

**TECHNOLOGY NEEDS ASSESSMENT
FOR
CLIMATE CHANGE**

BELIZE

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EXECUTIVE SUMMARY

An analysis of technology needs and requirements for addressing climate change for Belize is conducted and utilizes the United Nations Development Programme methodology and addresses both adaptation and mitigation issues. In order to assist the technology needs assessment process a stakeholder consultation occurred along with a review of key documents including sectoral and national development plans where available and national communications. However, reliance was placed on sectoral greenhouse gas inventories and sectoral vulnerability analyses. On this basis, and consistent with the methodology used, the energy and transportation sectors were identified as priority sectors as the greenhouse gas emissions from other sectors were very low. The residential and commercial sector was included based on projected growth and energy demand. Similarly, the adaptation technology analyses were conducted for the sectors for which vulnerability analyses reports were available.

ENERGY SECTOR

The Public Utilities Commission (PUC) is the government body whose role it is “to regulate the electricity, water, and telecommunications sectors in Belize to efficiently provide the highest quality services at affordable rates, ensuring the viability and sustainability of each sector”, and as a result the PUC is responsible for regulating the energy industry in Belize, and for formulating and implementing energy policies ¹. The energy sector in Belize relies heavily on fossil fuels and electrical power, both of

¹ Public Utilities Commission (PUC). 2001. About us. Accessed on 25 Jan 08 at <http://www.puc.bz/aboutus.asp>.

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which are imported. Electricity needs in Belize are sourced from a variety of sources including hydroelectric, biomass and renewable energy¹. Belize acquires its energy from four main sources: imported fossil fuels (66%), biomass (26%), hydro (3%), and imported electricity (5%). In 2006, the aggregate demand from Belize Electricity Limited (BEL) was 56 MW, sourced from Comision Federal de Electricidad (CFE) (25 MW), Mollejon Hydro Plant (three 8.4 MW turbines, thereby having an aggregate 25 MW installed capacity. BEL's generation capacity is derived from diesel generators which the company operates from different locations, with a total installed capacity of 19.8 MW), Chalillo Hydroelectric Dam has an installed capacity of 7.5 MW; Farmer's Light Plant Cooperative (Farmers LPC) with three diesel generators of 2 MW, 1MW and 750 KW ratings. Power generation is largely derived from the combustion of fossil fuels although it is estimated that just over 29% of the national energy needs are met from other sources, with biomass cogeneration contributing 26% (includes fuel wood), hydroelectricity contributing 3% and solar and wind less than 0.1%. However, due to its relatively small water storage capacity, the Mollejon Hydro Plant has only been able to provide 6.5 MW during the dry season and 10 MW during the wet season. For this reason, during the dry season BEL uses the plant as peak and emergencies backup, and during the wet season as a base load. BEL's demand forecast is for an annual increase of 9%. In 2002, aggregate peak demand was 54MW and 273 Gwh were sold to consumers that year. In 2010 peak demand is expected to reach 96MW and 523 Gwh are expected to be sold. Of electricity sold by BEL, 56% is for residential application, 31% for commercial application, 8% for street lights, and 5% for industrial application.²

While there is no written comprehensive policy approach for the energy sector in Belize, the energy mix currently present in Belize suggests that policy considerations are used in making decisions. In light of the findings of this

² Launchpad Consulting (LC). 2003. Energy for Sustainable Development Toward a National Energy Strategy for Belize Energy Sector Diagnostic. Report to Public Utilities Commission (PUC) for the Formulation of a National Energy Plan (Sector Diagnostic and Policy Recommendations) Project.

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report, a comprehensive written policy towards a sustainable energy mix may need to be formulated for focused direction and guidance in the development of the power generation sector. However, the trend has been to reduce dependence on fossil fuel-based electricity production towards other sources such as hydroelectricity and renewable energy technology. With the projected annual increase in demand estimated at 9%, several opportunities present themselves for the employment of relevant technologies to meet this demand.

A suitable framework for policy approaches can be based on the following:

- a. Expand and provide a reliable and efficient electricity distribution network.
- b. Facilitate and promote development of lower-cost energy, particularly from local renewable energy resources.
- c. Support the development and utilization of alternative and renewable domestic energy sources such as hydro, solar and wind through conducive physical planning policies.
- d. Increase energy supply to meet growing demands based on a philosophy of conservation and energy efficiency.
- e. Use of less carbon intensive fuel such as natural gas and liquefied petroleum gas (LPG).

Possible applicable technologies for Belize in the energy sector include:

- Bundled Mini-scale hydro
- Solar
- Wind power
- Biomass and Cogeneration
- Combine cycle gas turbines
- Demand-side management

Possible barriers to the implementation of the above technologies include:

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- Rainfall, water supply, land space and potential environmental impacts for hydro power;
- Technical capability and capacity to support technology;

ROAD TRANSPORT

Road transport accounted for a significant amount of carbon dioxide emissions primarily as a result of gasoline and diesel combustion and an increased demand arising out of a greater number of vehicles. Currently, all fuel for road transportation is imported and mainly dependent on gasoline and diesel powered vehicles with a smaller amount of commercial vehicles powered by liquefied petroleum gas (LPG). The number of licensed motor vehicles in Belize has increased by about 9% per year between 2000 and 2004, with a total of 48,300 vehicles registered in 2004. The majority of these (84%) were private passenger vehicles, mostly pick-up trucks and cars (29% and 25% respectively), followed by freight vehicles (9%), and public service vehicles (7%). No statistics are available about the breakdown of fuel types used by vehicles, though diesel is the cheapest fuel source and thus a very common engine choice for private and freight vehicles.

Policy approaches for the road transport sector can include:

- Development of a comprehensive transport plan aimed at minimizing traffic congestion;
- Incentives to purchase energy efficient vehicles;
- Incentives, such as tax reliefs, to encourage the use of alternative fuels such as CNG, LPG or bio-fuels;
- Mandatory installation of emission reduction devices such as catalytic converters;

Applicable technologies for the transportation sector include:

- Bi-fuel vehicles;

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- Conversion of existing vehicles to bi-fuel systems by installing conversion kits for the use of compressed natural gas (CNG) and liquefied petroleum gas (LPG);
- Flexible fuelled vehicles;
- Electric vehicles;
- Hybrid vehicles;
- Fuel cell vehicles (FCVs);

Barriers to the implementation of these technologies include:

- Cost of conversion kits;
- Technical expertise required for installing and maintaining conversion kits;
- Availability and storage of alternative fuels in the case of CNG;
- Retail infrastructure for making alternative fuel available to consumers;
- Policy barriers regarding the importation of hybrid and electric vehicles.

RESIDENTIAL AND COMMERCIAL ENERGY DEMAND

In 2007 the population of Belize stood at 311,480³ with an estimated population growth of about 3.3% per year, a rate that, if sustained, would cause Belize to double its population in 21 years. However, population models predict slower growth to approximately 499,835 persons in 2050 with an estimated growth rate of 2.7% from 1980-2000⁴.

Assuming continued increase in population growth, there would be a concomitant increase in demand for housing, an increase in housing units and an increased demand on energy resources for residential and commercial purposes as new communities are established (with a corresponding increase in greenhouse gas emissions) over the next few decades. Based on a projected overall annual

³ Statistical Institute of Belize (SIB). 2007a. Belize: Midyear Population Estimates By Region and Sex. Statistical Institute of Belize, Belmopan.

⁴ Statistical Institute of Belize (SIB). 2007b. Belize: Total Population Estimates and Projections (1980-2050). Statistical Institute of Belize, Belmopan.

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energy demand of 9%, the residential and commercial sector can offer opportunities for energy conservation and efficiency.

Possible applicable technologies for this sector include:

- Energy efficient appliances;
- Energy saving lamps (fluorescent vs. incandescent);
- Solar technology (water heating and air-conditioning);
- Energy efficient building designs in future housing developments;
- Time of use devices for switching on and switching off appliances

Possible Barriers to the implementation of the above technologies include

- Cost of the technology;
- Availability of technology;
- Expertise to operate and maintain technology;
- Institutional and legal framework.

FORESTRY AND TERRESTRIAL ECOSYSTEMS

Developmental pressures are being brought to bear on forest resources and forests are of vital importance to sustainable development, particularly in relation to watersheds and water supply, fuel wood, slope stabilization and the prevention of erosion and landslides, preservation of biological diversity and critical habitats; and carbon sequestration.

Possible applicable technologies for this sector include:

- Geographical Information Systems (GIS) and remote sensing techniques and technology;
- Complementary database development and management utilizing appropriate hardware and software would also be necessary for a comprehensive assessment of the resources;
- Silvicultural techniques.

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Possible barriers affecting the applicability of the above technologies in this sector include

- Cost and technical capacity;

COASTAL ZONE

Vulnerability issues in respect of projected climate change and sea level rise for this sector are identified as follows:

- Intensification of coastal erosion patterns
Increase in sea level would increase tidal reach and the high water mark and can result in an increase in coastal erosion, particularly during extreme weather events when the storm surge would be greater.
- Saline intrusion and coastal flooding
Increase in sea level would result in salt water intrusion and increased coastal flooding. Saline intrusion can have secondary impacts such as the salinisation of agricultural soils and contamination of freshwater aquifers.
- Mangrove ecosystems including fisheries habitat
An increase in sea level would place migration pressures on mangroves and have direct adverse consequences on the fisheries that they support.
- Coral reefs
Increasing sea surface temperatures can be expected to cause increased incidences of coral bleaching and coral destruction leading to adverse impacts on coastal fisheries and increase in wave energy impacts on the coastal shores resulting in accelerated erosion.
- Impacts on coastal human settlements

Impacts on coastal human settlements can result from sea level rise, inundation and flooding from storm surges during extreme weather events and coastal erosion.

Possible Applicable adaptation Technologies include adaptation measures in the coastal zone and these can be categorised in three forms:

1. Retreat

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2. Accommodate, and
3. Protect

Possible barriers to the implementation of the above technologies include:

- Cost;
- Physical barriers such as land space and capability;
- Technical capacity and capability;

WATER RESOURCES

The vulnerability of water resources to the adverse impacts of climate change are related to:

- a. Increase in temperature leading to higher evaporation and evapo-transpiration rates;
- b. Changes in intensity, quantity and frequency of precipitation events, and
- c. Rise in sea level.

Possible applicable technologies for this sector include:

- Domestic water conservation technologies such as water efficient faucets, toilets and showerheads;
- Irrigation technologies including sprinkler systems and drip irrigation;
- Rainwater harvesting;
- Technologies for soil and water conservation (also applicable to the agricultural sector) such as storage ponds;
- Desalination (potentially costly option).

Possible barriers affecting the implementation of the above technologies include:

- Compatibility of plumbing codes;
- Maintenance cost and technical requirements;
- Cost of retrofitting;

AGRICULTURE

For sugarcane, the CROPWAT model projected 11.9% reduction in yield for 2028 with 12mm less rainfall and 17.4% reduction for 2050 with 20mm less rainfall. Using the 2028 scenario with an additional 12mm rainfall yields still fell by 4.5%. The temperature rise shortened the growing period of the crops, which lowered their yields. Changes in precipitation did not affect the growing season. However, it did affect the yield, especially when there were periods of low or high rainfall.

For citrus, in 2028 with 12mm less rainfall the predicted reduction was 3.4% in yields and 5% reduction for 2050 with 20mm less rainfall. Using the 2028 scenario with an additional 12mm rainfall yields remained the same. The temperature rise shortened the growing period of the crops, which lowered their yields. Changes in precipitation did not affect the growing season. However, it did affect the yield, especially when there were periods of low or high rainfall since no irrigation is used.

Possible applicable technologies include:

- Early warning systems for forecasting of wet and dry periods;
- Adoption of drought-resistant cultivars;
- Geographical Information Systems (GIS);
- Change of sowing and harvesting periods;
- Pesticide application technologies and practices;
- Integrated Pest Management (IPM) systems and practices;
- Soil management technologies and practices;
- Aquaculture and mariculture technologies.

Possible Barriers to the application of the above technologies include:

- Cost;
- Technical capacity and capability;
- Cultural acceptability of introduced cultivars;

- Human resource requirements.

HUMAN SETTLEMENTS

Human settlements are largely concentrated in the coastal zone. Adverse impacts of climate change on human settlements are likely to arise from:

- a. Extreme weather events such as storms and hurricanes;
- b. Sea level rise and coastal flooding.

Projected increases in population and settlement patterns is likely to exacerbate the vulnerability of human settlements.

Technologies and possible barriers applicable to human settlements are the same as those that can be applied to coastal zones for coastal protection; and the adoption of stricter building codes to withstand extreme weather events.

HUMAN HEALTH

Adverse impacts of climate change on human health are likely to arise from:

- a. Higher temperatures and precipitation (creation of favourable conditions for the thriving of vectors of transmissible diseases);
- b. Flooding and inundation, giving rise to unhygienic conditions as well as water borne diseases;
- c. Deterioration of water quality (arising from more arid conditions).

Possible applicable technologies for this sector include:

- Deployment of fogging machines for vector spraying;
- Use of insecticide-treated nets;
- Integrated vector management systems (IVM) (process for managing vector populations in such a way as to reduce or interrupt transmission of disease).

Possible barriers to the implementation of the above technologies include:

- Cost;
- Technical capacity for maintenance;

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- Supporting infrastructure and human resources;
- Technical capacity and capability.

TOURISM

The tourism product is a combination of the various sectors that offer attractions to visitors such as natural and historical features. Additionally, since this is a service-oriented industry, it depends on various other support sectors and adverse climate change impacts on these support sectors would have an impact on the tourism sector. The projected impacts of climate change in the tourism sectors are likely to arise from the following:

- Flooding of coastal areas, increasing beach erosion, rising water tables and higher wave energy resulting from sea level rise. This will result in increased costs and damage to tourism based infrastructure;
 - Damage to coastal ecosystems such as coral reefs as a result of sea level rise, extreme weather events and increased sea surface temperatures;
 - Decrease in freshwater availability and increase in associated costs;
 - Deterioration of outdoor conditions;
 - Deterioration of indoor conditions resulting in increase in demand for air conditioning systems;
 - Deterioration of landscapes;
- Indirect impacts resulting from food security issues.

Due to the very nature of the tourism industry in terms of its structure, there are no specific technologies that can be identified to reduce the vulnerability of this sector. Technology application in related vulnerable sectors will ameliorate impacts on the tourism sector, particularly those identified in the coastal zone, agriculture, water and forestry sectors.

CONCLUSIONS AND RECOMMENDATIONS

This study provides an indication and guidance as to the possible technologies that can be applied in specific sectors. Further analysis has to be done to prioritise technology applications, including cost-benefit analyses, more detailed environmental impact assessments based on the receiving environment, and most critically, an analysis of the enabling environment to receive the technology. In this respect, a comprehensive overview of the institutional, policy and legislative barriers would have to be conducted in the context of the identified technology. Such an analysis is outside the scope of this study, which sought to identify technology needs that can address climate change issues which were identified in various reports.

Technology requirements can be expected to change with changes in policy, development objectives and changes in the technologies themselves. It should therefore be cautioned that the technology needs identified here may only have a limited timeframe of application. Any choice of technology should at least satisfy a set of basic requirements and criteria which are determined at the national level, including consideration of sustainable development criteria. However, as a general requirement the following should be taken into account:

- Longevity of the technology;
- Technical support requirements of the technology at the time of availability;
- Cost;
- Social acceptance/environmental impact;
- Contribution to sustainable development objectives as identified.

Identified nexuses among and across the sectors can also aid in maximising technology choices and are illustrated in the Table A below.

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Table A Inter-Sectoral Linkages and Synergy

Sector	ENERGY	ROAD TRANSPORT	FORESTRY & TERRESTRIAL ECOSYSTEMS	COASTAL ECOSYSTEMS	WATER RESOURCES	AGRICULTURE & AQUACULTURE	HUMAN SETTLEMENTS	HUMAN HEALTH	TOURISM
Energy		√				√	√		√
Road Transport	√							√	
Forestry & Terrestrial Ecosystems				√	√	√			√
Coastal Ecosystems			√		√	√	√		√
Water Resources			√	√		√		√	√
Agriculture	√		√	√	√			√	√
Human Settlements	√			√				√	√
Human Health		√			√	√		√	√
Tourism	√		√	√	√	√	√	√	

1.0 INTRODUCTION AND BACKGROUND

Belize submitted its Initial National Communication (INC) in July 2002, pursuant to its obligations under the United Nations Framework Convention on Climate Change (UNFCCC). The INC addressed various aspects of the national circumstances of the country including a greenhouse gas emissions inventory by sector as well as assessments of vulnerability to climate change. The INC did not address issues related to technology needs in respect of mitigating greenhouse gas emissions nor adapting to climate change. The Second National Communication undertakes to conduct a technology needs assessment for addressing climate change for Belize. This report presents the results of the technology needs assessment.

1.1 Methodology and Approach

The methodology used in conducting the TNA follows that described in the UNDP handbook⁵ on conducting technology needs assessments for climate change as far as possible. Sectors addressed were a guided by sectoral reports on greenhouse gas emissions and sectoral vulnerability assessments, where available, as well as stakeholder consultations. Additionally, issues and recommendations identified during stakeholder consultations were taken into consideration when identifying technologies (See Appendix I and II). Generally, activities focused on:

1. Identification of vulnerable sectors;
2. Identification of greenhouse gas emitting sectors;
3. Identification of applicable technologies;
4. Screening of suitability of technologies based on criteria outlined in the UNDP handbook;

⁵ Gross, R., Dougherty, W. and Kumarsingh, K. (2004) Conducting Technology Needs Assessments for Climate Change. UNDP, New York, US, 26pp.

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5. Identification of possible barriers to transfer and implementation of identified technologies;

1.1.1 Objectives and Scope of Study

Belize is currently preparing its Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC). This document builds on earlier work carried out under the First National Communication, and the GEF funded National Capacity Self-Assessment Project, among other interventions.

The Technology Needs Assessment being undertaken as an important outcome of the SNC exercises allows developing nations such as Belize to capitalize on one of the more important recommendations of the convention, “the development and transfer of technology”. This outcome is particularly important in helping Belize to cope with an ever evolving climate system. The TNA to be undertaken will follow the advice of the Subsidiary Body on Science and Technology Advice (SBSTA) as a guide to its preparation. TNA preparation will be undertaken through a three step approach including Preliminary sector overviews intended to identify major emitting sectors as well as vulnerable sectors, establishment of national criteria for identification, assessment and selection of appropriate technologies/ best practices, prioritization of sectors and selection of key technologies, and the identification of national barriers and policy needs as they relate to implementation of selected criteria. The process is meant to be highly consultative in nature involving a broad cross section of governmental and private sector entities. The TNA synthesis report will be complemented by a report on the implementation mechanism which will identify actions and opportunities for implementation.

It should be noted that the recommendations for technology needs made in this report are only an assessment based on issues related to climate change mitigation and adaptation as identified in various reports,

stakeholder consultations and possible applicability and adaptability of technologies as well as a consideration of proposed developmental plans and policies in the various sectors, where they exist. Policy recommendations are made only in so far as they may have relevant technology implications. This report does not constitute an endorsement of one type of technology over another nor does it base its recommendations on any technology that has been tried and tested in Belize. Any choice of a particular technology would require further analysis based on cost-benefit and policy considerations as well as environmental impact of the technology, which are outside the scope of this study. Although some general assessment of impacts are presented, detailed environmental impact assessment would need to be done based on the peculiarities of the receiving environment.

1.2 General Description of National Circumstances

Belize is located on the Central American mainland, forming part of the Yucatan Peninsula and lying between 15°45' and 18°30' north latitude, and 87°30' and 89°15' west longitude. It is bounded to the north by Mexico, to the west and south by Guatemala and to the east by the Caribbean Sea. The total land area is 22,960 sq. km. (8,867 square miles) of which 95% is located on the mainland and five per cent is distributed over more than 1,060 islands. Total national territory (including territorial sea) is 46,620 sq. km. (approximately 18,000 square miles). Most of the northern half and much of the southern third of the country, plus the entire coastal area and all the islands, are flat and low-lying. Large sections of the coastline have an elevation of less than one metre to a distance of several kilometers inland. In the north, the land rises to an elevation of approximately 250 meters above sea level (asl) in the extreme west of the country. The central part of the country is dominated by the Maya Mountain/Mountain Pine Ridge massif, rising to 1,124m asl (3688 ft) at its highest point. Northern Belize has a subtropical climate with an annual rainfall of 1,500 mm (60 inches). Southward, the climate becomes increasingly tropical and

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annual rainfall increases to 3,800 mm (150 inches). The climate is characterized by marked wet and dry seasons separated by a cool transitional period. Belize lies within the hurricane belt. Historically, tropical storms and hurricanes have affected the country once every three years. Belize City, the former capital, was destroyed twice by hurricanes in the 20th century. Hurricanes can affect any part of the country but are more frequent in the north.

As of 2006, the GDP at current market prices was US\$1213.65 million (mn), with a per capita GDP of approximately US\$3,896 mn⁶ (CBB 2006). GDP growth during the nineties averaged 4.6% and growth between 2000 and 2006 averaged 6.5%. The service and wholesale/retail trade sectors contribute most significantly to GDP (20% and 14.5% respectively in 2006), followed by manufacturing (10.6%), transport and communication (10.4%), government services (9.8%), and agriculture and forestry (9.1%). Tourism is a large contributor to both the service and wholesale/retail trade sectors. In 2006, tourist arrivals totaled 903,000 and tourist receipts amounted to US\$199 mn, or about 16% of the GDP⁷ (SIB 2007c).

⁶ Central Bank of Belize (CBB). 2006. G1: GDP at Current Prices by Activity. Belize City.

⁷ Statistical Institute of Belize (SIB). 2007c. Trade Statistics 2000 to 2006. Statistical Institute of Belize, Belmopan.

2.0 MITIGATION TECHNOLOGIES

According to the greenhouse gas inventory conducted for the years 1994, 1997 and 2004 as presented in the sectoral greenhouse gas inventories⁸, the major source of carbon dioxide for Belize is as a result of energy consumption in:

- the land use and land use change sector
- road transport and national navigation
- energy industries – power generation

According to the greenhouse gas inventories by sector for the years 1994, 1997 and 2000, there were no significant emissions of carbon dioxide from industrial processes, waste and agricultural sectors and very small emissions of the other greenhouse gases (methane, non-methane volatile organic carbon, nitrous oxide). Sectors for which mitigation measures were identified in the sectoral mitigation analysis reports were the ones for which the TNA was conducted. However, the sectors identified above offer the greatest potential for greenhouse gas mitigation.

⁸ a) **Error! Main Document Only.** Greenhouse gas inventory of the Energy Sector in Belize Belize's Second National Communication Climate Change Project. Submitted to The Ministry of Natural Resources and the Environment Prepared by Jose G. May Energy Sector Consultant April, 2007;

Error! Main Document Only. b) Greenhouse gas inventory of Industrial Processes in Belize Belize's Second National Communication Climate Change Project. Submitted to The Ministry of Natural Resources and the Environment Prepared by Mario Fernandez Energy Sector Consultant April, 2007

Error! Main Document Only. c) Greenhouse gas inventory of Agricultural Sector in Belize Belize's Second National Communication Climate Change Project. Submitted to The Ministry of Natural Resources and the Environment Prepared by Anselmo Castañeda, Agriculture Sector Consultant April, 2007

Error! Main Document Only. d) Greenhouse gas inventory of the Land Use, Land Use Change and Forestry Sector. Belize's Second National Communication Climate Change Project. Submitted to The Ministry of Natural Resources and the Environment. Prepared by Oswaldo Sabido. April, 2007

e) Enabling Activities for the Preparation of Belize's Second National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change. Activity 3. Greenhouse Gasses Inventory: Waste Sector. Evaristo Avella. April 2007.

2.1 ENERGY

2.1.1 Development Objectives and Policy

While there is no comprehensive policy approach for the energy sector in Belize⁹, the energy mix currently present in Belize suggests that policy considerations are used in making decisions. In light of the findings of this report, a comprehensive written policy towards a sustainable energy mix may need to be formulated for focused direction and guidance in the development of the power generation sector. However, the trend has been to reduce dependence on fossil fuel-based electricity production towards other sources such as hydroelectricity and renewable energy technology. A Public Utilities Commission-sponsored energy sector diagnostic report (LC 2003) emphasized the importance of energy security for Belize, citing the heavy reliance of imported fossil fuels as a factor that creates vulnerability. The report states that “the best Belize can aspire to, in order to improve energy security is to reduce the dependency on imports in the electricity sub-sector, practice energy conservation and review the possibility of biofuels to ameliorate the extreme dependence in the transport sub-sector”¹⁰ (LC 2003).

Table 1 illustrates the projected demand in the immediate short term. With the projected annual increase in demand estimated at 9%, several opportunities present themselves for the employment of relevant technologies to meet this demand.

⁹ Sectoral Report. Technical Needs Assessment of Belize Energy Sector. Belize Second National Communication to the UNFCCC. Climate Change Project . The Ministry of Natural Resources and the Environment. June 2007.

¹⁰ Launchpad Consulting (LC). 2003. Energy for Sustainable Development Toward a National Energy Strategy for Belize Energy Sector Diagnostic. Report to Public Utilities Commission (PUC) for the Formulation of a National Energy Plan (Sector Diagnostic and Policy Recommendations) Project.

Table 1. Energy sales and forecasts for demand (2008-2010)

Year	Total Sales (GWhs)	Total System Growth (%)	Grid Sales (GWhs)	Grid Generation (GWhs)	Grid Peak (MW)
2000	229.4	14.96	214.4	245.4	40.9
2001	256.6	11.88	242.5	277.3	46.2
2002	273.4	6.56	263.0	293.1	47.8
2003	298.0	9.00	295.2	329.0	54.3
2004	321.3	7.81	318.1	354.5	58.5
2005	349.4	8.73	349.4	389.4	64.2
2006	379.6	8.65	379.6	423.1	69.8
2007	411.9	8.52	411.9	459.1	75.7
2008	446.6	8.43	446.6	497.8	82.1
2009	483.8	8.33	483.8	539.3	89.0
2010	523.6	8.22	523.6	583.6	96.3

Adapted from BEL 2001¹¹ in LC 2003.

2.1.2 Possible Technologies

In keeping with observed trend, and recommended policy, technology applications to reduce energy demand and consumption. Demand-side management can also offer opportunities for meeting projected increased demands.

2.1.2.1 Power Generation

- Hydroelectric

Belize already has established hydroelectric-based generation capacity and technical experience. However, any expansion or addition of hydroelectric plants would require detailed, site-specific environmental impact assessment. Additionally, projected changes in precipitation as a result of projected climate

¹¹ Belize Electricity Limited (BEL). 2001. Generation Planning Report.

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change indicates a net decrease in annual precipitation for Belize¹² will affect potential stream flow and impact on the scale and design of plants and needs to be carefully considered.

- Wind

There is potential for tapping wind energy for electricity generation and is especially true for the Baldy Beacon area. There is already a small number of wind turbines in this area, estimates indicate that up to 20 MW can be developed at the site over a ten year period. Even though this site has a minimum wind speed of up to 7 m/s, there is no country wide data available¹³ and further feasibility studies need to be conducted.

- Biomass

Biomass (bagasse) is already used in the sugar industry for cogeneration and fuel wood for domestic cooking and industrial applications (lime industry). With a well established sugar industry, expanded use of bagasse for cogeneration should be explored. In 2004, Belize Cogeneration Energy Limited (BELCOGEN) announced it had signed a 15-year Power Purchase⁴ Agreement with BEL to supply 13.4 MW to the national grid. This project proposes to use all available bagasse produced by BSI, thereby maximizing the adoption of this technology.⁴ However, any consideration of expanding sugar cultivation needs to take into account the adverse impacts of climate change on this crop.

2.1.3 Possible Barriers

Hydroelectric generation

¹² <http://country-profiles.geog.ox.ac.uk> Visited 17th November 2008.

¹³ Sectoral Report. Technical Needs Assessment of Belize Energy Sector. Belize Second National Communication to the UNFCCC. Climate Change Project . The Ministry of Natural Resources and the Environment. June 2007.

⁴ Sectoral Report. Technical Needs Assessment of Belize Energy Sector. Belize Second National Communication to the UNFCCC. Climate Change Project . The Ministry of Natural Resources and the Environment. June 2007

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Hydro power depends on rainfall and water supply. Variability of annual rainfall can determine the feasibility of the application of hydro power. A growing population would place additional demands on water resources and would also need to be considered in determining the feasibility of this type of technology. Additionally, environmental impacts of such projects can be significant depending on the environmental characteristics of the chosen site, including impacts on water supply, and biodiversity resulting from the damming of water. The site chosen would also be contingent on feasibility studies, which are not part of the scope of the present report.

- Cost of the technology, depending on scale.
- Sustained stream flow and hydrologic conditions suitable for sustained generation in light of projected changes in precipitation due to projected climate change.
- Potential significant environmental impacts arising from damming, depending on the sensitivity of the receiving environment.

Wind

- High initial capital investment, depending on proposed scale.
- Lack of expertise in wind energy technology for maintenance and technical support.

Biomass

- Climate change impacts on sugar cane
- Economic feasibility

2.1.4 Possible approaches to removing barriers

Hydroelectric generation

- “Bundling” of more than one small-scale or mini-hydro plants in a single network depending on feasibility of sites. This would minimise potential large-scale environmental impacts as well as reduce demands on hydrological conditions for sustained power generation.

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Wind

- Exploration of “bundling” more than one set of sites where wind speed is feasible.
- Seek out opportunities under the Clean Development Mechanism of the Kyoto Protocol to defray capital costs.

2.1.5 Residential and Commercial

In 2007 the population of Belize stood at 311,480¹⁴ with an estimated population growth of about 3.3% per year, a rate that, if sustained, would cause Belize to double its population in 21 years. However, population models predict slower growth to approximately 499,835 persons in 2050 with an estimated growth rate of 2.7% from 1980-2000¹⁵.

Assuming continued increase in population growth, there would be a concomitant increase in demand for housing, an increase in housing units and an increased demand on energy resources for residential and commercial purposes as new communities are established (with a corresponding increase in greenhouse gas emissions) over the next few decades. Based on a projected overall annual energy demand of 9%, the residential and commercial sector can offer opportunities for energy conservation and efficiency.

Possible applicable technologies for this sector can therefore include:

- Energy efficient appliances
- Energy saving lamps (light-emitting diodes and compact fluorescent vs. incandescent);
- Solar technology (water heating and air-conditioning);
- Energy efficient building designs in future housing and commercial

¹⁴ Statistical Institute of Belize (SIB). 2007a. Belize: Midyear Population Estimates By Region and Sex. Statistical Institute of Belize, Belmopan.

¹⁵ Statistical Institute of Belize (SIB). 2007b. Belize: Total Population Estimates and Projections (1980-2050). Statistical Institute of Belize, Belmopan.

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developments;

- Time-of-use devices for switching on and switching off appliances and security lights.

2.1.5.1 Possible Barriers

- Cost of the technology
- Availability of technology
- Expertise to operate and maintain technology
- Institutional and legal framework

2.1.5.1.1 Possible approaches to removing barriers

- Solar technology is relatively well developed and already being utilised in Belize. Where cost is determined as prohibitive depending on the scale of application, tax incentives and/or subsidies can be introduced to encourage the use of solar technology.
- Almost all white goods (appliances) are now manufactured with an energy rating that can be used to gauge desired benefits. Consumer standards can be developed to regulate import and manufacture of energy efficient appliances. Appropriate incentives for consumers to purchase energy-efficient appliances can be formulated based on availability, cultural preferences, etc.
- Improvement of capacity and technical competence for use and maintenance of the technology through appropriate training programmes.

2.1.6 Demand Side Management

This approach, while not a technology in and of itself, offers the option of modernising electricity planning in respect of demand projections in various consumption sectors. In this respect, energy consumption can be managed from the user or demand side by employing relevant energy conservation and energy

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efficient technologies. The following technologies can be applied and should be considered together with the technology applications for the residential sector:

- Energy-saving lamps
- Energy efficient appliances
- Energy efficient industrial equipment
- Building designs for energy efficiency
- Electricity pricing mechanism (to make renewable technologies more competitive with other conventional types).

Other issues related to the energy sector were raised at the stakeholder consultation held¹⁶ :

- An overarching barrier highlighted one of fiscal and overall policy related to adapting to energy efficiency technologies and practices and suitable approaches including policy reform may be needed to address this;
- Inefficient incineration of medical wastes may result in undesirable consequences such as the release of dioxins and furans. Relevant technologies may be needed to address this;
- The reduction in global sugar demand may provide opportunities for the co-generation potential using a more fibrous variety of sugar cane as well as the potential of the biofuel production sector;
- Biomass-based energy can also be sourced from other wastes from other sectors such as wood waste and other crops;
- There is a need for implementation, monitoring, regulation and enforcement of energy related issues pursuant to various regional initiatives.

2.2 ROAD TRANSPORT

2.2.1 Current circumstances

Road transport accounted for a significant amount of carbon dioxide emissions

¹⁶ Stakeholder consultation held at the ,,,,,,,Hotel, Belmopan March 6 2009. See Appendix for list of participants.

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identified in Belize's First National Communication and also identified as an important greenhouse gas emitting activity within the energy sector in the inventories conducted over 1997-2000, primarily as a result of gasoline and diesel combustion and an increased demand arising out of a greater number of vehicles. Currently, all fuel for road transportation is imported and mainly dependent on gasoline and diesel powered vehicles with a smaller amount of commercial vehicles powered by liquefied petroleum gas (LPG). The number of licensed motor vehicles in Belize has increased by about 9% per year between 2000 and 2004, with a total of 48,300 vehicles registered in 2004. The majority of these (84%) were private passenger vehicles, mostly pick-up trucks and cars (29% and 25% respectively), followed by freight vehicles (9%), and public service vehicles (7%)¹⁷ No statistics are available about the breakdown of fuel types used by vehicles, though diesel is the cheapest fuel source and thus a very common engine choice for private and freight vehicles. The total number of motor vehicles licensed increased from 33,088 in 2000 to 48,300 in 2004¹⁸

2.2.2 Development Objectives and Policy Approaches

Policy approaches for the road transport sector can include:

- Development of a comprehensive transport plan aimed at minimizing traffic congestion;
- Development of an efficient public transport system operating on alternative fuel;
- Incentives to import and purchase energy efficient vehicles;
- Incentives, such as tax reliefs, to encourage the use of alternative fuels such as CNG, LPG or bio-fuels, which can be linked to sugar production and use of bagasse for cogeneration;
- Mandatory installation of emission reduction devices such as catalytic converters;

¹⁷ Central Statistical Office (CSO). 2005. Belize Abstract of Statistics 2005. Central Statistical Office, Belmopan, Belize.

¹⁸ Department of Transport and Belize City Council

Applicable technologies for the transportation sector include:

- Bi-fuel vehicles;
- Conversion of existing vehicles to bi-fuel systems by installing conversion kits for the use of compressed natural gas (CNG) and liquefied petroleum gas (LPG);
- Flexible fuelled vehicles;
- Electric vehicles;
- Hybrid vehicles;
- Fuel cell vehicles (FCVs);

Barriers to the implementation of these technologies include:

- Cost of conversion kits;
- Technical expertise required for installing and maintaining conversion kits;
- Availability and storage of alternative fuels in the case of CNG;
- Retail infrastructure for making alternative fuel available to consumers;
- Policy barriers regarding the importation of hybrid and electric vehicles.

2.2.3 Possible Technologies

Currently, all fuel for road transportation is imported and mainly dependent on gasoline and diesel powered vehicles with a smaller amount of vehicles powered by liquefied petroleum gas (LPG). Possible approaches and technologies that can be used to reduce greenhouse gas emissions from the road transport sector include:

- **Bi-fuel vehicles**

A bi-fuel vehicle is one designed to operate on two fuel systems and allows for the switching between fuels, for example gasoline and compressed natural gas (CNG). These systems result in significant reduction in greenhouse gas emissions as well as an improvement of ambient air quality.

- **Conversion of existing vehicles to bi-fuel systems by installing conversion kits for the use of CNG and LPG**

Conversion kits allow for the modification of an existing gas-operated vehicle to use CNG and LPG.

- **Flexible fuelled vehicles**

These types of vehicles allow the use of a mixture of fuels such as gasoline mixed with ethanol or methanol. The emissions of such vehicle contain less greenhouse gases than those powered solely by gasoline.

- **Electric vehicles**

These vehicles are powered by a rechargeable battery that is charged from an electric power source. There are no emissions from an electric vehicle and they are ideally suited for short distances.

- **Hybrid vehicles**

A hybrid vehicle is one that combines the best features of two different energy sources, one of which is electric power. They use conventional fuel types such as gasoline to initially power the vehicle, then switches to electric power.

- **Fuel Cell Vehicle (FCV)**

This is an emerging technology that powers the vehicle by electricity generated by fuel cells onboard the vehicle, which creates electricity through a chemical process using hydrogen fuel and oxygen from the air. FCVs can be fueled with pure hydrogen gas stored onboard in high-pressure tanks or hydrogen-rich fuels such as methanol, natural gas, or gasoline. However, these fuels must first be converted into hydrogen gas by an onboard device called a reformer.

FCVs fueled with pure hydrogen emit no pollutants; only water and heat; while those using hydrogen-rich fuels and a reformer produce only small amounts of air pollutants. In addition, FCVs can be twice as efficient as

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similarly sized conventional vehicles and may also incorporate other advanced technologies to increase efficiency.

2.2.4 Technologies that can be adopted

Of the possible applicable technologies, electric, hybrid and fuel cell vehicles are emerging technologies that are probably not mature enough for the local environment. Additionally, cost and availability of the technology can be prohibitive at this stage of their development. The technical expertise required to maintain the technology may also be a barrier, as it requires specialized training.

The possible adoptable technologies can therefore be restricted to:

- Bi-fuel vehicles and installation of conversion kits;
- Flexible-fueled vehicles;
- Policy approaches

2.2.5 Possible Barriers

Bi-fuel and flexible fueled vehicles

- Cost of installation of conversion kits;
- Technical expertise required for installing and maintaining conversion kits;
- Availability of alternative fuel;
- Retail infrastructure for making fuel available to consumers;

2.3 CONCLUSIONS

Any consideration of mitigation technologies cannot be done in isolation of the cross-cutting linkages. Therefore, before any definite choice can be made on the technology, consideration would have to be given to cost-benefit analyses, environmental impacts, trade and other possible market-based barriers and possibly funding sources. These considerations are outside the scope of this report. However, this report can be used as a basis for narrowing the choices of technology in terms of the needs to address the particular mitigation as well as for further consultation and studies for determining the specific technology that can be actually put in place.

3.0 TECHNOLOGIES FOR ADAPTATION

The identification of potential technologies for adaptation is a function of the extent of vulnerability of the particular sector for which the technology is potentially applicable. Accordingly, the assessment of technologies for adaptation was carried out taking into consideration the vulnerable sectors identified in the various sectoral vulnerability reports^{19(a,b,c,d)} and the Initial National Communication (INC). In this assessment, consideration was given to:

- *Extent of vulnerability*
- *Scale*
- *Economic importance of the sector*
- *Applicability (if the technology can be applied to reduce the identified vulnerability)*
- *Adoptability (if the technology can be applied in its original form)*
- *Adaptability (if the technology can be modified to conform to the specific needs, taking into consideration scale, circumstances, receiving environment).*

The sectors identified as vulnerable in the INC are:

- Forestry and terrestrial ecosystems
- Coastal ecosystems

¹⁹ a) Vulnerability Assessment of the Belize Coastal Zone. Enabling Activities for the preparation of Belize's Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC) Project UNDP/GEF Climate Change Project Prepared by: Dwight Neal, Eugene Ariola, and William Muschamp. Belmopan, May 2008

b) Vulnerability and Adaptation Assessment of the Fisheries and Aquaculture Industries to Climate Change Final Report for the Second National Communication Project Prepared by Vincent Gillett & George Myvette Strategic Studies Consultancy Group May, 2008

c) Inception Report. Vulnerability and Adaptation Assessment for the Health Sector in Belize. Proposal to conduct a climate change vulnerability and adaptation assessment for dengue and dengue hemorrhagic fever in Belize. Belize Second National Communication (SNC) project. Vanzie Health Services LTD. 2 Collins Blvd, San Ignacio, Cayo, Belize. October, 2008.

d) Tourism in Belize. Vulnerability and Capacity Assessment. Submitted for Belize's Second National Communication to the United Nations Framework Convention on Climate Change. Prepared by Robert B. Richardson, PhD. Michigan State University (USA). Galen University (Belize). August 2007.

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- Water resources
- Agriculture
- Human settlements
- Human health
- Tourism

Additionally, information was taken from Belize's Initial National Communication as well as gleaned from recent climate observations and projected climate change²⁰ to augment the vulnerability assessments as well as to inform sectors for which no recent reports on vulnerability analyses were either conducted or made available.

Recent climate trends and projected climate changes

a) Temperature

- Mean annual temperature has increased by 0.45°C since 1960, an average rate of 0.10°C per decade. The average rate of increase is most rapid in the wet seasons (May, June, July and ASO) at 0.14-0.15°C per decade and slower in the dry seasons (November, December, January and February, March, April) at 0.08-0.09°C per decade.
- The mean annual temperature is projected to increase by 0.8 to 2.9°C by the 2060s, and 1.3 to 4.6 degrees by the 2090s. The range of projections by the 2090s under any one emissions scenario is 1.5-2°C.
- The projected rate of warming is a little more rapid in the wet seasons, May, June, July and August, September, October than the dry seasons November, December, January and February, March, April.

²⁰ <http://country-profiles.geog.ox.ac.uk> UNDP Climate Change Country Profiles. Visited 17th November 2008.

b) Precipitation

- Mean annual rainfall over Belize has decreased at an average rate of 3.1mm per month per decade since 1960, but this trend is not statistically significant. Whilst all seasons appear to have shown decreasing precipitation trends since 1960, only February, March, April has a statistically significant trend.
- Projections of mean annual rainfall from different models are broadly consistent in indicating decreases in rainfall for Belize. Ensemble median values for almost all seasons and emissions scenarios are negative. Projections vary between -64% and +20% by the 2090s with ensemble median values of -11 to -22%.
- Changes in rainfall projected show the strongest decreasing signal in May, June, July rainfall, at -83 to +22% by 2090s.
- The proportion of total rainfall that falls in heavy events is projected to decrease in May, June, July, consistent with decreases in total rainfall.

Additionally, the coastal lowlands in northern Belize may be vulnerable to sea-level rise. Sea-level in this region is projected by climate models to rise by the following levels²¹ by the 2090s, relative to 1980-1999 sea-level:

- 0.18 to 0.43m under SRES B1
- 0.21 to 0.53m under SRES A1B
- 0.23 to 0.56m under SRES A2

²¹ Intergovernmental Panel on Climate Change (IPCC) Working group I (*The Physical Science Basis*): Chapter 10 (Global Climate Projections) (Meehl *et al.*, 2007). Regional sea-level projections are estimated by applying regional adjustments (Fig 10.32, p813) to projected global mean sea-level rise from 14 AR4 models.

3.1 DESCRIPTION OF VULNERABILITY IN IDENTIFIED SECTORS, DEVELOPMENT OBJECTIVES AND POLICIES AND TECHNOLOGY RECOMMENDATIONS

3.1.1 Forestry and Terrestrial Ecosystems

There were no recent vulnerability studies available for this sector. Accordingly, the importance of this sector was gleaned from the Initial national Communication and national circumstances.

3.1.1.1 Current circumstances

The broad ecosystem classes for terrestrial and marine habitat types is shown in Table 2. Belize is located in the Mesoamerican biodiversity hotspot, a region characterized by exceptional levels of endemism and high levels of habitat loss (CIA 2007)²². Despite the fact that coral reefs and their associated habitats only comprise about 6% of the coastal zone, they are disproportionately important for their high levels of biodiversity (Hughes et al. 2003)²³, and the tourism and fisheries economies that they support. Coral reef systems are also highly vulnerable to the consequences of global change from increased temperatures, damage from severe storm events, and ocean acidification from increased levels of dissolved CO₂ (Hughes et al. 2003). Several severe coral bleaching events have been documented from Belize waters in the past decade as a result of temperature stresses to these ecosystems (McField 2001)²⁴.

²² Central Intelligence Agency (CIA). 2007. World Factbook: Belize. Accessed on 22 January 2007 at <https://www.cia.gov/library/publications/the-world-factbook/geos/bh.html>.

²³ Hughes, T.P., A.H. Baird, D.R. Bellwood, M. Card, S.R. Connolly, C. Folke, R. Grosberg, O. Hoegh-Guldberg, J.B.C. Jackson, J. Kleypas, J.M. Lough, P. Marshall, M. Nystrom, S.R. Palumbi, J.M. Pandolfi, B. Rosen, and J. Roughgarden. 2003. Climate change, human impacts, and the resilience of coral reefs. *Science* 301: 929 – 933.

²⁴ McField, M. 2001. The Influence of Disturbances and Management on Coral Reef Community Structure in Belize. Ph.D. dissertation from the College of Marine Science at University of South Florida.

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Table 2. Broad ecosystem classes for terrestrial (Meerman and Sabido 2001, 2004)²⁵ and marine habitat types. (Note that the marine figures do not take into account deep water pelagic figures beyond the Mesoamerican Barrier Reef).

ECOSYSTEM CLASS	%	KM²
<i>TERRESTRIAL</i>		
LOWLAND BROADLEAF FOREST AND SHRUBLAND	51.4	11,803
AGRICULTURE, ALL SUBCLASSES	16.7	3,835
SUBMONTANE AND MONTANE BROADLEAF FOREST	10.0	2,296
LOWLAND SAVANNA INCLUDING PINE SAVANNA	8.8	2,021
MANGROVE AND LITTORAL FOREST	4.2	964
SUBMONTANE PINE FOREST	2.1	482
WATER	2.1	482
WETLAND	1.9	436
LOWLAND PINE FOREST	1.4	321
COASTAL SAVANNA (MARINE SALT MARSH)	1.1	253
URBAN	0.5	115
<i>MARINE</i>		
SEAGRASS HABITATS	44.2	4152
DEEP WATER	35.1	3294
SAND/SILT WITH SPARSE ALGAE	11.8	1105
CORAL REEFS AND ASSOCIATED HABITATS	6.2	586
UNCLASSIFIED	2.4	227
SHALLOW GORGONIAN BEDS	0.4	33

According to Belize's Initial National Communication, seventy percent of Belize remains under natural vegetation cover. In 1994 767,000 ha or 33.4% of the country were in protected areas. Clearance occurs at approximately 1% per annum. About 9% of this occurs in the protected areas, revealing the inadequacy of monitoring and enforcement measures. Additionally, threats to the forest resources and protected areas are compounded by the inadequacy of resources to effectively manage and protect them. While the contribution of traditional forest products to the economy has decreased over the last thirty years and leveled off, demand for land, together with population pressures in key forested areas, is increasing.²⁶ The Forest Department grants logging

²⁵ Meerman, J., and W. Sabido. 2001. Central American Ecosystems: Belize. Programme for Belize, Belize City; and Meerman, J., and W. Sabido. 2004. Belize Ecosystems Map: 2004 Version. Accessed 7 February 2008 at <http://biological-diversity.info/Ecosystems.htm>.

²⁶ National Environmental Action Plan. Revised 1999. Government of Belize.

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concessions within Forest Reserves to local and international logging companies. Recently, in an effort to promote sustainable management of timber resources, the Forestry Department began granting long-term (40-year) logging concessions. These concessions are managed by stricter standards that regulate rotation times and harvest sizes to ensure sustainable harvest through the term of the concession. Table 3 illustrates the total cubic feet of timber harvested from the top four species from 1999 to 2004.

Table 3: Cubic feet of timber harvested from the top four species from 1999 to 2004 (CSO 2005)²⁷.

Species	1999	2000	2001	2002	2003	2004
Pine	833.0	710.2	1,404.4	1,410.6	21.9	1,689.6
Mahogany	140.3	81.3	126.8	134.2	137.8	868.1
Santa Maria	160.2	86.8	218.6	93.4	133.1	904.9
Yemeri	191.6	109.7	110.3	142.8	20.5	418.3

3.1.1.2 Development Objectives and Policies

According to the Belize National Environmental Action Plan (NEAP)²⁸, one of the most important environmental problems facing Belize concerns deforestation of lands that are not appropriate for other sustainable uses, and related land allocation problems. These pressures, combined with inadequate land use planning and management and agricultural emphasis on extensification rather than intensification, have resulted not only in deforestation, but also in increasing encroachment and excision within Forest Reserves and Protected Areas.

Deforestation resulting from development pressures can include the loss of forests and woodlands to agriculture and other uses, encroachment of catchment areas, increased soil erosion and landslides, degradation of coastal and marine ecosystems, pollution of the sea and coastal aquifers, loss of wildlife and destruction of antiquities. The NEAP recognizes forestry as vital for protective

²⁷ Central Statistical Office (CSO). 2005. Belize Abstract of Statistics 2005. Central Statistical Office, Belmopan, Belize.

²⁸ National Environmental Action Plan. Revised 1999. Government of Belize.

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purposes (watershed, soil and slope stabilization, carbon sequestration, preservation of biological diversity and critical habitats) and for its contribution to the tourism sector (second highest hard currency revenue earner for Belize). Apart from the expansion of agriculture, there are other important sources of deforestation which are more difficult to quantify. Logging, both legal and illegal, fuelwood collection for cooking and other uses and land clearing for the exclusive objective of establishing property rights appear to be important sources of forest losses. Important factors that tend to accelerate the process of deforestation are poverty of small farmers, lack of access to other sources of income, inadequate land management, weak tenure rights, lack of access to technologies that are appropriate for cultivation under fragile ecological conditions, and the biased price incentive structure that promote land-intensive crops such as maize. The NEAP proposes to improve land management practices through, inter alia, a system of land title registration and taxation.

In respect of conservation of terrestrial habitats, the number of protected areas has increased the proportion of the country protected in this way to about 42 %. There are some reports of intrusions into protected areas, mostly due to the difficulty of regular monitoring and surveillance of activities within these areas.²⁹ In 2005,³⁰ a comprehensive National Protected Areas Policy and Systems Plan was completed with high level representation from relevant agencies to “ensure that the potential contribution of the protected areas system to national development and poverty alleviation is maximized, thereby putting it on a sound and rational footing” (Meerman and Wilson 2005)³¹. Major results of this process include:

1. *Formulation of a comprehensive protective area policy* that creates a policy framework in which the plan will be implemented.

²⁹ Belize NEAP. Revised 1999.

³⁰ Draft National Circumstances. Chapter 2. Second National Communication. Peter C. Esselman and Ed Boles. 29 January 2008

³¹ Meerman, J., and J.R. Wilson. 2005. The Belize National Protected Areas System Plan. Taskforce on Belize's Protected Areas Policy and Systems Plan.

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2. *A protected area system assessment and analysis* that evaluates the adequacy and coherency of the network and makes recommendations for maximizing these.
3. *Management procedures and sustainable use* recommendations that address shared governance of the network and supporting legal instruments.
4. *Strengthened management and monitoring* procedures for building capacity, information driven decision making, and financing.

Currently the recommendations of the National Protected Area Plan are being implemented over a 6-year time period (Meerman and Wilson 2005). It is anticipated that at the end of the process the protected area system will be consolidated and managed in a streamlined manner to better meet the economic needs of the nation while maintaining its functionality as a place where biological diversity and ecosystem services can continue to function unhindered.

3.1.1.3 Possible Applicable Technologies

In order to conserve and protect forest and terrestrial ecosystems, there needs to be proper monitoring and accounting of existing resources. The following technologies can be applied to this end:

- Geographical Information Systems (GIS) and remote sensing techniques and technology;
- Complementary database development and management utilizing appropriate hardware and software would also be necessary for a comprehensive assessment of the resources;

The establishment of sustainable forests for the purpose of providing agro-forestry products to ease the pressure for resources such as timber and firewood, as well as achieving collateral benefits such as soil and watershed conservation and enhancing wildlife habitat, can be pursued through the use of the following techniques/technologies:

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- Silvicultural techniques

Silviculture is the art and science of sustainably growing trees to meet present and anticipated needs. These needs may be human needs for pretty scenery, wood products, or safe places to recreate. Conversely, these needs may be ecological, such as, providing a suitable place to live for a particular type of animal or sustaining a particular type of forest.³² There are various silvicultural techniques that can be applied depending on the needs of the particular area identified. Suitable techniques can be employed to achieve effective management of forest resources. On the basis of projected climate change impacts, an assessment of suitable forest types that would tolerate drier conditions while at the same time support wildlife habitat and provide sustainable agro-forestry products would need to be done before a selection of the specific silvicultural technique/technology can be made.

- Establishment of a database to record forest-related data.

Other applicable techniques and technologies have synergy with those identified for water and soil conservation (see below).

- Management strategies and approaches.

While not hard technologies per se, management approaches can be used to enhance the effectiveness of technology application. For example, the following can be considered in areas where appropriate.

- Restrict development near environmentally sensitive areas that are incompatible with the environment. Where development may be feasible, developers should be required to protect any features of a site that are deemed to be of environmental or ecological significance.
- Enforce laws prohibiting unauthorised nature tours in forest reserves and water catchment areas.

³² <http://www.fs.fed.us/r8/boone/resources/silvics/index.shtml> Accessed November 24th 2008.

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- Reforest disturbed areas with species that will accelerate the succession process, protect exposed soils, enhance the landscape pattern and provide nesting and feeding areas for wildlife.

An issue identified at the stakeholder consultation³³ is one of land use and poverty and the need for an information management system at the national level to monitor and implement policies related to sustainable land management, including maximizing the use of Geographical Information Systems (GIS) to this end.

3.1.1.4 Possible Barriers

The main barriers to the possible applicable technologies would be one of cost and technical capacity. Training in applications, relevant software and hardware as well as capability in database development and management would be required. Silvicultural techniques and technologies are widely applicable and largely based on practices rather than hard technology although some hard technology would be required.

3.1.2 COASTAL ZONE

The coastal zone is defined in the vulnerability report³⁴ as the area extending from the mean high water mark along the coast, to the limits of the territorial sea, including all coastal waters. For the purposes of this report the coastal zone boundaries were extended to include lowland areas susceptible to flooding consistent with the vulnerability study. The Belize coastal zone is of social and economic importance. Belize has an open economy with a per capita GDP of

³³ Stakeholder consultation held at the ,,,,,,,Hotel, Belmopan March 6 2009. See Appendix for list of participants.

³⁴ Vulnerability Assessment of the Belize Coastal Zone. Enabling Activities for the preparation of Belize's Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC) Project UNDP/GEF Climate Change Project Prepared by: Dwight Neal, Eugene Ariola, and William Muschamp. Belmopan, May 2008

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over \$8,000. The three major industries, in the coastal zone, tourism, aquaculture and fisheries, account for some \$600 million Belize Dollars in 2006. Tourism is the largest income earner, averaging \$500 million of the \$600 million BZD. Fisheries and Aquaculture earn \$25 and \$70 million BZD respectively. The technology needs assessment for the coastal zone is also conducted to include tourism, aquaculture and fisheries, coastal human settlements, and coastal agriculture as sub-sectors of the coastal zone, within the context of activities and sub-sectors within the coastal zone and consistent with the vulnerability study.

Vulnerability assessment was conducted using the A2 SRES scenario of the IPCC. Major impacts on biophysical resources will be from sea level rise, increased sea surface temperatures, changes in weather patterns and increased storm activity. Additionally, the coastal lowlands in northern Belize may be vulnerable to sea-level rise. Sea-level in this region is projected by climate models to rise by the following levels : 0.23 to 0.56m under SRES A2 by the 2090s, relative to 1980-1999 sea-level (see above).³⁵

Issues in respect of projected climate change and sea level rise for the coastal zone are identified in the Initial National Communication and the coastal zone vulnerability study as follows:

- Intensification of coastal erosion patterns
Increase in sea level would increase tidal reach and the high water mark and can result in an increase in coastal erosion, particularly during extreme weather events when the storm surge would be greater.
- Saline intrusion and coastal flooding
Increase in sea level would result in salt water intrusion and increased coastal flooding. Saline intrusion can have secondary impacts such as the salinisation of agricultural soils and contamination of freshwater aquifers.
- Mangrove ecosystems including fisheries habitat

³⁵ <http://country-profiles.geog.ox.ac.uk> UNDP Climate Change Country Profiles. Visited 17th November 2008.

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An increase in sea level would place migration pressures on mangroves and have direct adverse consequences on the fisheries that they support.

- Coral reefs

Increasing sea surface temperatures and changes in pH due to increased carbon dioxide solution can be expected to cause increased incidences of coral bleaching and coral destruction leading to adverse impacts on coastal fisheries and increase in wave energy impacts on the coastal shores resulting in accelerated erosion. Corals reefs will be minimally affected by sea level rise, and healthy reefs are expected to adapt readily to sea level rise. The projected increases in sea level of less than 1 m over the next 50 years are not expected to be sufficient to negatively impact even those species that occur at the limits of depth³⁶.

- Impacts on coastal human settlements

Impacts on coastal human settlements can result from sea level rise, inundation and flooding from storm surges during extreme weather events and coastal erosion.

3.1.2.1 Current circumstances and projected impacts on coastal zone resources and amenities

Coastal Erosion

According to the Initial National Communication, coastline erosion is already considered a major concern. It is inevitable that accelerated sea level rise would exacerbate the rate of erosion and possibly destroy all existing beaches within this new century. Research undertaken under a US Country Studies Program vulnerability assessment reveals that a 50 cm rise, consistent with the A2 SRES scenario, would claim over half the existing beaches, while a 100 cm rise in 100 years would destroy over 90% of these beaches.

³⁶ Vulnerability Assessment of the Belize Coastal Zone. Enabling Activities for the preparation of Belize's Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC) Project UNDP/GEF Climate Change Project Prepared by: Dwight Neal, Eugene Ariola, and William Muschamp. Belmopan, May 2008

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Inundation and coastal flooding

Approximately 60% of coastal areas are already inundated. Considering that most of the mainland coastline between the existing communities is wetland dominated, a one meter rise in sea level would transform the wetlands to lakes. Dry land within a few meters of high tide levels would provide potential areas for new wetland formation.

It is estimated that approximately 45% of the population reside in the coastal zone. In 2000 it was estimated that some 45% of the population lived in the coastal zone. While the 2007 estimates show a decline in the percentage of the population residing in the coastal zone, from 45% to 38%, the actual number of persons has increased from an estimated 112,000 in 2000 to an estimated 120,000 in 2007. With the exception of Punta Gorda Town, elevation in coastal communities is between 0 – 3 m above sea level. Fueled by the continued growth in tourism, development in coastal communities and along the coast continues at an accelerated pace. The four coastal districts of Corozal, Belize, Stann Creek and Toledo have large urban and rural development zones that are prone to seasonal flooding and inundation. All these districts have human settlements concentrated in areas that range from 0 to 5 meters above sea level. The projected sea level rise during the new century will permanently inundate most cayes, including the heavily populated Ambergris Caye (average elevation of 2 feet). The mainland several kilometers inland of the coastline will also be inundated.

Coral reefs

In 2006 the MBRS reported³⁷ on the synoptic monitoring that has been done. Six indicators were used to determine general reef health, species composition,

³⁷ As cited in: Vulnerability Assessment of the Belize Coastal Zone. Enabling Activities for the preparation of Belize's Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC) Project UNDP/GEF Climate Change Project Prepared by: Dwight Neal, Eugene Ariola, and William Muschamp. Belmopan, May 2008

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live tissue cover, colony size, mortality, disease and bleaching. Analysis of monitoring data for 2004 – 2005 showed that for the Belize Barrier Reef:

- Mean live coral cover was 25.75% and varied from a low of 11.11% to a high of 44.58% across the sampling locations. This compares favourably with the mean of 26% for the Wider Caribbean and Brazil. The coral species monitored are reef builders and the live coral cover is an indication of the rebuilding capacity of the system. A live coral cover of greater than 20% is considered to be good while less than 10% is considered to be poor.
- Mean species richness was 11, with a high of 22 and a low of 5. Species richness is the number of species present and is a quick and easy parameter to measure.
- Mean colony size had a height of 23.21 cm and a diameter of 37.67 cm. Smaller colonies are a general indicator of slower growth (or frequent re-growth) and greater stress. Colonies with heights above 30 cm and diameters above 35 cm are considered in the best health.
- Mean mortality was 44.65%. Mortalities of 0 – 15% are considered to be optimum while 35 – 55% is considered average and over 80% is considered to be poor.
- Rates of bleaching were very low. On average less than 5% of colonies were observed with bleaching. This value would be lower if not for the high incidents of bleaching (almost 20% of colonies) observed in Glovers Reef. All other locations reported less than 1% of colonies with bleaching.
- Rates of disease were less than 1%. Again colonies in Glovers Reef were observed with the highest percentage of colonies that were diseased.

The conclusion of the report is that the reefs in Belize are good for most categories and would benefit from continued management. In the absence of any other recent definitive work on the reef system, this can be considered to be the state of the Belize Barrier Reef to date.

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Mangroves

In 1993 it was estimated that mangrove forests covered some 760 km² of land area in Belize. Distribution is primarily along low-lying sections of coast and river banks, cayes, estuaries and coastal lagoons. The largest percentage of cover is found in the northern portions of the country and in the cayes, particularly the Turneffe Atoll. (Coastal V&A study).

The major threats to mangroves from climate change are changes in weather patterns and the increase in frequency and severity of climatic events. Changes in rainfall patterns could affect distribution and species composition because rainfall regulates salt concentrations in soil and plants, as well as providing a source of freshwater for the mangroves. However, if high rainfall occurs over a short period and other months of the year are prone to drought, the conditions could become unfavourable for the growth and distribution of mangroves (Hong 2006 as cited in Coastal Zone V&A study).

Major anthropogenic threats include mangrove clearance and loss of habitat. The recent surge in tourism has resulted in an attendant surge in coastal development. There is no information on the current status of mangroves in Belize.³⁸

Seagrass

Sea grass beds are an important nursery for a number of important marine species, some of which are harvested commercially in Belize. Extensive sea grass beds are found in the northern portion of the barrier lagoon, the central

³⁸ Vulnerability Assessment of the Belize Coastal Zone. Enabling Activities for the preparation of Belize's Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC) Project UNDP/GEF Climate Change Project Prepared by: Dwight Neal, Eugene Ariola, and William Muschamp. Belmopan, May 2008

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lagoon of Turneffee Islands, some coastal and back reef strips in the southern barrier lagoon and in the coastal lagoons and estuaries. The predominant sea grass species in Belize are the Turtle grass (*Thalassia testudinum*), Eel grass (*Syringodium filiforme*), and three other species with no local names, *Halophila baillonii*, *Halophila decipiens*, and *Halodule wrightii*. (Short et al, 2005 as cited in coastal zone V&A study). They stabilize coastal sediments, capture and recycle nutrients, and reduce wave energy. In Belize, as much as 50% of the spiny lobster and 40% of conch production are from sea grass beds. This equates to some \$10 million BZD annually.

Seagrass beds are not expected to be impacted from sea level rise over the next century, but increased frequency of extreme weather events such as storms can result in a shorter recovery time. The greater threat to seagrass beds is expected to come from anthropogenic impacts.

Coastal Areas and Cayes

The coastal areas and cayes are important economically and socio-culturally. For most people it is the preferred location for recreation and residence. For tourism, the coast and cayes are an integral part of the “sea, sun and sand” concept.

A large percentage of the recent development in the tourism industry has been along the coast or in the cayes. Cayes on the crest of the main barrier reef and on the windward side of the atolls tend to have higher elevation but also experience greater wave action. The major threat to the cayes is increased erosion from increased sea level and damage from storm surges.

Threats to beaches, cayes and low-lying areas are primarily from sea level rise, the changes in weather patterns, and the increase in frequency and severity of storms. Low-lying areas such as Belize City are currently prone to partial flooding at high spring tides and will be vulnerable to inundation caused by higher tides. Modeling work done by Cayetano *et al* in 1996 using the Brunn Equation indicates that a mean sea level increase of 30 cm in fifty years would result in the

loss of approximately 30 m of beach in areas north of Dangriga and 16 m on beaches south of Dangriga.

3.1.2.2 Development Objectives and Policies

The NEAP³⁹ recognises that the Sustainable management of fisheries resources is integrally related to the health of the reef and its environs. The impacts of pollution from pesticides and fertilizers, as well as the disposal of waste from these industries in coastal areas, have a damaging effect on water quality as well as on the mangroves, on whose natural productivity the fisheries depend. Coastal areas of Belize contain a wealth of natural resources with enormous potential for tourism use and revenue generation. The NEAP therefore seeks to:

- Enhance integrated coastal zone management;
- Increase the extent and scope of water monitoring activities;

Additionally, the following measures were proposed in the First National Communication in order to adapt to projected impacts of climate change in the coastal zone:

- a) Establish setbacks for undeveloped coastal areas
- b) Construct and improve seawalls
- c) Undertake Beach nourishment
- d) Relocate vulnerable coastal communities
- e) Prepare post-disaster reconstruction plans
- f) Monitor relative sea level rise and local wave climate
- g) Monitor the shoreline
- h) Develop an education and public awareness campaign
- i) Develop a national water management system
- j) Obtain comprehensive knowledge of nation's water resources
- k) Prepare a national water resources plan
- l) Promote effective and efficient use of water

³⁹ National Environmental Action Plan. 1999. Government of Belize.

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- m) Develop local management and technical expertise
- n) Relocate point sources of potable water in the coastal zone to points above influence of saline intrusion
- o) Encourage use of cisterns
- p) Adopt forest management plans
- q) Adopt agricultural practices based on availability of water
- r) Relocate agricultural activity away from the coastal zone

Gibson *et al*⁴⁰ conducted an adaptation to climate change in the coastal zone and proposed the following measures:

Biophysical:

- a) Make Integrated Coastal Zone Management an integral part of Belize's action plan for climate change;
- b) The National Biodiversity Strategy and Action Plan be formally adopted;
- c) Reef and Mangrove Monitoring and Research;
- d) A network of Marine Protected Areas;
- e) Improved land use and agricultural practices;
- f) EIA requirements for coastal development;
- g) Adoption of a Marine Dredging Policy;
- h) Update and implement the national mangrove management plan;
- i) Initiate a programme for the planting of mangroves in critical areas;
- j) The protection of specific wetland areas.

Socioeconomic:

- k) Develop an integrated water management policy, support watershed management and control water abstraction;
- l) Change the land use policy – formal adoption of the Cayes Development Policy;
- m) Consider measures for reducing pressure on heavily exploited stocks;

⁴⁰ As cited in: Vulnerability Assessment of the Belize Coastal Zone. Enabling Activities for the preparation of Belize's Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC) Project UNDP/GEF Climate Change Project Prepared by: Dwight Neal, Eugene Ariola, and William Muschamp. Belmopan, May 2008

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- n) Encourage the diversification into the exploitation of new stocks and expansion of the EEZ;
- o) Improve the management of catch levels;
- p) Adopt policies that promote “green” marine based tourism;
- q) Maintain and expand the mooring buoy system;
- r) Conduct site-specific research on the carrying capacity for critical and marine protected areas.

3.1.2.3 Possible Applicable Technologies

Based on the foregoing, the following is proposed. Sectoral issues (such as water resources, agriculture etc. are addressed specifically under those sectors). Physical adaptation measures in the coastal zone can be categorised in three forms:

- (i) Retreat
- (ii) Accommodate, and
- (iii) Protect

Retreat

This measure involves the displacement of all infrastructure further inland in anticipation of sea level rise and its impacts such as coastal erosion as well as storm surge arising out of extreme events such as storms and hurricanes, themselves a likely consequence of climate change. These measures along with possible barriers to implementation are summarised in Table 4 below.

Accommodate

This measure involves a continuation of occupation of the land (as opposed to retreat) but involves a change in practices that would cater for the proposed impacts of sea level rise and climate change e.g. building on piles, changing agricultural crop-types to more salt-tolerant species etc. These measures along with possible barriers to implementation are summarised in Table 5 below.

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Protect

These measures are designed to physically protect the land and maintain the present land use. The measures may range from the establishment of hard, physical structures such as sea walls and coastal defences infrastructure such as revetments, to beach nourishment. These measures along with possible barriers to implementation are summarised in Table 6 below.

Table 4: Summary of retreat measures and possible barriers to implementation

Technology	Description	Possible barriers to implementation
Replacement casements	Alternative casements such as coastal access roads and related infrastructure may need to be rearranged	<ul style="list-style-type: none"> • Cost. These measures should be taken where infrastructure is at risk of submergence and may need to be replaced in any event. Coastal engineering works can be expensive • Physical barriers. Availability of inland space for placing alternative casements
Establishment of building setbacks	Buffer zone between the shoreline and permanent structures for the protection of these properties from sea level rise, storm surges and flooding. The setback distances would vary	<ul style="list-style-type: none"> • Limitation of already built development that may be in breach of proposed setback distances. <p>Uncertainty of magnitude of sea level rise to estimate and</p>

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	depending on the coastal type e.g. beaches vs. cliffs.	establish setbacks.
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Table 5: Summary of accommodation measures and possible barriers to implementation

Technology	Description	Possible barriers to implementation
Inland flood defences	<ul style="list-style-type: none"> • Development of new coastal strip to reduce vulnerability to coastal flooding. May involve retreat measures in part depending on site and location characteristics and specifications. 	<ul style="list-style-type: none"> • Cost. These measures should be taken where infrastructure is at risk of submergence and may need to be replaced in any event. • Physical barriers. Availability of inland space for new development.
Establishment of building codes	<ul style="list-style-type: none"> • Building on elevation or piles to reduce impact of flooding a storm surge. • Hurricane-resistant buildings 	<ul style="list-style-type: none"> • Cost of renovations and retrofitting existing buildings
Coastal drainage	<ul style="list-style-type: none"> • Maintenance and enhancement of natural drainage systems such as rivers by frequent dredging of river 	<ul style="list-style-type: none"> • Cost.

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	<p>mouths.</p> <ul style="list-style-type: none"> • Installation of pumps to aid in land drainage where flooding is acute. 	
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Table 5 cont'd: Summary of accommodation measures and possible barriers to implementation

Technology	Description	Possible barriers to implementation
Coastal drainage	<ul style="list-style-type: none"> • Establishment of dammed areas to accommodate flood waters in areas of acute flooding • Establishment and maintenance of buffer zone behind mangrove systems to allow for natural retreat in response to sea level rise. Allow also for natural flood relief. • Storm drains 	<ul style="list-style-type: none"> • Limitation of physical land space for placement of dams. • Limitation of physical space for already built-up areas.
Flood warning systems	<ul style="list-style-type: none"> • Provision of real-time forecasts of high tides, surges and over-topping 	<ul style="list-style-type: none"> • Cost • Technical capacity

Table 6: Summary of protection measures and possible barriers to implementation

Technology	Description	Possible barriers to implementation
Maintenance of existing natural features	<ul style="list-style-type: none"> • Establishment, restoration and 	<ul style="list-style-type: none"> • Physical characteristics may

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	maintenance of mangrove systems	not be conducive to establishment of new mangrove systems
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Table 6 cont'd: Summary of protection measures and possible barriers to implementation

Technology	Description	Possible barriers to implementation
Coral reef establishment and restoration	<ul style="list-style-type: none"> Creation of appropriate media for coral to grow on such as used tyres, steel structures⁴¹ 	<ul style="list-style-type: none"> Energy dynamics of coastal area may pose a challenge in deployment Technical capacity
Gabions	<ul style="list-style-type: none"> Wire or plastic baskets filled with rocks. Baskets are placed together as building blocks as a last line of defence against storm surges and wave action. 	<ul style="list-style-type: none"> Generally low-cost Physical site may not possess characteristics to properly accommodate baskets Technical capacity to adequately assess potential of site for the technology as well as possible adverse impacts of technology such as up-current or down-current erosion as a result of changes in shoreline structure, residual tidal currents and sediment dynamics.

⁴¹ There are established technologies that utilize steel structures and solar generated electrical currents to stimulate coral growth. These technologies have been successfully deployed in small island systems in the Caribbean, the Pacific and Indian oceans.

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Groynes	<ul style="list-style-type: none"> Structures placed perpendicularly to the shore to trap sediments. 	<ul style="list-style-type: none"> Cost.
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Table 6 cont'd: Summary of protection measures and possible barriers to implementation

Technology	Description	Possible barriers to implementation
Groynes cont'd	Often used in areas of acute erosion.	<ul style="list-style-type: none"> Physical characteristics may not be conducive to establishment of new mangrove systems Technical capacity to assess impacts of technology. Adverse impacts can be similar to those described for gabions
Revetments	Slope consisting of loose, inter-locking units. Normally applied to banks and cliffs that are composed of easily erodable material	<ul style="list-style-type: none"> Cost Technical capacity to assess impacts of technology. Adverse impacts can be similar to those described for gabions
Bulkheads and seawalls	Retaining walls made of concrete or interlocking rocks. Primary purpose is to prevent movement of terrain while affording protection against light to moderate wave action	<ul style="list-style-type: none"> Cost Technical capacity to assess impacts of technology. Adverse impacts can be similar to those described for gabions

Table 6 cont'd: Summary of protection measures and possible barriers to implementation

Technology	Description	Possible barriers to implementation
Storm surge barriers	<ul style="list-style-type: none"> • Sophisticated coastal defence structures that can protect tidal inlets, rivers and estuaries from storm surges. 	<ul style="list-style-type: none"> • Cost
Beach nourishment	<ul style="list-style-type: none"> • Replacement of beach sand lost due to erosion, storm events or sand mining 	<ul style="list-style-type: none"> • Reliable and continuous source of sand.

3.1.2.4 Technologies that can be adopted

The technologies outlined and described in Tables 4-6 above can be applied in general coastal areas with identified problems for which they are designed to alleviate. However, characteristics of coastal areas are unique to particular environments such as ecosystems, sediment dynamics, current regime etc. and technologies cannot be usually transplanted from one scenario to another. All three types of measures and associated technologies (retreat, accommodate and protect) may be applied to the coastal environment of Belize in keeping with stated development objectives and policy, and existing legal framework. ***Any final choice of technology must be done on further assessment of the unique receiving environment to avoid medium and long-term usually very costly impacts of the technology itself.***

3.1.3 WATER RESOURCES

The vulnerability of water resources to the adverse impacts of climate change are related to:

- a. Increase in temperature leading to higher evaporation and evapotranspiration rates;
- b. Changes in intensity, quantity and frequency of precipitation events (less projected rainfall but higher frequency See section 3.1 on projected climate changes above), and
- c. Rise in sea level (increasing sea levels can cause salt-water intrusion into aquifers thereby exacerbating problems of water availability).

3.1.3.1 Current circumstances

National water resources are used in situ or extracted and moved about to support life (potable supplies, domestic use); agriculture (irrigation, livestock, processing); industrial processes (mining, manufacturing, cooling); recreation and aesthetics (sports, tourism, religion, culture, landscape).⁴²

3.1.3.2 Water demand

Access to safe water in Belize has improved significantly in the 1991-1995 period. In certain areas the coverage increased from 95% to about 100%, in rural areas from 51% to 78%. Nevertheless, the increased growth in population, especially with new immigrants, will place great stress on available water supply.⁴³ In the absence of official figures, future water demand is likely to be derived from population increase; increased in the number of households; higher levels of consumption; and the overall broadening of the economic base of the country. The housing sector and the tourism industry are likely to be the major consumers of the country's potable water supply.

⁴² Draft Policy Document. National Integrated Water Resources Management Policy for Belize. October 2007.

⁴³ National Environmental Action Plan. 1999. Government of Belize

More than 80% of overnight visitors to Belize come from the USA, Canada, and Europe (BTB, 2007)⁴⁴

3.1.3.4 Development Objectives and Policies

The Draft National Integrated Water Resources Management Policy 2007, which takes into account climate change impacts, outlines the following policy approaches for the water resources sector, *inter alia*:

- Establish and operate capacity and mechanisms to obtain knowledge, assess and maintain a comprehensive database of the country's water resources and adopt and be guided by an integrated management system in terms of the quantity and quality of all surface and ground water resources. Use the knowledge in future planning, decision making and resource management in order to expand and keep current a national inventory of water resources.
- Establish a permanent National Water Commission with responsibility for integrated water resources management, control and coordination, acting upon the interests of all stakeholders and adaptation measures necessary in response to climactic changes.
- Promote and account for increased investment in the development of water storage infrastructure. This will include the use of “no regret” and other adaptation measures to respond to the predicted adverse effects of Global Climate Change on water resources.
- Make safe potable water supplies available in adequate quantities twenty-four hours a day to the entire population by Yr 2020 and ensure that every property is provided with an approved means of disposal of domestic wastewater and water borne wastes.
- Recognize the impacts of climate change in all areas of water resources management and direct the efforts to:

⁴⁴ As cited in: Tourism in Belize. Vulnerability and Capacity Assessment. Submitted for Belize's Second National Communication to the UNFCCC. Prepared by Robert B. Richardson. Michigan State University (USA). Galen University (Belize). August 2007.

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- a. Obtain and conserve the nation's water resources at standards of quality appropriate to use.
- b. Institute standards and mechanisms for enforcement to assure efficiency and minimize degradation in systems for water.
- c. Mainstream and increase public awareness about conserving the national water resources by efficient use and pollution prevention.

3.1.3.5 Possible applicable technologies

In order comprehensively and efficiently address water resources issues in Belize, an adequate database needs to be developed as a priority. Accordingly, there is the need for the establishment of suitable monitoring equipment for tracing, identifying and quantifying leakage and development of a water balance account based on supply, consumption, and leakage. For example, it is estimated that the unaccounted-for-water in Belize City varies between 40-60%.⁴⁵

Water Conservation Technologies

Given the likely increase in demand due to population increase and increased demand in the tourism and agricultural sector water conservation technologies would be useful in addressing projected decreases in precipitation and water supply. It needs to be recognised that there are overlaps and synergy in the application of water and water efficient technologies and the technology needs in other, related sectors such as agriculture and human health. Where there is potential for maximising the application of technology across sectors, these are specifically indicated.

Domestic Water Conservation Technologies

Domestic water conservation technologies can be applied in any facility that includes restrooms, kitchens, bathrooms and laundry areas that are used

⁴⁵ Belize Water and Sanitation Sector Analysis. Draft Final Report. Accessed from www.bvsde.paho.org/muwww/fulltext/analsis/belice/belice.htm on 20 December 2008.

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regularly, particularly in hotels in the tourism sector as well as in domestic households. Table 7 illustrates the application of the technology and the possible potential barriers to their application.⁴⁶

⁴⁶ www.eere.energy.gov/femp retrieved December 26 2008.

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TABLE 7: Domestic and Commercial Water Conservation Technologies, possible applications, benefits and potential barriers.

Technology	Description	Application	Co-benefits/advantages	Possible Barriers
<i>Water efficient mechanisms</i>	Low-flow aerators conserve water by reducing the flow by mixing air with the water.	Kitchens, showerheads, older faucets can be retrofitted with efficient aerators. (flow rate of 7.6 lpm ⁴⁷ at 60 psi ⁴⁸ is usually satisfactory)	Energy conservation	Plumbing codes may not be compatible and threading may not accommodate retrofitting.
Low-flow aerators				
Faucet controls	Mechanic, electronic or battery-operated control devices used to turn faucets on and off.	Commercial buildings for kitchen and lavatory faucets. Older faucets can be retrofitted.	Energy conservation. Low cost.	Frequent maintenance and associated capacity and costs.
Low-flush and composting toilets	Pressure-assisted toilets use compressed air to assist the flush. The pressure in a facility's line compresses the air.	General application at domestic and commercial facilities.	More efficient disposal of wastes.	Costly. Requires a minimum pressure of 25 psi ²¹ , which may not be available at all times.
	Pump-assisted toilets use a pump to assist the flush.	General application at domestic and commercial facilities	More efficient disposal of wastes	Costly. Increased energy costs for pump. Parts and maintenance costs.

⁴⁷ litres per minute

⁴⁸ pounds per square inch

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Table 7 cont'd: Domestic and commercial water conservation technologies, possible applications, benefits and potential barriers.

Technology	Description	Application	Co-benefits and advantages	Possible Barriers
<i>Water efficient mechanisms</i>				
Low-flush and composting toilets	<p>Vacuum – assisted toilets utilise a vacuum inside the tank to pull the wastes.</p> <p>Ultra-low-flush tank toilets</p> <p>Composting toilets use little or no water and not connected to traditional plumbing systems; converts wastes to compost by anaerobic decomposition;</p>	<p>Niche applications such as boats and planes.</p> <p>Hospitals and prisons.</p> <p>Remote areas not serviced by utility systems; recreation areas.</p>	<p>Human health</p> <p>Low cost</p> <p>Provision of fertilizers from compost; minimization of water contamination and human health benefits in rural areas where there is no sewerage</p>	<p>Costs. Limited application.</p> <p>Plumbing codes. Retrofitting potential of older systems.</p> <p>Not cost-effective in areas serviced by utility plumbing. Cultural acceptability.</p>

Table 7 cont'd: Domestic and commercial water conservation technologies, possible applications, benefits and potential barriers.

Technology	Description	Application	Co-benefits and advantages	Possible Barriers
<i>Water efficient mechanisms</i>				
Low-flush and composting toilets	<p>Flushometer toilets utilise a flush valve that allows a metered amount of water to enter the toilet under pressure; flushed manually or automatically by a sensor device.</p> <p>Waterless urinals require no water except for occasional cleaning;</p>	<p>Commercial buildings, airports etc. Requires pressures of between 25 and 40 psi.</p> <p>Commercial building with high user rate;</p>	<p>Low volume of water required;</p> <p>No additional water-supply plumbing; easy maintenance; can be cost-effective; human health benefits by less water contamination</p>	<p>Costly. Operating pressure may not be available at all times. Complete retrofitting required; older systems may not be able to be modified.</p> <p>Cost of retrofitting existing systems.</p>

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Table 7 cont'd: Domestic and commercial water conservation technologies, possible applications, benefits and potential barriers.

Technology	Description	Application	Co-benefits and advantages	Possible Barriers
<i>Water efficient mechanisms</i>				
Water efficient appliances	<p>Clothes washers: Horizontal axis washers rotate the clothes in a relatively shallow pool of water.</p> <p>Efficient dishwashers : Special sensors to gauge amount of food and adjusts water as necessary; more efficient spray arms and pumps</p>	<p>Commercial laundries; hotels</p> <p>Commercial operations such as restaurants and hotels; also applicable to residential uses.</p>	<p>Low volume of water required; less energy intensive, less moisture in clothes for quicker drying times; cost-competitive.</p> <p>Energy savings.</p>	<p>Costly. Initial costs may be high but longer term benefits may be favourable.</p> <p>Initial costs.</p>
Pressure-reducing valves	Device that reduces line pressure	Commercial and residential	Reduces water consumption; relatively inexpensive	Initial costs. Required only if existing pressure warrants it.

It should be noted that in the application of any of these technologies, a comprehensive audit of water consumption at the application site would be required before a final selection, which is outside the scope of this study.

Irrigation Technologies

Water demand for the agricultural sector was not identified as a critical issue in the documentation reviewed⁴⁹ but is addressed as cultivated land amounts to about 3,835 km² or 17% of the national land area and the majority of land used for agriculture (37%) has been classified as shifting cultivation and unimproved pasture, followed closely by mechanized agriculture of corn, beans, and rice (33%)⁵⁰ as well as a projected decline in lagoon and river levels as a consequence of decrease in precipitation and its implications for the aquaculture industry.⁵¹ Accordingly, technologies for irrigation are presented in the overall context of water conservation.

Irrigation includes any practice that stores, directs or exploits water such as water harvesting, use of low-lying wetlands and groundwater as well as the more traditional techniques of diverting or lifting water for distribution using surface, sprinkle or trickle irrigation methods.⁵² There is no indication of current irrigation techniques used currently, but Table 8 provides a description of modern irrigation

⁴⁹ 1. National Environmental Action Plan. 1999. Government of Belize
2. Initial National Communication of Belize
3. Draft Policy Document. National Integrated Water Resources Management Policy for Belize. October 2007.
4. Climate Change Vulnerability and Adaptation Assessment for Sugarcane and Citrus. Belize Second National Communication Project. Final Report. Prepared by Carlos G. Santos and Sergio Garcia. August 2008.

⁵⁰ Meerman and Sabido 2004. Cited in Draft National Circumstances Chapter of Second National Communication of Belize. Prepared by Peter C. Esselman and Ed Boles. 29 January 2008

⁵¹ Vulnerability and Adaptation Assessment of the Fisheries and Aquaculture Industries to Climate Change. Final Report for the Second National Communication Project. Prepared by Vincent Gillete and George Myvette. May 2008.

⁵² FAO 2001. International Programme for Technology and Research in Irrigation and Drainage. Knowledge Synthesis report No. 3. Smallholder Irrigation Technology: Prospects for Sub-Saharan Africa. IPTRID Secretariat. Food and Agriculture Organization of the United Nations.

technologies that may be applicable. The term 'modern technology' in relation to irrigation usually refers to on-farm irrigation systems such as sprinkler and trickle irrigation. It can also mean the introduction of piped distributions systems for surface irrigation as well as the use of treadle pumps (a recent innovation in Africa) or the use of petrol and diesel driven pumps in areas where such technology is not normally used. Some professionals and policy-makers perceive modern technologies as an intervention that can improve crop yields and quality and, at the same time, reduce water wastage (a better term to use than irrigation efficiency which can be misleading)⁵³.

Sprinkle Irrigation Systems

Sprinkle irrigation systems were developed for large farms and may not be flexible enough to be adapted to smaller systems such as small plots normally found in subsistence farming cultures. However, it may be applicable to large farming and agriculture systems. A summary is provided in the table below.

⁵³ FAO 2001. International Programme for Technology and Research in Irrigation and Drainage. Knowledge Synthesis report No. 3. Smallholder Irrigation Technology: Prospects for Sub-Saharan Africa. IPTRID Secretariat. Food and Agriculture Organization of the United Nations.

Table 8: Modern Irrigation Technologies and their possible applications

Technology	Description	Application	Co-benefits and advantages	Possible Barriers
<i>Sprinkle irrigation systems</i>				
Conventional systems	<p>Portable: hand-move roll move, tow line, utilizes small rotary impact sprinklers</p> <p>Semi permanent: sprinkler hop, pipe grid, hose pull</p>	<p>Widely used on all field crops</p> <p>Similar to portable</p>	<p>Portable; could be financially viable.</p> <p>Lower labour input.</p>	<p>Labour intensive. May not be suitable for small plots.</p> <p>High capital cost. May not be suitable for small plots</p>
Mobile gun systems	Large gun sprinklers that can be replaced by boom; hose pull; hose drag.	Good for supplementary irrigation.	Mobile	Cost. May not be suitable for small plots

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Table 8 cont'd: Modern Irrigation Technologies and their possible applications

Technology	Description	Application	Co-benefits and advantages	Possible Barriers
<i>Sprinkle irrigation systems</i>	Centre pivot Linear move	Ideal for large farms.	Mobile; low labour requirements; possibly financially viable.	Initial cost. May not be suitable for small plots.
Mobile lateral systems				
Spray lines	Stationary Oscillating Rotating	Suitable for small gardens and orchards	Low labour requirements; possibly financially viable	Initial cost. May not be suitable for small plots.
<i>Trickle or drip irrigation</i>	System of pipes and emitters that can deliver small frequent irrigations to individual plants;	Areas where soil is poor; water is scarce or saline; can be applied to small plots;	Easy operation; ease of application of nutrients; can be adopted for small plots;	High initial costs; skilled management for operation and management; may be inappropriate for resource-poor smallholder farmers;

Rainwater harvesting

There is no information on rainwater harvesting in Belize. This can be identified as a traditional technology, but its potential needs to be fully developed. This technology provides an opportunity for inexpensive infrastructure and effective results and should be explored.

Technologies for Water and Soil Conservation

Projected increases in temperature along with a projected decrease in precipitation can have exacerbated impacts on agricultural production since there are implications for soil moisture content and soil conservation. The discussion under this item takes into consideration the possible nexuses between the water resources sector, the agriculture sector and the land management sector. Technologies for water and soil conservation are essential especially in drought-prone areas⁵⁴ as there are strong links between soil conservation and water conservation measures.

Soil and water conservation can be approached through agronomic and engineering procedures. Agronomic measures include:

- contour farming;
- off season tillage;
- deep tillage;
- mulching and providing vegetative barriers on the contour.

⁵⁴ R.K. Sivanappan. Technologies for water harvesting and soil moisture conservation in small watersheds for small-scale irrigation. In: Irrigation Technology Transfer in Support of Food Security. (Water Reports - 14). Proceedings of a Sub Regional Workshop Harare, Zimbabwe 14-17 April 1997. FAO - Food And Agriculture Organization of the United Nations. Rome, 1997

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These measures mainly prevent soil erosion but will also help in improving soil moisture availability in the watershed.

The following technologies can be applied to reduce surface water run-off and subsequent use for irrigation:

- **Check dams:** Check dams can be a temporary structure constructed with locally available materials. The various types are: Brush wood dam, loose rock dam and woven wire dam. The main function of the check dam is to impede the soil and water removed from the watershed. This structure is relatively inexpensive, but lasts about 2-5 years. A permanent check dam can be constructed using stones, bricks and cement. Small earth work is also needed on both sides. Costs vary depending upon the length and height of the dam. A little water is also stored above the dam, which can recharge the groundwater.
- **Percolation Pond:** The percolation pond can serve as a multipurpose conservation structure depending on its location and size, as it stores water for livestock and recharges the groundwater. It is constructed by excavating a depression, forming a small reservoir or by constructing an embankment in a natural ravine or gully to form an impounded type of reservoir. The water can then be used for irrigation.
- **Irrigation Tank:** The main function of this storage structure is irrigating crops. It is constructed below the above-mentioned structures in a watershed.

Apart from the above, to increase moisture availability to agricultural and tree crops, *in situ* moisture conservation techniques must be adopted in addition to the large scale soil and moisture conservation and water harvesting structures in the watershed.

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The following are some of the *in situ* moisture conservation measures which can be practiced in the watershed to increase production:

- For agricultural crops, the measures adopted are forming ridges and furrows, broad bed and furrows, basins, tie ridging (random tie ridges) and water spreading.
- For tree crops micro catchment, saucer basin, semi-circular bund, crescent shaped bunds, V ditch technology, catch pits and deep pitting can be practiced.

In addition to the above measures and structures, small storage structures with a water storage capacity for an area of about 0.4 to 0.5 hectares can be constructed in large numbers one for every 10 to 20 hectares catchment or watershed at the foot hills slopes and hilly areas. These storage facilities would attenuate the floods during storms. These measures will also ensure soil moisture for good growth of trees grown down stream recharging the groundwater in the region and making available more water for drinking and irrigation water.⁵⁵

3.1.3.6 Technologies that can be adopted

In addition to the possible technologies outlined above, the following can also be adopted:

Increasing surface storage capacity

Impounding of surface water runoff by establishing suitable structures. Impounded water can be used for treatment and potable use or irrigation depending on identified scales which can be feasible. Such determination would need to take into consideration environmental impacts of the technology such as

⁵⁵ R.K. Sivanappan. Technologies for water harvesting and soil moisture conservation in small watersheds for small-scale irrigation. In: Irrigation Technology Transfer in Support of Food Security. (Water Reports - 14). Proceedings of a Sub Regional Workshop Harare, Zimbabwe 14-17 April 1997. FAO - Food And Agriculture Organization of the United Nations. Rome, 1997

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development of algal blooms, wetland ecology development as well as introduction of alien invasive species such as wetland birds etc. Additionally, stagnant water can be the breeding ground for vectors that cause diseases such as dengue and malaria.

Desalination

This technology involves the conversion of sea water to freshwater by removing the salt content. There are various technologies for removal of the salt which will vary in cost. Generally, this technology is very expensive and will include a consideration of environmental impacts of the technology such as disposal of removed salts and its effects on flora and fauna.

Wastewater recycling

There is good potential for recycling of wastewater and there are already established technologies for this.

Reduction of leakages

This is a critical issue for which there should be urgent attention. A significant amount of water can be saved if leakages can be reduced. However, the solutions to be applied would depend on the identification of the problem, such as the replacement of water mains etc. Nonetheless, as a first step, the establishment of a suitable database for monitoring leakages should be put in place.

3.1.3.7 Possible Barriers to Implementing Technology

- Cost;
- Availability of land;
- Maintenance capacity and capability.

3.1.4 AGRICULTURE

The vulnerability of the agriculture sector in Belize⁵⁶, has been projected using two models, the DSSAT 4 and Cropwat crop modeling software utilizing different outputs from the PRECIS Climate Model for sugarcane and citrus. Future climate scenarios of 1° and 2.5° Celsius warmer accompanied by a $\pm 12\%$ for the year 2028 and $\pm 20\%$ for the year 2050 change in precipitation were selected.

For sugarcane, the CROPWAT model projected 11.9% reduction in yield for 2028 with 12mm less rainfall and 17.4% reduction for 2050 with 20mm less rainfall. Using the 2028 scenario with an additional 12mm rainfall yields still fell by 4.5%. The temperature rise shortened the growing period of the crops, which lowered their yields. Changes in precipitation did not affect the growing season. However, it did affect the yield, especially when there were periods of low or high rainfall.

For citrus, in 2028 with 12mm less rainfall the predicted reduction was 3.4% in yields and 5% reduction for 2050 with 20mm less rainfall. Using the 2028 scenario with an additional 12mm rainfall yields remained the same. The temperature rise shortened the growing period of the crops, which lowered their yields. Changes in precipitation did not affect the growing season. However, it did affect the yield, especially when there were periods of low or high rainfall since no irrigation is used.

Climate change would affect the normal environmental conditions required by the crops, consequently affecting their cycles. Some crops, such as maize, that are produced in Belize under rain-fed conditions are usually affected by soil water

⁵⁶ Climate Change Vulnerability and Adaptation Assessment for Sugarcane and Citrus. Belize Second National Communication Project. Final Report. Prepared by Carlos G. Santos and Sergio Garcia. August 2008.

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deficiencies during summer. These crops would be negatively impacted by future climate change with a decrease in precipitation. The effects of climate change on crop production would differ depending on the crop involved. While an increase in temperature might be detrimental particularly for certain crops, it could have a positive effect on some summer crops such as rice. The overall sustainability of the sugar and citrus subsector and the overall agricultural sector would probably not be at a significant risk.

Given that the impacts of climate change on agriculture is related to precipitation, technologies for agriculture therefore have a direct nexus with those in the water resource sector.

3.1.4.1 Current circumstances

Agriculture continues to be a major contributor to the Belize economy and is the foundation of the productive sector and rural areas (Table 9). At least 35% of GDP (\$338 million at current prices) and 41% of total employment is directly dependent on agriculture, fisheries & forestry since 90% of all manufacturing (which constitutes 17% of GDP and 12% of employment) is based on inputs from the primary sectors of agriculture, fisheries and forestry (sugar, citrus concentrate, animal feed, agriculture chemical, furniture, jams, jellies, chips, juices, milk, ice cream, sausages, packaging etc). Primary agriculture and fisheries are responsible for 29% of employment and more than 21% of GDP (current prices).

The farming population of Belize is estimated at approximately 12,000 farmers, operating a total land area of 265,000 acres (5% of the total land area), of which 146,000 acres are utilised for crops and 119,000 acres are under pasture. Small farmers (those with less than 20 acres under cultivation) account for more than 75% of all farmers. These include a large number of milpa subsistence farmers.

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Belize's foreign exchange earnings and trade are greatly influenced by the performance of the agricultural export sector, particularly the traditional products of sugar, bananas, citrus and, in recent years, marine products. In 2002 agricultural exports contributed 86% to total domestic exports. The traditional crops (sugar, citrus and bananas) and fish products accounted for 92% of total agricultural exports (excludes forestry products) while non-traditional agricultural exports (papayas, peanuts, black eye peas, cocoa beans, honey, chicle, and pepper products) accounted for only 8% of agricultural exports.

Belize's agriculture policy has emphasized market-led strategies, increasing diversification and self-reliance for food products. This has resulted in the development of new export commodities (papayas, aquaculture, habanero peppers), and an expansion of the food crop and livestock sub-sector; however, the sugar, banana and citrus industries still remain the three most important agricultural export sub-sectors. Non-traditional export promotion programs and projects have been a key dimension of the efforts by the Ministry of Agriculture to facilitate small farmer development. There have been farming communities throughout the country that have gone into habanero pepper and papaya production under these schemes. Small scale packaging houses have set up as buying centres, cleaning, treating and packing facilities for export, mainly in the northern sugar producing districts. Food crops, fruits and vegetables, sorghum, tubers, and some livestock, mainly produced by small farmers, face great difficulties and constraints to meet market requirements in terms of volume, quality and regularity. There is a need for assistance in adopting adequate marketing techniques and application of modern technologies in the production and distribution processes in order to expand their food production systems making them more efficient and competitive.

Table 9. Gross domestic product (million US\$) of different agriculture crops. (CSO 2005⁵⁷; SIB 2007c⁵⁸).

Product (mn US\$)	2003	2004	2005	2006
Citrus Concentrate	39.05	40.30	53.60	54.50
Oranges	1.20	1.40	1.75	1.45
Citrus Juice	0.95	1.65	0.40	0.05
Sugar	35.60	40.75	34.95	50.05
Molasses	1.25	0.90	1.40	2.10
Banana	26.30	26.20	24.95	25.30
Livestock production	19.55	20.90	N/A	N/A
Papayas	8.40	11.40	13.45	15.50
Black Eye Peas	1.70	1.20	1.85	1.70
Red Kidney Beans	0.85	1.20	2.60	0.95

Agricultural production in Belize is basically rain-fed and is affected by climate variability and climate change. The Initial National Communications of Belize considered the impact of climate change on maize, dry beans (as a substitute for R.K. beans), and rice. The results from the crop simulations for these cultivars suggested a general reduction in yields resulting from a shortened growing period because of warmer conditions under a doubling of carbon dioxide concentration. The effects of rainfall variability under the climate change scenario was minimal for maize, but resulted in lower yields for bean and rice for a 20% decrease in precipitation.

3.1.4.3 Possible applicable technologies

Technology application in the agriculture sector that is directly related to increasing water availability and water and soil conservation is not repeated here but reference is made to the technology recommendations under the water resources sector. Particularly referenced here are irrigation technologies.

⁵⁷ Central Statistical Office (CSO). 2005. Belize Abstract of Statistics 2005. Central Statistical Office, Belmopan, Belize.

⁵⁸ Statistical Institute of Belize (SIB). 2007c. Trade Statistics 2000 to 2006. Statistical Institute of Belize, Belmopan.

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Early warning systems

Though not an agricultural technology per se, early warning systems that would allow accurate weather forecasts of extreme weather events can provide adequate lead-time for contingency planning and minimizing losses.

Adoption of drought-resistant cultivars

Drought-resistant cultivars can be developed to minimise water consumption. However, choices of cultivars would require a thorough consideration of impacts of introduction including biodiversity considerations and cultural preferences.

GIS systems

Although geographical information systems are not agriculture technologies in the strictest sense, database development and monitoring would provide the information for more effective management practices, including the mapping of micro-climate effects given the geographical spread of subsistence farming practices.

Change sowing and harvest periods

Sowing and harvest periods can be adjusted to suit the changing climate in respect of seasonal changes in temperature and precipitation. However, long term monitoring would be needed and the usefulness of GIS is particularly referenced here.

Pesticide application technologies and practices

A shift to more intensive crop production would require an increased use of pesticides to maximise yields, particularly as there may be changes in

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occurrences of pest invasions in a changing climate. The application of pesticide application technologies and practices is likely to also have beneficial impacts on other sectors particularly the management of water contamination in a scenario of reduced precipitation and decreased water availability.

Sprayer calibration and nozzle selection

The goal of calibration is to assure that sprayers deliver a predictable dose of pesticide as improper pesticide concentrations can have adverse environmental impacts such as water contamination and impacts on beneficial insects and wildlife.⁵⁹ Additionally, appropriate application equipment should be chosen to avoid pesticide spread.

Pest Management Practices

Integrated pest management (IPM) programmes rely on pest identification, field monitoring and monitoring techniques in making pest management decisions. Management methods may vary, but may include singly or in combination, the following:

- Biological control (use of natural enemies);
- Cultural practices (field level practices that can intensify pest infestation);
- Pheromone disruption (population control);
- Pesticide treatment.

A critical technology would therefore be database establishment and maintenance such as GIS systems (see above). A full discussion on pest management strategies for different plantation types is beyond the scope of this assessment.

⁵⁹ Agricultural Technologies and Practices. Draft Report. May 2002. California Environmental Protection Agency. Regional Water Quality Control Board Central Valley Region.

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Soil management technologies and practices

Soil conservation practices are important for sustainable agriculture in a future climate change scenario of increased temperature and decreased precipitation.

Tillage

Tillage includes practices such as ploughing, ripping, disking, aerating and harrowing, which are designed to loosen soil and encourage vegetation growth.

Ripping

Ripping increases the storage capacity of soils.

Aeration

Aeration also increases the water infiltration.

3.1.4.4 Technologies that can be adopted

There are already many low-cost, tried-and-true technologies that can be adopted to suit the changing circumstances. These include:

- GIS database to record soil capability, flood zones, pest incidences, water availability etc.
- Integrated Pest management practices;
- Soil conservation practices;
- Pesticide management practices;
- Alternative cultivars and seed banking.

3.1.4.5 Possible Barriers

The possible barriers to implementing the technologies in this sector would be the same as those barriers identified for related and applicable technologies in other, related sectors such as water resources. Additionally, the following can be identified:

- Cost;
- Technical capacity and capability for maintenance;

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- Cultural barriers to the introduction of alternative cultivars.

Fisheries and aquaculture⁶⁰

The spiny lobster, the queen conch and the pink “sea” shrimp are important species harvested with respect to production and economic value. Practically all the fishing is done in the shallow waters of the Belize Barrier Reef (reef flat and reef slope) and the shallow waters of the Turneffe Islands, Glovers Reef and Lighthouse Reef (Three atolls which lie east of the Belize Barrier Reef). Fishing occurs within an estimated 4700 km² of sea space to a depth range of 1.5 to 10 km.

The inland freshwater fisheries activities are primarily subsistence in nature. The total volume and value of the fishery remain undocumented. A few cichlids species are known to be targeted in rivers and lagoons and includes the Baysnook (*Petenia splendida*), the Crana (*Cichlosomas urophthalmus*) and the Tilapia (*Oreochromis niloticus*). The tarpon (*M. atlanticus*), two species of catfish (*Ictalurus furcatus* and *Ictalurus sp.*) and the freshwater turtle or hicatee (*Dermatemys mawii*) are also important species in the fishery. The primary gears utilized by inland fishermen are hand lines and gill nets.

Belize has a tremendous potential for aquaculture development. This includes both inland freshwater and coastal landbased impoundment production systems, as well as subtidal sea-based production system. Although only three (3) species are currently being cultured in Belize, the potential exists for the husbandry of a wide range of finfish and macro-invertebrate species. The full scope for aquaculture development has been estimated at \$908,200,000 per annum.

⁶⁰ Vulnerability and Adaptation Assessment of the Fisheries and Aquaculture Industries to Climate Change. Final Report for the Second National Communication Project. Prepared by Vincent Gillete and George Myvette. May 2008.

Current circumstances

Shrimp farming production is based on the culturing of the Pacific White Shrimp *Penaeus vannamei*. The engineering containment technology for both shrimp farming and commercial-scale Tilapia culture in Belize are land-based embankment earthen ponds. These ponds are situated on the lower coastal plain immediately behind the mangrove zone for the shrimp farms. The pond systems for the Tilapia farming operation, is located in inland Belize, above the flood plain. The primary engineering containment infrastructure for Cobia culture is sea-based floating cages.

The aquaculture production system that would be subjected to the greatest risk from projected climate change Cobia cage culture, which is a function of geography and the impact of the change of various water quality parameters on the migration and consequent availability of broodstocks for hatchery seedstock production. However, beneficial impacts on Cobia cage culture as a result of projected climate change include:

- the increase in metabolic rate and growth performance as a function of increase in sea surface temperature (SST), and
- saline wedge penetration upstream as a consequence of sea level rise, which should increase the quantum of space available for Cobia cage culture.

Climate change impacts on Tilapia culture in Belize relate to the increase in stratification of pond water as a consequence of higher inland water temperature, and the decline in lagoon and river levels as a consequence of decrease in precipitation.

Possible applicable technologies

The applicable technologies for coastal protection are applicable to the shrimp and Cobia cage fishery and will not be repeated here. Additionally adaptation practices have been identified for the Cobia cage fishery⁶¹, *inter alia*:

- the definition and implementation of research programmes on the impacts of sea level rise on Cobia populations and availability of broodstocks,
- the incorporation of more heavily engineered stock containment technology such as more robust oceanic cages to withstand the ravages of hurricanes and other storm events, and
- the development of storm risk insurance for husbandry stocks and primary containment infrastructure to cope with the losses from storms.

Similarly, adaptation practices for the Tilapia fishery have also been recommended⁵⁶:

- the shift to embankment ponds that are shallower and that are marked by improved engineering design to promote improved mixing of pond water and consequently decrease in stratification,
- the judicious monitoring and management of water quality particularly dissolved oxygen (DO) and nitrogenous wastes, and
- decrease pumping cost by adapting recirculation technology and decreasing water exchange rates for semi-intensive Tilapia farming systems.

Since large volumes of water are required to maintain aquaculture systems, water efficiency practices are important to reduce the demands on source water

⁶¹ Vulnerability and Adaptation Assessment of the Fisheries and Aquaculture Industries to Climate Change. Final Report for the Second National Communication Project. Prepared by Vincent Gillete and George Myvette. May 2008.

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in the face of reduced availability in projected climate change scenarios. In this regard, the following technologies may be applicable⁶²:

- Determine minimum flow rates needed to maintain required tank/raceway conditions such as temperature, dissolved oxygen, and dissolved solids concentrations. Maintain these rates and regularly monitor specific tank conditions;
- Maintain or install accurate mechanisms to control flows throughout the aquaculture system. Devices include sealed weir boards and pipe valves;
- Install flow meters or sharp crested weirs for proper flow measurements. This allows for more accurate control of tank flow rates and water conditions;
- Minimize water use for tank and facility washing. Use pressurized culture water along with physical scrubbing, rather than clean source water, for cleaning;
- Routinely check for leaks in all areas of the facility. Regularly repair leaking pipes, tanks and channels. Retrofit old channeled systems with valved pipes;
- Establish a routine maintenance program;
- Upgrade older infrastructure with newer tanks and piping as the old ones wear out;
- Circulate water from hatchery or early stage containments to later fingerling or yearling containments;
- Utilize state-of-the-art recirculation technology wherever possible. These systems often employ a technique called a swirl separator, comprised of a cone-shaped tank and whirlpool, to remove fish wastes and are used in conjunction with treatment and aeration;

⁶² MRI Water Conservation Technical Bulletin # 3, Water Conservation Best Management Practices for Aquaculture; New England Interstate Water Pollution Control Commission, Wilmington, MA; 1996.

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- Implement efficient alternative processes for culturing fish. Processes may include installing aeration systems to control dissolved oxygen levels and minimizing the flow required to maintain saturated conditions;
- Sweep or shovel floors, drives, parking lots, and walkways rather than hosing down;
- Wash fleet vehicles less often. Consider using spent culture water for washing purposes;
- Use hose nozzle shutoff devices;
- Minimize high water use landscaping. Utilize natural plantings. Most native plants are drought-resistant and hardy, requiring no additional water application.
- Employ a pumping and treatment system to recycle water. Aquaculture treatment methods are designed to remove dissolved solids and reduce nitrate, nitrite and ammonia. Temperature and trace contaminants are also factors that must be considered when assessing the feasibility of a recycling system. The following is a list of treatment methods used in aquaculture:
 - Nitrogen/sulfide gas strippers;
 - Screens and particulate filters, e.g., cartridge, sock filters, remove large particles that could potentially damage pumps and plug pipes and valves;
 - Bio-filters, comprised of an appropriate media-filled container, remove nitrate, nitrite and ammonia;
 - Rapid sand filters remove nitrate, nitrite, ammonia and particulates;
 - Activated carbon filters/ion exchange systems remove nitrate, nitrite, ammonia and other cations;
 - Membrane filters, e.g., reverse osmosis, micro-, nano-, ultra-filtration, remove nitrate, nitrite, ammonia, salts and metals;
 - Ultra-violet radiation or ozone systems for pathogen loads in source water.

Possible barriers:

- Cost;
- Technical capacity and capability for maintenance;

3.1.5 HUMAN SETTLEMENTS

The Initial National Communication identifies that approximately 45% of the population reside in the coastal zone. The adverse impacts of climate change on human settlements are likely to arise largely from extreme weather events such as storms and hurricanes, and coastal inundation and flooding. Further, salt water intrusion into freshwater aquifers is likely to affect potable water availability to these communities. Accordingly, technologies and the barriers to their implementation that are applicable to coastal defence in terms of physical infrastructure would also be applicable to protecting human settlements and is not repeated here. Additionally, the adoption of stricter building codes and designs for buildings capable to withstanding extreme weather events is a recommended measure.

3.1.6 HUMAN HEALTH

Within the Health Sector, the Global Circulating Models for climate change projects that in tropical low latitude areas such as Belize, a warmer climate system resulting from a doubling in carbon dioxide concentration in the atmosphere will lead to increased frequency of warm spells/heat waves, intense droughts, heavy rainfall events. It is projected that these conditions will exacerbate those that increase the risk and incidences of vector-borne diseases and illnesses⁶³. Based on available data, there appears to be a direct relationship between the outbreak of dengue and rainfall, with higher incidences

⁶³ Inception Report. Vulnerability and Adaptation Assessment for the Health Sector in Belize. Proposal to Conduct a Climate Change Vulnerability and Adaptation Assessment for Dengue and Dengue Hemorrhagic Fever in Belize. October 2008.

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occurring in the wetter months of the year⁶⁴. Accordingly, projected climate change is expected to result in:

- Higher temperatures and precipitation that would create favourable conditions for the thriving of vectors of transmissible diseases (rodents and insects);
- Flooding and inundation, giving rise to unhygienic conditions as well as water borne diseases;
- Increasing temperatures giving rise to aridity and drought, which can see deterioration of water quality with the resultant effects associated with water borne diseases;

3.1.6.1 Current circumstances

The main dengue vector in Belize is the *Aedes aegypti* mosquito. To date studies have not revealed the presence of other vectors such as the *Aedes albopictus*. Since the environmental conditions as it relates to temperature, humidity, rainfall and altitude are within the ideal ranges in all districts, the entire country is considered to be at risk of dengue transmission.

The National Public Health System in Belize provides universal access to personal and population based services, essentially at no direct cost to the individual. This includes the provision of pharmaceuticals and other support services. The Government is the main provider of health services, though recently there has been an expansion of the private sector as it relates to secondary and tertiary care. The main financing source for the public sector is the consolidated fund of central government. A system of rural health centers with permanent staff is supplemented by mobile health services, community

⁶⁴ Inception Report. Vulnerability and Adaptation Assessment for the Health Sector in Belize. Proposal to Conduct a Climate Change Vulnerability and Adaptation Assessment for Dengue and Dengue Hemorrhagic Fever in Belize. October 2008.

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nursing aides, voluntary collaborators and traditional birth attendants working throughout the rural communities of the country.⁵⁹

Promotional, preventive and curative services provided by the Ministry of Health are organized into programs addressing different technical areas for the purpose of managing health care delivery throughout the country. One such program is the Vector Control Program. This program has responsibility for the maintenance of a healthy environment that provides for the prevention and control of Malaria, Dengue and Chagas Disease. Unlike Malaria, Dengue does not have a dedicated surveillance system and cases are diagnosed at the point of patient contact with the health sector and reported to the health information system of the Ministry of Health.

The inadequate supply of safe water and sanitation services to rural areas has made Belize susceptible to outbreaks of gastrointestinal and other water/sanitation related diseases. Gastroenteritis and hepatitis B have increased in Belize, particularly in rural areas. In 1993, 135 cases of cholera were reported in Belize and the incidence of hepatitis B in certain rural areas was comparatively high. Almost 98% of the population in these areas had been exposed to hepatitis B. Given the small population of Belize, the cholera cases of 1992 reflect a high incidence of the disease. Most of the cholera cases have been detected in rural areas, particularly the Toledo and Cayo districts, where influx of immigrants and transboundary water pollution occurs.⁶⁵

⁵⁹ Inception Report. Vulnerability and Adaptation Assessment for the Health Sector in Belize. Proposal to Conduct a Climate Change Vulnerability and Adaptation Assessment for Dengue and Dengue Hemorrhagic Fever in Belize. October 2008.

⁶⁵ National Environmental Action Plan. 1999. Government of Belize

3.1.6.2 Development Objectives and Policies

The National Environmental Action Plan 1999 proposes:

- study the possibility of expanding and improving rural water and sanitation services, including improved water quality testing;
- an effective public health extension and education campaign.
- Improving the malaria control system
- an expansion of the spraying program into high risk areas

3.1.6.3 Possible applicable technologies

The main direct threat of climate change is the probable increase in disease-causing vectors such as mosquitoes; technology applications can be focussed on activities aimed at controlling these vectors:

- Deployment of fogging machines for spraying (consideration needs to be given to the resistance developed by vectors in the abuse of insecticide application);
- Insecticide-treated nets (minimal impact on environment and ecosystems);
- Integrated vector management systems (IVM) (process for managing vector populations in such a way as to reduce or interrupt transmission of disease).
- Expansion of immunization programmes country-wide, particularly to vulnerable communities.
- Increased used of bed nets as a simple technology;
- Waste management practices such as proper disposal to minimize the creation of breeding sites for vectors.

It should be noted that the effectiveness and degree of efficacy in deploying simple technologies and practices is significantly based on the extent and quality of outreach and education programmes.

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In order to minimize the risk of water borne diseases, the following technologies may be applicable:

- Expansion of sewerage coverage;
- Chlorination of water stores collected from sources other than pipe borne. Application of chlorination tablets is a simple technology that can be employed.

3.1.6.4 Possible Barriers

- Cost;
- Supporting infrastructure and human resources;
- Technical capacity and capability.

3.1.7 TOURISM

The tourism product is a combination of the various sectors that offer attractions to visitors such as natural and historical features. Additionally, since this is a service-oriented industry, it depends on various other support sectors and adverse climate change impacts on these support sectors would have an impact on the tourism sector. According to the vulnerability assessment conducted for the tourism sector⁶⁶, the vulnerability of tourism in Belize to climate change stems from three biogeophysical impacts. Rising sea levels pose risks for flooding, inundation, saltwater intrusion, and erosion, which threaten water supplies, infrastructure, and coastal areas. Warmer sea water threatens the coral reefs along the coast of Belize that comprise the longest barrier reef in the western hemisphere and attract thousands of tourists for snorkeling and scuba diving activities. Also, warmer sea surface temperatures are associated with increasing frequency and intensity of tropical cyclones or hurricanes, which threaten coastal settlements and infrastructure. Based on present spending levels, it is estimated that between 45% to 70% of the tourism sector is highly vulnerable to the effects of climate change.

⁶⁶ Tourism in Belize. Vulnerability and Capacity Assessment. Submitted for Belize's Second National Communication to the UNFCCC. Prepared by Robert B. Richardson. Michigan State University (USA). Galen University (Belize). August 2007.

Additionally, projected impacts of climate change on the tourism sector can include:

- Flooding of coastal areas, increasing beach erosion, rising water tables and higher wave energy resulting from sea level rise. This will result in increased costs and damage to tourism based infrastructure;
- Damage to coastal ecosystems such as coral reefs as a result of extreme weather events and increased sea surface temperatures;
- Decrease in freshwater availability and increase in associated costs;
- Deterioration of outdoor conditions;
- Deterioration of indoor conditions resulting in increase in demand for air conditioning systems;
- Deterioration of landscapes;
- Indirect impacts resulting from food security issues.

3.1.7.1 Possible applicable technologies

Since the tourism industry is dependent on a variety of ancillary support services from other sectors that may themselves be vulnerable to climate change, there are no specific technologies that can be identified to reduce the vulnerability of this sector. Technology application in related vulnerable sectors will ameliorate impacts on the tourism sector, particularly those identified in the coastal zone, agriculture, water, human health and forestry sectors.

3.2 SECTOR NEXUS AND TECHNOLOGY SYNERGY AND SELECTION

The foregoing discussions have revealed obvious cross-sector linkages, nexuses and the potential for technology synergy. Table 10 below provides a matrix that attempts to illustrate the possible synergy and inter-linkages. The table should be read across only to avoid confusion among the relationships between the sectors. The purpose of the table is to aid in prioritising technologies that can have multiple or collateral benefits in other sectors. It should be noted that the identified inter-linkages is based on the possible applicable technologies only.

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Table 10: Inter-Sectoral Linkages and Synergy

Sector	ENERGY	ROAD TRANSPORT	FORESTRY & TERRESTRIAL ECOSYSTEMS	COASTAL ECOSYSTEMS	WATER RESOURCES	AGRICULTURE & AQUACULTURE	HUMAN SETTLEMENTS	HUMAN HEALTH	TOURISM
Energy		√				√	√		√
Road Transport	√							√	
Forestry & Terrestrial Ecosystems				√	√	√			√
Coastal Ecosystems			√		√	√	√		√
Water Resources			√	√		√		√	√
Agriculture	√		√	√	√			√	√
Human Settlements	√			√				√	√
Human Health		√			√	√			√
Tourism	√		√	√	√	√	√	√	

4.0 CONCLUSIONS & RECOMMENDATIONS

This study provides an indication and guidance as to the possible technologies that can be applied in specific sectors. Further analysis has to be done to prioritise technology applications, including cost-benefit analyses, more detailed environmental impact assessments based on the receiving environment, and most critically, an analysis of the enabling environment to receive the technology. In this respect, a comprehensive overview of the institutional, policy and legislative barriers would have to be conducted in the context of the identified technology. Such an analysis is outside the scope of this study, which sought to identify technology needs that can address climate change issues which were identified in various reports.

Technology requirements can be expected to change with changes in policy, development objectives and changes in the technologies themselves. It should therefore be cautioned that the technology needs identified here may only have a limited timeframe of application. Any choice of technology should at least satisfy a set of basic requirements and criteria which are determined at the national level, including consideration of sustainable development criteria. However, as a general requirement the following should be taken into account:

- Longevity of the technology;
- Technical support requirements of the technology at the time of availability;
- Cost;
- Social acceptance/environmental impact;
- Contribution to sustainable development objectives as identified.

