complex processes make it necessary to collect a dataset that must be consistent with the rest of the features mentioned.

A wealth of research outcomes on the best method to employ in forecasting tourism demand is available in the literature (Archer 1976; Crouch, 1992; Enders, 2004; Frechtling, 2001; Green, 2003; Lim, 1997; Lim and McAleer, 2001a; Makridakis and others, 1998; Sinclair and Stabler, 1998; Smeral and Witt, 1996; Smeral and Wuger, 2005; Song and Witt, 2000; Song and others, 2003; Song and Li, 2008, Simpson 2008b).

It is generally recognized that tourism demand has two main variable expressions: visitor arrivals (tourists, cruise passengers and sea landed travellers) and visitor expenditure. The first is commonly used for marketing purposes and the second for economic analysis. Since the objective of the present section is to forecast water demand from tourists, stopover arrivals will be used as the dependent variable.

Thus, several explanatory variables will be used. One of the driving forces in mainstream tourism is transportation costs. Tourists (stopovers, as defined by the United Nations World Tourism Organization (UNWTO)) mainly arrive at Turks and Caicos Islands via air transport. Only a small percentage of visitors arrive by sea. Some of them are stopovers (using accommodation), while the remainder use their own boats and yachts as lodging. Thus, air fares are directly connected with tourist arrivals, as an explanatory variable. The main component of the cost of an air ticket is the air fuel price (around 28 % to 35 % of total cost). In this case, the prices were obtained from sources in the United States of America. Historical data for arrivals were obtained from the Turks and Caicos Islands Tourism Board.

Other economic explanatory variables will be included in visitor expenditure calculations. The United States of America Gross Domestic Product (GDP) was included for two reasons: firstly, the economy of the United States has strong links with that of the Turks and Caicos Islands. Secondly, it is known that the main tourism source markets for the Islands are cities in the United States. Also, most of the Caribbean's import-export business is with the United States of America and the majority of Caribbean tourists are citizens of that country, suggesting that the source of funds for travel is derived from that economy.

GDP current prices functions as a proxy for purchasing power. However, GDP forecasts have a high degree of uncertainty. The recent world financial and economic crisis has demonstrated how difficult it is to project GDP into the future. Also, it must be noted that longer term projections generally have a higher level of uncertainty. Nevertheless, the main goal is to develop an approach to present to policymakers. In this regard, sensitivity analysis and performance indices are useful for covering future possibilities in order to prepare actions that would mitigate risks. GDP for the United States of America is taken from its Department of Commerce, Bureau of Economic Analysis. To keep pace with expenditure, all these series are rebased to 2008 prices.

The United Kingdom has recently introduced a new Air Passenger Duty in an attempt to curb greenhouse gas emissions. The United States of America and Canada are not considering, for the moment, the enforcement of any such levy. However, European countries, like the United Kingdom, may well increase duties or Emissions Trade Systems (ETS) early in 2012. As was stated by Simpson (2008a), “If climate policy as currently envisaged by the EU is implemented, prices for air travel would increase fairly substantially by 2012 (US$ 42.2 per tonne of carbon dioxide (CO_2) emitted) to reach a price level of US$ 72.3 per tonne of CO_2 by 2020. This would translate into an estimated decline in demand by 0.6% to 1.8% in the year 2012 relative to overall holiday costs”. This would be an important challenge to Turks and

Caicos Islands tourism in the near future, notwithstanding the relatively short distances between Turks and Caicos Islands destinations and main source markets.

B. CHOOSING A MODEL

Qualitative methods, usually based on experience and expertise of individuals, have been in use for quite some time, the Delphi being one of the most commonly used. Quantitative methods can be generally divided in three major areas which differ in the mathematical and statistical nature of the approaches taken, namely, time series, econometric (causal) and artificial intelligence methods. An examination of these models follows.

The first area deals with methods which consider the variable itself (whether it is tourism arrivals or average expenditure) in its historical development only. Relying on the chronological behaviour of the variable, these methods establish the main components of time series, such as trend, cycle and seasonality, and then forecast the future values of the variable over a defined time frame. Examples of these methods are naive, exponential smoothing and the ARIMA (autoregressive integrated moving average) family.

The second area comprises the most widely-used methods in economic variables forecasting, that is, those that establish causality between variables described through unknown functions, which, in this case, are regularly called demand functions. Thus, an econometric model of demand (or demand model) fixes a variable describing the demand such as visitor expenditure, as a function of a number of other variables that have a direct causal relation to the first one. The former is referred to as a dependent variable, while the latter are called explanatory variables, and the mathematical expression of the function, which is generally unknown, is approximated through specific methods. Examples of these methods range from simple regression to the statistically sophisticated Time Varying Parameters (TVP), Computable General Equilibrium (CGE) and panel data models, among others (Kulendran and Witt, 2001, 2003; Turner and others, 1997; Turner and Witt, 2001).

The third and last area is populated by the comparatively more recent approaches generally classified as Artificial Intelligence (AI). These methods, based on results that mathematically model processes in natural and human development, have been increasingly used in demand forecasting, as it will be shown, with significant outcomes in comparison to the other two methods. Some of the most widely used among these methods are fuzzy logic, artificial neural networks (ANN), genetic algorithms (GA), and combinations of these.

The present study attempts to forecast tourism demand for the Turks and Caicos Islands for the long run that comprises the forty years between 2011 and 2050. Four types of demand forecast scenarios are employed, using methods belonging to the second and third areas, econometrics and AI: regression in a business as usual (BAU) scenario, and regression taking into consideration the A2 and B2 scenarios.

In terms of the functional form of the demand models, there appears to be an almost universal agreement that the multiplicative (log-linear) functional form is superior to the additive or linear form (Johnson and Ashworth, 1990; Crouch, 1994). The multiplicative model often fits the demand data better and conveniently provides constant demand elasticities (Morley, 1991). Such demand elasticity is then used to formulate policies and examine how consumers respond to changes in demand variables. However, a study by Qiu and Zhang (1995) found that the estimation of functional forms (log-linear and linear forms) could show variation from country to country, suggesting that the linear form can also be useful with particular types of data.

Taking into consideration the different methods and techniques found in the literature, and due to its features, it was decided to employ an Artificial Neural Networks (ANN) approach. The use of artificial neural networks instead of multiple regression analysis has recently gained popularity in different fields (Gorr, 1994). A number of studies have also used ANN in the area of tourism and hospitality with respect to market segmentation (Mazanec, 1992, Bigné, 2008, Delgado and Fernández, 2010, Delgado and Abreu, 2010), destination choice behaviour modelling (Jeng and Fesenmaier, 1994), product positioning (Mazanec, 1995), and visitor behaviour (Pattie and Snyder, 1996). The demand function used is represented by the formula:

$$TA_t \text{ (Tourist arrivals)} = f\,(AirCost_t\,,\ GDPUS_t,\ MaxTemp_t,\ RelHumidity_t,\ WindSpeed_t,\ Precip_t)$$

Thus, tourist arrivals include the climate component and the main influence factors, namely, cost of transportation and purchasing power of the main market. For the BAU projections, only fuel prices and GDP of the United States of America were considered as explanatory, the climate variables being excluded since BAU is a "climateless" scenario. Data for the variables selected with the models were analysed to search for outliers and other error-generating causes.

C. SUMMARY OF SCENARIOS FOR MODELLING AND RESULTS

The business as usual (BAU) scenario is the baseline calculated only for comparison. It is forecast using non-linear time series of its explanatory variables from a historical dataset of 14 years. It is important to note that the BAU scenario will never exist because GHG emissions have continued to increase in larger proportions than ever before. The A2 and B2 scenarios were used to reflect the impact of climate change on the dependent variables (visitor arrivals and visitor expenditure). Climate data for these scenarios helped to build the corresponding Tourism Climatic Index (TCI) which, in turn, was used as an explanatory variable to forecast arrivals.

Finally, several different ANN methods were employed to find the best fitting of subsequent forecast. Generalized Regression, Radial Basis Functions and Multilayer perceptions were the most widely used. Forecasts of tourist arrivals per scenario are presented in table 13 and figure 13.

D. WATER CONSUMPTION INDEX FOR VISITORS

Bien (2009) presented a study of water consumption by tourists, taking a level between 666 and 856 litres per person per day in hotels with 150 or more rooms as acceptable levels. He found that the water consumption of tourists from the United States of America, which is the Turks and Caicos Islands main market, set their mean water consumption level at 716 litres per day. These three values were used to create the three scenarios for water consumption by tourists: low (666 litre/day), medium (716 litre/day) and high (856 litre/day) level water consumption.

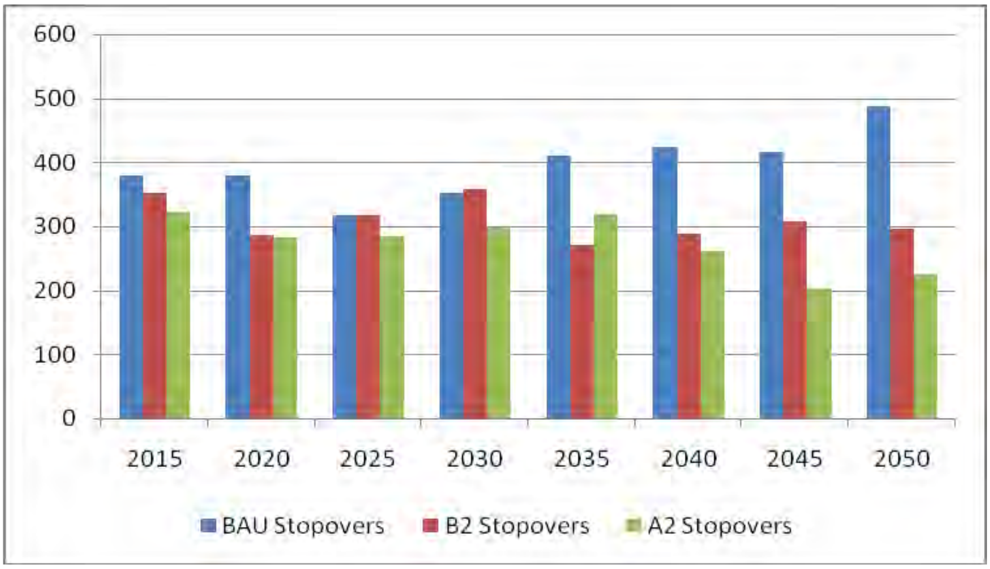
Using these figures, water consumption for tourists and cruise passengers was projected as in table 15.

Table 13: Forecast Turks and Caicos Islands stopover arrivals

Thousands of arrivals			
Year	**BAU**	**B2**	**A2**
2015	379.4	353.1	322.4
2020	379.9	287.4	282.7
2025	317.4	318.3	285.2
2030	352.2	357.8	297.9
2035	410.7	271.2	320.1
2040	424.4	289.3	261.0
2045	416.9	306.8	203.0
2050	488.2	296.8	224.9

Source: Author's estimates

Figure 13: Stopover arrivals in Turks and Caicos Islands



Source: Author's estimates

Water consumption for the BAU is expected to range from 2.2 million m^3 in 2015 to 2.8 million m^3 in 2050. Nevertheless since BAU is not a real scenario, it is only used for comparative purposes. Water demand forecasts under the A2 and B2 scenarios are shown in tables 14 and 15.

Table 14: Water consumption by tourists under the BAU scenario (m^3)

Year	Stopover arrivals	Average tourist nights	Stays	Low level water use (0.666 m^3)	Medium level water use (0.716 m^3)	High level water use (0.856 m^3)
2015	379 352	6.75	2 560 623	1 705 375	1 833 406	2 191 893
2020	379 878	6.75	2 564 179	1 707 743	1 835 952	2 194 937
2025	317 412	6.75	2 142 533	1 426 927	1 534 054	1 834 008
2030	352 209	6.75	2 377 408	1 583 354	1 702 224	2 035 062
2035	410 709	6.75	2 772 283	1 846 341	1 984 955	2 373 074
2040	424 407	6.75	2 864 744	1 907 920	2 051 157	2 452 221
2045	416 886	6.75	2 813 978	1 874 109	2 014 808	2 408 765
2050	488 198	6.75	3 295 338	2 194 695	2 359 462	2 820 809

Source: Author's estimates

Table 15: Water consumption by tourists under the A2 scenario

Year	Stopover arrivals	Average tourist night	Stays	Low level water consumption	Medium level water consumption	High level water consumption
				0.666 m^3	0.716 m^3	0.856 m^3
2015	322 394	6.75	2 176 159	1 449 322	1 558 130	1 862 792
2020	282 705	6.75	1 908 256	1 270 899	1 366 311	1 633 467
2025	285 169	6.75	1 924 890	1 281 977	1 378 221	1 647 706
2030	297 947	6.75	2 011 142	1 339 421	1 439 978	1 721 538
2035	320 142	6.75	2 160 958	1 439 198	1 547 246	1 849 780
2040	260 958	6.75	1 761 465	1 173 136	1 261 209	1 507 814
2045	203 009	6.75	1 370 312	912 628	981 143	1 172 987
2050	224 886	6.75	1 517 980	1 010 975	1 086 874	1 299 391

Source: Author's estimates

Water consumption under the B2 scenario is lower, due to fewer arrivals than under BAU (table 16). Ranges for this scenario decrease from 2.0 million cubic metres in 2015 to 1.7 million cubic metres in 2050. Under the A2 scenario, which is the high emissions scenario, decreased tourist arrivals reduce forecast consumption from 1.9 million cubic metres of water in 2015 to 1.3 million cubic metres in 2050. Thus, a diminishing number of tourist arrivals amounts to less pressure on water consumption, yielding the relation BAU>B2>A2 for water demand levels from tourism.

Based on the assumption that there is a fixed number of cruise passenger arrivals (550,000) per year, and using the same indices of water consumption, an estimate of water demand for cruise passengers was made, as shown in table 17. Projected water demand in Turks and Caicos Islands to 2050 is shown in table 18.

Table 16: Water consumption by tourists under the B2 scenario

Year	Stopover arrivals	Average tourist nights	Stays	Low level water consumption	Medium level water consumption	High level water consumption
				0.666 m^3	0.716 m^3	0.856 m^3
2015	353 085	6.75	2 383 323	1 587 293	1 706 460	2 040 125
2020	287 413	6.75	1 940 040	1 292 067	1 389 069	1 660 674
2025	318 257	6.75	2 148 235	1 430 725	1 538 137	1 838 889
2030	357 755	6.75	2 414 849	1 608 289	1 729 032	2 067 111
2035	271 155	6.75	1 830 298	1 218 978	1 310 493	1 566 735
2040	289 300	6.75	1 952 776	1 300 549	1 398 187	1 671 576
2045	306 836	6.75	2 071 144	1 379 382	1 482 939	1 772 899
2050	296 778	6.75	2 003 251	1 334 165	1 434 328	1 714 783

Source: Author’s estimates

Table 17: Water demand by cruise passengers (selected years)

Year	Arrivals	Low level water consumption	Medium level water consumption	High level water consumption
		0.666 m^3	0.716 m^3	0.866 m^3
2015	550 000	366 300	393 800	470 800
2020	550 000	366 300	393 800	470 800
2025	550 000	366 300	393 800	470 800
2030	550 000	366 300	393 800	470 800
2035	550 000	366 300	393 800	470 800
2040	550 000	366 300	393 800	470 800
2045	550 000	366 300	393 800	470 800
2050	550 000	366 300	393 800	470 800

Source: Author’s estimates

Table 18: Projected water demand in Turks and Caicos Islands to 2050

	BAU / Population – 0.15 m^3			B2 / Population – 0.225 m^3			A2 /Population – 0.3 m^3		
	BAU 0.666 m^3	BAU 0.716 m^3	BAU 0.856 m^3	B2 0.666 m^3	B2 0.716 m^3	B2 0.856 m^3	A2 0.666 m^3	A2 0.716 m^3	A2 0.856 m^3
2015	5 930 127	6 085 658	6 521 145	5 812 045	5 958 711	6 369 376	5 674 073	5 810 381	6 192 044
2020	6 148 538	6 304 247	6 740 232	5 732 862	5 857 364	6 205 969	5 711 694	5 834 606	6 178 762
2025	6 073 254	6 207 880	6 584 835	6 077 051	6 211 963	6 589 716	5 928 303	6 052 048	6 398 532
2030	6 429 299	6 575 669	6 985 507	6 454 234	6 602 477	7 017 556	6 185 366	6 313 423	6 671 983
2035	6 882 597	7 048 711	7 513 830	6 255 234	6 374 249	6 707 491	6 475 454	6 611 002	6 990 536
2040	7 111 601	7 282 338	7 760 403	6 504 230	6 629 369	6 979 758	6 376 817	6 492 391	6 815 996
2045	7 215 104	7 383 302	7 854 259	6 720 376	6 851 433	7 218 393	6 253 622	6 349 638	6 618 481
2050	7 649 679	7 841 946	8 380 293	6 789 149	6 916 812	7 274 267	6 465 959	6 569 358	6 858 875

Source: Author's estimates

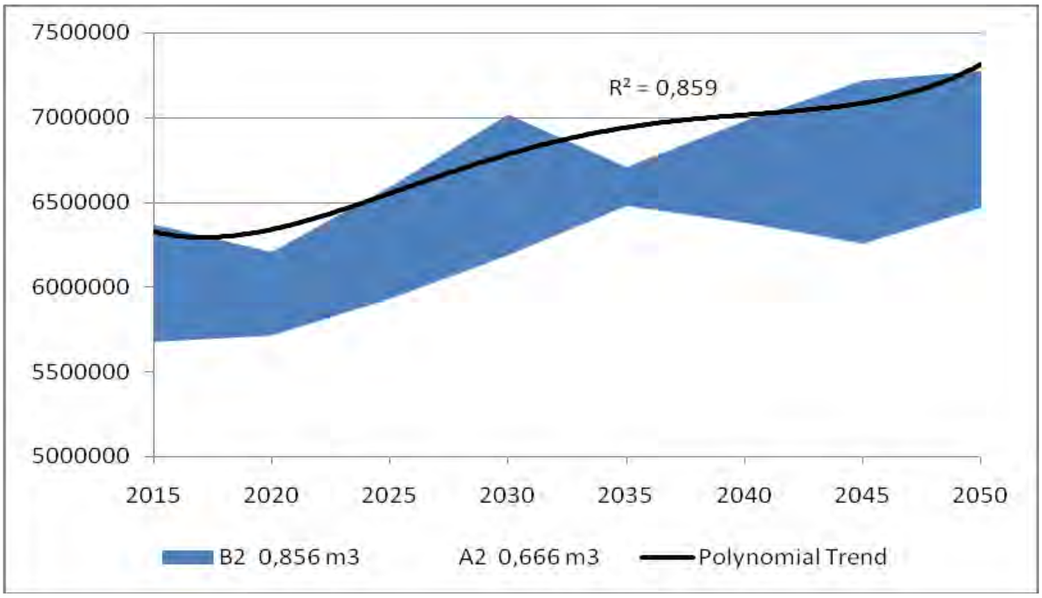
The mean difference in water demand between the A2 and B2 scenarios is 661.4 thousand cubic metres for the period under consideration (table 19 and figure 14).

Table 19: Water demand (maximum and minimum) in the Turks and Caicos Islands to 2050 under A2 and B2 scenarios

	B2 (0.856 m^3)	A2 (0.666 m^3)	Difference
2015	6 369 376	5 674 073	695 303
2020	6 205 969	5 711 694	494 276
2025	6 589 716	5 928 303	661 413
2030	7 017 556	6 185 366	832 190
2035	6 707 491	6 475 454	232 037
2040	6 979 758	6 376 817	602 940
2045	7 218 393	6 253 622	964 771
2050	7 274 267	6 465 959	808 308

Source: Author's estimates

Figure 14: Water demand (maximum and minimum) in the Turks and Caicos Islands to 2050 under A2 and B2 scenarios



Source: Author's estimates

VIII. ADAPTATION OPTIONS FOR TURKS AND CAICOS ISLANDS

Desalination of sea water is the correct solution when all other more expensive options have been examined. Water is reused in many countries and cities. Water recycling requires 50% less energy due to the significantly lower salt content and produces fresh water at 30% less cost to the consumer, without the damage to marine life and ecosystems common to desalination plants. International desalination experiences show that cost estimates for that option are between US$ 0.45/ US$ 0.49 and US$ 0.53 per cubic metre.

Conditions for desalination differ. Several studies have shown that the desalination option may be more cost-effective than large-scale recycled water for drinking, and more cost-effective than mandatory installation of rainwater tanks or storm water harvesting infrastructure. In this sense, an assessment for Turks and Caicos Islands is needed.

One of the main environmental considerations of ocean water desalination plants is the impact of the open ocean water intakes, especially when colocated with power plants, due to the potential impact on marine life. Alternatives that address this concern require increased energy inputs and invoke higher costs.

Limiting environmental impacts when returning the brine to the ocean and reducing salinity may be achieved if it can be diluted with other streams of water entering the ocean, such as the outfall of waste water from waste-water treatment plants, or warm waste water from power plants. Another solution is to use runoff water in site catchment.

A solution to the challenge of selecting the best technology to be used for the Turks and Caicos Islands is not directly related to climate change but exists rather in the information related to existing plants and their capacity. Some information on the plants is provided as follows:

Plant: Amanyara (Providenciales)

Location: Lat: 21°49'57.35" N and Long: 72°19'36.23"O

Production: Between 60,000 and 110,000 gallons per day (gpd)

Owner: TSG Water Resources

Plant: Provo Water (Providenciales)

Location: Lat: 21°47'55.69"N Long: 72°10'0.09"O

Production: 300,000 000 gallons per year (gpy)

Owner: Turks and Caicos Water Company (TCWC)

Plant: Windmills (Salt Cay)

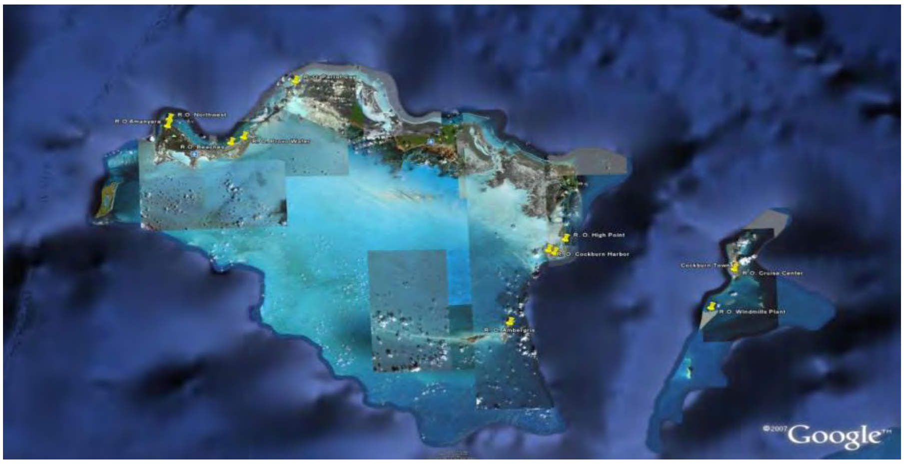
Location: Lat: 21°20'25.94"N Long: 71°11'59.19"O.

Production: 10,000 gallons per day (gpd)

Owner: Government.

The total estimated capacity is about 1,270,800 m^3/ year with 80% capacity load for these three plants. However, almost 11 desalination plants have been detected on Turks and Caicos Islands (see figure 15). Information on the capacity of these plants is needed, to estimate long term investment to match possible water demand and to suggest more complex adaptation options.

Figure 15: Reverse osmosis plants on Turks and Caicos Islands



Source: Data compiled by author

Water-Producing Greenhouses for Small Tropical Islands: Ahead of their time of a Timely Solution. R. V, Wahgren

Water scarcity on small tropical islands limits water and food security for inhabitants. A Water-producing Greenhouse (WPG), using water-from-air (dehumidification) technology, can increase carrying capacity and life quality. In 2003, Canadian and Turks and Caicos Islands researchers completed a Viability Study, supported by the Canadian International Development Agency (CIDA), for a WPG on Grand Turk. Despite years of fund-raising efforts, this WPG remains to be built. Importing food and drinking water continues to be easy. Revisiting the study in today's context is valuable given increasing transportation costs coupled with carbon emission reduction responsibilities. A 200,000 L/d WPG is feasible for humid tropical climate on Grand Turk and saline, reverse-geothermal-gradient groundwater with 15 °C coolant water drawn from 400–500 m depths. Establishing the business needs US$ 5 million (2003; new estimates may be higher). Business opportunities include: sales of hydroponically-grown produce to wholesalers, retailers, restaurants, and value-added manufacturers of salsas and juices; sales of drinking water to the government, tanker-truck operators, breweries, and to bottling plants; export sales of premium brand 500 ml water bottles; sales of sport drinks; and sales of greenhouse tours and bottled water to cruise-ship tourists.

A. ADAPTATION POLICIES WITH REGARD TO WATER SUPPLY

There are several options for adaptation policies:

- Maintain an accurate water balance, and collect water data to develop sound strategies
- Develop pricing and regulation policies
- Wastewater, sewerage and sanitation management
- Facilitate institutional capacity-building of the water department.

These options are not only related to climate change and would form part of the "no regrets" strategy. A tourism industry study on tourism-carrying capacity would complement these adaptation strategies, so as to ensure that Turks and Caicos Islands remains an important tourist destination, especially for citizens from the United States of America.

An adaptation option with regard to climate change is the construction of elevated, storm-resistant water reservoirs of at least 30 metres in height. The unit cost of the storage capacity is the sum of capital costs and operational and maintenance costs. Electricity costs to pump water are optional, as water should, and could, be stored for several months (table 20).

The Net Present Value (NPV) of costs are discounted at an 8% discount rate in perpetuity.

The costs arising for water storage are in the range of US$ 0.22 /m^3 without electricity costs. For instance Pérez Monteagudo (2000) estimated water prices around US$ 2.64 /m^3 in stand points, US$ 7.92 /m^3 for government offices and US$ 13.2 /$m^3$for cistern truck vehicles.

Table 20: Costs related to establishment of elevated torm-resistant water reservoirs

Capacity unit (m^3)	1 400
Lifetime (years)	25
Capital costs (thousand US$)	2 800
O&M costs (thousand US$)	50 (each 5 years)
NPV of capacity unit (m3)	16 345
NPV O&M (US$)	857
NPV of investment (Million US$)	-
Discounted cost of investment (US$/$m^3$)	171.3
Discounted costs of O&M (US$/$m^3$)	0.6
Unit capacity costs (US$/$m^3$)	171.9

Source: Data compiled by author

IX. MITIGATION OF GREENHOUSE GAS EMISSIONS

A. ESTIMATING ENERGY DEMAND AND THE CONSTRUCTION OF EMISSION SCENARIOS

Given the assumption that Turks and Caicos Islands will continue to depend on tourism and RO for obtaining freshwater as an unavoidable condition to maintaining and increasing GDP and population welfare, dependence on fossil fuels and vulnerability to increasingly volatile prices constitute important limitations. In this sense, mitigation is synergistic with adaptation since reducing dependence on fossil fuels and introducing solar energy are necessary conditions for achieving a sustained water supply and an increased capacity for adaptation. Turks and Caicos Islands is not a major producer of total carbon emissions, but per capita emissions are high. The following section of the present report is based on emissions data and the author's assumptions.

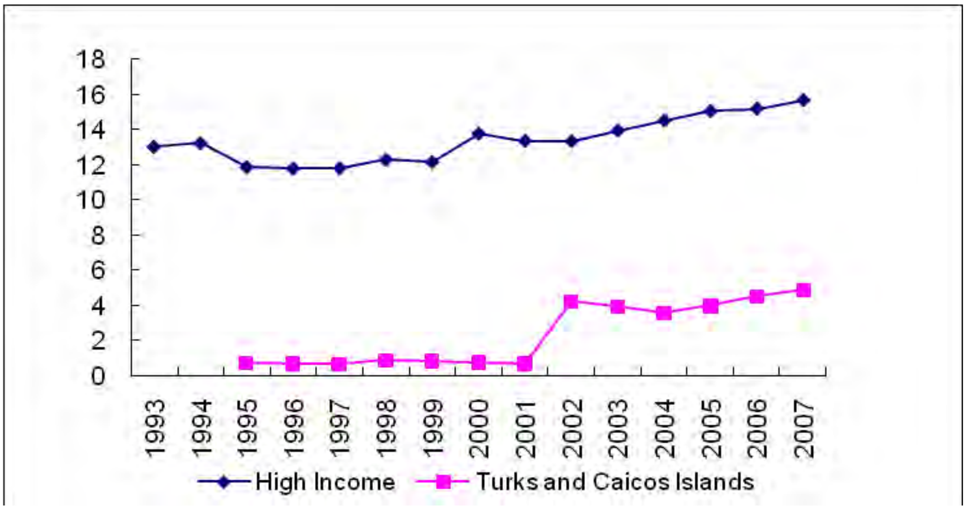
B. ENERGY DEMAND AND CO_2 EMISSIONS

An important constraint in the present study is the availability of adequate, consistent, and appropriate data in forms that support the construction of scenarios reliably. Data on CO_2 emissions are needed to estimate the primary energy supply. Figure 15 shows that Turks and Caicos Islands has not been a significant producer of carbon dioxide emissions relative to high-income countries.

The emissions of CO_2 per capita in Turks and Caicos Islands were around 5 t CO_2 per capita, similar to Bahamas (6.7 t CO_2), and Antigua and Barbuda (6 t CO_2). The commercial sectors on these islands, as on Turks and Caicos Islands, are major contributors in terms of GDP (UNDP Human Development Report 2007-2008). Using an emission factor of 2.6 t CO_2 per capita, and a population of 33,000 inhabitants, primary energy demand was estimated to be 110,000 tonnes for Turks and Caicos Islands.

As no data on electricity demand are available, per capita demand was estimated using proxies from the Caribbean region (similar to Saint Kitts and Nevis; 3,333 kWh/ year). Total electricity demand was also estimated as 110 GWh, used mainly for residential, commercial, tourism and water desalination purposes. The number of households was estimated at 10,500 with maximum electricity consumption of 8 kWh daily and 240 kWh monthly, which represents 33 GWh, 30% of electricity demand.

Figure 16*: Carbon dioxide emissions (metric tons per capita)*



Source: World Development Indicators, World Bank.

Taking into consideration the number of tourist arrivals in Turks and Caicos Islands, the number of rooms and an occupancy rate of 70%, total electricity was estimated at a minimum as180 kWh monthly or 28 GWh (25% of total electricity consumption). With the exception of an agricultural experimental farm on North Caicos, there is no significant agricultural activity on Turks and Caicos Islands. Even then, there is no expansive irrigation system, as agricultural production is limited to the experimental farm and the mostly subsistence farming on the other islands.

Residential and tourist water demand: Domestic demand for water resources has been increasing on the islands. Properties constructed after 2006 are not required to be fitted with private catchment systems. At the private-public water production entity on Providenciales, total water demand is well below the production capacity of the current water production facilities.

Industrial and commercial water demand: There is no significant commercial activity on the islands. On Providenciales, the most densely populated of the islands, commercial properties are required to be fitted with catchment systems to supply piped water. Eleven seawater reverse osmosis (SWRO) plants have been detected on Turks and Caicos Islands and, at present, capacity exceeds demand. Depending on the technology used, electricity consumption for the RO process requires between 9-11 kWh per m^3. Total electricity demand is presented in table 21.

Table 21: Turks and Caicos Islands: Electricity demand by main sector in 2008

	Demand (GWh)	Share (%)
Total electricity demand	110	100
Residential sector	33	30
Tourist sector	28	25
Water supply and disposal/treatment	12	11
Others (industrial and commercial sectors)	29	26
Input in electric generation and loss in transmission and distribution	8	7

Source: author's estimates

Small electricity supply systems based on diesel technologies have specific consumption rates ranging from 0.22 kgoe[9]/kWh (diesel motors), to 0.315 kgoe/kWh at peak plants and gas oil turbines for isolated systems. Total fuel estimated for electricity generation of 110 GWh is about 44 Mtoe[10] which is 40% of estimated total primary energy demand. Table 22 gives an outlook of economic and energy indicators.

[9] Kilogram(s) of oil equivalent (kgoe) is a normalized unit of energy. By convention, it is equivalent to the approximate amount of energy that can be extracted from one kilogram of crude oil. It is a standardized unit, assigned a net calorific value of 41 868 kilojoules/kg and may be used to compare the energy from different sources.

[10] The tonne of oil equivalent (toe) is a unit of energy and represents the amount of energy released by burning one tonne of crude oil, approximately 42 GJ.

Table 22: Turks and Caicos Islands: Main economic and energy indicators

	2008	Share (%)
GDP (Million US$, base year 2000)	606.2	-
Income (US$ base year 2000/per capita)	18 199	
Primary energy demand (thousand toe)	110	100
Input to electricity generation (thousand toe)	44	40
Final energy demand (thousand toe)	66	60
Electricity (thousand toe)	10	9 (15 VS final demand)
Fossil fuels (thousand toe)	56	51 (85 VS final demand)
Primary energy per capita (toe/per capita)	3.3	-
Electricity use per capita (kWh/ per capita	3 300	-
Energy intensity (toe/million US$)	0.181	-
Electricity intensity (kWh/million US$)	181	-

Source: author's estimations

B. SCENARIOS: BAU AND MITIGATION

The BAU scenario suggests that energy use should be supported by imported fossil fuels accompanied by important improvements in energy efficiency. The mitigation scenario explores the use of solar energy such as photovoltaics, concentrated solar power and wind energy, for which Turks and Caicos Islands has significant potential. As a follow-up to the present preliminary study, the local potential and locations need to be identified to provide more relevant estimates. Macroeconomic assumptions are the same for both scenarios (see table 23). By 2050, Turks and Caicos Islands could demand 60 Mt less than for the BAU scenarios.

Table 23: Turks and Caicos Islands: Macroeconomic assumptions for the BAU scenario

	Annual growth rate 2000-2008 (%)	Annual growth rate 2009-2050 (%)
GDP	9.8	2.0
Population	5.0	1.1
Income	2.0	2.0
Tourist arrivals	10.6	1.0
Water demand	8.0	3.5

Source: author's estimates

Mitigation scenarios suggest that, by 2050, almost one million tonnes of CO_2 emissions could be avoided, despite the fact that emissions under the mitigation scenarios are estimated to reach almost 13 million tonnes between 2009 and 2050 (see table 24).

Table 24: Turks and Caicos Islands: Energy demand by sector for all fuels for the BAU scenario ('000 tonnes of oil emissions (toe))

	2015	2020	2040	2050
Industrial and commercial sectors\Diesel	0.1	0.0	-0.5	-1.2
Industrial and commercial sectors\Electricity	-2.1	-3.8	-13.3	-20.0
Industrial and commercial sectors\Gasoline	-0.6	-1.0	-3.6	-5.4
Residential\Electricity	0.0	0.0	-0.1	-0.1
Residential\LPG	-0.1	-0.2	-0.6	-0.9
Residential\Solar	0.0	0.0	0.3	0.6
Tourism\Diesel	-0.9	-1.7	-5.2	-7.5
Tourism\Electricity	0.0	0.0	-0.1	-0.2
Tourism\Solar	0.0	0.1	0.9	1.8
Water supply\Diesel	-1.4	-2.8	-13.9	-25.0
Water supply\Electricity	0.0	0.0	-0.1	-0.2
Total	-5.0	-9.4	-36.2	-58.1

Source: Long-range Energy Alternatives Planning System (LEAP). (SEI).

Table 25 provides estimates of avoided emissions mitigation scenarios and BAU scenarios.

Table 25: Avoided emissions mitigation scenarios by sector to 2050 for Turks and Caicos Islands (thousand tonnes CO_2 equivalent)

	2015	2020	2040	2050
Demand\Industrial and commercial sectors\Diesel	0.2	0.1	-1.5	-3.7
Demand\Industrial and commercial sectors\Gasoline	-1.6	-3.0	-10.5	-15.8
Demand\Residential\LPG	-0.4	-0.6	-2.0	-2.8
Demand\Tourist\Diesel	-2.8	-5.0	-16.0	-22.9
Demand\Water supply\Diesel	-4.2	-8.5	-42.4	-76.2
Transformation\Electricity Generation\Processes	-68.4	-123.2	-393.0	-528.0
Total	-77.2	-140.2	-465.4	-649.4

Source: Long-range Energy Alternatives Planning System (LEAP), Stockholm Environment Institute (SEI).

Table 26: Mitigation potential to 2050 compared with the baseline for all fuels for Turks and Caicos Islands (Cumulative thousand tonnes CO_2 equivalent)

Units: Thousand ton CO_2 Equivalent	2015	2020	2040	2050
Demand\Industrial and commercial sectors\Diesel	0.7	1.5	-7.9	-34.1
Demand\Industrial and commercial sectors\Gasoline	-6.4	-18.6	-151.1	-283.9
Demand\Residential\LPG	-1.4	-4.0	-30.0	-54.0
Demand\Tourist\Diesel	-11.1	-31.7	-241.9	-439.1
Demand\Water supply\Diesel	-15.9	"-49.2"	-519.7	-1116.9
Transformation\Electricity Generation	-268.5	-772.7	-5981.9	-10853.3
Total	-302.4	-874.7	-6932.3	-12781.4

Source: Long-range Energy Alternatives Planning System (LEAP). Stockholm Environment Institute (SEI).

Consequently, when projected to 2050, the substitution of fossil fuels produces significant reductions in fuel imports (see tables 26 and 27), by more than US$ 900 million (2000).

Table 27: Turks and Caicos Islands: Estimated costs of mitigation by fuel type with respect to the 2008 baseline (discounted 2000 cumulative million US$).

	2015	2020	2040	2050
Gasoline	-0.4	-1.2	-9.6	-16.2
LPG	-0.1	-0.3	-2.1	-3.3
Diesel	-33.7	-94.2	-577.6	-897.8
Total	-34.2	-95.7	-589.3	-917.3

Source: Long-range Energy Alternatives Planning System (LEAP): SEI.

Table 28: Turks and Caicos Islands: Costs scenario: mitigation vs. baseline cost: Capital costs of electricity generation (2008 baseline discounted 2000 cumulative million US$).

	2015	2020	2030	2050
Base load diesel	-6.1	-10	-19.1	-34.3
Base load solar	259.2	408.1	644	830.6
Base load wind	6.1	14.5	34.8	67.7
Total	259.2	412.6	659.7	864

Source: Long-range Energy Alternatives Planning System (LEAP). Stockholm Environment Institute (SEI).

It is very clear that a scenario that potentially introduces solar energy and an energy policy where efficiency plays an important role would result in reduced energy dependency, providing both energy security for the SWRO plants and project the image of a more attractive, cleaner tourism destination (table 28).

Cost estimates for avoided emissions for the period 2009-2050, (avoided capital costs and avoided oil import costs) of - US$ 4 / t (2000) are very attractive for win/win projects translated to minimum detectable limit (MDL) options as a financial contribution to future energy policy, and would require more in-depth research.

Operating and maintenance (O&M) costs for solar energy are considerable compared to diesel, which has significantly lower fixed and variable costs. Diesel motor costs are of the order of US$ 10 /kW to US$ 30 /kWh. In solar (CSP) and wind energy plants, O&M costs are around US$ 14 /kW, and costs for CSP plants may be even more substantial, depending on the technology (see table 29). Costs associated with the employment of wind energy are shown in table 30.

Table 29: Costs associated with implementation of Concentrated Solar Power

Annual costs ($)	Mitigation	BAU	Increase
Unit capital costs ($/HH)	300 000 000	20 000 000	280 000 000
Lifetime (years)	35	35	
Annualized investment	29 741 267	1 982 751	27 758 516
Total capital costs	29 741 267	1 982 751	27 758 516
Annual O&M costs	9 198 000	3 066 000	6 132 000
Fuel costs	-	35 378 409	(35 378 409)
Total annual costs	38 939 267	40 427 160	**(1 487 893)**
GHG emissions (tons) 2030	Mitigation	BAU	increase
CO_2	-	121 114	121 114
N_2O	-	1	1
CH_4	-	3	3
Total CO_2 equiv.	-	122 148	**122 148**
Ton CO_2 avoided/unit			122 148.24
$/ton CO_2 equivalent			**$ (12.18)**

Source: author's estimates

Table 30: Wind energy option

Annual costs (US$)	Mitigation	BAU	Increase
Unit capital costs ($/HH)	140 000 000	20 000 000	120 000 000
Lifetime (years)	20	35	
Annualized investment	15 886 737	1 982 751	13 903.986
Total capital costs	15 886 737	1 982 751	13 903 986
Annual O&M	490 560	1 226 400	(735 840)
Oil costs	-	123 824 433	(123 824 433)
Total annual costs’	16 377 297	127 033 584	**(110 656 286)**
GHGs emissions (tons) 2030	Mitigation	BAU	Increase
CO_2	-	423 898	423 898
N_2O	-	3	3
CH_4	-	11	11
Total CO_2 equivalent	-	427 519	**427 519**
Avoided t/ CO_2 avoided			427 518.84
$/Ton CO2 equivalent			**$ (258.83)**

Source: author’s estimates

The main indicators of mitigation scenarios in electricity generation and the combined effects of several energy options are presented in table 30.

Table 31: Summary of main energy sector indicators

	Capacity		Electrical power		Energy input	
	(MW)		(GWh)		(Thousand toe)	
	2008	2050	2008	2050	2008	2050
Base load diesel	50	30	1 000	29 400	99.3	2 907
Base load solar	0	65	0	6 000	0	514
Base load wind	0	52	0	9 500	0	816
Total Turks and Caicos Islands	50	147	1 000	44 900	99.3	4 237

Source: Data compiled by author

Table 31 presents accumulated costs relative to 2008, projected to 2050 and discounted at 5%. Payments for foreign fuel imports are drastically reduced (almost 40% of imports in 2008), and O&M costs, actually very high for diesel motors used in electricity generation (table 32).

Table 32: Costs discounted 2000 by 10%: Cumulative discounted to 2008 (Millions of US$)

	2050		
	Mitigation	BAU	Mit/BAU
Transformation Fixed OM	122.6	21.6	101
Transformation Variable OM	139 000	228 600	-89 600
Transformation Capital	945.5	81.5	864
Fuel Import	3 083.2	4 000.5	-917.3
Total cost	143151.3	232703.6	-89552.3

Source: Data compiled by author

X. CONCLUSION

Climate change impacts on the water sector in Turks and Caicos Islands are less associated with precipitation reduction since Turks and Caicos Islands has a tradition of desalination using reverse osmosis. The use of water catchment devices and other water management options needs further research to provide cost benefit estimates of water use reduction. Precipitation reduction may cause increases in sea water salinity and changes in marine ecosystems that need to be explored, especially with regard to their impacts on the tourism industry and on desalination. Sea level rise will very likely affect coastlines but the impact on reverse osmosis plants is uncertain. In this context, salt water intrusion seems to be less important.

There is an important synergy in the Turks and Caicos Islands between adaptation and mitigation, related to the reduced dependence on fossil fuels. Although GHG emissions in the Turks and Caicos Islands are irrelevant in the global context, per capita emissions are high. Mitigation options to reduce fossil fuel dependency need more detailed assessment, of technologies to be used, the timing of their introduction, and the exploration of scenarios for future electricity-generating systems.

Studies on climate change pose a challenge to the Turks and Caicos Islands because accurate data sets are needed for further research. Policy implementation in this direction is crucial.

ANNEX

TURKS AND CAICOS ISLANDS GROSS DOMESTIC PRODUCT BY ECONOMIC ACTIVITY					
AT CURRENT PRICES: 2003-2007 Preliminary					
(US$ '000)					
ECONOMIC ACTIVITY	**2003**	**2004**	**2005**	**2006**	**2007**
Agriculture & Fishing	5 245	6 232	6 644	7 020	7 541
Agriculture	988	911	882	1 186	1 269
Fishing	4 257	5 321	5 762	5 834	6 272
Mining & Quarrying	2 471	3 692	5 164	8 031	10 039
Manufacturing	11 355	11 314	11 912	12 424	13 440
Electricity & Water Supply	15 834	20 021	23 686	25 151	26 396
Electricity	12 493	15 509	18 271	19 195	19 963
Water	3 341	4 512	5 416	5 956	6 433
Construction	30 883	46 148	64 547	100 388	125 485
Wholesale & Retail Trade	16 101	19 211	22 845	28 026	31 389
Hotels & Restaurants	122 852	134 522	156 088	193 793	222 119
Accommodation	11 443	123 585	142 806	177 324	203 641
Restaurants	8 421	10 937	13 282	16 468	18 478
Transport, Storage & Communication	38 722	46 829	54 642	57 682	61 411
Road Transport	312	3 401	3 707	4 364	5 062
Sea Transport	1 012	1 043	1 095	1 150	1 207
Air Transport	8 160	8 582	8 694	9 527	10 384
Auxiliary Transport Activities & Storage	4 844	6 648	8 686	9 162	10 084
Communications	21 585	27 155	32 460	33 480	34 673
Financial Intermediation	27 243	41 611	55 738	77 751	88 203
Banks	20 605	30 114	42 417	62 529	70 658
Insurance	5 949	1 074	12 351	14 204	16 477
Auxiliary Financial Intermediation	689	757	970	1 018	1 069

Real Estate, Renting & Activities Business	43 452	45 822	50 639	56 106	59 710
Real Estate	4 714	4 777	5 234	5 648	6 100
Owner Occupied Dwellings	27 657	29 237	30 000	31 676	34 273
Renting of Machinery & Equipment	1 726	2 093	4 301	6 600	6 798
Computer & Related Services	881	985	1 001	1 021	1 092
Business Services	8 475	8 730	10 103	11 161	11 447
Public Administration & Defence; Compulsory Social Security	26 484	32 262	36 873	48 412	61 793
Education	11 624	13 390	16 327	19 602	21 969
Public	8 740	10 127	11 912	14 587	16 410
Private	2 884	3 263	4 415	5 016	5 559
Health & Social Work	9 884	11 845	13 124	16 317	18 073
Public	6 788	8 247	9 203	11 950	13 444
Private	3 096	3 598	3 921	4 367	4 629
Other Community, Social & Personal Services	14 152	14 790	17 068	18 512	19 365
Public	132	151	167	184	202
Private	13 221	13 651	15 759	17 135	17 969
Activities of private households	799	988	1 142	1 193	1 193
Less FISIM	18 357	22 741	36 185	52 520	59 347
GROSS VALUE ADDED					
in Basic Prices	357 945	424 949	499 114	616 697	707 584
Growth Rate (%)	10.96	18.72	17.45	23.56	14.74
Taxes on Products	52 406	61 466	80 174	105 949	121 841
Less Subsidies on Products	597	815	642	754	829
GROSS DOMESTIC PRODUCT					
in Market Prices	**409 754**	**485 599**	**578 646**	**721 891**	**828 596**
Growth Rate (%)	11.74	18.51	19.16	24.76	14.78

Source: Turks and Caicos Islands Statistical Office

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