BELIZE TECHNOLOGY NEEDS ASSESSMENT MITIGATION

Identification and Prioritization of Mitigation Technologies for Belize

FINAL REPORT

September 26th, 2017

Technology Needs Assessment Climate Change Adaptation Report
National Climate Change Office Ministry of Agriculture, Fisheries, Forestry, the Environment and Sustainable Development 2 Slim Lane Forest Drive Belmopan, Belize
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Coordinators

Mr. Lennox Gladden	Director of the National Climate Change Office, Belize
Mr. Colin Mattis	Assistant TNA Coordinator

Lead Author

Mr. Ramón Frutos	Lead Consultant, Eco Solutions and Services

UNEP DTU Team

Mr. Gordon Mackenzie	UDP, UNEP DTU Partnership
Fundación Bariloche	UNEP Regional Office, Argentina

Table of Contents

List of Figures

List of Tables

Abbreviations

APAMO	Association of Protected Areas Management Organization
BECOL	Belize Electric Company Limited.
BELCOGEN	Belize Co-Generation Energy Limited
BELTRAIDE	Belize Trade & Investment Development Service
BFSD	Belize Framework for Sustainable Development
BNCCC	Belize National Climate Change Committee
BNE	Belize Natural Energy
BTB	Belize Tourism Board
BZD	Belize Dollar
CAT	Category of Hurricane
CCAD	Central American Commission for Environment and Development
CARDI	Caribbean Agriculture Research and Development Institute
CARICOM	Caribbean Community
CCCCC	Caribbean Community Climate Change Centre
CCD	Climate Change Department
CCFC	Climate Change Finance Committee
CCTF	Climate Change Trust Fund
CEO	Chief Executive Officer
CNG	Compressed Natural Gas
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COP	Conference of the Parties
COTED	Council for Trade and Economic Development (CARICOM)
CSF	Critical Success Factors
CZMAI	Coastal Zone Management Authority and Institute
DC-AC	Direct Current-Alternating Current
DDSFS	Douglas D`Silva Forest Station
DTU	Technical University of Denmark
ECLAC	United Nations Economic Commission for Latin America and the Caribbean
EE	Electrical energy

EST	Environmentally Sound Technology
EU-GCCA	European Union- Global Climate Change Alliance
FCD	Friends for Conservation and Development
FCPF	Forest Carbon Partnership Facility
GEF	Global Environment Facility
Gg	Gigagram
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GOB	Government of Belize
GPRS	Growth and Poverty Reduction Strategy
GSDS	Growth and Sustainable Development Strategy
H_2	Hydrogen
HML	Hydro Maya Limited
HSSP	Belize Health Sector Strategic Plan
INC	Initial National Communication of Belize
INDC	Intended Nationally Determined Contribution
IPCC	Inter-Governmental Panel on Climate Change
LCDS	Low Carbon Development Strategy
LPG	Liquefied Petroleum Gas
LULUCF	Land Use, Land-Use Change and Forestry
MAC	Mitigation Abatement Curves
MAFFESD	Ministry of Agriculture, Forestry, Fisheries, Environment and Sustainable Development
MCCAP	Marine Conservation and Climate Adaptation Project
MCA	Multi-Criteria Analysis
MCDA	Multi-Criteria Decision Analysis
MDG	Millennium Development Goals
MESTPU	Ministry of Energy, Science and Technology, and Public Utilities
MFFSD	Ministry of Forestry, Fisheries and Sustainable Development
MNRA	Ministry of Natural Resources and Agriculture
MOU	Memorandum of Understanding
MPR	Mountain Pine Ridge
MPRFR	Mountain Pine Ridge Forest Reserve
MRV	Monitoring, Reporting, and Verification
NAMAS	Nationally Appropriate Mitigation Actions

NC	Necessary Conditions
NCCC	National Climate Change Committee
NCCO	National Climate Change Office
NCCPSAP	National Climate Change Policy, Strategy, and Action Plan
NDC	Nationally Determined Contribution
NEMO	National Emergency Management Organization
NEPF	National Energy Policy Framework
NGO	Non-Governmental Organization
NMVOC	Non-Methane Volatile Organic Compound
NO	Nitrous Oxide
NO_2	Nitrogen Dioxide
NOAA	United States National Oceanic and Atmospheric Administration
NOx	Nitrogen Oxides
NPSC	National Project Steering Committee
NSDS	National Sustainable Development Strategy
NSTMP	National Sustainable Tourism Master Plan
O&M	Operation and Maintenance
OECs	Organization of Eastern Caribbean States
PACT	Protected Area Conservation Trust
PAHO	Pan American Health Organization
PRECIS	Providing Regional Climate for Impact Studies
PV	Photo Voltaic
RE	Renewable Energy
REDD	Reducing Emissions from Deforestation and Degradation
R-PP	Readiness Preparation Proposal
SDG	Sustainable Development Goal
SIB	Statistical Institute of Belize
SIDS	Small Islands Developing States
SWH	Solar Water Heating
TAP	Technology Action Plan
TNA	Technology Needs Assessment
TNC	Third National Communication
UNDESA	United Nations Department of Economics and Social Affaires
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme

UNFCCC	United Nations Framework Convention on Climate Change
UNWTO	United Nations World Tourism Organization
USA	United States of America
VED	Vehicle Emission Duty
WHO	World Health Organization

Glossary of Terms

Adaptation
Adaptation is a short for 'climate change adaptation', adjustment in natural or human systems in response to actual or expected climate stimuli or their effects, which moderate harm or exploit beneficial opportunities (IPCC, 2007). Adaptation is a process, not an outcome.

Afforestation
Direct human-induced conversion of land that has been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources.

Ancillary benefits
Policies aimed at some target, e.g. climate change mitigation, may be paired with positive side effects, such as increased resource-use efficiency, reduced emissions of air pollutants associated with fossil fuel use, improved transportation, agriculture, land use practices, employment, and fuel security. **Ancillary impacts** are also used when the effects may be negative. Policies directed at abating air pollution may consider greenhouse-gas mitigation an ancillary benefit.

Barrier
Obstruction or impediment that impedes technology transfer; a reason why a target is adversely affected, including any failed or missing countermeasures that could or should have prevented the undesired effect(s).

Biofuel
Any liquid, gaseous, or solid fuel produced from plant or animal organic matter. E.g. soybean oil, alcohol from fermented sugar, black liquor from paper manufacturing process, wood as fuel, etc.

Biomass
The total mass of living organism in a given area or of a given species usually expressed as dry weight. Organic matter consisting of, or recently derived from, living organisms (especially regarded as fuel) excluding peat. Biomass includes products, by-products and waste derived from such material.

Capital goods
Machinery and equipment used in the production of other goods, e.g. consumer goods such as boilers, motors, steel or pumps. May also mean 'producer goods'.

Carbon dioxide (CO_2)
CO_2 is a naturally occurring greenhouse gas, and a by-product of burning fossil fuels or biomass, of land-use changes and of industrial processes. It is the principal anthropogenic greenhouse gas that affects Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured and therefore it has a Global Warming Potential of 1.

Climate Change (CC)
Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and /or variability of its properties, and that persist for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

Carbon price
What has to be paid (to some public authority as a tax rate, or on some emission permit exchange) for the emission of 1 ton of CO_2 into the atmosphere.

Consumer Goods
Good and products specifically intended for the mass market and purchased by (private) consumers.

Cost-benefit analysis
Monetary measurement of all negative and positive impacts associated with a given action. Costs and benefits are compared in terms of their difference and/or ratio as an indicator of how a given investment or other policy effort pays off seen from the society's point of view.

Diffusion
The process by which a technology is spread or disseminated through various channels over time in a society, where the technology is gradually adopted by more and more members of the society (people, institutions, companies, etc.).

Enabling Environment
The set of resources and conditions within which the technology and the target beneficiaries operate. The resources and conditions that are generated by structures and institutions that are beyond the immediate control of the beneficiaries should support and improve the quality and efficiency of the transfer and diffusion of technologies.

Energy
The amount of work or heat delivered. Energy is classified in a variety of types and becomes useful to human ends when it flows from one place to another or is converted from one type to another. **Primary energy** or **energy sources** is the energy embodied in natural resources (e.g. coal, crude oil, natural gas, uranium) that has not undergone any anthropogenic conversion. Primary energy is transformed into **secondary energy** by cleaning (natural gas), refining (oil into oil products) or by conversion into electricity or heat. **Final energy** is secondary energy delivered at the end-use facilities (e.g., electricity at the wall outlet), where it becomes **usable energy** (e.g., light).

Global Warming
Global warming refers to the gradual increase, observed or projected, in global surface temperature, as one of the consequences of radiative forcing caused by anthropogenic warming.

Global warming refers to the global increase, observed or projected, in global average surface temperature, as one of the consequences of radiative forcing caused by anthropogenic emissions.

Greenhouse effect
Greenhouse gases effectively absorb infrared radiation, emitted from the Earth's surface, by the atmosphere itself due to the same gases and by clouds. Atmospheric radiation is emitted to all sides, including downward to the Earth's surface. Thus, greenhouse gases trap heat within the surface-troposphere system. This is called the greenhouse effect.

Hardware The tangible aspects of technology, such as equipment and machinery.

Innovation
Innovation refers to both the processes of research and development and the commercialization of the technology, including its social acceptance and adoption.

Land-use
The total of arrangements, activities and inputs undertaken in a certain land-cover type (a set of human actions). The social and economic purposes for which land is managed (e.g. grazing, timber extraction, and conservation). Land-use change occurs when, e.g., forest is converted to agricultural land or to urban areas.

Low-carbon technology
A technology that over its life cycle causes less CO_2-eq. emissions than other technological options do.

Measures
Measures are technologies, processes, and practices that reduce GHG emissions or effects below anticipated future levels. Examples of measures are renewable energy technologies, waste minimization processes and public transport commuting practices etc. Measures can also be factors (financial or non-financial) that enable or motivate a particular course of action or behavioural change, or is a reason for preferring one choice over the alternate. Often the word 'incentive' is used synonymously, sometime with a slightly different interpretation.

Mitigation
Mitigation is short for 'climate change mitigation', meaning an action to decrease the concentration of greenhouse gasses, either by reducing their sources or by increasing their sinks.

National Action Plans
Plans submitted to the COP by parties outlining the steps that they have adopted to limit their anthropogenic GHG emissions. Countries must submit these plans as a condition of participating in the UNFCCC and, subsequently, must communicate their progress to the COP regularly. The National Action Plans form part of the National Communications, which include the national inventory of GHG sources and sinks.

Nitrous oxide (N_2O)
One of the six types of greenhouse gases to be curbed under the Kyoto Protocol.

Non-market goods
Goods not traded in a market

Orgware
The institutional framework, or organizational aspects, involved in the diffusion and uptake of a technology.

Reforestation
Direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was previously forested but converted to non-forested land.

Renewable Energy
Renewable energy is energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, biomass, wind, rain, tides, waves and geothermal heat.

Sequestration
Carbon storage in terrestrial or marine reservoirs. **Biological sequestration** includes direct removal of CO_2 from the atmosphere through land-use change, afforestation, carbon storage in landfills and practices that enhance soil carbon storage in agriculture.

Sinks
Any process, activity or mechanism that removes a greenhouse gas or aerosol, or a precursor of a greenhouse gas or aerosol from the atmosphere.

Stakeholder
Any identifiable individual or group with a direct or indirect interest (stake) in the success of an institution in delivering intended results. A formal definition of *stakeholders* is '…those who have an interest in a particular decision, either as individuals or representative of a group. This include people who influence a decision, or can influence it, as well as those affected by it' (Earth Summit 2002 in Technology Executive Committee, UNEP DTU, 2016).

Technology
Technology is a piece of equipment, technique, practical knowledge or skills for performing a particular activity. It is common to distinguish between three different elements of technology: the tangible aspect such as equipment and products (hardware); the know-how, experience and practices (software) associated with the production and use of the hardware; and the institutional framework, or organization, involved in the transfer and diffusion of a new piece of equipment or product (orgware).

Technology transfer
Technology transfer involves vertical technology transfer, which is understood as the movement of technologies from the R&D stage to the commercialization, and horizontal transfer, which involves the spatial relocation or diffusion of technologies across space.

Vulnerability
Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity and adaptive capacity.

Executive Summary

Belize is one of 26 participating countries in Phase II of the Technology Needs Assessment (TNA) project, which has its origin in the Strategic Programme on Technology Transfer approved by the GEF in 2008. The aim is to assist developing country parties to the UNFCCC determine their technology priorities, for mitigation of greenhouse gas emissions and adaptation to climate change. The TNA project is being implemented by the United Nations Environmental Programme (UNEP), and executed by a UNEP-Technical University of Denmark (UNEP-DTU) Partnership, on behalf of the Global Environment Facility (GEF).

The National Climate Change Office (NCCO) of Belize is coordinating the TNA Project and a National TNA Steering Committee, comprising of members of the Belize National Climate Change Committee, oversees the implementation of the project. A National Consultant has been recruited to provide technical assistance to the Belize TNA process.

In fulfilling some of its obligations as a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), Belize has moved to develop policies, strategies, and plans that address climate change in the development sectors. These policies, strategies, and plans have been designed to address both mitigation and adaptation to climate change. Some of the instruments relevant to *mitigation* to climate change are the National Adaptation Strategy and Action Plan to address Climate Change in the Water Sector in Belize (CCCCC, 2010); the National Integrated Water Resource Management Policy (including Climate Change) for Belize (GOB, 2008); the National Integrated Water Resources Act (GOB, 2010); the National Sustainable Tourism Master Plan 2030 (GOB, 2012); the National Climate Change Policy, Strategy and Action Plan 2015 – 2020 (GOB, 2015); the Growth and Sustainable Development Strategy (GOB, 2015); the National Agenda for Sustainable Development (GOB, 2015); Belize's Third National Communication to the United Nations Framework Convention on Climate Change (GOB, 2016); Belize Nationally Determined Contribution under the UNFCCC (GOB-NCCO, 2016); Belize Sustainable Energy Action Plan (GOB-MESTPU, 2015); and regionally, Delivering Transformational Change 2011-2021: Implementing the CARICOM "Regional Framework for Achieving Development Resilient to Climate Change", (CARICOM-CCCCC, 2012), among others.

Belize's First, Second, and Third National Communication to the UNFCCC assessed the vulnerability of certain productive sectors to the impacts of climate change. These sectors were considered as potential areas for technology interventions. These include: Energy; Transport; Agriculture; Land Use, Land-use Change and Forestry; Water; Coastal and Marine Ecosystems; Human Settlements; Human Health; Tourism; Agroforestry; and Terrestrial Ecosystems. During the preparation of the Belize TNA, both adaptation and mitigation technologies were considered, but this report focuses primarily on mitigation technologies. The National Climate Change Policy, Strategy and Action Plan 2015–2020 (GOB, 2015) addresses eleven sectors vulnerable to climate change and climate variability, namely: Agriculture; Forestry; Fisheries & Aquaculture; Coastal & Marine Resources; Water Resources; Land use and Human Settlements; Human Health; Energy; Tourism; Transportation; and Solid Waste.

Belize's Nationally Determined Contribution (NDC) to the UNFCCC (GOB-NCCO, 2016) highlights key sectors for which adaptation and mitigation strategies, and action plans are being addressed. These include: Agriculture, Forestry, Fisheries and Aquaculture, Coastal and Marine Resources, Water Resources, Land use and Human Settlements, Human Health, Energy, Tourism, Transportation, Solid Waste, and Infrastructure.

Belize's NDC is consistent with the over-arching goal of the Growth and Sustainable Development Strategy (GSDS), which integrate medium-term economic development, poverty reduction, and longer-term sustainable development. The GSDS is the country's primary development blueprint. Specifically, the GSDS identifies four "Critical Success Factors" (CSFs), for national development and a better way of life for its citizens today and in the future. It also provides organizing framework for the objectives and actions grouped underneath them (under the headings of "Necessary Conditions" or "NCs" and "Actions"). Each CSF is linked to a set of measurable targets. The climate change mitigation potential of Belize according to the NDC, is action-based among multiple sectors, namely: forestry, energy (electricity), waste, and transport.

At the regional level, Caribbean states in development mode should also consider inevitable emission reductions in their response plan to climate change (Taylor, *et.* al., 2012). The targets of regional cutbacks in GHGs should be in all areas of energy usage: electricity generation, road, shipping and aviation transportation, industry and building. The response strategy should be led by national governments and regional policy-setting and economic groupings (e.g., CARICOM, OECS, etc.). It is recommended that reduction should come from a mixed of more efficient use of fossil fuels, oils, liquefied natural gas (LNG) and/or clean coal, as well as the introduction of renewable energy technologies, i.e., transitioning to a low-carbon economy (Taylor *et. al.*, 2012). The medium and long-term benefits would be reduced economic costs, increased productivity and improved quality of life.

During the initial consultations and two workshops, stakeholders selected: Land use, Land-use and Agroforestry; Energy; and Transport as the sectors for technology transfer interventions under the TNA-Belize Project. Several factsheets per Sector were drafted and presented to stakeholders during the second workshop. However, the majority of these factsheets were incomplete or poorly prepared, and had to be discarded. The Consultants revised some of the factsheets and proceeded with the MCA process to prioritized the vetted factsheets. They then drafted the TNA Adaptation and Mitigation Reports and submitted the same in early 2016. The Reports were unacceptable to the TNA review committee, and a recommendation was forwarded that the entire process should be revisited and redrafted for submission.

Subsequently, the newly hired Consultants, together with the TNA Assistant Coordinator re-organized key stakeholders in the pre-selected Sectors, and proceeded with a series of public consultations and small group meetings to select appropriate technologies and draft corresponding factsheets. In the end, a total of nine mitigation technology factsheets were drafted and presented to small working groups of key stakeholders per vulnerability sector. These mitigation technology factsheets were the following:

Energy:

i. Solar PV Off-Grid Systems.
ii. Solar PV On-Grid Systems.
iii. Solar Water Heaters Systems.
iv. Micro-Hydro Systems.
v. Gasification Systems.

Transport:

vi. Improved Urban/Suburban Public Transport System using more fuel-efficient buses.
vii. Retrofitting of existing vehicles with Liquid Petroleum Gas (LPG) Systems.
viii. Levying duty on imported motor vehicles based on carbon emission rates.

Land Use, Land-use Change and Agroforestry:

ix. Improved Tropical Hardwood & Pine Caribe Species Nurseries and Reforestation (MPR & Chiquibul Forest Reserves);
x. Integrated Landscape Forest Management: A Management Alternative in the Vaca Forest Reserve.

The Mitigation Consultant, in coordination with the Lead Consultant and the TNA Assistant Coordinator (National Climate Change Office), facilitated consultative meetings and work sessions with key sector stakeholders, for the Multi Criteria Analysis (MCA) process for the Land Use, Land-use Change & Agroforestry; Energy; and Transport sectors. The results of the MCA exercise along with the mitigation factsheet technologies were later forwarded to the TNA Country Coordinator for review and vetting.

The prioritized technologies per sector and score are:

Energy

i)	Solar PV Off Grid	65.1
ii)	Gasification	63.1
iii)	On-Grid Solar PV	52.6

Transport

iv)	Levying duty on imported motor vehicles based on Vehicle fuel efficiency	50.0
v)	Retrofitting of existing vehicles with LPG systems	47.0

Land Use, Land-use Change and Agroforestry

vi)	Integrated Landscape Forest Management: A Management Alternative in the Vaca Forest Reserve	59.0

All the prioritized mitigation technologies reviewed in this report are in harmony with the medium and long-term strategy of the government of Belize to develop, adopt and implement policies and measures/actions to reduce its carbon footprint, transition its development pathway from a fossil-based economy to cleaner, renewable energy use, and increase the country's resilience to the adverse effects of Climate Change. At the same time, the implementation of these technologies will contribute to the over-arching goal of the Growth and Sustainable Development Strategy (GSDS), which integrate medium-term economic development, poverty reduction, and longer-term sustainable development.

CHAPTER 1. Introduction

1.1 The Belize Technology Needs Assessment Project

A Technology Needs Assessment (TNA) is a country-driven set of activities directed mainly at the identification and prioritization of climate change mitigation and adaptation technologies. The Technology Needs Assessment project comes from the Strategic Programme on Technology Transfer approved by the Global Environmental Fund (GEF) in 2008. It assists developing country parties to the UNFCCC determine their technology priorities for the mitigation of greenhouse gas emissions and adaptation to climate change. The Technology Needs Assessment project aims at assisting participating countries to identify and analyse priority technology needs, which can be processed into a portfolio of projects and programmes to facilitate the transfer and access to climate technologies and capacity building through implementation of Article 4.5 of the UNFCCC Convention (UNEP, 2015).

Since 2001, a number of developing countries which are Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have conducted TNAs within the framework of their national development plans and strategies. However, the revisions of these early TNA processes revealed significant operational and methodological constraints that compromised the quality, comprehensiveness and utility of the resulting country's TNA reports.

A new project has been designed to assist countries in carrying out improved TNAs supported by the Global Environment Facility (GEF) grant financing. Project activities include in-depth analysis and prioritization of technologies, analysis of potential barriers hindering the transfer of prioritized technologies, and analysis of potential market opportunities at the national, regional and international level. All activities were organized around three main components, namely: i) support for the development or strengthening of TNAs; ii) development of tools and provision of methodological information to support the TNA and Technology Action Plan (TAP) processes; and iii) establishment of a cooperation mechanism that aids preparation and refinement of the TNA and TAP implementation and dissemination.

This project is intended to assist countries, like Belize to complete a TAP on the basis of strong consensus amongst stakeholders on prioritized technologies, including relevant actions in order to accelerate the transfer and deployment of clean and viable technologies.

Hence, TNAs are central to the work of Parties to the Convention on technology transfer (i.e. Article 4.5), and present an opportunity to track an evolving need for new equipment, techniques, practical knowledge and skills, which are necessary to mitigate greenhouse gas (GHG) emissions and/or reduce the vulnerability of sectors and livelihoods to the adverse impacts of climate change. In accordance with UNEP (2015), the main components of the TNA Project are:

1. The identification and prioritization of technologies that can contribute to adaptation and mitigation goals of participating country parties that are compatible with their national sustainable development goals and priorities, via a country-driven, participatory process.

2. The identification of barriers hindering the acquisition, deployment, and diffusion of prioritized technologies, and formulating/recommending enabling frameworks to overcome barriers and enhance the transfer, adopting and diffusion of prioritized technologies.

3. The development of Technology Action Plans (TAPs) highlighting activities and enabling frameworks at the sectoral and cross-cutting levels to overcome the barriers and facilitate the transfer, adoption, and diffusion of selected technologies.

The United Nations Environment Programme (UNEP) is responsible for the implementation of the Project. Cognizant that barriers to technology transfer, including the lack of an enabling environment conducive to the successful diffusion of new or improved technologies are the limiting factors to the success of the TNA project, UNEP aims at providing practical and operational guidance on how to assess and overcome the barriers. To this end, UNEP has forged a partnership with the Technical University of Denmark (UNEP/DTU) to serve as the executing partner of the project, and provide overall project oversight and strategic coordination. This partnership between UNEP and the Technical University of Denmark has as an acronym: UDP.

The Ministry of Agriculture, Forestry, Fisheries, Environment and Sustainable Development (MAFFESD) through the National Climate Change Office (NCCO), is responsible for the implementation of the TNA Phase II Project in Belize, and this is facilitated under the terms of a Memorandum of Understanding (MOU) crafted for this purpose. The UDP and the Ministry have signed the MOU. The National Climate Change Coordinator was designated as the National TNA Coordinator, and an Assistant National Coordinator was contracted as a consultant to the project. A National Consultant was contracted to provide technical support for the implementation of the project.

A National TNA Committee comprising of members of the National Climate Change Committee has been set-up within the Ministry of Agriculture, Forestry, Fisheries and Sustainable Development to oversee the implementation of the project. The National Consultant will support and facilitate the TNA process.

1.2 National Policies and Regional Initiatives on Climate Change

Like most developing countries, Belize is a small contributor to global GHG emissions, but it is among those that are severely impacted. As a Non-Annex I Party to the UNFCCC, Belize is not obligated to adhere to quantitative commitments for reducing GHG emissions (CCCCC-GOB, 2016). However, it recognizes that all efforts to emission reduction contribute towards the global challenge to abate global warming. In this regard, the country has made significant progress towards fulfilling the objectives of the Convention through the development and implementation of new policies, projects and programmes aim at the abatement of GHG emissions, and the goal to gradually transition to an overall, low-carbon development (GOB-NCCO, 2016).

Belize ratified the United Nations Framework Convention on Climate Change (UNFCCC) on October 31, 1994, the Kyoto Protocol in 2003, and submitted its Initial National Communication (INC) to the UNFCCC in 2002, its Second National Communication in the second quarter of 2012, and the Third National Communication (TNC) in early 2016. Also in 2016, Belize ratified the Paris Agreement, which aims to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels, and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius (UNFCCC, 2016). Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change.

As a Party to the UNFCCC, Belize committed itself to develop, adopt and implement policies and measures to adapt to the adverse effects of Climate Change and contribute to the global effort to reduce GHG emissions. Cognizant of the medium and long-term benefits, the Government of Belize (GOB) has taken initiatives to mainstream Climate Change into its national development plan and mechanisms. These initiatives include the establishment of a National Climate Change Office under the Ministry of Agriculture, Forestry, Fisheries, the Environment, and Sustainable Development (MAFFESD), the adoption of climate sensitive response mechanisms for some economic development sectors, and the drafting and adoption of a comprehensive National Climate Change Policy, Strategy and Action Plan (GOB, 2015). The NCCPSAP and the follow-up Growth and Sustainable Development Strategy for Belize: 2016-2019 (GSDS, 2016) provide policy guidance for the development of an appropriate administrative and legislative framework, in harmony with other sectoral policies, for the pursuance of a low-carbon development path for Belize.

Some of the prominent policy instruments relevant to *mitigation* to climate change are: the National Adaptation Strategy and Action Plan to address Climate Change in the Water Sector in Belize (CCCCC, 2010); the National Integrated Water Resource Management Policy (including Climate Change) for Belize (CCCCC-GOB, 2008); the National Integrated Water Resources Act (GOB, 2010); Belize Horizon 2030 (Barnett et al., 2011); the National Energy Policy Framework, 2011: Towards Efficiency, Sustainability, and Resilience for Belize in the 21st Century (GOB-MESTPU, 2012); the National Sustainable Tourism Master Plan 2030 (GOB, 2012); the National Climate Change Policy, Strategy and Action Plan 2015 – 2020 (CCCCC-GOB, 2015); the Growth and Sustainable Development Strategy (GOB, 2015); the National Agenda for Sustainable Development (GOB, 2015); Belize's Third National Communication to the United Nations Framework Convention on Climate Change (CCCCC/GOB, 2016); Belize Nationally Determined Contribution under the UNFCCC (GOB/NCCO, 2016); Belize Sustainable Energy Strategy and Action Plan 2014 (GOB-MESTPU, 2015); Belize Sustainable Energy Roadmap to 2035; and regionally, 'Delivering Transformational Change 2011-2021: Implementing the CARICOM "Regional Framework for Achieving Development Resilient to Climate Change"', (CARICOM-CCCCC, 2012), among others.

1.2.1 National Sustainable Tourism Master Plan of Belize 2030

The National Sustainable Tourism Master Plan 2030 (NSTMP) aims to achieve a set of quantitative and qualitative specific objectives by 2030 (GOB, 2012). This Master Plan sets out the strategy and action plan which is expected to take Belize into the future with a dynamic, competitive, and sustainable tourism industry. The Master Plan defines the NSTMP structures and programs, and the strategic approaches that should guide its implementation. The Plan also outlines a framework to organize activities to attract funding from different sources.

The NSTMP list of objectives are as follows:

- To increase tourism arrivals and tourism movement within the region and the country.
- To reduce health hazards and visual and environmental pollution.
- To reduce consumption of scarce resources.
- To improve application of green technologies recycling and energy conservation.
- To enhance transportation capacity by meeting increasing tourist arrivals and flows.
- To enhance transport safety and reliability.
- To enhance the tourism destination's competitiveness.
- To increase the tourism satisfaction level.

The NSTMP describes Belize as a tourism destination characterized by its excellent natural resources and strong cultural heritage that make it possible for eco-tourism, adventure and cultural tourism to flourish as its main tourism motivations (GOB, 2012). The NSTMP also describes Belize as host to four "unique tourism assets" which are accredited with international recognition. These assets are the Belize Barrier Reef Reserve System, the Blue Hole Natural Monument, the Caracol Mayan site, and the Chiquibul Caves System.

Opportunities for development of the tourism sector are offered through the national and natural assets. The rich cultural history is reflected in numerous Archaeological sites, many of which are Mayan sites that remain covered and difficult to access by road. The diverse ethnicity of the Belizean population provides a unique opportunity for visitors to experience. The geographic location of the country bridging the Central American and the Caribbean sub-regions also offers great opportunity for further tourism development. The relatively underdeveloped condition offers great opportunity to foster tourism growth guided by sustainable development criteria.

The NSTMP illustrates some of the constraints affecting tourism development which include: inaccessibility by land to some tourist attractions due mainly to poor road conditions; restricted accessibility by air, due mainly to the limited international flight connections from tourist origins like Europe; scarcity of Belizean-made handicrafts; inadequate management of Belize's natural, cultural & historical assets, due mainly because of the lack of public awareness and education of the importance of these assets; inadequate waste disposal and sewage systems, resulting in unhealthy conditions and pollution; threats to Belize's coastal zone and marine ecosystems related to global warming and climate change; and lack of urban land planning and land use regulation, resulting in haphazard and inadequate urban development, beach erosion, and land use conflict, among others.

The NSTMP recognizes that in order to maximize the positive impacts derived from tourism, the destination must be equipped with basic transportation infrastructure, tourism services, facilities and skilled human resources. Two programs designed to address these issues have been implemented, namely:

1. The upgrading of basic infrastructure and support services, and;
2. Development of national connectivity.

Tourism has become one of Belize's main industries, and in 2015 was the country's number one foreign exchange earner (BTB, 2015), and remain so through 2016. The second quarter of 2015 saw a drop of 3% of total overnight tourist arrivals to Belize compared to the same period in 2014. However, by the fourth quarter of 2015, overnight arrivals were almost 26% above the fourth quarter figure for 2014 (BTB, 2015). The National Sustainable Tourism Master Plan is expected to bring resilience to the sector through the balanced development of all the destinations based on their different potentials.

Stakeholders of the TNA Phase II project in Belize are knowledgeable about Belize's development priorities and have identified those sectors which the project should consider for technology transfer. Sectors for technology consideration related to the tourism development are: water resources, transportation, green technology, and renewable resources for sustainable energy production, consumption and energy efficiency.

1.2.2 Growth and Sustainable Development Strategy 2015–2017

The Growth and Sustainable Development Strategy (GSDS) is the guiding development plan for the period 2015–2018 (GOB, 2015). It adopts an integrated, systemic approach and encompasses medium-term economic development, poverty reduction and longer-term sustainable development issues. The GSDS builds on previous documents especially Horizon 2030: National Development Framework for Belize 2010 – 2030 (GOB, 2015). The GSDS is Belize's primary planning document, providing detailed guidance on priorities and on specific actions to be taken during the planning period. The GSDS is the product of the merger between the National Sustainable Development Strategy (NSDS) 2012 (GOB, 2012) and the Growth and Poverty Reduction Strategy (Catzim-Sanchez, 2015). These strategies were being developed at about the same time by two different government ministries. The stakeholders participating in the development process decided to merge the products. The national sustainable development planning process occurred in stages beginning in 2012 with the incorporation of sustainable development into a ministerial portfolio. In 2014 the objective of the planning process was to replace the Millennium Development Goals (MDGs) with Sustainable Development Goals (SDGs). In 2014 the country received financial and technical support from the United Nations Department of Economic and Social Affairs (UNDESA) and the United Nations Development Programme (UNDP) for the development of the NSDS as a single coherent medium-term development planning document.

Stakeholder consultations were also conducted in 2014 to develop the NSDS. The process of strategy development was completed within the framework of Horizon 2030 (Catzim-Sanchez, 2015). This particular strategy addresses national development priorities.

This Growth and Sustainable Development Strategy adopts an integrated, systemic approach based on the principles of sustainable development, and on three notable drivers that are common to successful developing countries: a proactive role for the state, tapping into global markets, and innovative social policy.

At the core of the GSDS is a hierarchical framework of inter-related goals and objectives called the "Belize Framework for Sustainable Development" (GOB, 2015).The Framework provides the structure for the "Program of Action"; which in turn describes the actions to be taken in realization of the goals and objectives, which are referred to as "Critical Success Factors" ("CSFs") and "Necessary Conditions" for the attainment of the Overall Goal: "To improve the quality of life for all Belizeans, living now and in the future." The GSDS also includes planning guidance on implementation and institutional arrangements, resource mobilization including human resources, capacity development, and monitoring and evaluation of results.

At the core of the GSDS is a commitment to achieve a single overriding goal: to improve the quality of life for all Belizeans, living now and in the future. To achieve this goal, the GSDS provides a strategic framework, a set of clear policy aims, a considered mix of highlighted and prioritized action areas, and guidance on the necessary institutional arrangements and procedures. Specifically, the GSDS identifies four "Critical Success Factors" (CSFs) or subsidiary goals that also provide an organizing framework for the objectives and actions grouped underneath them. Each CSF is also linked to a set of measurable targets. Table 1 is a summary of the Critical Success Factors and corresponding key actions with respect to climate change and development, as illustrated in the GSDS.

Table 1: Growth and Sustainable Development Strategy CFCs and Climate Change

Critical Success Factors (CFCs)	Key Actions with Respect to Climate Change and Development
CFC 1. Optimal National Income and Investment	• coordinate implementation of the National Climate Change Policy, Strategy and Action Plan, and other planning documents. • building institutional capacity to encourage technological adaptation and innovation while also taking into account climate change resilience considerations. • securing investments in expanding electricity, with special emphasis on renewable energy, and articulation of a low-carbon development strategy.
CFC 2. Enhance Social Cohesion and Resilience	• reduce at least by half the proportion of people living in poverty by 2030

CFC 3. Sustained or Improved Health of Natural, Environmental, Historical and Cultural Assets	• an implemented National Land Use Policy and Integrated Planning Framework. • completion of a Water Master Plan, a National Ground Water and Surface Water Assessment and a Water Vulnerability Profile. • implementation of sustainable forest management, including protected areas management as a tool to ensure watershed protection for water and food security. • continued mainstreaming of climate change considerations into national development planning. • completion and implementation of other critical policies, plans and projects in the area of forests, fisheries, oil spill contingency, land-based and marine pollution, readiness for the Green Climate Fund, sustainable livelihoods, and technology for climate change mitigation and adaptation
CFC 4. Enhance Governance and Citizen Security	• pursuing a philosophy of "engaged governance" by setting up institutional arrangements that link citizens and representative organizations more directly to the decision-making process of the state to positively impact their social and economic lives.

1.2.3 National Climate Change Policy, Strategy and Action Plan 2015

Although Belize is an insignificant contributor to global GHG emissions, it is among those countries that are, and will continue to be severely impacted by climate change. Belize has ratified both the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. Recently in 2016, Belize ratified the Paris Agreement.

The Government of Belize (GOB) is cognizant that Climate Change is already having a negative impact on the social, economic and productive sectors; the physical environment including land, and infrastructure; as well as the sustainability of natural resources such as marine and coastal areas, natural ecosystems, and biological diversity (GOB-NCCO, 2016). It also acknowledged that Climate Change will increase the constraints on development which depend on these resources. As a result, the GOB is committed to taking all necessary and feasible actions at the national, regional and international levels to meet the stipulations of the UNFCCC and the Kyoto Protocol, an increase the country's resilience to current and future impacts.

It has thus committed itself to developing, adopting and implementing policies and measures to reduce its carbon footprint, and increase the country's resilience to the adverse effects of Climate Change.

The Government of Belize (GOB) has initiated actions to mainstream Climate Change into its national development processes and mechanisms. These initiatives include the establishment of a National Climate Change Office under the Ministry of Agriculture, Forestry, Fisheries, the

Environment and Sustainable Development (MAFFESD), and the preparation of a comprehensive National Climate Change Policy, Strategy and Action Plan (NCCPSAP) which will provide policy guidance for the development of an appropriate administrative and legislative framework, in harmony with other sectoral policies, for the pursuance of a low-carbon development path for Belize (CCCCC-GOB, 2015; GOB–NCCO, 2016). The Government of Belize has sought to initiate policy-based activities, at the sector level to adapt to and mitigate the impending impacts of Climate Change. Examples of the policy initiatives undertaken to date are as follows:

- Integrated Coastal Zone Management Plan (2013);
- Establishment of the Ministry of Energy, Science, Public Utilities;
- Transport, Communications and National Emergency Management Strategic Plan 2012-2017;
- Sustainable Energy Strategy and Action Plan 2014 for Belize;
- Integrated Water Resource Management Policy (2009);
- Growth and Sustainable Development Strategy 2014 – 2017;
- The National Climate Resilience Investment Plan (2013);
- Belize Sustainable Energy Roadmap to 2035.

The National Climate Change Policy, Strategy, and Action Plan (NCCPSAP) to address Climate Change in Belize (CCCCC-GOB, 2015), was prepared for the Caribbean Community Climate Change Centre (CCCCC) and the Government of Belize, with financing from the European Union Global Climate Change Alliance (EU-GCCA) Caribbean Support Project, and the United Nations Development Programme GEF Third National Communication Project.

The goal of the NCCPSAP is to provide guidance for the short, medium and long-term processes of adaptation and mitigation to Climate Change in accordance with national objectives for sustainable development, in addition to regional and international commitments.

Its objectives are to:

1. Integrate Climate Change adaptation and mitigation into key national development plans, strategies and budgets;
2. Build Climate Change resilience to prevent, reduce or adapt to the negative impacts of Climate Change on key sectors, economic activity, society and the environment through policies and strategic processes;
3. Promote capacity building and networking across all implementing/involved agencies;
4. Source and secure adequate financing over the short, medium and long-term periods for effective and timely adaptation and mitigation responses; and
5. Capitalize on opportunities currently available through Climate Change negotiation processes that can enhance the economic and social development prospects of the nation.

In coordinating the implementation of the NCCPSAP, the National Climate Change Office (NCCO) considers the need to:

a) Facilitate the provision of adequate support on mitigation and adaptation measures to all stakeholders;

b) Monitor the impact of the strategy against the goals and objectives that have been set and;

c) Make appropriate adjustments to the policy and strategy in light of intended or unintended changes in the general environment.

The NCCPSAP is a five-year programme (2015-2020), which is intended to provide the foundation for the country's capacity and resilience to meet the challenges of Climate Change. The Action Plan is divided into two thematic areas namely adaptation and mitigation. The sectors for which adaptation and mitigation strategy and action plans will be addressed are:

- Agriculture
- Forestry
- Fisheries and Aquaculture
- Coastal and Marine Resources
- Water Resources
- Land use and Human Settlements
- Human Health
- Energy
- Tourism
- Transportation
- Solid Waste

The list above includes all "Sectors" selected for attention under the TNA Phase II project in Belize.

The implementation of the NCCPSAP requires the establishment of a coherent, over-arching governance structure, consisting of clear policy directives and supported by an enhanced institutional framework which can provide direction and coordinate the efforts of other entities and Line Ministries, all of which have equally important roles to play in Climate Change adaptation and mitigation. The NCCPSAP recommends that GOB consider the establishment of a Climate Change Department (CCD) in the newly established Ministry of Agriculture, Forestry, Fisheries, the Environment and Sustainable Development, and revise the mandate of the Belize National Climate Change Committee (CCCCC-GOB, 2015).

The CCD is expected to play a crucial role in the coordination, policy direction, oversight and guidance of the Government's Climate Change programme. It will also seek to create partner-ships among various stakeholders to ensure integrated and systematic implementation of the national climate change response agenda.

The re-configuration and streamlining of the Belize National Climate Change Committee (BNCCC) would be to align its perceived role of providing policy guidance and facilitating the mainstreaming of Climate Change adaptation and mitigation efforts. The NCCPSAP proposed that the size of the BNCCC be reduced to a total of eleven (11) members with three sub-committees, namely: 1) Vulnerability Assessment and Adaptation; 2) Mitigation; and 3) Public Education and Outreach.

The NCCPSAP also considers the issue of financial assistance to build resilience and sustainable development. Several funding possibilities have been identified, including locally generated resources, for obtaining the required resources to undertake the structural changes envisaged to address Climate Change adaptation and mitigation. In order to adequately prepare Belize to access those funds it is recommended that GOB establish a Climate Change Trust Fund (CCTF). It is recommended that Trust Fund could be established as a separate entity, but managed initially by the Protected Areas Conservation Trust (PACT). It is also recommended that GOB confers on PACT, responsibility for the management of that Fund. It is recommended that Cabinet establish a Climate Change Finance Committee (CCFC) as a standing committee of the PACT whose main function will be resource mobilization in support of climate change related interventions.

Recommendation for the full implementation of the NCCSAP is a call for the Cabinet to give approval to the following:

a) Adopt the National Climate Change Policy and Strategy as the official government policy and strategy to enable the country achieve the adaptation and mitigation goals.
b) Amend key sectoral laws to make them consistent with the UNFCCC and to ensure that all actions under the Ministry responsible for Climate Change have the legislative basis to be implemented and translated from concept to practice.
c) Establish a Climate Change Department in the Ministry responsible for Climate Change with the role of primary coordination, policy direction, oversight and guidance across all levels of government.
d) Approve the revised mandate of the BNCCC to provide policy guidance and oversee the operations of the CCD. Among the duties of the BNCCC will be the regular revision of the NCCPSAP.
e) Establish a Climate Change Trust Fund, confer on PACT, responsibility for the management of that Fund, and establish a Climate Change Finance Committee as a standing committee of the PACT.

The country has also embarked on several other initiatives to review sector policies, legislation and measures which will address issues of adaptation and mitigation in sectors most vulnerable to the impacts of Climate Change. These include projects that are currently being implemented, such as:

- The Marine Conservation and Climate Change Adaptation Project (MCCAP) (GOB-Fisheries Dep./WB/TNC, 2011; BET, 2015), and the

- Management and Protection of Key Biodiversity Areas (World Bank, 2014)

In addition, other initiatives have been carried out towards the development of policies to address climate change adaptation and mitigation in other sectors including:

- The National Agriculture Sector Adaptation Strategy and Action Plan to Address Climate (FAO, 2010).

- Readiness Preparation Proposal (R-PP) to the Forest Carbon Partnership Facility (UNREDD-WB/FCPF, 2014).

1.2.4 Belize's Nationally Determined Contributions

In early 2016, Belize submitted a first draft of its Nationally Determined Contribution (NDC) to the UNFCCC, with the intention to utilize existing frameworks, policies, projects and activities that provide mitigation and sustainable development co-benefits to realized its objectives (GOB/NCCO, 2016).

Belize's NDC highlights key sectors for which adaptation and mitigation strategy and action plans will be addressed. These include: Agriculture, Forestry, Fisheries and Aquaculture, Coastal and Marine Resources, Water Resources, Land use and Human Settlements, Human Health, Energy, Tourism, Transportation, Solid Waste, and Infrastructure.

Belize's NDC is consistent with the over-arching goal of the Growth and Sustainable Development Strategy (GSDS), which integrate medium-term economic development, poverty reduction, and longer-term sustainable development. The GSDS is the country's primary development blueprint, and outlines four critical success factors for national development and a better way of life for its citizens today and in the future.

The climate change mitigation potential of Belize according to the NDC, is action-based among multiple sectors, namely: forestry, energy (electricity), waste and transport.

1.2.5 Low Carbon Development Roadmap

In order to achieve the goal of reducing the country's carbon footprint, a national roadmap was developed that created a framework for low carbon growth in residential, commercial and industrial sectors while ensuring that national growth remains robust (Cocco, *et al.,* 2014 – South Pole Group). The roadmap was based on local considerations, best management practices and key stakeholders' consultations. The phases of the road map are as follows:

Phase I: (short-term, horizon 2015). This phase focused on urgent needs at the technical, policy, and institutional levels, namely updating the GHG inventory and setting GHG emission reduction targets, finalizing the National Climate Change Policy, Strategy, and Action Plan, and reforming/building capacity for key institutions to reinforce Climate Change management.

Phase II: (medium-term, horizon 2020). This phase focused on building technical capacity, strengthening institutions and policies, facilitating public-private partnerships and engaging stakeholders to adopt sustainable practices, designing technical tools such as Baseline Scenarios, and Mitigation Abatement Curves (MAC), along with developing and operating policy instruments tailor-made for the identified priority sectors, while implementing current sustainable plans.

Government of Belize: Moving towards a Low Carbon Development Path

The GOB has always kept a strong focus on sustainable development and decoupling its economic growth from the rise in its emissions levels. In April of 2016, the GOB submitted its Nationally Determined Contribution to the United Nations Framework Convention on Climate Change (UNFCCC), as part of its contribution to achieving the ultimate international goal on climate change, with the aim of keeping global temperature rise well below 2 °C (GOB-NCCO, 2016).

The GOB is also part of the "Pilot Country" initiative of the United Nations Department of Economic and Social Affairs (UNDESA). This initiative provides capacity development assistance to Belize to better integrate approaches to national planning that are in harmony with the Sustainable Development Goals (SDGs).

Since 2014, the GOB has worked with South Pole Group as strategic partner for the development of three mandates with the aim of creating a Low Carbon Development Strategy (LCDS).

The first activity in 2014 was the identification of priority mitigation projects and their linkages to the global carbon market, so as to identify the ones with highest potential that can be packaged into the Nationally Appropriate Mitigation Actions or NAMA

Secondly, in 2015 the objective was to design and implement a capacity building program and to create a roadmap for the development and implementation of a LCDS. Finally, in 2016, the goal was to update the LCD roadmap and align it to Belize's most recent public policy document, the Growth and Sustainable Development Strategy (GSDS).

Source: South Pole Group, 2016.
http://thesouthpolegroup.com/client/belize-case-study-1

The outcomes of the activities brought to light areas of opportunity to decouple economic growth from carbon emissions. They also provided a sound list of projects with the potential of delivering tangible sustainable development benefits. Together, these outcomes have strengthened Belize's Low Carbon Development (LCD) path, while helping the country reach its sustainable development goals and contribute to a brighter and cleaner future for all (South Pole Group, 2016).

1.2.6 Horizon 2030

Horizon 2030 is a national, long-term development planning framework that embraces all sectors for Belize. It was developed through a national consultation process that occurred

across the country and it envisions Belize as a "*country of peace and tranquillity where citizens live in harmony with the natural environment and enjoy a high quality of life. Belizeans are energetic, resourceful and independent people looking after their own development in a sustainable way*" (Barnett *et al.*, 2010). The Horizon 2030 framework addresses national development planning through several thematic areas covered under four main headings or "pillars", but this report will only describe two of the pillars that appear to be most relevant to national planning and sustainable development.

Pillar 1: Democratic Governance for effective public Administration and Sustainable Development.

The consultations held during the preparation of Horizon 2030 took stakeholders' opinions and perspectives into consideration. The national consultations indicated that there was much evidence of breakdown in the governance structure and the social fabric, but the majority of citizens felt that the situation can be fixed. The goals for democratic governance are:

- Strong "watchdog" groups in the non-government sector to hold politicians accountable.
- Persons in public life demonstrate the highest ethical standards.
- Government departments are free of corruption, modernized and focused on providing quality service to the public.
- Party politics is in its proper place so that it is less intrusive and divisive in the daily lives of citizens.
- Critical aspects of the political reform process are completed.

Pillar 3: Economic Resilience: Generating Resources for long-term development.

The key economic goals for 2030 under this "Pillar" are to building economic resilience, promoting productivity and competitiveness, and ensuring the environmental sustainability of economic activity by:

- Increasing agricultural production in a sustainable way and increase local value - added through the development of agro-processing.

- Ensuring a sustainable and profitable tourism sector.

- Developing a strong small business sector, a strong work force, and a strong corps of entrepreneurs.

- Ensuring that government is able to make timely investments in key economic infrastructure.

Strategies to realize the goals under this heading include promoting and developing the domestic market through better regulation of illegal imports; make key public investments in economic infrastructure — especially the road network and transportation system; promote investment in agriculture, local manufacturing, agro-processing and other productive activities; support reforestation and sustainable logging by local communities to create jobs and reduce poverty; foster entrepreneurship among young people, and invest in science and technology education to promote innovation, and reduce the costs of access to technology.

This is an overarching vision for sustainable development across all sectors in Belize, and indirectly justifies the selection of technologies suggested in this report.

1.2.7 National Energy Policy Framework 2011-2012

A first draft of this document was produced in 2011, and updated in 2012. It was the result of the effort of the Ministry of Energy, Science and Technology, and Public Utilities to develop a National Energy Policy. The document entitled "National Energy Policy Framework, 2011: Towards Efficiency, Sustainability, and Resilience for Belize in the 21st Century" (GOB-MESTPU, 2012) was developed to chart a course for Belize to achieve energy efficiency, sustainability and resilience over the next 30 years. It provides policy recommendations to policy-makers and decision-makers, and discusses the pros and cons of various policy instruments that can be used to achieve policy objectives. It is therefore a proposed roadmap of what the goal is, how to reach that goal, and what it will take to achieve that goal.

While the National Energy Policy Framework outlines mitigation measures in the Energy sector to reduce GHG emissions, technologies which utilize renewable energy from natural resources are crucial. Resources such as hydro, biomass, solar, and wind are probably not fully explored as yet, so opportunities to apply these technologies still exist. The National Energy Policy Framework proposes actions to develop other means of generating and utilizing energy to build resilience within this sector in Belize.

The National Energy Policy Framework recommends the following:

1) Establish a National Energy and Electricity Planning Institute with responsibility for formulating energy plans and policies in coordination with selected stakeholders, for disseminating these policies and plans to relevant stakeholders, and for monitoring and enforcing adherence to the plans and policies by the bodies charged with administering them.

2) Create an Energy Sector Planning Framework to guide the process of formulating a least-cost, long-term plan for future development of the Belize energy sector along the path of sustainability and resilience (National Energy Policy Framework, 2011).

The Energy sector in Belize offers opportunities to invest in mitigation and adaptation technologies.

1.2.8 Belize Sustainable Energy Roadmap to 2035

The overarching objective of the Energy Roadmap to 2035 is to raise the standard of living of Belizeans and meet Belize's Sustainable Development Goals for 2020 and beyond.

The principal strategic components of Belize's Sustainable Energy Roadmap (GOB-MESTPU, 2016c) are as follow:

- *Energy Efficiency* in

  i) appliances and buildings,
  ii) transport.

The aim of interventions for appliances and buildings is to improve these product markets, using a combination of market/financial instruments with standards/codes to enhance widespread adoption of technologies and products superior in quality and lower costs. In the case of transport, the purpose of the intervention is to support national goals and international commitments under the SDGs and NDC for affordable and accessible mobility through energy policies that encourage the use of cleaner fuels and improved vehicle technologies.

- *Renewable Energy*

The aim is to shift the energy use away from fossil-base fuels to alternative renewable energy technologies.

- *Clean Production*

The objective here is to upgrade production systems in agriculture and forestry to use less energy and related raw materials, increase productivity, improve waste management practices and co-produce a range of energy products such as bio-fuels and/or electricity.

- *Modernizing the Energy Infrastructure*

Introduce smart electric grid that is more unified and integrated.

- *Universal Access*

Universal access is an essential pillar of the country's energy strategy. Modern energy services are key to socio-economic development and critical to lifting living standards. The 2020 target is the achievement of universal access to electricity by the end of the decade.

1.2.9 Implementing CARICOM's "Regional Framework for Achieving Development Resilient to Climate Change"

At the regional level, Caribbean states (SIDS) including Belize, have formulated and agreed on a number of declarations and strategy for transformational change in light of the imminent threats posed by climate change on the region's socio-economic development (CARICOM-CCCCC, 2012).

The declarations call for:

i) Long term stabilization of the GHG concentrations at levels which will ensure that global average surface temperature increase will be limited to below 1.5 °C of pre-industrial level; Global GHG emissions should peak by 2015, and ultimately reducing GHG emission by more than 95% of 1990 CO_2 levels by 2050.

ii) Adaptation and capacity-building must be prioritized and a formal and well-financed framework established within and outside the UNFCCC to address the immediate and urgent, as well as the long-term adaptation needs.

iii) Need for financial support for SIDS to enhance their capacities to respond to the challenges brought on by climate change, and to access the technologies required to undertake needed mitigation actions, and to adapt to the adverse impacts of climate change.

The proposed strategic elements to significantly increase the resilience of CARICOM member states' social, economic and environmental systems are:

- Mainstream climate change adaptation strategies in the sustainable development agendas of member states;
- Promote the implementation of specific adaptation measures to address key vulnerabilities in the region;
- Promote actions to reduce greenhouse gas emissions though fossil fuel reduction and conservation, and changing over to renewable and cleaner energy (mitigation);
- Encourage actions to reduce the vulnerability of natural and human systems to the impacts of changing climate; and
- Promote actions to derive social, economic, and environmental benefits through the prudent management of standing forest in CARICOM countries. Figure 1 below is an illustration of the high-level overview of the Regional Implementation Plan.

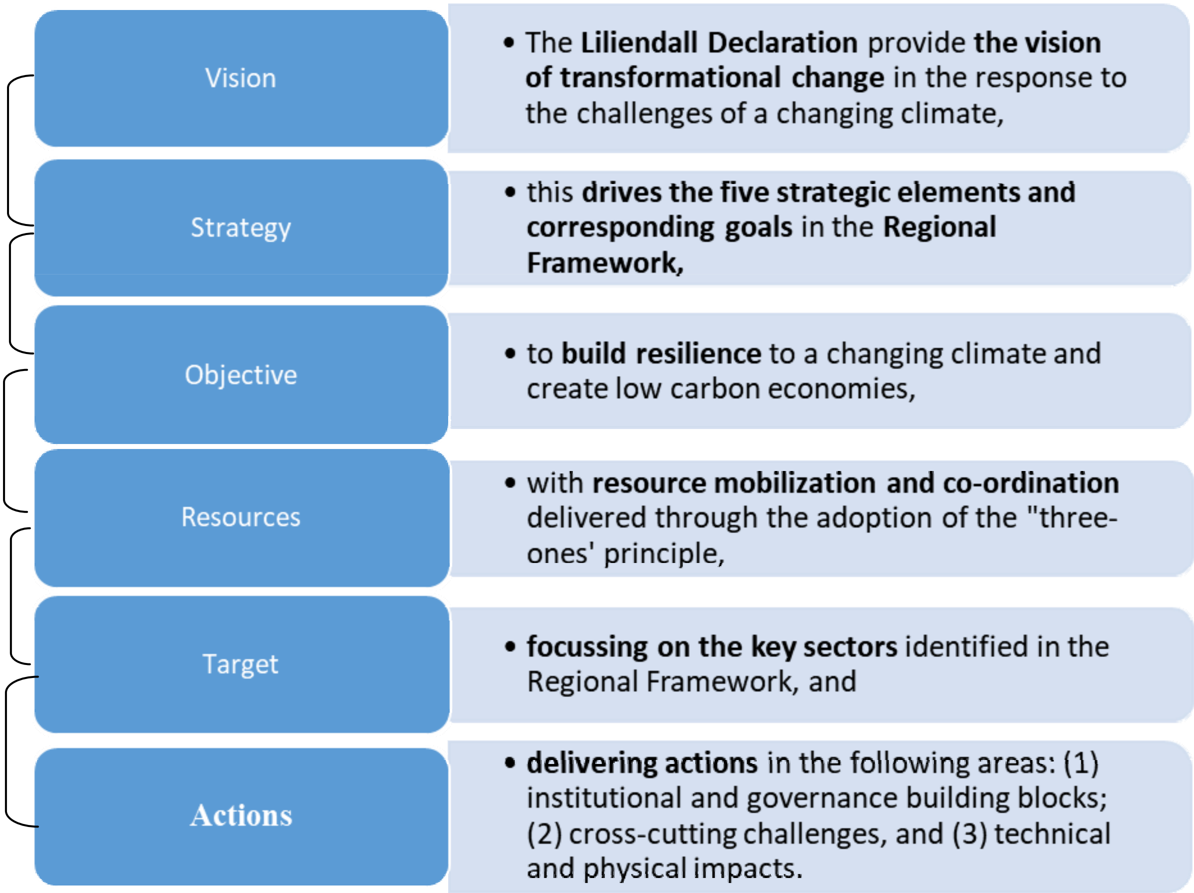


Figure 1: High Level Overview of Implementation Plan

Sectors identified in the Regional Framework are illustrated in Figure 2. As can be observed, impacts in one sector has consequences and feedback on the others.

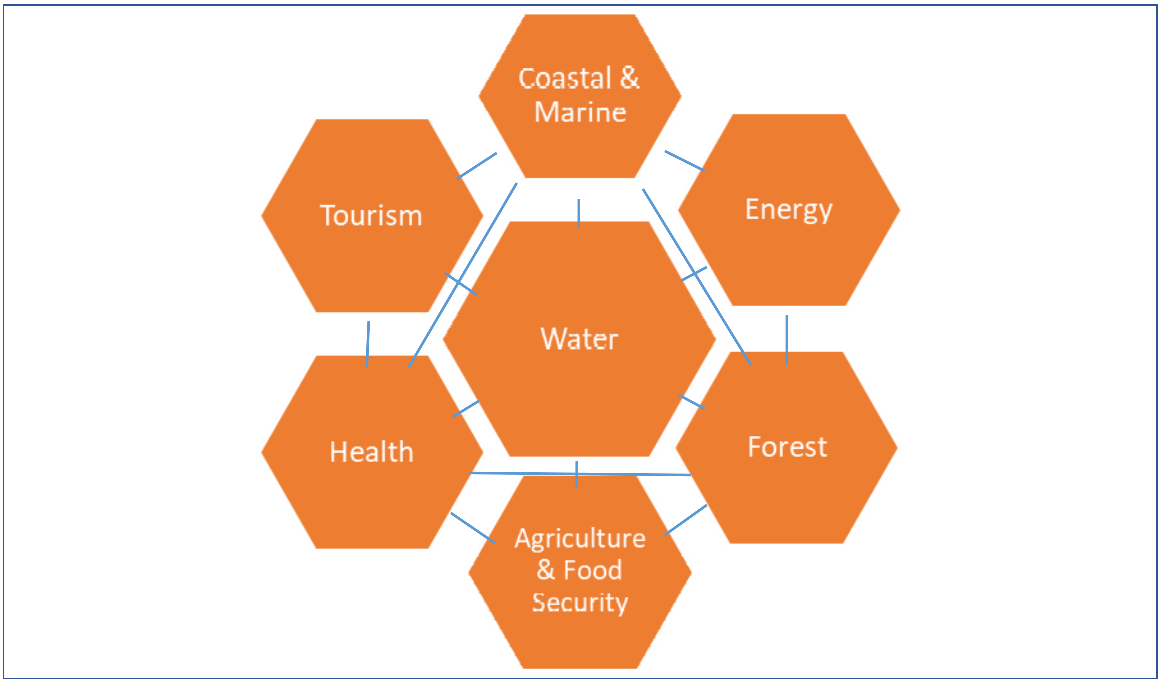


Figure 2: Consequences and Feedback of Impacts Among Sectors

1.2.10 The Paris Agreement

The Paris Agreement aims to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius (UNFCCC, 2016). Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. To reach these ambitious goals, appropriate financial flows, a new technology framework and an enhanced capacity building framework will be put in place, thus supporting action by developing countries and the most vulnerable countries, in line with their own national objectives.

1.2.11 Nationally Appropriate Mitigation Actions

The Belize Government is committed to transition to low carbon development and concurrently, strengthen the country's resilience to the negative impacts of climate change (GOB-NCCO, 2016 a). Through the Nationally Appropriate Mitigation Actions (NAMAs) initiative, Belize has identified and prioritized two mitigation activities in the Energy and Waste Management sectors for a Mitigation Project Portfolio for funding. This was conducted by consultants (Cocco, M., Koch, F., Singh, H., 2014 — South Pole Group Ltd.) in coordination with the National Climate Change Office, and in collaboration with relevant stakeholders, namely: the Belize Trade and Investment Development Service (BELTRAIDE), the Ministry of Energy, Science, Technology and Public Utilities (MESTPU), and the Belize Solid Waste Management Authority ((SWMA).

The two NAMAS being considered are: *On-grid Feed-in-Tariff + Off-grid Subsidy Scheme for RE Generation*, and *Non-Industrial Waste (Household + Municipal) Waste Management Program*.

- **On-grid Feed-in-Tariff + Off-grid Subsidy Scheme for RE Generation**

This NAMA consists of a multi-technology renewable energy mitigation action for grid-connected and off-grid generation. The technologies include: wind, solar (both PV and Thermal), hydro (especially mini and pico hydro), and biomass power generation.

The Programme will be administered by the Ministry of Energy and operated by a designated NAMA Entity. A draft NAMA design document was presented at the COP 21 in Paris (December 2015). Further steps of NAMA Development (namely, Detailed Design and Piloting) will continue in 2015-2020 with the objective to have the NAMA implemented and fully operational by 2020.

The NAMA will help to reduce CO_2 emissions, namely through the promotion of Renewable Energy sources and fuel switching activities that would replace fossil fuel-based energy generation (and electricity imports from Mexico).

- **Non-industrial Waste (Household + Municipal) Waste Management Program**

The Government of Belize is expanding its nation-wide Waste Management program to improved waste management practices for non-industrial waste. When fully implemented, the program me will target waste management at the household level (for both human and animal waste), and municipal landfills, basically using composting techniques.

The Belize Solid Waste Management Authority (under the supervision of the Ministry of Energy, the Ministry of Agriculture, Fisheries, Forestry, the Environment and Sustainable Development, and the Ministry of Natural Resources and) will spearhead the operation through a designated NAMA entity. It is planned that the present NAMA will undergo a concept designed phase, followed by a more detailed designed and piloting phase during 2015-2020, with the objective of having the NAMA fully implemented and operational by 2020.

The NAMA will help to reduce CH_4 (methane) emissions, namely through the promotion of non-industrial Waste Management activities that would reduce methane emissions through improved practices and utilization of methane to produce energy (thermal and electricity).

The policy target of this NAMA is to improve present waste management practices above baseline levels. To establish the emission factor baseline, and given the unavailability of data, the following basic assumptions were made during the drafting of this NAMA:

- The waste composition is assumed to be constant across the country.
- Global warming potential for CH_4 is 25 times the CO_2 potential.
- The calculations are based on the Small-Scale CDM Tool for estimation of emissions from dumping of municipal solid waste disposal sites, 'Emissions from Solid Waste Disposal Site'.

- The amount of emissions per ton for the next 20 years is estimated to be increasing from 0.2 to 0.8. tCO_2 /ton of waste.

A recent, third NAMA in the Energy Sector submitted to the NCCO for review and development (NCCO/MESTPU, July 2017) was:

- **Solar Water Heating (SWH) NAMA Concept for Industrial, Commercial and Residential Sectors in Belize**

The objective of a solar water heating NAMA in Belize is to address the lack of access to cost-effective, safe and sustainable renewable energy source for water heating for the industrial, commercial and residential sectors, thereby reducing the demands for conventional, fossil-based electric energy for such purpose.

The implementation of this NAMA will potentially result in the reduction of GHG emissions and may also have other non-emission reduction impacts, such as potential, sustainable development benefits arising from increased commercialization and utilization of solar water heating systems in Belize.

Some of the barriers identified in the draft SWH NAMA are:

i. Accessing star-up capital: Difficulties to find investment capital from banks, despite having contracts with the government.
ii. Sustaining regulatory support: Uncertainty because of modifications in tax regulations.
iii. Developing an effective product.
iv. Building consumer awareness and marketing

1.2.12 Motor Vehicle and Road Traffic Act, Revised Edition 2000

The Motor Vehicles and Road Traffic Act, establishes a Transport Advisory Council, that shall advise the Minister on all policy matters such as: road transport, traffic, fees and charges, vehicle licensing, among others (Section 6). The Act allows the Minister to make regulations to: define the use and road worthiness of buses (Section 112), restrict certain vehicles from entering the country and levy fees to control the entry of specified classes of vehicles (Section 112(1), (GOB, 2000).

1.3 National Circumstances

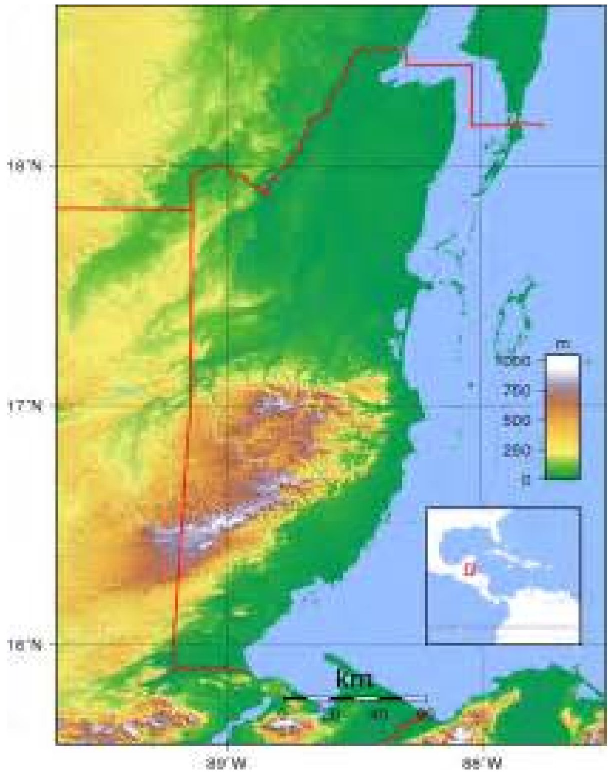
1.3.1 Physical Features

Belize is a small, independent country located on the east coast of Central America along the southern fringes of the Yucatan Peninsula. The country is bounded on the north by Mexico, on the south and west by Guatemala, and on the East by the Caribbean Sea (See Figure 3 and Figure 4: Physical & Political maps of Belize). The country's total area is 22,966 km^2 (8,867 sq. mile) of which 95% is located on the mainland and five per cent is distributed among more than 1,000 islands or cayes. There are about 1,540 km^2 (595 sq. mile) of lagoons on the mainland, reducing effective land area to some 21,420 km^2 (8,270 sq. mile). The total national territory, including territorial sea is 46,629 km^2 or approximately 18,000 sq. mile. The average dimensions of Belize rectangle are about 260 km north-south and 180 km east-west. The land is generally low, with most of the coastal plain and northern areas below 100 m above mean sea level. The elevation rises toward the southwest in the Maya Mountains that straddle the SW portion of the territory.

The oldest rocks in Belize are found in the Maya Mountains. The Victoria Peak is located in the Cockscomb Range and has an elevation of 1,120 m (3,675 ft.). However, the highest elevation in Belize is Doyle's Delight at 1,124 m (3,689 ft.).

Despite its relatively small size, Belize boasts a wealth of natural resources. Among them is an extensive barrier reef along its approximately 386 km of coast, which comprises the single, largest portion of the Mesoamerican Barrier Reef, a system that extends for approximately 1,000 km across several countries and is the largest reef system in the Western Hemisphere (Burke and Sugg, 2006). Belize also has a wealth of flora and fauna of at least 1,014 native species of vertebrates and 3,411 native species of plants, approximately 69.0 percent of forested land area, and 18 major river watersheds (CSO, 2004a). There are over 100 protected areas that cover 34.9 percent of the country's total land area and about 10.6 percent of the total sea area (LIC, 2009). In total, protected areas cover 22.8 percent of the national territory.

Belize has six districts, nine municipalities and some 197 villages. The capital and the seat of Government is Belmopan, located about 50 miles inland from the coast, in the Cayo District.



Physical map of Belize

Political map of Belize

Figure 3: Physical and political maps of Belize

1.3.1.1 Climate

The climate of Belize is sub-tropical, characterized by seasonal rainfall with local variation from north to south, evident by a pronounced wet and a dry season. The rainy season extends from June to November and the dry season from March to May. A cool, moist transition period extends from December to February, marked by northerly winds associated with the frequent incursions of arctic air masses from the continental USA and Canada. Historic mean, annual rainfall ranges from 60 inches (1,524 mm) in the northern districts to 160 inches (4,064 mm) in the south. Figure 4 is an isohyet map of the 1960-90 mean, annual, rainfall across Belize. The cool, transition period rainfall (DJF) contributes about 16% to the total, annual value.

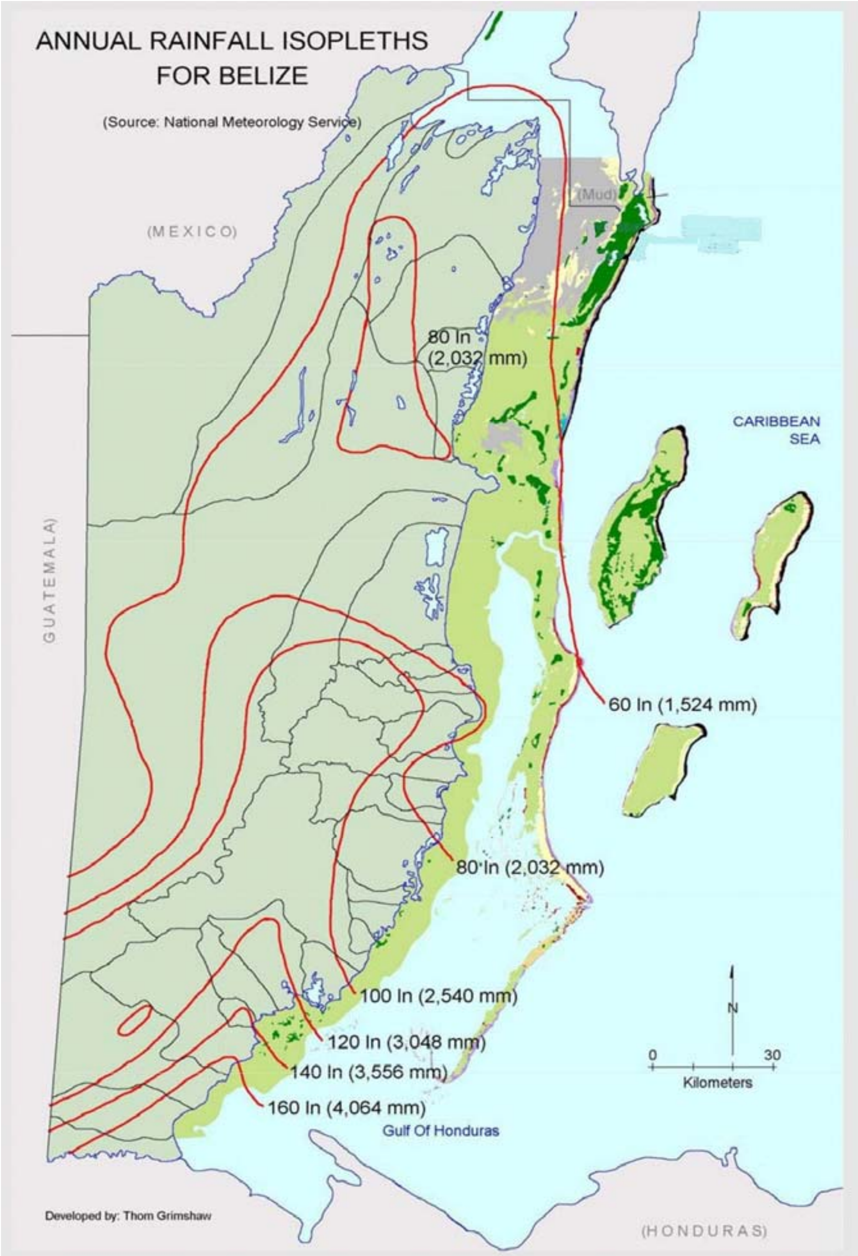


Figure 4: Mean annual rainfall in Belize

The rainfall regime is bi-modal over central and northern Belize, with rainfall peaks in June-July and September-October. A short break in rainfall occurs in August, known locally as the "*meagre*" season or mid-summer drought. In the south, the mid-summer dry spell is less pronounced and the rainfall regime is modal, with peak rainfall in September-October.

Seasonal differences in rainfall are greatest in central and northern localities, where monthly rainfall less than 100 mm is not unusual in March and April. The dry season is longer in central and northern regions (Mid-February to May), while in the south, the dry season extends from March through mid-May.

Surface air temperatures in Belize are moderated by the Caribbean Sea, such that the coastal zone exhibits a maritime climate, while the local climate in the interior is more extreme, particularly during the height of the dry season, and during significant change in air mass during the cool, moist, transition period. Mean annual temperature in Belize ranges from 27 °C along the coast to 21 °C in the interior, with the coldest month being January and the warmest temperatures experienced in April-May. The night-time minimum temperature can drop to 10 °C or less in the higher elevation of the Mountain Pine Ridge in extreme cold spell events (NMS, 2016; GOB-CCCCC, 2014). The mean, daily humidity ranges from near 82 % in the coastal zone to near 78 % in the interior (www.hydromet.gov, NMS 2016). The humidity is generally higher in the summer months (June–August).

1.3.1.2 Tropical cyclones

A review of the North Atlantic hurricane annals for the past 107 years reveals that Belize sits snugly along the re-curving track of the infamous Cape Verde Islands hurricanes, and along the pathway of the western Caribbean storms that so often ravaged Central America with deadly force, and end up exhausting their latent energy over some part of country, before regaining their strength once they are over the warmer waters of the southwestern Gulf of Mexico.

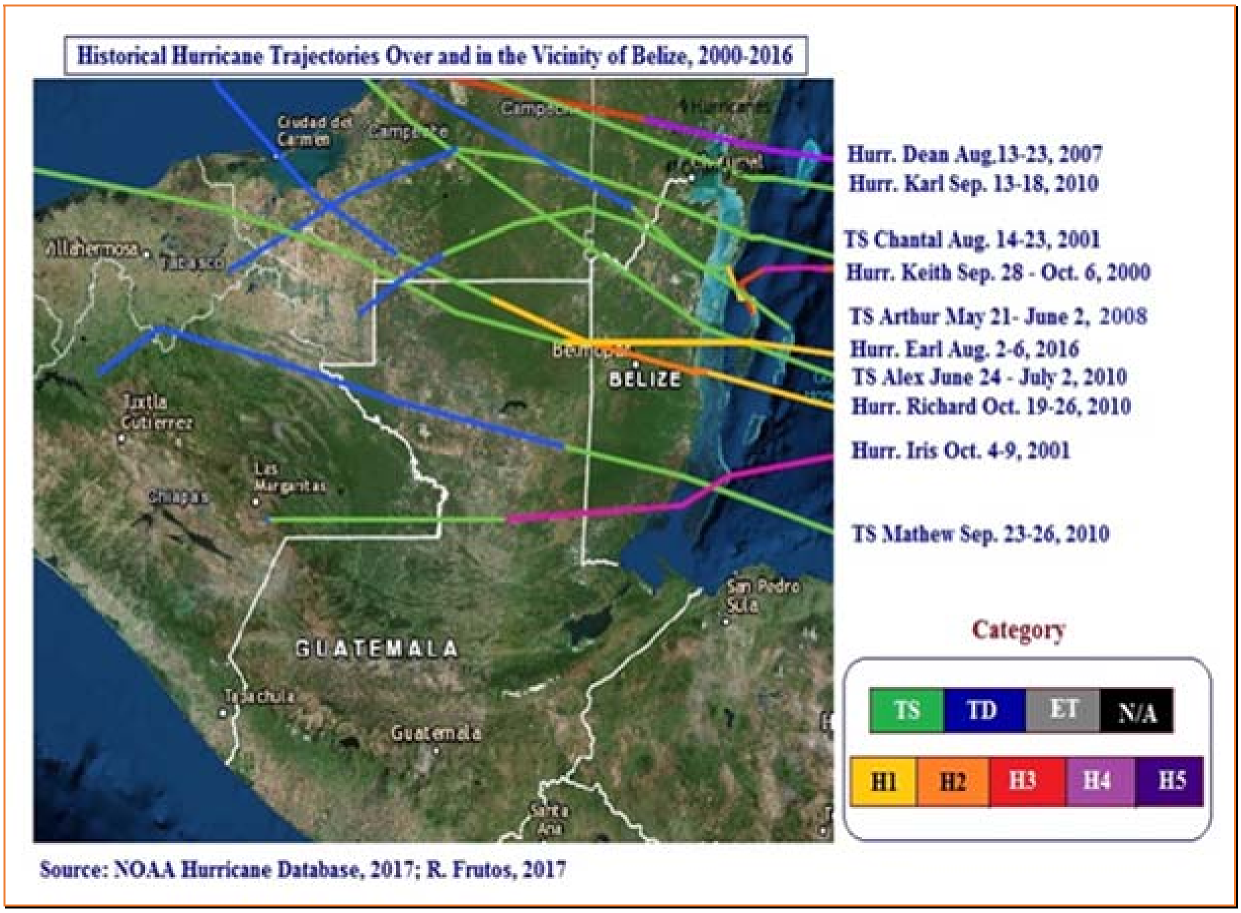


Figure 5: Tracks of land-falling tropical cyclones over Belize (2000-2016)

Updated analysis based on hurricane tracking maps and reports since 2000 showed that nine (9) hurricanes and four (4) tropical storms affected Belize. Ten (10) of these tropical cyclones impacted the northern Cayes (pronounced Keys), and northern and central zones of the country, with torrential rainfall, storm surge and sustained, hurricane force winds, resulting in extensive beach erosions, coastal and inland flooding, infrastructural damage, degradation of forests and agricultural assets, and the loss of human life. Figure 5 is a map showing the trajectories of these tropical cyclones. Table 3 is a list of the recent hurricanes that significantly impacted the coastal zone. Foremost among these were Hurricane Keith of September-October 2000, Hurricane Richard of October 2010 and Earl of August, 2016.

Table 2: List of Some Major Tropical Cyclones that Affected Belize

Hurricane	CAT	Landfall Date	Max Wind at Landfall	Impacts and Damage US $
Hattie	4	31 Oct. 1961	150 mph	Land fall was just south of Belize City, generating a 15 feet storm surge. Destroyed forests and generated extreme flood conditions. Large acreage of bushfire scars during subsequent years following landfall.
Greta	3	19 Sep. 1978	110 mph	Made landfall near Dangriga Town; produced torrential rainfall in the Maya Mountains and northern Belize. Losses US $25 million.
Hurricane Mitch	5	1998		Dangerous Hurricane Mitch threaten Belize, powerful wave actions degraded beach fronts, but Mitch moved southward across the Bay Islands & Honduras Serious coral bleaching and die-off on reefs. The rains associated with Mitch generated flooding in the lower Belize River watershed, and large-scale evacuation of families from the Cayes and the coastal zone, including Belize City. Approximately 30,000 persons evacuated.
Hurricane Keith	4	29 Sep. – 2 Oct., 2000	135 mph	Powerful Hurricane Keith impacted San Pedro, Ambergris with a storm surge of 4 – 5 feet, and caused extensive beach erosion. Torrential rainfall accompanying the hurricane provoked record-setting floods in the Belize River Valley and the lower Belize River watershed. Keith set the record for the highest 24-hour rainfall of 482 mm at the Philip Goldson International Airport Met Station; now considered a 1:100-year event. Damage: US$ 204.8 million.
Tropical Storm		26 May – 2 June 2010		Formed just offshore central Belize from the remnants of

Arthur				Pacific tropical storm Alma. Produce flooding over central and northern Belize. Damage: US$ 42.8 million.
Tropical Depression 16		October 2010		Remnants of TD 16 generated torrential rainfall and extensive floods in the Belize River Valley and the project zone that inundated several sections of the Philip Goldson Highway (PGHW). Damage: US$ 1.4 million.
Richard	1	Oct. 24,2010	90 mph	• Cat 1 Hurricane Richard tracked over southern Turneffe Atoll and made landfall near Gales Points. Gale force winds damage much of the vegetation along the storm path. Broken and fallen tress cluttered the stream channels, and the dry matter became fuel for widespread bush fire in the very active 2011 Fire Season. Damage: US$ 24.6 million.
Earl	1	August 3, 2016	90 mph	Hurricane Earl made landfall over Southern Belize district on August 3, producing a storm surge of 2 – 3 feet and widespread beach erosion and localized coastal flooding. Damage: US$ 56.8 million.

(Source: CRRE, 2013; NMS, 2016; NOAA, 2016)

Table 3 is a summary of the estimated loss is USD resulting from land falling hurricanes in Belize over the past two decades. The costliest tropical cyclone in the recent past to impact Belize was Category-4 Hurricane Keith of October, 2000. The total in losses was estimated at USD 205 million. Hurricane Keith also set the record for the highest, one-day rainfall of 457 mm at the Philip Goldson Airport, 536 mm at Saint John’s College, Belize City, and 448 mm at La Milpa, Orange Walk District (Golder Associates, Feasibility Study for Philip Goldson Highway rehabilitation, July 2017).

Table 3: Costs of Impacts caused by Land falling Tropical Cyclones in Belize (2000-2016)

No.	EVENT	Date	Sector	Direct Cost	Indirect Cost	Total Damage
			Impacted	USD	USD	USD
1	Hurr. Keith	Oct 1, 2000	All	204,779,630	0	204,779,630
2	TS Chantal	Aug. 22, 2001	All	8,737,005	11,771,000	20,508,005
3	Hurr. Iris	Oct. 8, 2001	All	107,841,500	53,250,925	161,092,425
4	Hurr. Dean	Sep. 21, 2007	All	50,279,000	45,350,000	95,629,000
5	TS Arthur	May 31, 2008	All	42,806,908	0	42,806,908
6	TD 16	Oct. 30, 2008	All	1,390,937	0	1,390,937
7	Richard	Oct. 24,2010	All	24,590,000	0	24,590,000
8	Earl	Aug. 4, 2016	All	56,750,000	0	56,750,000
					Total	**607,546,905**

The frequency of tropical storms and categories of hurricanes making landfall over Belize have varied over the past 118 years (Table 4). Three Category 3 hurricanes, two Category 4 hurricanes, and two Category 5 hurricanes affected Belize during the period (1889-2008). Since June, 2000, five tropical cyclones have affected Belize. Notably one of the category 3 (Keith), one of the category 4 (Iris), and one of the category 5 (Dean) hurricanes that have affected the country were in this decade.

Table 4: Return Period of land-falling tropical cyclones in Belize (GOB, 2007)

Intensity	Events	Return Period
Tropical Storm	32	1 in 4.42 years
Category 1	7	1 in 12 years
Category 2	6	1 in 15.5 years
Category 3	3	1 in 34.5 years
Category 4	2	1 in 40 years
Category 5	2	in 52 years

In summary, the return period for a category 5 hurricane is about once every fifty years. However, a category five hurricane is possible in the western Caribbean in any season, particularly during the 10-15-year cycle of seasonal Accumulated Cyclone Energy (ACE) upsurge, as was the case between 1995-2010, and 1960–1979.

1.3.1.3 Watersheds

Belize's has 16 major watersheds which originate in the Maya mountains and discharge into the Caribbean Sea. Five of these watersheds are transboundary river basins shared with the neighbouring countries of Guatemala and Mexico (see illustrated regional map in Figure 7). The mainland of Belize has many rivers, waterways, inland and coastal lagoons, wetlands and swamps (CCCCC, 2014). Most of the wetlands are found along coastal and northern regions of the country. A variety of terrestrial, marine, and freshwater ecosystems form part of the tourism attraction of Belize, but are equally important for their environmental and economic importance. The national ecosystems have some degree of protection through the network of protected areas, which includes 26.2% of the total national area.

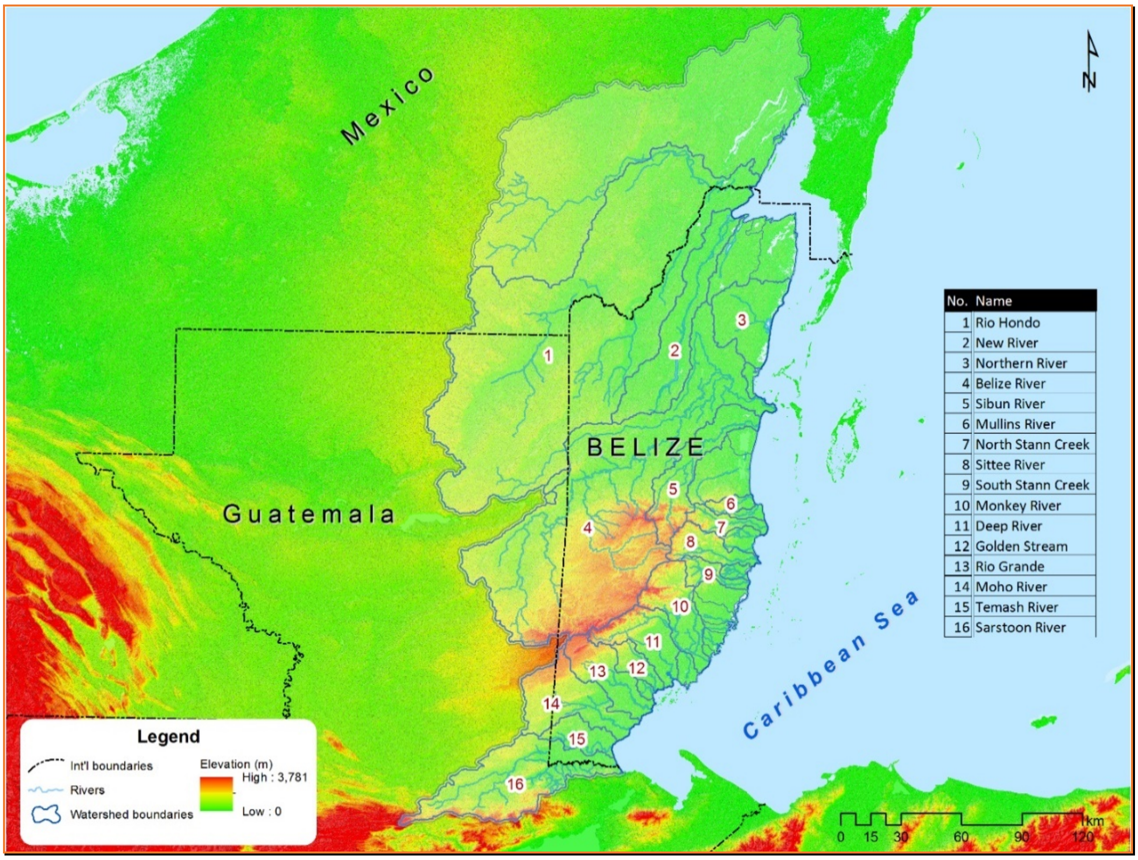


Figure 6: Major watershed and transboundary river basins in Belize
(Source Cherrington et al., 2014)

Figure 7 below is a detail map showing all the major watersheds in relation to six districts of Belize, the major highways, and the capital Belmopan, Belize City, and the main district towns.

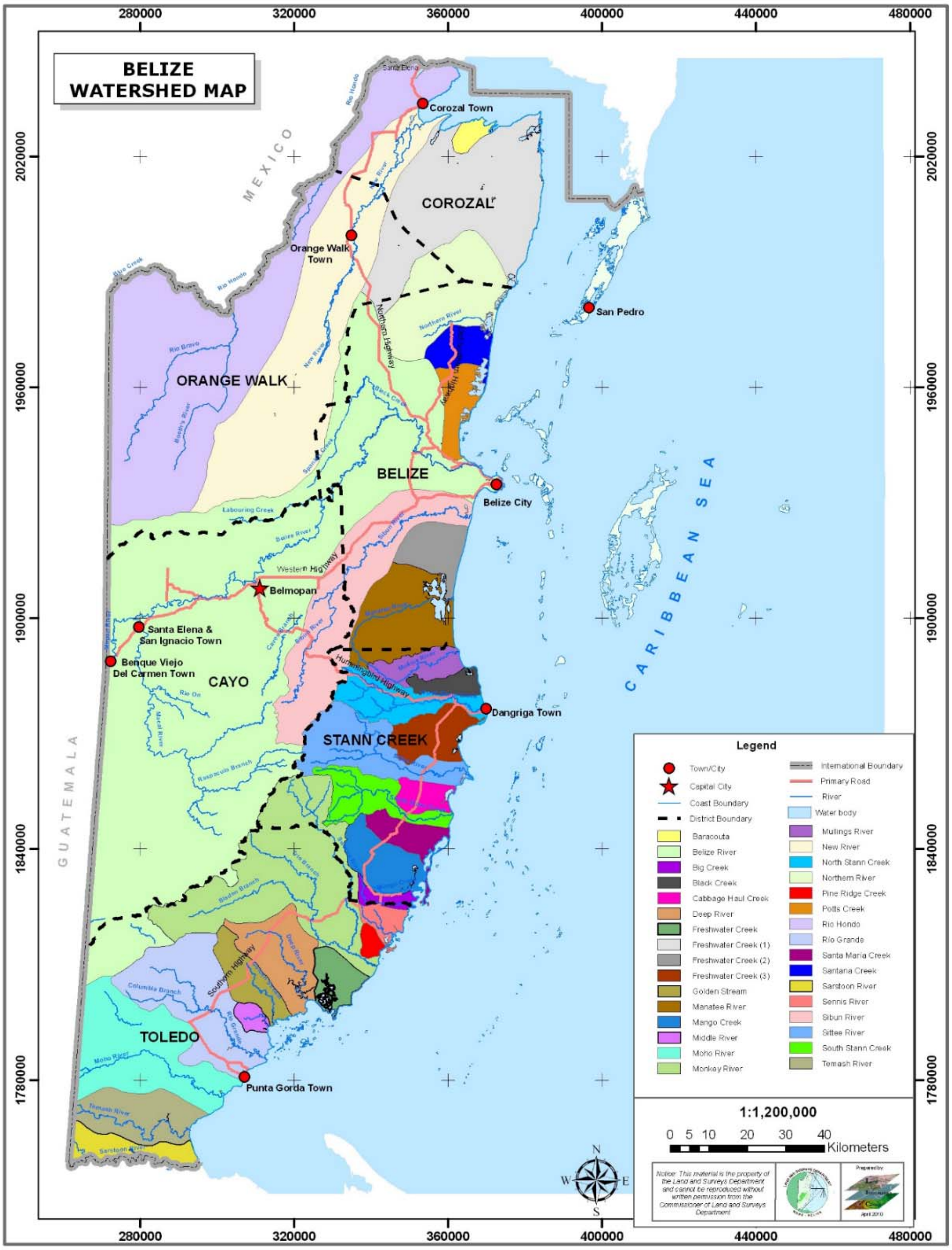


Figure 7: Watersheds and districts of Belize

1.3.1.4 Forest Cover and Land Use

Forest cover

The Central American Ecosystems Mapping Project (Meerman and Sabido, 2001) identified 87 distinct types of terrestrial and marine ecosystems in Belize, with the highest diversity occurring in the southern portion of the country where mean, annual rainfall is just over 4,000 mm. The predominant natural vegetation cover is moist and wet subtropical broadleaf forest. The coastal savannahs extend along the coast and form an integral part of the wetland ecosystem of the country. Mangroves also line the entire coast and are occasionally under threat of clearance for development projects.

According to the most recent vegetation surveys, about sixty percent (60%) of Belize is forested, with only about twenty percent (20%) of the country's land subject to human uses (such as agricultural land and human settlements). Savannah, scrubland and wetland constitute extensive parts of the landscape. As a result, Belize's biodiversity is rich, both marine and terrestrial, with a host of flora and fauna. About twenty-six percent (26%) of Belize's land territory falls under some form of official protected status (Romero, 2010), but only about 14% of the forests (about 303,000 hectares) are available or appropriate for sustainable forest management for timber production (UNEP, 2011).

The greater proportion of forests are located within Forest Reserves and other Protected Areas, while smaller acreages are in public and private domain (Cherrington et al., 2010). Legislations governing the management of forests, wildlife and protected areas are old and outdated and are not entirely compatible with present needs and trends. Open pine formations are found farther inland and along coastal savannahs, which are fire-prone ecosystems. The savannah ecosystem is specialized and adapted to xeric and acidic conditions. Soils easily saturate and dry out, moreover the subsoil is impermeable. The result is poor nutrient availability; consequently, the savannah ecosystems are mostly unsuitable for agriculture (King et al., 1992). Savannahs ecosystems are characterized by extremes in water availability, a recurring fire regime and vegetation that is highly adapted to drought conditions (Meerman and Sabido, 2001). Closed pine forests are found in the Mountain Pine Ridge.

The loss of 17.4% of forest area over a 30-year (1980-2010, See Figure 8) span represents an annual rate of deforestation of 0.6%. In absolute numbers, this translates to 725,173 acres of forest cover loss with an average forest loss per year of 24, 835 (Cherrington et al., 2010). Currently, one of the greatest threat and challenge to this sector is illegal logging, looting, hunting, and poaching from Guatemalan incursions into Belizean territory, especially in the Vaca Forest Reserve, Chiquibul National Park and Bladen Nature Reserve. Additionally, private forested lands are being converted to agricultural lands and/or being used for urban expansions or simply over exploitation; the rates however have not been fully quantified. In the case of the Vaca Forest Reserve in the southwestern Cayo District, farmers in the buffer, de-reserved area have been exploiting forest resources and impacting negatively on its ecological services. Improved management and co-management of forest reserves are therefore critical, to maintain their integrity and carbon sink potentials.

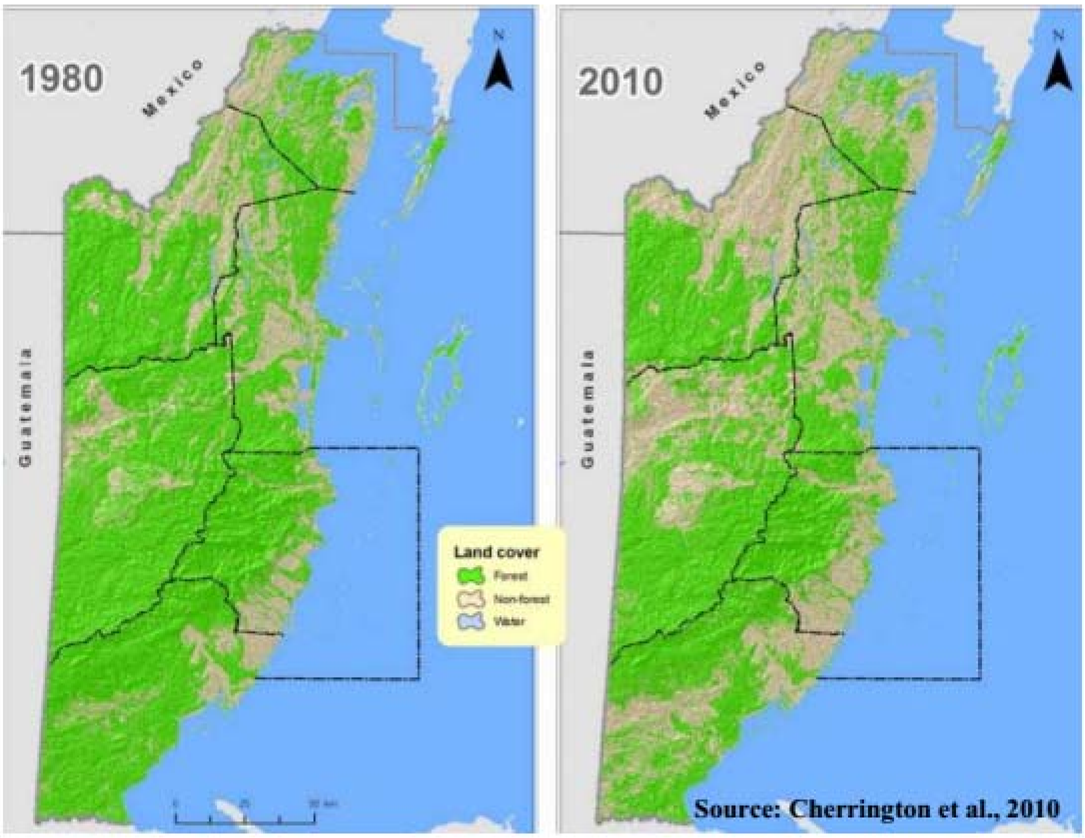


Figure 8: Forest cover in Belize for 1980 and 2010

Notwithstanding these challenges, the forestry sector can still be considered as healthy due to 60% of forest cover.

1.3.1.5 Groundwater

Groundwater is product of the rainfall regime and the geology of the landscape. Belize's geology is predominantly limestone, with the notable exception of the Maya Mountains that is composed of igneous, metamorphic, and sedimentary rocks that are from 125-320 million years old (Buckalew, *et al.* 1998). The main groundwater provinces in Belize are the Campur, the Coastal Shelf, Coastal Plain and Shelf, the Vaca Plateau, Savannah, and the Maya Mountain (See Figure 9).

The Campur: Province coincides with the outcrop of the Campur limestone north of the Maya Mountains extending eastward toward Belmopan and the coast and northward to the boundary of the Coastal Plains & Shelf Province. It includes the northern Cayo District and southern Belize district. In this Province, semi-confined and perched aquifers are primarily quaternary alluvial deposits and Miocene-Pleistocene sedimentary materials that overlie the porous and fractured Palaeocene-Eocene limestone formations. Aquifers in this Province are recharged from direct infiltration and runoff from the Maya Mountains.

Wells in the inland semi-confined aquifers penetrate to depths up to 150 metres with static levels rising to 26 metres below the surface. In the coastal alluvium deposits well penetrate to a maximum of 32 metres with static water levels rising to near 2 metres below the surface. Confined aquifers were identified at 158 metres in the north-eastern portion of this Province.

Maximum inland well yields are near 1125 L/min, average hardness is 286 mg/L while in the coastal region maximum yields are near 4000 L/min. The confined aquifer yielded 19600 L/min of brackish water.

The Vaca Plateau Province straddles the western border in the northern Cayo district and includes the western slopes of the Maya Mountains. It is composed of fractured and karstic Triassic superior limestone and dolomites. Springs are abundant and aquifers may be semi or unconfined. Aquifers are recharged from surface runoff in the Chiquibul drainage basin.

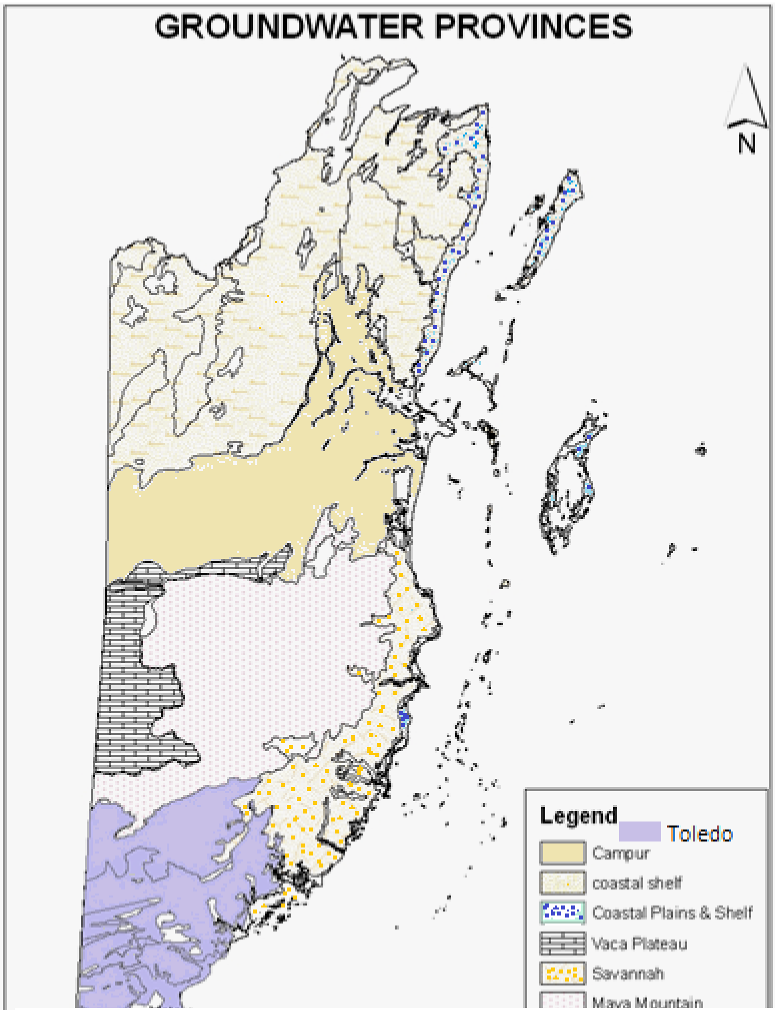


Figure 9: Groundwater provinces of Belize (Source: Buckalew, *et al.*, US Army Corps of Engineers, 1998)

The Maya Mountains Province: is composed of late Carboniferous-Permian volcanic material. The rocks have been metamorphosed with abundant dense granitic intrusions.

No major aquifer material is expected in this region; however, weathered and fractured metamorphosed mudstones, clay stones, phyllites and slates may have exploitable fresh water. There is no evidence of successful wells tapping this Province. Identification of exploitable groundwater resources in this Province will require advanced remote sensing techniques.

The Coastal Plain and Shelf Province: This includes Corozal and Orange Walk districts and north-eastern Belize district.

Aquifers in this Province are composed of weathered and fractured Miocene-Pleistocene limestone and marls overlain with clay and marl alluvial deposits. Aquifers are generally confined or semi-confined inland and or perched near the coast. Aquifers are recharged from surface runoff.

Wells penetrating the unconfined aquifers range from depths of 14 to 50 metres with static levels ranging between 10 and 28 metres below the surface. Static water levels range from 10 to 26 metres below the surface. Deeper confined limestone aquifers were identified as deep as 585 metres below the surface. Yields from the perched and unconfined aquifers average 75 L/min. The deeper and confined aquifers yield on average 331 L/min while maximum yields are near 4550 L/min. water quality is characterized by an average hardness is 372 mg/L and average sulphate content of 69 mg/L.

1.3.1.6 Water withdrawals and use in Belize

Internal renewable surface water resources have been estimated at 15.258 km^3/year and internal renewable groundwater resources at 7.51 km^3/year (IGRAC, 2012). The overlap between surface water and groundwater being estimated to be 100 percent; total internal renewable water resources are thus 15.258 km^3/year (IGRAC, 2012). The flow of the border river Hondo with Mexico is estimated at 0.864 km^3/year, of which 50 percent or 0.432 km^3/year is counted for Belize. The flow from Mopan and Sarstoon rivers from Guatemala is estimated at 6.042 km^3/year. This brings the total renewable water resources to 21.732 km^3/year (Table 5). The total actual renewable freshwater resources per capita in Belize were 67.074 thousand cubic meters in 2013.

1.3.1.7 Water Supply and Demand

Belize Water Services Limited

Belize Water Services Limited is the water and sewerage utility for the country of Belize, serving the larger municipal areas of the country, including 23 villages adjoining urban areas (BWSL, 2014-15). The two exceptions to this are Placencia Peninsula and Caye Caulker, both rapidly developing tourism destinations. Belize Water Services Ltd. serves approximately 200,000 people in urban centres, and an additional 28,000 in villages through approximately 50,000 metered water connections (CDB, 2013). BWSL operates sewerage systems only in Belize City, Belmopan, and San Pedro Town, where it has some 10,000 sewage connections.

Village Water Boards

There are currently 125 Village Water Boards, serving 159 villages and communities. The village potable water services are Rudimentary Water Systems (RWS). The majority of the RWS source their water from groundwater sources via wells, using electrically-powered or self-generated-powered water pumps to move the water to elevated reservoirs, and then distribute the treated water through basic networks to each household or lots. Chlorine is used as the primary form of water treatment. The more recently-installed systems have household meters for all connections and charge volumetric tariffs, while the older systems charge a flat monthly rate. The Rural Development Department and the Social Investment Fund (SIF) offer grants to the Village Water Boards for capital expansion based on applications and needs.

Table 5: Belize Water Resources 2012-2013

Belize Water Resources

Renewable freshwater resources:			
Precipitation (long-term average)	-	1 705	mm/yr
	-	39 160	million m^3/yr
Internal renewable water resources (long-term average)	-	15 258	million m^3/yr
Total actual renewable water resources	-	21 732	million m^3/yr
Dependency ratio	-	30	%
Total actual renewable water resources per inhabitant	2012	67 074	m^3/yr
Total dam capacity	2013	122	million m^3

(Source: AquaStat/FAO, 2013)

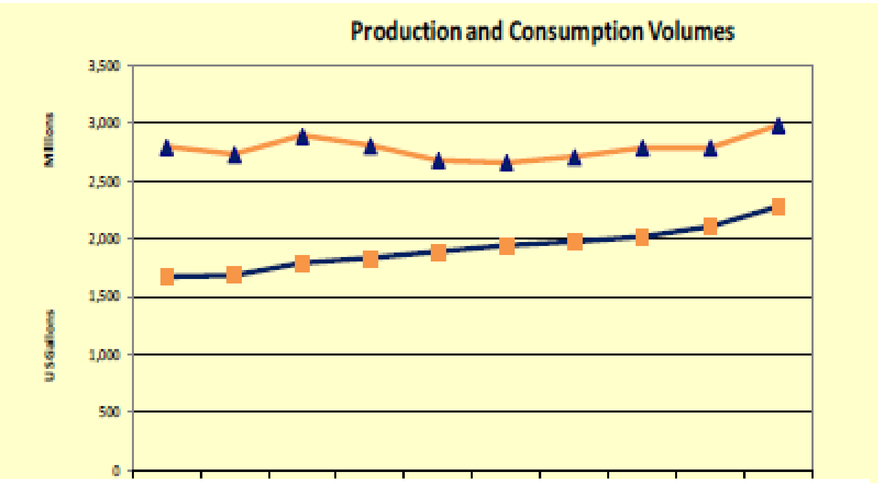


Figure 10: BWSL production and consumption volumes of water

Belize produces 45 million litres per day (mLD) of water, and the main water sources in Belize are: Surface Water 61.6 %; Groundwater 32.2 %; and Desalinized 6.2 %, from brackish water sources abstracted from wells on the mainland and seawater on the Cayes (CDB, 2013).

Of the 45 mLD of water produced in Belize the percentage of potable water utilized by sector are as follow: Residential 74.3 %; Commercial 18.7 %, Agriculture 6.9 % (Source: Belize Water Services Ltd., March 2012). Rural Water Systems not managed by Belize Water Services Limited produce about 10 mLD. Figure 10 shows a time series of BWSL water production and consumption from 2005-06 to 2014-15.

During the financial year 2014-15, the Belize Water Services (BWS) Limited served approximately 44,000 customers with a total average water demand of some 150 million US gallons per month (BWS Annual Report, 2014-15).

Over 60% of the water supplied was produced using conventional water treatment processes with rivers as its source. Satellite water wells are used for the majority of the other water systems. In San Pedro, BWS distributes water which has been treated by Reverse Osmosis, the conversion of sea water to drinking water. Since 2001, BWS has increased its investment in assets and implemented improved procedures and controls to increase its efficiency.

Sales volume saw an increase of 8.2 % in the financial year 2014-2015, as customers consumed 2,278 million US gallons (MUSG) of potable water when compared to 2,105 MUSG in the previous financial year. The increase in consumption was also attributed to expansion program and the focus to ensure the accuracy of customer meters. The water production for 2014-2015 totalled 2,982 million US gallons, which represented a 7.0 % increase compared to the financial year 2013-14. The increase in production resulted from a direct increase in consumption.

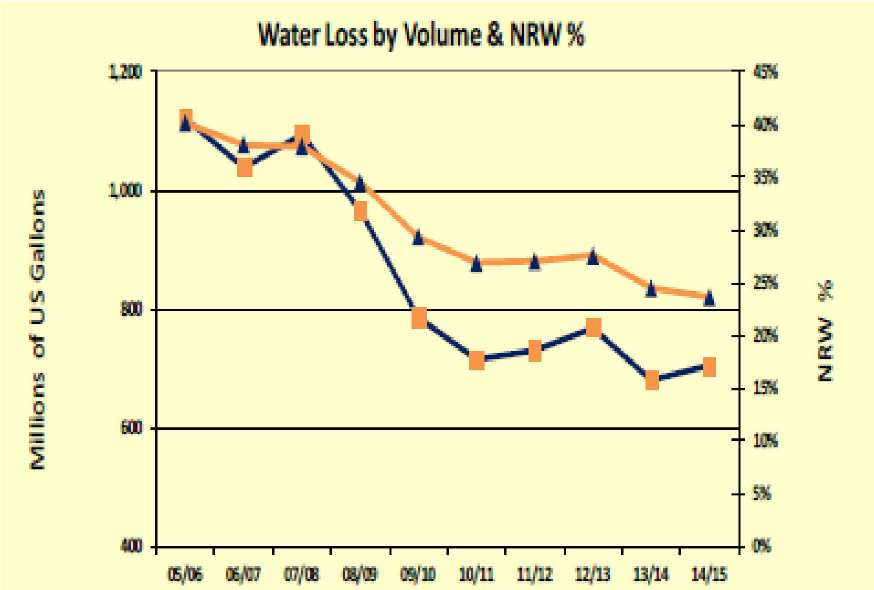


Figure 11: BWSL water loss by volume and Non-revenue water

Despite the increase in production, the overall NRW percentage loss was reduced from 25.4 % in 2013-14 to 23.6 % in 2014-15, the lowest in the company's fourteen-year history. However, water loss volume did increase from 682 million US Gallons in 2013-14 to 704 MUSG for 2014-15, a mere 3.3 %. Figure 11 is a graph showing water loss by volume and non-revenue water. BWSL's water loss reduction programme included proactive searching and repairing of leaks, replacing older water mains, identification/removal of illegal connections, and pressure management control. During the preceding year, the company focused on replacement of aged infrastructure, the identification and elimination of unauthorized connections and tampering.

Ongoing and Future Activities

- International certification program for key personnel;
- Planned replacement for aged infrastructure;
- Continued program on improvement in water quality and sewer effluent quality;
- Continued accuracy testing and replacement of customer meters;
- Continued focus on reduction of Non-Revenue Water.

Looking forward, BWSL proposes to proceed on two fronts: 1) develop a country-wide Master Plan to address the attendant issue of wastewater generation and its treatment, and 2) adopt measures to mitigate against Climate Change and Natural Hazards.

1.3.1.8 Population Profile

The population estimate according to the Statistical Institute of Belize (SIB, 2015) revealed that there were approximately 358,899 persons living within the borders of the country of Belize by mid-2014, with an annual growth rate of around 2.56%. If this growth rate is maintained the population should double in the next

forty years. The SIB indicates that this growth rate will be accompanied by a decreasing infant mortality rate and increasing life expectancy. Consequently, the population will be larger and older, with greater demands for food and nutrition. Hence, the growth rate of the agriculture sector must correspond or exceed the rate of population growth, if Belize should remain food secured and productive.

1.3.1.9 The Economy

Belize is a small, upper-middle income country with a population of about 359,000 and a per capita income of US$ 4,906 in 2016 (World Bank, 2017). Belize's economy has experienced significant economic transformation over the last two decades, mainly due to the growing tourism industry and to the commercial oil discovery in 2005. Tourism and agriculture are the main sources of income and employment. Tourism represents almost one fourth of GDP, while agriculture approximately 13 percent (Statistical Institute of Belize, 2015 data). The country also hosts the largest living coral reef in the world and is a paradise for divers and marine wildlife.

Belize's small-size economy which is highly dependent on exports and imports, and its exposure to natural disasters, make the country highly vulnerable to terms-of-trade shocks and volatility. Real GDP growth slowed from 4.1 percent in 2014 to 2.9 in 2015, and contracted in 2016 at -1.5 percent (preliminary data), amid declining agricultural and fishery outputs and the impact of Hurricane Earl that hit the country in August 2016. The fiscal situation in Belize remains difficult (World Bank, 2017). On the upside nonetheless, the US economic expansion has significantly boosted the tourism sector.

The primary productive sector consists of agriculture, forestry and logging, fishing and mining (including crude oil); while the secondary sector includes manufacturing, electricity, water, and construction; and the service or tertiary sector encompasses: trade, restaurants, hotels, transportation, communication, finance, insurance, real estate, business services, public administration and other services.

Although all 3 sectors have grown proportionately with the national economy, the most important has been the service or tertiary sector. The increase of the service sector is attributed mainly to the healthy growth of the tourism industry, which took off during the late 1980s and was still growing until the impact of the global recession took effect in 2008 and 2009. During this period of global economic downturn, tourism inflows brought US$ 118.85 million as foreign exchange for Belize in 2008 and US$ 111.5 million in 2009.

Since the 1980's, sector contributions to GDP have moved from being primarily agricultural-based to one that is more service-oriented. In 2007, the service sector contributed 59.9% to GDP, while the primary sector contributed 12.8%. In 2010, the service sector remained the largest GDP contributor at 54.1%, however, the primary sector saw a further decline in its GDP contribution to 11.4%. The secondary sector saw an increase contribution from 17.7% in 2007 to 20.9% in 2010. Petroleum exports, which have provided a boost to the economy since 2006, increased sharply from US$ 71.6 million in 2007 to US$ 115.5 million in 2008, before declining to US$ 60.32 million in 2009 (CDB, 2013).

The value of the country's Gross Domestic Product (GDP) for 2013 was US$ 1.6 Billion, and in 2016 it was US$ 1.77 Billion (see Figure 10). The primary industries which include agriculture and forestry (10.15%), fishing (3.08%) and mining and quarrying (0.46%) account for the smallest contribution of 13.69% to GDP, which totalled US$ 190.5 million or BZ$ 381 million dollars. Secondary industries such as Manufacturing (9.90%), construction (2.81%) and electricity and water supply (3.33%) were the second highest income earners; contributing 16.03% to GDP or a total of BZ$ 407.2 Million. Tertiary industries, which include the tourism and services sector, contributed 60.29% to GDP, or equivalent to a total of BZ$ 1,589.1 Million dollars in 2013. This includes, inter alia, wholesale and retail trade and repairs (15.36%), hotels and restaurants (4.72%), transport and communications (11.01%), financial intermediation (6.65%), real estate (10.15%) and community services (4.72%).

The tourism industry per se has become the largest contributing sub-sector to the GDP in Belize. Tourism is considered to be the largest earner of foreign exchange and is very important for the sustained wealth of the country. The sub-sector itself was said to contribute BZD 432.5 million (13.5% of GDP) to the GDP in 2013 and approximately BZD $450.3 million in 2014, rising by 4.1% (GOB, 2015).

Belize GDP Growth Rate 1994-2017

Figure 12 shows a time series plot of Belize's Gross Domestic Product (GDP) from 2007 to 2016. As can be observed the GDP has seen a gradual rise over the past decade.

Figure 12: Belize gross domestic product (2007-2016)

The record show that country's GDP has been growing steadily at an average of 4% per year for the past two (2) decades. Future increases in GDP are predicted to result from further diversification of the Belizean economy, which includes the expansion of the tourism, agriculture and oil industries. Specifically, the oil industry had given the economy a boost in 2005/06. Studies have shown a high probability for the existence of more oil deposits, which if located and exploited, could lead to a shift in the economic base of Belize over a relatively short time span. Energy production in Belize comes from sources such as wood (6.13%), petroleum gas (2.77%), hydro (7%), biomass (15.47%) and crude oil (68.63%) (Tillett *et al*., 2012). One company, Belize Natural Energy (BNE) is the only agency currently producing oil at about 3,000 barrels a day, with an estimated 20 million barrels of recoverable oil reserves.

The Gross Domestic Product (GDP) in Belize expanded 2.10 percent in the first quarter of 2017 over the previous quarter (See Figure 13). GDP Growth Rate in Belize averaged 2.08 percent from 1994 until 2017, reaching an all-time high of 13.45 percent in the fourth quarter of 2000 and a record low of -10.62 percent in the first quarter of 2001, not shown.

Figure 13: Belize GDP growth rate (%)
(Source: http://www.tradingeconomics.com; Statistical Institute of Belize, April, 2017)

GDP per Capita

The Gross Domestic Product per capita in Belize was last recorded at US$ 4,320 in 2016 (Figure 14). The GDP per Capita in Belize is equivalent to 34 percent of the world's average. GDP per capita averaged US$ 2,752.40 from 1960 until 2016, reaching an all-time high of 4,446.80 USD in 2015 and a record low of 1,072.49 USD in 1960 (www. tradingeconomics.com/Belize/ 2017; SIB, 2017).

Figure 14: Belize GDP per capita in USD for 2007-2016

Table 6 is a summary of Belize's medium term economic outlook. The medium-term outlook remains weak according to the IMF as public debt and current account deficits remain high. However, projected higher prices for agriculture products and stable weather favour improved economic performance in 2017. Table 7 is a summary of the Social, Environmental and Economic indicators for Belize updated in 2016.

Table 6: Belize Economic Outlook 2017-2018

Belize Economic Outlook … July 11, 2017

"The Belize economy re-emerged from recession in Q1, growing for the first time since Q3 2015. According to a preliminary estimate, GDP grew 2.1% in the first quarter, fuelled by a strong agricultural sector which recovered from last year's Hurricane Earl. Despite the encouraging GDP reading, a recent IMF staff visit to the country considered that the medium-term outlook remains weak as public debt and the current account deficit are still high. The Fund advises Belize to step up its fiscal consolidations efforts in order to solve these issues.

Higher prices for agricultural products and better weather conditions should allow the economy to rebound this year. The experts expect the economy to expand 2.5% in 2017, which is unchanged from last month's forecast, and see growth edging down to 2.3% in 2018.

Source: http://www.focus-economics.com/countries/belize retrieved July 31, 2017.

Table 7: Social, Environmental and Economic indicators for Belize, 2016

Belize	1990	2000	2010	2016
Population, total (millions)	0.19	0.25	0.32	0.37
Population Growth (annul %)	2.2	3.4	2.4	2.1
Surface area (sq. km, thousands)	23.0	23.0	23.0	23.0
Population density (people per sq. km of land area)	8.2	10.8	14.1	16.1
Poverty (%)	…	34.0	41.3	41.0
Life expectancy at birth, total (years)	71	68	70	70
Fertility rate, total (birth per woman)	4.5	3.6	2.7	2.5
Forested area (sq. km, thousands)	16.2	14.6	13.9	13.7
Terrestrial and marine protected areas (% of total area)	10.1	17.8	…	18.6
Annual freshwater withdrawals total (% of internal resources)	0.1	0.7	…	0.7
Improved water sources (% of population with access)	73	85	97	100

Improved sanitation facilities (% of population with access)	76	83	89	91
Energy use (kg of oil equivalent per capita)	566	…	597	…
CO_2 emissions (metric tons per capita)	1.66	1.68	1.68	1.50
Electric power consumption (kWh per capita)	…	678.9	631.1	1,950.0
GDP (current US$, billions)	0.41	0.83	1.40	1.77
GDP per capita (US$)	…	…	4344	4320
GDP Growth (annual %)	10.6	13.0	3.3	-0.8
Inflation, GDP deflator (annual %)	2.8	0.5	1.1	2.1
Agriculture, value added (% of GDP)	20	17	13	11
Industry, value added (% of GDP)	22	21	22	18
Services, etc., value added (% of GDP)	58	62	65	71
Exports of goods and services (% of GDP)	62	53	58	57
Imports of goods and services (% of GDP)	60	74	57	68
Time required to start a business (days)	..	..	43	43
Domestic credit provided by financial sector (% of GDP)	26.7	43.5	69.6	72.4
Tax revenue (% of GDP)	21.4	17.8	23.6	23.4
Mobile cellular subscriptions (per 100 people)	0.0	7.0	62.9	61.0
Individuals using the Internet (% of population)	0.0	6.0	28.2	41.6
High-technology exports (% of manufactured exports)	0	0	5	0

(Source: World Development Indicators database, WB, 2017; SIB, Belize, 2017)

Poverty

As a lower middle-income country, Belize experienced a slowdown in growth and an increase in poverty after the global economic crisis, which accompanied increases in the prices of food and fuel in 2008. The most recent Country Poverty Assessment indicates that between 2002 and 2009, the overall poverty rate increased from 34% to 41%, while extreme poverty increased from 11% to 16%. In 2010, the country resumed growth, with GDP growth reaching 2.9% (Warlich, 2013).

Although Belize's economy has traditionally relied on agriculture, the services sector grew in importance during the 1990s. According to the World Bank, it is now the country's largest contributor, accounting for 60% of GDP.

Data indicates that the overall economic growth experienced by the country might have failed to translate into an equal distribution of wealth and well-being. The Country Poverty Assessment states that, "inequality is therefore the manifestation of a central structural problem, which development policy in Belize must address". The government of Belize continues to put the primary focus of its strategies on the fight against poverty.

1.4 The National Climate Change Office

The National Climate Change Office (NCCO) was established in 2015 under the then Ministry of Forestry, Fisheries, and Sustainable Development (MFFSD), now the Ministry of Agriculture, Forestry, Fisheries, the Environment and Sustainable Development (MAFFESD). The NCCO headed by a National Climate Change Coordinator, is the government agency responsible for Climate Change. The main task of the NCCO is to coordinate the country's Climate Change program on behalf of the government of Belize. The NCCO is the secretariat to and is supported by the Belize National Climate Change Committee (BNCCC), which comprises of eleven members from various government ministries, non-government organizations, and members of the private sector (GOB-NCCO, 2016). Ministries represented in the BNCCC include those in charge of: Works; Transport; Economic Development; Agriculture, Forestry, Fisheries, Environment and Sustainable Development; Health; Tourism and Culture; Local Government and Rural Development; and Energy. The committee has one representative from the private sector and a recognized non-government organization, respectively. The University of Belize is also represented on the committee.

The NCCO is implementing and coordinating the Technology Needs Assessment project in Belize. A new governance architecture structure for the administration of climate change in Belize as presented in the National Climate Change Policy, Strategy and Action Plan, 2015 is presented in Section 2.1.

1.4.1 The Third National Communication

The Third National Communication (TNC) has expanded on the studies and assessments of climate change related issues presented in the Initial National Communication (INC) and Second National Communication (SNC), (GOB/NCCO, 2015). The Belize National Climate Change Office (NCCO) spearheaded the preparation of the Greenhouse Gas (GHG) inventories and the National Communications for Belize, since its founding in 2012. The Caribbean Community Climate Change Centre (CCCCC) provided technical support for the Third National GHG inventory. The GHG inventory utilized data for the reference years: 2003, 2006, and 2009.

Since the submission of the SNC in 2012, Belize has made progress in fulfilling the objectives of the Convention through the implementation of new policies, projects and programmes to reduce emissions and foster low carbon development (GOB-NCCO, 2016). Some of these initiatives are:

- Integrated Coastal Zone Management Plan

- Ministry of Energy, Science & Technology and Public Utilities (MESTPU) Strategic Plan
- National Agenda for Sustainable Development
- The National Climate Resilience Investment Plan
- Growth and Sustainable Development Strategy
- Nationally Determined Contribution
- Nationally Appropriate Mitigation Activities (NAMAS)

The Government of Belize has taken steps to mainstream some climate change mitigation actions into national development processes and mechanisms. Two recent initiatives include the establishment of a National Climate Change Office in 2015 under the then Ministry of Forestry, Fisheries and Sustainable Development, and the drafting and approval of a National Climate Change Policy, Strategy and Action Plan (NCCPSAP). This document identifies activities to be undertaken to mitigate and address the adverse impacts of Climate Change. The NCCPSAP also provides policy guidance for the development of a suitable administrative and legislative framework, which is coherent with other sectoral policies, for the achievement of a low-carbon development path for Belize (GOB-NCCO, 2016; GOB 2016).

The mandate of the National Climate Change Office is to respond to the cross-sectoral challenges of climate change adaptation and mitigation, and coordinate and manage the national response to Climate Change.

The findings in the TNC were critical to inform policies, strategies and actions contained in the NCCPSAP. The outputs of the National Communication are now linked to the decision-making process and development planning and the national and sectoral levels.

As it relates to mitigation, the TNC focused on the Energy and Transport Sectors.

In the case of the Energy sector, the TNC determined that the following mitigation measures must be organized and initiated:

- Improve energy efficiency to dramatically lower energy intensities across key economic sectors Transport, Industry, Buildings (Commercial & Residential), Public lighting and Agriculture
    a. Improve energy efficiency in buildings and appliances.
    b. Promote transition to sustainable transportation.
    c. Develop appropriate financial and market-based mechanisms that support energy efficiency and renewable energy.
- Develop renewable energy to shift the energy matrix away from fossil fuels (especially oil) to alternative renewable energy technologies.
    a. Develop Belize's human, technological and institutional capacity to accelerate the uptake of appropriate clean energy and clean production technologies.

- Promote and facilitate Clean Production systems in the processing of Agriculture and Forestry outputs to co-produce bio-fuels and/or electricity.

Emission of Greenhouse Gases from the Transport Sector

Carbon dioxide emissions from the transportation sub-sector (within the Energy sector) accounted for the third highest level of GHG emissions in 2000, according to SNC (GOB, 2011b).

The Third National Communication (GOB-NCCO, 2016 b) emission estimates for the Energy sector show an overall decrease in emissions of carbon dioxide (CO_2) for the reference period 2003, 2007 and 2009. The contributions of the sources showed a decline from liquid fuels and a major increase in biomass use and the supplies of hydroelectricity. In regards to emissions from biomass, the two main contributors are fuel wood and bagasse.

For the Transport sector, the TNC determined that the following mitigation measures must be organized and initiated:

- Comprehensive assessment of transportation/communications infrastructure and their vulnerability to storm surges, floods and other forms of natural disasters, especially the major productive such as tourism and agriculture.
- Review and update standards for construction and maintenance of transportation infrastructure to include an additional protective margin for the expected risks associated with Climate Change.
- Develop risk assessments and response plans, including mapping and identification of high-risk and critical infrastructure (related to the productive sectors), and implementing key infrastructure reinforcements and relocations.
- Promote energy efficiency in the transport sector through appropriate policies and investments: These improvements should include:

    a) Undertaking a traffic management study aimed at reducing traffic congestion in urban areas and along the Philip Goldson Highway into Belize City

    b) Improving public transportation

    c) Upgrading maintenance of bus fleet

    d) Improving scheduling

    e) Upgrading the industrial fleet

    f) Promoting the use of bio-fuels

1.5 Climate Change and Impacts on Vulnerable Sectors

1.5.1 Expected climate change impacts

Belize is a small tropical country, with a population of around 358,899 (mid-2014 estimates), and whose history has, in a large part, been shaped by its vulnerability to disasters. Belize's vulnerability to climate change is attributed to its geographic location and development characteristics. For example: The loss of life and economic damages associated with Hurricane Hattie in 1961, prompted the Government of Belize to build a new administrative capital further inland in Belmopan. Recently, it is estimated that an average of 3.26% of GDP was lost annually in Belize between 1993 and 2012 due to natural disasters (Kreft and Eckstein, 2014). Belize's vulnerability to natural disasters is exacerbated by the effects of climate change, as natural hazards are expected to intensify both in terms of frequency and severity (GOB-CCCCC, 2014, IPCC, 2007). More than 50 percent of the population and business centres are on or near the long, low lying coastline, most of which is at or near sea-level. The country and its infrastructure, especially in the low lying coastal areas, are highly vulnerable to frequent tropical storms and hurricanes, flood damage and rising sea levels, especially the old capital Belize City. Underdeveloped and dilapidated infrastructure, particularly in the transport sector, is key constraint to reduce vulnerability to disasters.

1.5.2 Signs of Climate Change

Analysis of historic climate records for Belize shows evidence of a changing climate (CCCCC, 2014; UNDP, 2009).

a) Air Temperature

Mean annual temperature for the central observation station at the Philip Goldson International Airport (PGIA) in the Belize District has increased by 0.9 °C for the period 1960-2005, with an average rate of 0.2 °C per decade (Richardson, 2009). The average rate of increase was most rapid in the wet seasons (May - October) and slower in the drier portion of the climatological year (November - April).

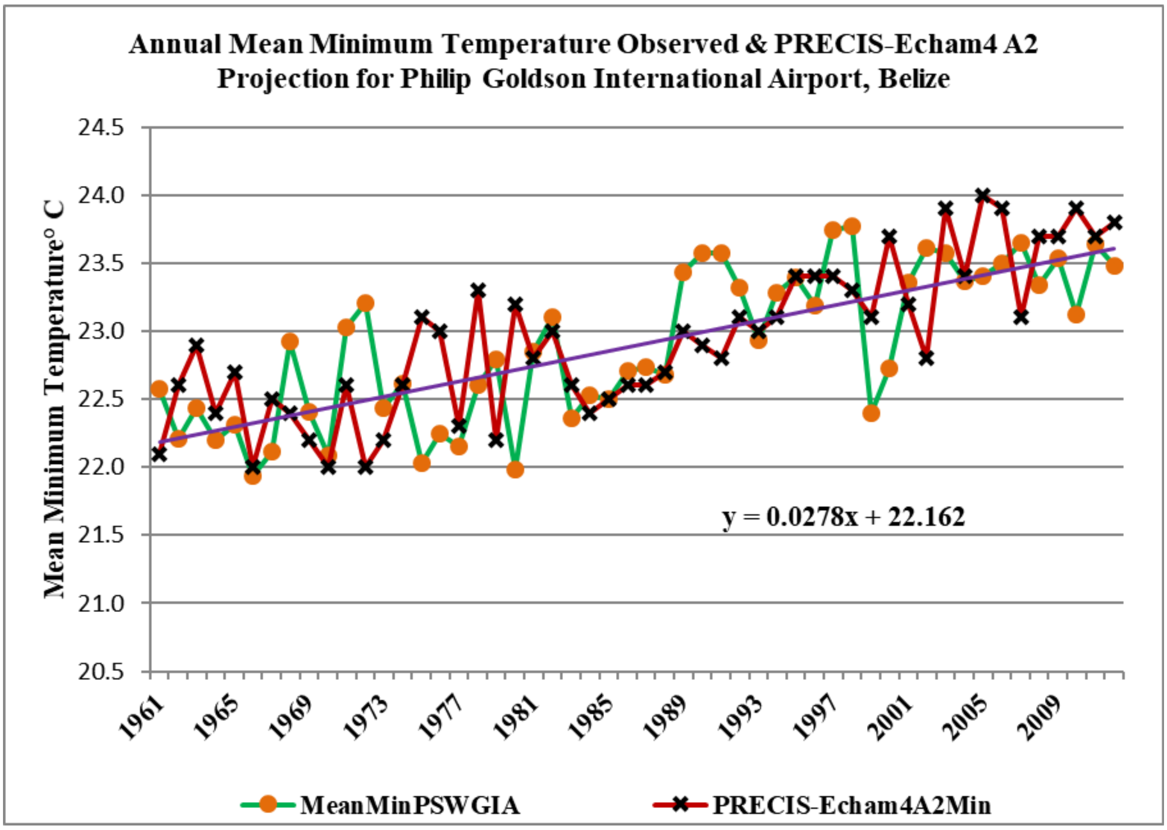


Figure 15: Actual & PRECIS-ECHAM4 A2 annual minimum temperature, PGIA, 1961-2013
(Source: R. Frutos, 2014)

Analysis of mean, minimum temperature for the period 1961 – 2013 at PGIA shows increasing trend in minimum, night-time temperature. The mean, minimum temperature curve (Figure 15) showed an annual increase of near 0.028 °C per annum or an increase of about 1.5 °C since 2061. Figure 16 shows the combined minimum temperature time series plot of actual minimum temperature at the PGIA and the regional model PRECIS ECHAM4 simulation for the same period.

In summary, the nights are getting warmer, and the records show notable warming from the 1990s to the present.

b) Rainfall

The annual rainfall trend for the Philip Goldson International Airport for the period 1960-2013 is presented in Figure 16. The red line is the annual rainfall trend and the yellow line is the 10-year running average. Over the fifty-three years spanning 1960–2013, the analysis shows a slight increase in rainfall of about 1.4 mm per annum (slope of trend-line equation), which amounts to about 74 mm increase in observed rainfall at PGIA for the entire period under review. The annual average rainfall at this locality is 2003 mm for the period 1970 – 2000.

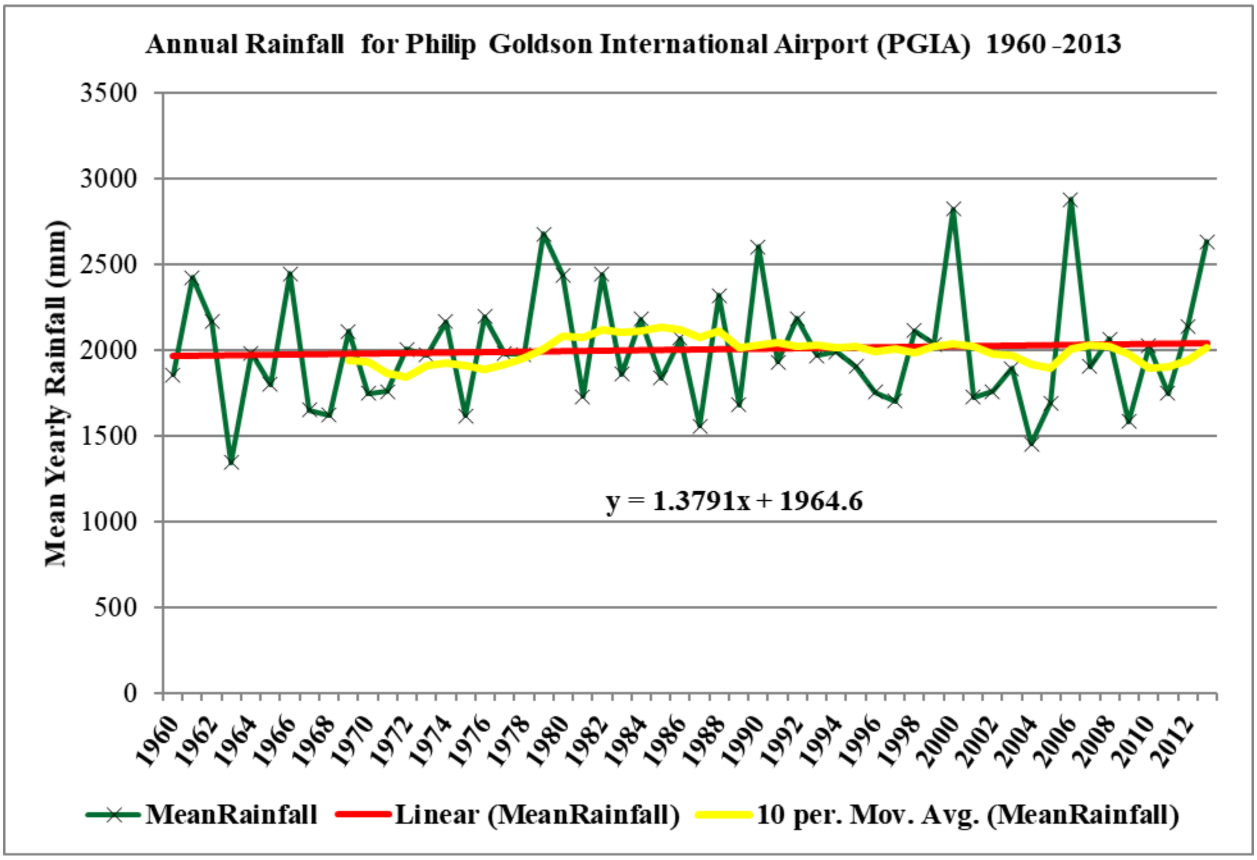


Figure 16: Annual rainfall for Philip Goldson International Airport (1961-2013)
(Source: R. Frutos, 2014)

c) Sea Level Rise and Coral Bleaching

The coastal lowlands in northern Belize are vulnerable to Sea-level rise (McSweeney, *et al.* 2012). The IPCC Fifth Assessment Report (AR5) indicates that sea level rise varies between regions mainly due to complex interactions. Globally, the rate of sea level rise since the 1850s has been larger than the average during the previous 2,000 years (*high confidence)* (IPCC, 2013, IPCC, 2014) at a rate of 1.3-1.7 millimetres (mm) per year during much of the 20th century, but increasing to 2.8-3.6 mm per year since 1993.

In the Caribbean, observed average rate of sea level rise over the past 60 years was generally similar to the global average of approximately 1.8 mm per year (IPCC, 2014; CDKN, 2014).

Coral bleaching

Global Warming and Climate Change threatens the physical and chemical properties of tropical marine environment in many ways according to numerous studies on the subject (IPCC, 2007). Some of the most critical effects can be summarized as follows:

- When ocean temperatures rise, corals bleach and entire marine populations can lose their only shelter and food source.

- When ocean temperatures rise, mobile species relocate, and entire marine populations are exposed to new competitors, predators, parasites and diseases, while non-mobile species perish.
- When sea levels rise, nursery habitats are flooded and entire marine populations face extinction, with no place left to reproduce.
- When upwelling patterns change, the food chain is dramatically altered, and entire marine populations can starve to death.
- When carbon dioxide emissions rise, ocean acidity rises, and the calcium-based structure of entire marine populations – from plankton to coral to clams – crumbles.

Acidification Effects on Coral Reefs

As carbon dioxide is absorbed into the ocean, the ocean chemistry drastically changes (Pandolfi, 2015). Greater carbon dioxide concentration released into the oceans leads to increased ocean acidity. This in turn leads to a reduction in phytoplankton density. As a result, there is less ocean plants able to take up greenhouse gases. Also, increased ocean acidity threatens marine life, such as corals and shell fish, which may become extinct later this century due to the chemical effects of carbon dioxide.

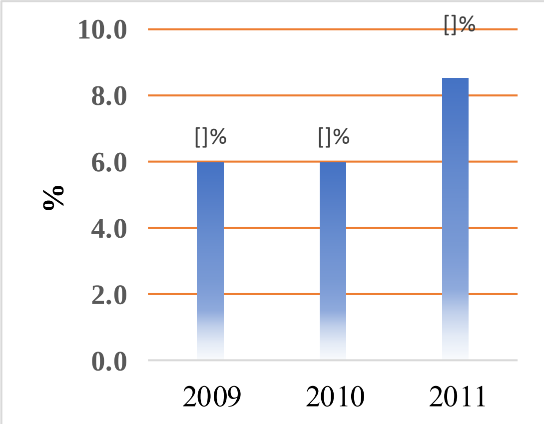


Figure 17: Mean annual bleaching in the Belize Barrier Reef, 2009-2011

(Source: CZMAI, 2014)

Coral secretes tiny shells of calcium carbonate in order to form its skeleton. However, as carbon dioxide is absorbed by ocean water, acidification increases and the carbonate ions vanish. This results in weaker extension rates or weaker skeletons in most corals. Coral bleaching, the breakdown in the symbiotic relationship between coral and host algae or Zooxanthellae, is occurring more frequently with warmer ocean temperatures. Since Zooxanthellae give the coral its unique coloration, increase in carbon dioxide in the oceans and seas causes coral stress and a discharge or release of these algae. This leads to the bleaching appearance of corals. When this relationship between corals and algae that is so important for marine ecosystems is disrupted, corals begin to weaken. As a result, food and habitats for a great number of marine life are also destroyed, and directly or indirectly impacts the fisheries sector.

Figure 17 shows the percentage of coral bleaching observed at 13 different locations across the Belize Barrier Reef and from a total of 87 sites for the period 2009 – 2011. Annual mean coral bleaching during this period was low with less than 10% mean bleaching annually (CZMAI, 2014).

It must be stated that higher rates of coral bleaching have been observed in Belize during El Niño years and years coinciding with historic, global bleaching events as illustrated in Figure 18.

Figure 18: Historic global coral bleaching events

(Source: The University of Queensland, http://www.globalcoralbleaching.org)

d) ***Increased Frequency of Tropical Cyclones***

The past 2 decades (1995-2016) has seen a surge in tropical cyclone activity in the North Atlantic Basin, including the Caribbean. The most destructive and costly hurricane, namely Katrina (1995), ploughed through the NW Caribbean and the Gulf of Mexico, devastating New Orleans and surrounding areas of the US Gulf Coast. Hurricane Mitch (1998) was a catastrophic Category V hurricane in the northwest Caribbean. It threatened Belize with destructive wave action and storm surge, but swung southwards into Honduras, where it devastated the landscape and resulted in the death of some 9,000 persons.

During this period Belize was impacted directly or indirectly by a total of 22 tropical cyclones. Seven of these systems were tropical storms and five were tropical lows or strong tropical depressions. Five major hurricanes affected Belize during the period, two of which reach Category V intensity in the NW Caribbean but did not make landfall along the coast of Belize, but significantly impacted the country. These were Hurricane Dean and Mitch. Table 8 is a summary of the tropical cyclones that impacted Belize during the North Atlantic Basin tropical cyclone surge of the past 22 years, which coincided with the 15 warmest years on record.

Table 8: Tropical cyclones that affected Belize during the period 1995-2016

		Period	No. Year	Hurricane Category				
				I	II	III	IV	V
1995-2016	**22**	**22**	**12**	**3**	**2**	**2**	**1**	**2**

(Source: R. Frutos 2017)

Projections of mean annual rainfall from different models are broadly consistent in showing 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 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.

e) State of the Climate 2016

The latest, international National Oceanic and Atmospheric Administration (NOAA) "State of the Climate" report, confirms that 2016 was the third consecutive year of record-setting global warming (NOAA, 2017). The report indicates that the effect of long-term global warming and a powerful El Niño earlier in 2016, enhanced the record-breaking warmth.

The NOAA "State of the Climate" report was based on contribution from nearly 500 scientists from more than 60 countries, using tens of thousands of measurements from several independent data sets. The conclusion is supported not only by NOAA, but also from renowned climate centres such a NASA, the UK Met Office and the Japan Meteorological Office.

The report indicates that the average global temperature across land and ocean surface areas for 2016 was 0.94 °C above the 20th century average of 13.9 °C, surpassing the previous record warmth of 2015 by 0.04 °C. As indicated earlier, the 2016 global temperature was greatly influenced by the strong El Niño condition earlier in the year, that gradually passed out in the spring. To date, all 16 years of the 21st century rank among the seventeen warmest on record (1998 is currently the eighth warmest). The five warmest years have all occurred since 2010.

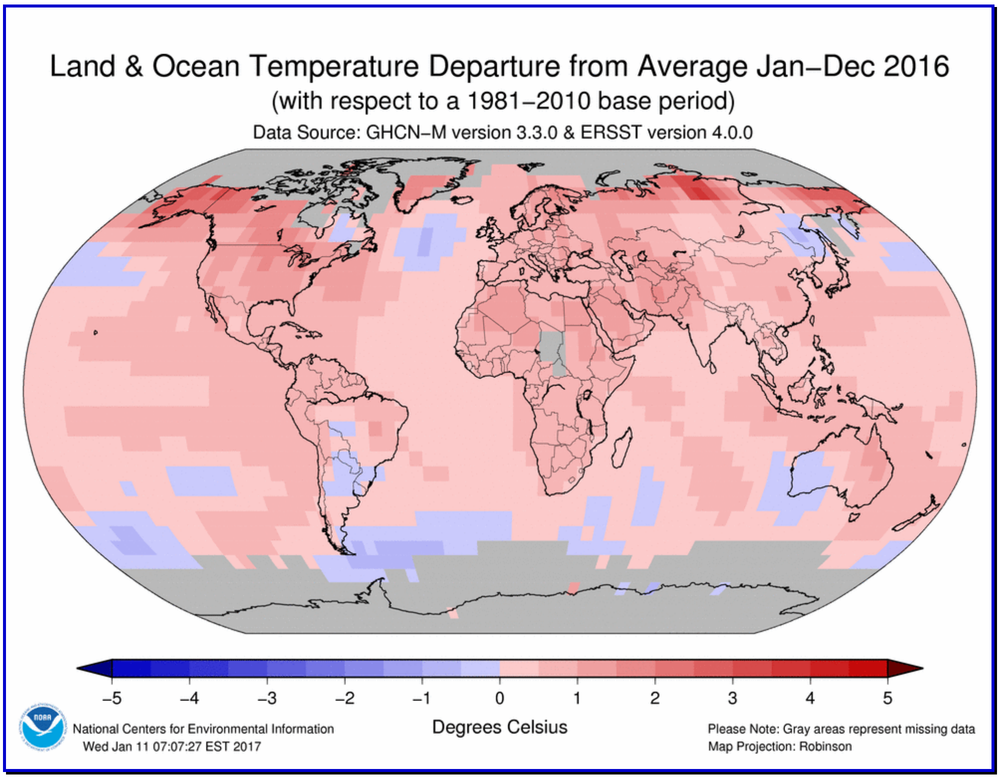


Figure 19: Average Jan-Dec 2016 Land and Ocean Temperature anomalies based on 1981-2010 climatology

The data shows the global annual temperature has increased at an average rate of 0.07 °C per decade since 1880, and at an average rate of 0.17 °C per decade since 1970. Figure 19 is the NOAA generated land and ocean surface temperature anomalies for January – December 2016, from 1981-2010 climatology. The greatest departures from the 1981-2010 climatology were in the subpolar and polar regions. In the Caribbean-Central America-Eastern Pacific tropical region, the departure was about 1 C°

Global average sea level reached a new record high in 2016 of 0.889 m (3.5 inches) above average sea level in 1993, the year when satellite altimetry record began (Walsh, 2017). Average Arctic surface temperature continued to warm, and global ice and snow cover continued to decline. Also, Antarctic sea ice extent hit record daily and monthly lows in August and November 2016.

Concentrations of major greenhouse gases in the atmosphere also reached new levels in 2016. Global concentration of carbon dioxide (CO_2), the primary driver of climate change, reached 402.9 ppm. Concentration of CO_2 surpassed 400 ppm for the first time in the modern atmospheric measurement record and ice core records dating back to 800,000 years (Walsh, 2017). The rise of 3.5 ±0.1 ppm rise in global annual mean CO_2 for 2015-2016 was the largest, annual increase ever observed in the 58-year measurement record.

1.5.3 Climate Model projections

The future climate for Caribbean, Central America and Belize will likely be characterized by increasing temperatures and high variability in rainfall but with a decreasing tendency (Richardson, 2009)

The IPCC 2007/2013 global climate model results for different climate scenarios for the Caribbean and Central America provide some guidance as to changes in temperature, rainfall and sea level rise in Belize, resulting from global warming.

Downscaled ECHAM5 and HadCM3Q11 global climate model results were utilize as input for the PRECIS regional climate model for climate simulation experiments of rainfall and temperature projections (GOB, 2015). In the case of Sea Level Rise projections, the figures were extracted from IPCC 2007 results for the western Caribbean and the IPCC 2013 Fifth Assessment Report (AR5). The climatology baseline period used was 1961 – 1990.

Rainfall

Global Climate Model projections for mean annual rainfall show that rainfall levels will decrease towards the 2090s. Rainfall is projected to decrease between one and twenty-six percent over the period (GOB, 2014)

IPCC annual rainfall projection, based on the A2 climate scenario for 2010-2100 for the Philip Goldson International Airport (PGIA) indicates a 100 mm decrease in annual rainfall over the 90-year period but with significant variability, which may be attributed to El Niño-Southern Oscillation (ENSO) in the central and eastern Pacific (Richardson, 2009). ENSO is an atmospheric–oceanic phenomenon characterized by changing pressure centres across the Pacific coupled with anomalous SST variations in the central and eastern Pacific Ocean. The warm phase of ENSO is characterized by sustained sea surface temperature anomalies in excess of 0.5 °C. ENSO has a cycle of 5 – 7 years and may last six months to over a year. ENSO triggers flooding, droughts and other oceanic/atmospheric phenomena around the world. Across Central America and the western Caribbean El Niño (ENSO warm phase) produces droughts especially along the Pacific coast, and tends to suppress hurricane development in the Tropical Atlantic Basin including the Caribbean. Climate change will likely invigorate the ENSO phenomenon.

The PRECIS/ECHAM5 model results indicate a slight increase in rainfall for the 2020s specifically in the early May and the late October – November period, with peak increases of about 2-4 mm/day in the Stann Creek District (GOB, 2015). The dry season and the mid-summer dry spell in August, on the other hand, are characterized by further decreases with largest reductions of about 4 mm/day in the Stann Creek and Cayo Districts. By the 2030s, reduced precipitation characterizes the rainfall regime across the entire country with exceptions only in early May and late November. The projections show that the 2050s should see an enhancement of the 2030s pattern of reduced rainfall to continue (-1 to -4 mm/day) during the cool transition period and through April.

Surface air temperature

According to the UNDP Country Profiles studies (Richardson, 2009) the mean annual air 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. Similarly, a general decrease in annual rainfall of about 10 % is projected by 2100.

Belize's Third National Communication to the UNFCCC reports that the average annual temperature is projected to increase between 0.4 °C and 1.7 °C by the 2030s depending on which climate change scenario (B1, A2, or A1B) is used in the models (GOB, 2016). Using the same scenarios, the average annual temperature is projected to increase by 0.8 °C to 2.9 °C by the 2060s, and 1.3 °C to 4.6 °C by the 2090s, (GOB, 2016).

The PRECIS ECHAM5 regional climate model projects an increase of surface air temperature near 1 °C for the 2020s decade across Belize, with increases of 1 – 1.18 °C through the 2030s, 1.8-2.9 in the 2050s, 2.5 -4.3 in the 2070s and 3.2-4.9 in the 2090s, relative to the 1961-1990 climatology (GOB, 2015). The 1 °C increase in surface air temperature projected for the 2020s is very likely to be surpassed before the time, based on rising temperature trend for the PGIA, and the consistent, global warming observed since 2000.

Monthly mean maximum temperatures are forecast to increase from 0-1.4 °C during the 2020s, relative to the 1961-1990 baseline. The largest increases of 1.2-2.2 °C are projected for the cooler season during the 2030s. During the remainder of the year in the 2030s decade, colder mean maximum temperatures are projected for the western Toledo, Cayo, and Orange Walk districts, with largest reduction of -0.5 to -1.5 °C foreseen for the western Cayo District, while the eastern half of the country will have increased values of mean maximum temperatures of 0.5 – 1.5 °C. Mean, maximum temperature projections for the decade of 2050s are 1.5 – 3.5 °C; for the 2070s 2.6 – 3.9 °C; and for the 2090s the mean, maximum temperature will be 3.4 – 6.6 °C over the 1961 – 1990 climatology.

Mean, monthly minimum temperatures are projected increase steadily over the 1961-1990 values through to 2100. The mean, monthly minimum temperature projection for the 2020s are 0.5 - 1.5 °C; for the 2030s, 0.5 - 1.2 °C; for the 2050s, 0.5 – 2.5 °C; the 2070s, 2.5 – 3.6 °C; and for the 2090s, 3.3 – 5.3 °C.

Winds

The ten-year change in wind speed is minimal with the variations frequently less than 1 m/s for most of the time slices. The model results show that not until the summer months of the 2090s does the wind speed exceed 1 m/s over the values of the 1961 – 1990 period. Even then, the difference was frequently less than 1.5 m/s.

Sea Level Rise

Projections of sea level rise in small island regions under an intermediate low-emissions scenario are similar to global projections of between 0.4 and 0.7 metres, ranging from 0.5 and 0.6 meters in the Caribbean for the 2081-2100 period relative to the 1986-2005 level (IPCC, 2014).

Another review (McSweeney, *et al.* 2012) indicates that climate models project sea-level rise in the region of the western Caribbean by the 2090s relative to 1980-1999 sea-level are as follow: 0.18 to 0.43 m under SRES B1 (IPCC low emission scenario); 0.21 to 0.53 m under SRES A1B (intermediate scenario); and 0.23 to 0.56 m under SRES A2 (high emission scenario).

Sea level is projected to rise steadily along the coast of Belize. In the IPCC low, medium and high emission scenarios, that is B1, A2 and A1B respectively, sea level rise is projected to exceed 10 cm by the 2030s. Heights of 22, 23 and 38 cm respectively are projected for the low, medium and high emission scenarios by 2050 and 34, 56 and 120 cm respectively by the end of the Century.

The damages to infrastructure resulting from sea level rise coupled with increased frequency of intense tropical cyclones, and the economic effects on the tourism sector, the largest contributor to GDP, could impact negatively on the sustainable development of Belize (UNDP, 2009).

In summary, the effects of climate change will be in three forms, namely:

i) Increased surface ambient and sea surface temperatures;
ii) Sea level rise; and
iii) Increased frequency of more intense hurricanes (Cat III or stronger) in hurricane basins around the world (IPCC, 2013).

Table 9 is a summary of the major, long-lived GHGs, their residence time in the atmosphere and their global warming potentials. For purposes of comparison, global warming potential values are calculated in relation to carbon dioxide, which is assigned a global warming potential equal to 1.

Table 9: Major long-lived Greenhouse Gases and their Characteristics

Greenhouse Gas	How is it produced?	Average lifetime in the atmosphere	100-year global warming potential
Carbon dioxide	Emitted primarily through the burning of fossil fuels (oil, natural gas, and coal), solid waste, and trees and wood products. Changes in land use also play a role. Deforestation and soil degradation add carbon dioxide to the atmosphere, while forest regrowth takes it out of the atmosphere.	see below*	1

Methane	Emitted during the production and transport of oil and natural gas as well as coal. Methane emissions also result from livestock and agricultural practices and from the anaerobic decay of organic waste in municipal solid waste landfills.	12.4 years	28–36
Nitrous oxide	Emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.	121 years	265–298
Fluorinated gases (CFCs)	A group of gases that contain fluorine, including hydrofluorocarbons, perfluoro-carbons, and sulphur hexafluoride, among other chemicals. These gases are emitted from a variety of industrial processes and commercial and household uses, and do not occur naturally. Sometimes used as substitutes for ozone-depleting substances such as chlorofluorocarbons (CFCs).	A few weeks to thousands of years	Varies (the highest is sulphur hexafluoride at 23,500)

(Source: US EPA, 2016)

This table shows 100-year global warming potentials, which describe the effects that occur over a period of 100 years after a particular mass of a gas is emitted. Global warming potentials and lifetimes come from the Intergovernmental Panel on Climate Change's Fifth Assessment Report.

** Carbon dioxide's lifetime cannot be represented with a single value because the gas is not destroyed over time, but instead moves among different parts of the ocean–atmosphere–land system. Some of the excess carbon dioxide is absorbed quickly (for example, by the ocean surface), but some will remain in the atmosphere for thousands of years, due in part to the very slow process by which carbon is transferred to ocean sediments.*

1.5.4 Major projects and programs to combat climate change

Table 10 shows recent, major projects and programs aimed at reducing vulnerability to climate change in the agroforestry, water, energy and transport sectors.

Table 10: Some major programs and projects to reduce vulnerability to Climate Change

Year		Programmes and Projects
2017		Sustainable Tourism Program II: IDB loan USD 13.35 M. Period 2017 – 2022. Objectives: i) to increase tourism employment, income and revenues generated by the sector; ii) promote disaster and climate resilience and environmental sustainability in tourism destinations; iii) improve sector governance, creating enabling conditions for private sector investment in overnight tourism. The components are: ***Component 1*: Enhancement of the tourism product** Aims to diversify the tourism product and enhance tourism services and experiences (primarily for nature and culture based tourism). ***Component 2*: Promoting disaster and climate resilient tourist destinations and environmental sustainability** Aims to improve capacity to manage risk of natural disasters and adapt to climate change. *Component 3*: **Institutional strengthening and capacity building-** aims to improve policy, planning and destination management of the tourism sector increasing participation of LIP and private sector.
2016		In April 2016, Belize Nationally Determined Contributions (NDC) was submitted to the UNFCCC In 2016, Belize drafted its NAMAS in coordination with the NCCO, and consultation with key public and private stakeholders, and the
2015		Belize submitted its Third National Communication to the UNFCCC Belize chosen to participate in the UNEP/UNFCCC second phase of the Technology Needs Assessment (TNA) project
2014		Under the Energy Resilience for Climate Adaptation Project (ERCAP), Belize strengthened the resilience of its energy distribution network as a result of a US$ 8 million grant from the Global Environment Facility (GEF). This project aimed to support the government's continued efforts to make energy and power systems better prepared and more resilient to storms, hurricanes and natural hazards. (World Bank, 2017)
2013		Belizeans are also strengthening the climate resilience of Belize's Coral Reef system and adopting sustainable alternative livelihoods as a result of a US$ 5.53 million Adaptation Fund project, the Marine Conservation and Climate Adaptation project (MCCAP), which is being executed by the Fisheries Department (MAFFESD). (World Bank, 2017)

		While the World Bank's lending envelope is comparatively small, the Bank has managed to leverage additional funding from: i) the Japan Social Development Funds in Belize to promote Sustainable Natural Resource-Based Livelihoods; and improve Children's Health and Nutrition in Poor Mayan Communities in Toledo, and ii) the Global Environment Facility to manage and protect key biodiversity areas.
2012		The Climate Resilience Infrastructure Project — CRIP (USD 30 million), is an innovative project leveraging a grant of approximately USD 750 k from the Global Facility for Disaster Risk Reduction to improve road resilience and climate risk management for more than 170,000 Belizeans (World Bank, 2017). This project is on-going, and will end in 2020.
2011		The Designated National Authority (DNA) to approve CDM projects was established in June 2011 in the Ministry of Natural Resources and the Environment, now the newly formed Ministry of Agriculture, Forestry, Fisheries, the Environment and Sustainable Development. In 2011, the Belize National Climate Change Committee (BNCCC) was established as a broad-based, multi-stakeholder committee, and comprises of non-state, public and private sector members, to coordinate the implementation of policies and measures designed to ameliorate the adverse effects of climate change on the environment and society, adapt to the negative impacts and facilitate the national commitment to strategically transition to low carbon development. It is expected that the BNCCC will facilitate the mainstreaming of climate change policies in the various sectors and address the gaps highlighted in the National Communications to the UNFCCC.
2010		In June 2010, the Government of Belize in collaboration with CCAD/GTZ hosted a REDD planning workshop in Belize. A draft national plan was formulated, and a basic organization structure for the REDD programme implementation was established and concrete steps for follow-up were defined. The Ministry of Agriculture, Forestry, Fisheries, the Environment and Sustainable Development has been designated as the government agency responsible for the coordination and implementation of climate change policies in Belize. To assist the MAFFESD to carry out its responsibilities, the Belize National Climate Change Committee (BNCCC) was established as a broad-based, mulita-stakeholder committee comprising of non-state, private and public sector members. The BNCCC is tasked to advise government on its responsibilities under the UNFCCC, and to implement appropriate policies and strategies to ensure continued economic growth given the impacts of climate change on Belize. The BNCCC was endorsed by Cabinet in November, 2010. The Government of Belize hosted its first United Nations Framework Convention on Climate Change (UNFCCC) workshop on 5-7 May, 2010 in Belize City. The objective of the UNFCCC regional workshop for Latin

		America and the Caribbean was to enhance the capacity of project developers in preparing project proposals that will meet the standards of international financial providers. Participants were trained to prepare project proposals for financing, in particular project proposals related to environmentally sound technologies to mitigate and/or adapt to climate change. The Government of Belize had representation in the Seventeenth Conference of the Parties in Durban, South Africa. A key concern for Belize was the level of ambition of existing commitments and actions to limit global temperature increase to below 2 degrees Celsius or 1.5 degrees Celsius. The Government of Belize signed a collaborative agreement with UNEP RISO Centre in May 2010, to participate in a Clean Development Mechanism (CDM) capacity building project. Under the CDM, countries that need to reduce emissions under the Kyoto Protocol are encouraged to invest in emission reduction projects in developing countries. A requirement of such projects is a contribution to sustainable development. This would be accomplished through job creation, technology transfer and climate-sensitive, low carbon development paths.
2009 - 2015		Sustainable Tourism Program I (STP-I), April 2009 – Jan. 2014. IDB Loan USD 13.32 M. The aim was: to increase the contribution of tourism to national economic growth in a manner that is environmentally and socially responsible. Its purpose was to support the consolidation of the overnight tourism market in light of its potential to optimize the sector's contribution to the Belizean economy. its objectives were to: (a) support the improvement, restoration and diversification of overnight destinations and their products; and (b) strengthen national and local capacity for sector policy, destination planning and management. Program successfully completed in January 2014. Belize participated in a number of regional initiatives. The Heads of CARICOM countries approved, “A Regional Framework for Achieving Development Resilient to Climate Change,” (the Framework), prepared by the Caribbean Community Climate Change Centre (CCCCC). The Framework clearly articulates the strategic direction for the region’s response to climate change risks. The strategy represents a long-term vision on climate issues and reflects the political will of the region. It is one of the first regional strategies drafted and adopted among developing states, joined by a common purposed to face the climate challenge of the 21st century. The Framework provides a roadmap for action for the period 2009 -2015 and builds on other initiatives pursued by the CCCCC. Having established the priorities in the Framework, a detailed Implementation Plan and a Monitoring and Evaluation Plan has been developed in consultation with regional, national and international stakeholders. The IP was presented and adopted in March

		2012, and is entitled: *Delivering Transformational Change 2011-21: Implementing the CARICOM 'Regional Framework for Achieving Development Resilient to Climate Change'.* The Implementation Plan of the Regional Framework was adopted by CARICOM's Council for Trade and Development (COTED). Belize also signed the Regional Strategy on Climate Change prepared by the Central American Commission for Environment and Development (CCAD), and in 2008-09, participated in the study entitled "*Economics of Climate Change in Central America",* spearheaded by the United Nations Economic Commission for Latin America and the Caribbean (ECLAC, 2010).
2008		In 2008, the National Integrated Water Resources Policy was finalized. The water resources sector was the only sector that mainstream Climate Change into its policy. As a follow up to the Policy, Belize adopted the National Integrated Water Resources Management Act in May 2010. The Act calls for the establishment of a National Integrated Water Resources Authority and the elaboration of enabling regulations to operationalize the Act. The Global Climate Change Alliance (GCCA) initiated by the European Commission has contributed 2.9 million Euros to the Government of Belize to address climate change. The GCCA project will support the institutionalization of the National Integrated Water Resources Authority, and will strengthen institutional capacities through the establishment of a Climate Change Office in the MNRE to coordinate the country's response to climate change.

1.5.5 Climate Change Impacts on Health

In view of that fact that climate has a significant influence on human health and well-being, climate change may very well further strengthen this relationship. Certain diseases such as vector-borne diseases such as dengue and malaria, respiratory diseases such as asthma and water borne diseases such as cholera and dysentery may become more acute and prevalent in the future with climate change. Important determinants of vector-borne disease transmission include: vector survival and reproduction; the vector's biting rate and the pathogen's incubation rate within the vector organism. Vectors, pathogens and hosts each survive and reproduce within a range of optimal climatic conditions: temperature and precipitation are the most important, while sea level elevation, wind, and daylight duration are also important (Lindsay and Birley, 1996; Martens, 1996).

Belize, under the direction of the Ministry of Health, prepared the Belize Health Sector Strategic Plan (HSSP) 2014 – 2024. The HSSP was developed with the collaboration of social partners and stakeholders, including but not limited to Government Ministries, Professional Organizations, United Nations Agencies, NGOs and the private sector, and the Pan American Health Organization (PAHO/WHO), which provided resources for the development of the Health Sector Strategic Plan.

The HSSP reiterated that since half of Belize's population lives in coastal areas, the vulnerability to natural disasters is extremely high. In addition to the recent hurricanes impacting Belize, a major threat continues to be flooding due to heavy rainfall, which increases the risk for infectious diseases, thus impacting negatively on social life and affecting the country's productive sector.

Furthermore, Belize's Second National Communication Report (GOB, 2011b) included a risk based hazard assessment of the vulnerability and adaptation to dengue and dengue haemorrhagic fever. While it was not possible to use modelling in this assessment, it was determined that there is a strong correlation between dengue seasonal variation and monthly average rainfall. The temperature, humidity, rainfall, and altitude above sea level in Belize are within the values, conducive to the sustainable transmission of dengue. Taking into consideration the status of the environmental, biological and socioeconomic factors in Belize, and also the present adaptation capacity, the country has been categorized as having a "medium level vulnerability". Following the risk management process, risk scenarios were developed depicting ways in which dengue (the hazard) could affect different sectors of society, in order to identify dengue risk events. Using standardized Direct Impact Rating tables, Frequency/Probability Rating tables and the Risk Assessment Matrix table, each dengue risk event was ranked as follows:

- Increased cost of health care delivery extreme risk
- Increased cost of outbreak control extreme risk
- Work absenteeism high risk
- Personal income loss high risk
- Reduced national production moderate risk
- School absenteeism moderate risk
- Cancelled tourist visits moderate risk

1.5.6 Climate Change Impacts on Agriculture

It is expected that climate change would have severe impacts on the agriculture sector of Belize. Current climate changes are already affecting the agriculture sector: variability of yields/harvests for rain fed agriculture is already suffering from changes in the timing and amounts of rainfall and there is widespread perturbation of the agricultural calendar. Intense rainfalls are causing problems of soil drainage and erosion and warmer temperatures are leading to the increased incidence of yield-reducing weeds, pests and diseases.

Changes in temperature, precipitation, and carbon dioxide concentration can affect crop productivity and yields, while rising sea levels will likely lead to the inundation of coastal agricultural land and the salinization of groundwater. Flooding and wind damage from hurricanes and tropical storms can cause severe damages to agricultural production (Richardson, 2009).

According to the Report "Belize and Climate Change: The Costs of Inaction", (Richardson, 2009), the future climate for Belize and the Central America and Caribbean regions are projected to be characterized by increasing temperatures and declining levels of precipitation. The agriculture and fisheries sectors are described as vulnerable to the effects of climate change due to their dependency on natural resources (soil, air, solar radiation and water). Furthermore, agriculture constitutes a relatively greater portion of national GDP in developing countries and most developing countries have less capacity to adapt to climate change. This is particularly so in Belize that is highly dependent on the export of its agriculture produce. Crops such as maize are increasingly vulnerable to increased temperature changes and drought, since this crop is near its limit of temperature tolerance (Frutos & Tzul, 1995, GOB-CCCCC, 2014).

A vulnerability assessment for agriculture and food security in Belize projected yield effects for three staple crops—rice, maize, and beans (Frutos & Tzul, 1995). The models projected shorter growing seasons for all three crops as well as decreases in yields of 10% to 20% across the various scenarios. Reductions in yields were projected at 14-19% for beans, 10-14% for rice, and 17-22% for maize. These three staple crops are important to Belize's food security as well as for export income, and reductions in yield for these crops alone would represent BZD 13 -18 million in lost revenue (Richardson, 2009). Sugar and banana production are likely to face risks from encroachment of salt water in nearby river streams.

Singh (2013) used the crop model DSSAT-CANEGROW to simulate aerial dry biomass at harvest (t/ha) and sucrose dry mass at harvest (t/ha) for sugarcane production in northern Belize, with observed Tower Hill station and modelled ECHAM5 and HadCM3Q11 climate data for 2000-2009 decade. The results showed that for the 2060-2069 decade, sugarcane aerial dry biomass will be reduced by -12.7% with the PRECIS- ECHAM5 model, and -20.9% with the PRECIS-HadCM3Q11 model. In the case of sucrose dry mass at harvest, the simulation results show a reduction of -21.7% with the PRECIS- ECHAM5, and 28.2% with the PRECIS-HadCM3Q11 model. Increased temperature results in increased rate of photorespiration which causes sugarcane to convert sucrose to glucose and fructose, reducing sugar concentration, which in turn leads to a reduction in yields (Singh, 2013).

1.5.7 Coastal Zone

Climate change and climate-driven sea level rise impose additional threats to coastal systems already under pressure from population concentration and increasing population growth in the future. Human presence, including infrastructure facilities, is becoming a significant direct and indirect control on coastal ecosystem functions and coastal processes.

Increased coastal erosion and more extensive inundation are expected from rising sea levels; storm surges may flood greater areas than now, thereby impacting on primary production, and may cause saline intrusion up estuaries and into groundwater aquifers. These biophysical impacts may cause loss of coastal habitats, property damage, flooding and loss of life, as well as having economic consequences for rural production and urban lifestyles. In many cases the effect of a change in climate and sea level are going to exacerbate problems that already exist. Furthermore, the adaptive capacities of local communities to cope with the effects of severe climate impacts decline if there is a lack of availability of physical, economic and institutional resources employed to combat the effects of the climate hazard, and to reduce the vulnerability of high-risk communities and groups exposed to them.

Communities already exposed to coastal erosion include the villages of Placencia, Monkey River and Hopkins, while the coastline of several islands were either inundated or severely altered as a result of storm surges during the passing of recent hurricanes. Examples include San Pedro which resulted in severely eroded coastlines after the passing of several hurricanes In addition, communities such as Placencia Village, and others that are part of the Placencia Peninsula, have been identified as vulnerable to climate change due to low-lying topographical and physical characteristics (Caribsave, 2012). The Caribsave Climate Change Risk Profile for Belize also identified Rocky Point at North Ambergris Caye and Caye Caulker as areas to lose significant beach area due to sea level rise.

1.5.8 Climate Change Impacts on Fisheries

The effect of climate change and sea level rise on the fisheries sector of Belize will be mostly indirect. Fisheries require healthy habitats to survive and reproduce. Essential fisheries habitats in Belize include all types of aquatic habitats, namely wetlands, coral reefs and sea grasses where fish spawn, breed, feed, or grow to maturity. Rising sea levels could lead to partial or complete disappearance of these habitats through inundation. On the other hand, rising near-surface water temperature and increasing acidification will continue to cause massive bleaching and dieback of corals.

As reported by Richardson (2009) in the Human Development Issues Paper, the IPCC (2007) noted that the reefs of the Caribbean Sea already live near their thresholds of temperature tolerance; thus, *higher sea surface temperatures impair reproductive functions and growth capacity and lead to increased mortality* (Richardson, 2009). With species such as mangroves and corals already stressed from anthropogenic activities, climate change would exacerbate these stresses. As an example, coral bleaching is expected to worsen as a result of temperature increase. Ocean acidification is another way in which coral species can be negatively impacted.

1.5.9 Climate Change Impacts on Water Resources

Climate change is very likely to have a significant impact on the water sector of Belize. Rainfall is projected to decrease slightly and become more variable leading to intense rains and flooding on the one hand and droughts on the other. Warmer temperatures would also exacerbate drought conditions (McSweeney et al, 2009; IPCC, 2007; IPCC, 2013). Adequate amounts of rainfall and predictability are critical to the economy of Belize. Not only would there be risks of flooding from excessive rainfall in the low-lying coastlands, but also agricultural production, a key contributor to GDP, would be subject to the alternating conditions of excessive rainfall and flooding on the one hand and drought on the other. Flooding could affect residences, infrastructure like road networks, and agriculture production. Industries such as aquaculture, construction, and tourism would all be affected. In 2015, for example, an extended drought resulted in significant crop loss in agriculture communities in Northern Belize. Belize's northern districts of Corozal and Orange Walk receive significantly less rainfall annually than the rest of the country; thus, increasing their vulnerability during an extended drought. Crops such as corn, soy bean and rice were devastated by this drought in 2015.

Sea level rise and storm surges, by-products of climate change, will also affect the water sector through saline intrusions into riverine channels, coastal aquifers, and soils. Storm surges will exacerbate flooding in coastal lowlands and towns, where some 40 % of Belize's population reside and work.

1.5.10 Climate Change Impact on Tourism

A changing climate, along with sea level rise, would result in loss of beaches, properties and public infrastructure and will make Belize less attractive as a tourist destination. The loss of beaches and coastline due to erosion, inundation and coastal flooding and loss of tourism infrastructure, natural and cultural heritage would reduce the amenity value for coastal users (IPCC, 2007; IPCC, 2013). Belize's tourism sector is largely nature-based and is therefore highly vulnerable to climate change (Richardson, 2009). Sea level rise pose risks such as flooding, inundation, saltwater intrusion and erosion to water supplies, threatening water supplies, properties, and coastal areas. Two of Belize's major tourist attractions are the barrier reef and the coastal areas, including the cayes. Richardson determined that the cost of inaction in addressing the vulnerabilities of the tourism would have major negative economic impact. Projected climate change effects on Belize would result in reduced tourism demand, loss of facilities from sea level rise, loss of beaches, and loss of ecosystems (Richardson, 2009). The economic impact of the Belize tourism sector due to the impacts of climate change was estimated at BZD 11 million by 2025, BZD 27 million by 2050, BZD 43.2 million by 2075, and BZD 59.3 by 2100 (Richardson, 2009).

Like many other low-lying coastal nations, Belize is vulnerable to the effects of climate change. Its geographical location leaves the country exposed to the risk of rising sea levels and increasing frequency and intensity of tropical storms. The United Nations Intergovernmental Panel on Climate Change (IPCC, 2013), issued an assessment based on a consensus of international researchers that stated global sea levels would likely rise from 1 to 3 feet by the end of the century.

The third and final economics sector considered in the Vulnerability Assessments is Tourism, which, for Belize is vulnerable because of its dependence on natural resources such as coastal beaches, coral reefs, wildlife and forests. Coastal tourism faces particular risks from erosion and flooding, sea level increases, salinization and the threats to physical property. Warmer seawater threatens the coral reefs which attract thousands of tourists for snorkelling 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. Tourism researchers have projected that climate change may reduce the appeal of tropical destinations because of heat stress, beach erosion, decline in reef quality and increased health risks.

The economic impact of climate change for the tourism sector in Belize is estimated at BZD 48.3 million, and includes the effects of reduced tourism demand, lost facilities from sea level rise, loss of beaches from coastal erosion and loss of reef-based ecotourism. Belize's cayes are prime tourist destinations, accounting for 70% of visitation and 80% undertaking reef-based activities (Richardson, 2009). Therefore, negative impacts of climate on these prime destinations can be devastating from an economic view.

It is reported by the World Tourism Organization and UNEP that the impending changing climate will have both direct and indirect impacts on tourism. These include a shift in attractive climatic conditions for tourism; shifts in the length and quality of suitable tourism seasons (i.e., sun-and-sea or ski holidays); change in seasonal operating costs, such as heating, irrigation and water supply and annual insurance costs; and weather extremes. Weather extremes due to climate change can result in increase in the number of hot days over nearly all land areas, greater tropical storm intensity and peak winds, more intense precipitation events, and longer and more severe droughts. These types of changes will affect the tourism industry through increased infrastructure damage, additional emergency preparedness requirements, higher operating expenses, and business interruptions (WTO, 2008).

In contrast to the direct impacts, the indirect effects of climate induced environmental change are likely to be mostly negative. Island and coastal destinations are considered particularly sensitive to climate-induced environmental change, as are nature-based tourism market segments. Belize falls under destinations that are especially sensitive to climate induced environmental change. Indirect impacts from climate change include changes in water availability, biodiversity loss, reduced landscape aesthetic, altered agricultural production (e.g., wine tourism), increased natural hazards, coastal erosion and inundation, damage to infrastructure and the increasing incidence of vector-borne diseases, all of which will impact tourism to varying degrees (WTO, 2008).

Research on Belize's vulnerability (Caribsave, 2012) also identified that livelihoods such as tour operations, water-sports, accommodation facilities, food and beverage operations, are related – and therefore dependant on tourism.

1.5.11 Climate Change Impact on Energy

Global warming and climate change will directly and indirectly impact the Energy sector in Belize in a number of ways. The impacts will affect the sources of energy production, transmission and distribution, and energy use at the level of consumers. The Belize Sustainable Energy Action Plan (GOB-MESTPU, 2015) is a tool to help Belize achieve its renewable energy (RE) and energy efficiency (EE) potential while meeting Government's economic, social, and environmental goals. Belize can expand its large scale renewable energy potential, particularly with hydro, biomass, waste, wind, and solar resources. Using these new sources of energy generation will decrease Belize's dependence on Mexican power. It will also lower costs for consumers and diversify supply, thereby making the country more energy secured.

The main activities in Belize's Sustainable Energy Action Plan to streamline the Energy sector in the face of climate change are:

- Help Households, Business, and Government be more efficient
- Expand access to electricity using RE
- Promote large-scale RE
- Build an efficient and enabling utility
- Prepare for distributed generation
- Increase awareness and enhance skills

1.5.12 Climate Change Impact on Transport and Road Infrastructure

Throughout Belize, critical infrastructure, such as public buildings and roads, are in need of rehabilitation or reconstruction. The road network is particularly vulnerable due to the lack of redundancy. Belize's road network consists of 4490 km of roads, of which 600 km are arterial roads or "highways", 778 km are secondary roads and 3110 km are rural roads. Only 17.6% of the road network is paved (GOB-CRIP, 2014). The existing network of roads and bridges is severely impacted by recurrent flooding. Insufficient maintenance coupled with poorly designed road alignments are contributing to both high internal freight costs and to one of the highest road fatality rates in the Latin American region. Belize's road infrastructure is vulnerable to extreme hydro-meteorological events, which are projected to become more frequent in a warmer climate (IPCC, 2007)

1.5.12.1 The Climate Resilient Infrastructure Project (CRIP)

The Climate Resilient Infrastructure Project (CRIP), funded by the World Bank - International Bank for Reconstruction (IBRD), aims at enhancing the resilience of road infrastructure against flood risk and impacts of climate change and at improving Belize's capacity to respond promptly and effectively in an Eligible Crisis or Emergency, as required (GOB-MOWs, 2015). The CRIP will finance climate resilience activities under four mutually reinforcing components: (i) Climate Resilient Infrastructure, (ii) Technical Assistance for Improved Climate Resilience Management, (iii) Project Management and Implementation Support and (iv) Contingent Emergency Response. The investments and technical assistance under the CRIP will be in line with the National Climate Resilient Investment Plan (NCRIP) that the Government of Belize developed in order to identify and strategically address the impacts of climate change on social and economic development. Through the NCRIP, the Government of Belize made great strides to prioritize road infrastructure investments for enhanced climate resilience based on two considerations: (a) socio-economic criticality of the road network; and (b) flood susceptibility of the primary and secondary road networks. Criticality of the roads was assessed through a participatory multi-criteria evaluation (MCE) process with government and key stakeholders while the flood susceptibility was carried out using a data-driven analysis.

1.5.13 Climate Change and Land Use, Land Use Change and Agroforestry

Sequestering atmospheric carbon (C) and storing it in the terrestrial biosphere is one of the options which has been proposed to compensate greenhouse gas (GHG) emissions, especially for agriculture and degraded land sources. Agricultural lands and degraded forests are believed to be a major potential sink, and could absorb large quantities of C if trees are reintroduced to these systems, and judiciously managed together with crops and/or animals (Albretch and Kandji, 2003). Thus, the importance of agroforestry as a land-use system is receiving wider recognition not only in terms of agricultural sustainability but also in issues related to climate change.

Carbon sequestration potential of tropical agroforestry systems produce a median sequestration value of 95 metric tonnes/ha/yr. (Albrecht & Serigne, 2003). Considering variables of location, soil type, rainfall and species it can be as high as 228 metric tons per hectare. Assuming a median of 95,000 kg divided by 1,250 trees per hectare one would get 76 kg (167 lb.) per tree. In a managed plantation, trees are culled back to about 600 trees per hectare, which would result in 158 kg (348 lb.) per tree per year (Albrecht & Kandji, 2003). Managed plantations generally produce 20 to 30 times more wood than do natural forests, resulting in higher sequestration rates per hectare (Dombro, 2015).

Soil Carbon sequestration is another realistic benefit in many agroforestry systems. The potential of agroforestry for CO_2 mitigation is well recognized. However, some shortcomings that need to be considered include the uncertainties related to future shifts in global climate, land-use and land cover, the poor performance of trees and crops on substandard soils, dry environments, and pests and diseases such as nematodes.

In the area of Silviculture Systems, Dombro (2013), cited studies in Science Daily, indicates that natural African tropical forests absorb about 600 kg (1,323 lb.) of carbon per hectare per year. If one takes 600 kg by 25 times more wood per hectare in a plantation setting, one gets 15,000 kg (33,000 lb.) per hectare per year divided by 600 plantation trees per hectare, which results in 25 kg (55 lb.) of carbon sequestered per tree per year. One of the topical species recognized as an efficient nitrogen fixing tree (NFT) is *Acacia mangium* (Dombro, 2013). A Springer publication cited by Dombro (2013) showed that NFT's sequester more carbon in the soil than do other types of tropical trees.

Agroforestry

In Belize, agroforestry is practiced mostly at the small farm level, on farms averaging between 10 to 25 acres, but there is at least one large commercial operation. A number of citrus farmers in the Stann Creek District are planting pineapples between the citrus trees. Bowen and Bowen Limited, one of the largest soft drink bottling companies operating in the country, plants coffee within the natural forest on its property in northwest Belize. The product is sold in local supermarkets countrywide. In the southernmost district, Toledo, which experiences the highest rainfall, an increasing number of farmers are growing cacao and raising bees under the cover of the natural forest. There is an ongoing project funded by the United Kingdom Department for International

Development which is providing assistance for expansion of this initiative. The organically grown cacao beans are for guaranteed sale to a certified buyer in the United Kingdom.

Some small to medium-sized farmers practice mixed farming in order to have different products at different times of the year. Combinations of corn, plantains, chickens, a few heads of cattle and pigs might all be included in the mix. Some who raise pigs or chickens may also plant corn in order to have their own source of feed.

The Forest Department conducts hardwood seed harvest twice per year (April & November) and nursery operations and reforestation on a small scale (Mr. Oscar Ulloa, Forest Officer, Cayo District, personal comm. May, 2017). Most of the nursery saplings are donated to schools and private entities for private reforestation programmes. Figure 20 shows two scenes of nursery operations at the Forestry Department branch headquarters in San Ignacio, Cayo District.

Figure 20: Nursery for hardwood species, Forest Dep. Cayo District, Sep. 2016

The Friends for Conservation and Development (a local NGO in the Cayo District)/GEF- Small Grant Programme (FCD/GEF-SGP) project, "*Reducing land degradation in the Vaca Forest Reserve through bee-keeping*", was a pilot project meant to provide credibility to the innovative concept for community participation in the use and management of the forest reserve. The general objective of the project was to reduce land degradation and unstainable use of forest resources in the Vaca Forest Reserve (VCR), by stimulating apiculture activities with fifteen farmers operating inside the reserve and in the buffer zone as a viable economic industry, while promoting a stewardship program among these stakeholders for the long-term conservation of this protected area. Figure 21 a-b show scenes of farmers who participated in the FCD apiary programme in 2011-2012.

a.

(Source: FCD Project Evaluation Report, June, 2012)

b.

Figure 21: Farmers doing honey production in the buffer zone of the Vaca Reserve

1.6 Process and Results of Sector Selection

The process to prioritize the sectors and technologies was formally started on the first day of the TNA Inception Mission to Belize on 23rd March, 2015. However, on 19th March 2015, the National Climate Change office had initiated discussions with key government stakeholders on the matter of priority sectors. The Inception Mission then marked the official start of the Phase II project in Belize, with one of the first tasks being to introduce the project to national stakeholders. During the first day of the Inception Mission, one of the presentations evolved into general discussions related to prioritization of sectors and technologies. This produced the preliminary prioritization of the sectors and technologies.

Participants were in general agreement that priority sectors and technologies covered in the first phase of the project were still applicable for this second phase. The sectors chosen for mitigation are energy, transport, agriculture and “land use and land use change and forestry”.

Another activity of the Inception Mission was to interview potential candidates to provide service as the National Consultant. The next event which occurred under the project was the National Inception Workshop held on 23rd June at the Best Western Biltmore Plaza Hotel in Belize City. The purpose of this meeting was the verification of the sectors selected for mitigation and adaptation technologies, and the updating of the Work Plan. The output of that meeting was selection of the Mitigation sectors, namely: *Land Use, Land Use Change and Forestry; Transport; and Energy for technological interventions*.

The national consultants were tasked with developing a minimum of three Fact Sheets for each of the sectors identified by the national stakeholders in the Inception Mission. These Fact Sheets would provide information on viable technologies that could later be prioritized and implemented locally in sectors such as Energy, Transport, Solid Waste, Agriculture, Water, Coastal and Marine Ecosystems, and Land Use Change and Forestry. These Fact Sheets were submitted to the Assistant National TNA Coordinator who circulated them to the members of the Working Groups in preparation for a workshop held on 6th October 2015, during which the proposed list of technologies was reviewed. The purpose of the Working Groups session was to review the content of the fact sheets and to recommend additional mitigation technologies that might be applicable to Belize other than those the consultants had proposed.

Along with the submission of the Factsheets for the Working Group workshop, the national consultants had made recommendations for the composition of the technology Working Groups, identifying institutions and government departments, and in a few cases individuals who would contribute to the discussions based on training and/or experience. A short-list of criteria to be used for the review was also offered. The Assistant National Coordinator completed the membership by selecting other sector representatives and invited them to form the Sector Working Groups. Stakeholders of the Technology Working Groups represented organizations such as the Fisheries Department; Belize Electricity Company Limited (BECOL); Beltraide; Lands and Survey Department; Ministry of Natural Resources and Agriculture; Programme for Belize; Ministry of Forestry, Fisheries, and Sustainable Development; Department of Transport, Public Utilities Commission, Ministry of Rural Development, Ministry of Energy, Science and Technology, and Public Utilities; Coastal Zone Management Authority and Institute; Belize Enterprise for Sustainable Technology; Ministry of Tourism, Civil Aviation, and Culture; and the National Climate Change Office.

Most of the preparations for the Working Group Meeting were coordinated by the Assistant National TNA Coordinator. Throughout the process to date, effort has been made to ensure the participation of stakeholders. Invitations were extended by the Assistant National Coordinator to participate in a half-day meeting during which the TNA Working Group members would review the fact sheets and determine which should be processed further. This workshop was scheduled and held at the George Price Centre in Belmopan, on 6th October 2015. The main output of that workshop was a revised list of Fact Sheets that would be further analysed and prioritized at follow-up workshop by a broader group of stakeholders.

The members of the Working Groups were highly interactive in evaluating the sectors and technologies offered for consideration. The participation turned out to be higher than the confirmed invitees, with 11 confirming by the end on the day before the workshop, but twenty-five persons turned up. The working groups considered sectors under both mitigation and adaptation categories. The meeting began as a large group for purposes of introductions, background information and presentations, and short discussions on the shortlist of criteria and instructions for the process.

The participants then separated into four smaller groups to discuss the technology fact sheets prepared for the mitigation sectors.

The sectors considered for review at the working group meeting were:

- **i.** Land Use, Land Use Change and Forestry
- **ii.** Transport
- **iii.** Energy, and
- **iv.** Solid Waste.

Instructions given to Working Groups:

- Review the content of the factsheets (Background notes, implementation barriers, reduction in emissions, impact on country priorities, cost, lifetime, etc.)
- Provide critical feedback about the feasibility of the technologies for implementation in Belize. This should help us to determine whether a technology deserves further consideration or whether it should not be considered at all.
- Suggest other technologies that should be considered within the sector.

The Working Group session was considered a pre-screening for the Prioritization process which used the Multi Criteria Decision Analysis tool. Some criteria for evaluation were presented to participants, and after some discussion, the list of mitigation criteria was finalized to include the following:

- Capital cost
- Maintenance cost
- Operating cost
- Job creation
- GHG emissions reduction
- Air and water quality
- Energy security
- Technology replication
- Life of the technology, and
- Implementation time.

As a result of the Working Group debate, recommendations were made that the following mitigation technologies be further reviewed, and the fact sheets prepared for the prioritization process. Technologies such as Advanced Bio-hydrocarbon Fuels, Bio-methane CNG Hybrid Fuels; and Solar PV were recommended for the Energy sector; Improved Private Vehicles Operating Standards, Intelligent Transport Systems, Non-Motorized Transport, Bio-methane Hybrid Fuels for the Transport sector; and for the LULUCF sector Wetlands Restoration and, Agroforestry (mitigation) were recommended.

A follow-up two-day Technology Prioritization workshop was held on 14th and 15th October 2015 at the Black Orchid Resort in Burrell Boom Village, Belize District. This workshop had the participation of the members of the Working Group as well as other representatives of the TNA project management team. Shortly before the Technology Prioritization workshop, a planning meeting was held between the Assistant National Coordinator and the national consultants' team leader in order to finalize the stakeholders' recommendations on the study sectors. Eleven Fact Sheets were eventually prepared and circulated for consideration.

Thirty-one persons attended the first day of the Technology Prioritization Workshop and twenty-two on the second. After background presentations, and introductions, the participants were instructed on the procedures for the workshop. They were then separated into two groups in order to review the Fact Sheets by categories; one group dealt with mitigation technologies while the other evaluated the adaptation technology Fact Sheets. The two groups reconvened as one at the end of the first day to present their findings to make recommendations for the next day's work. This report discusses the results of the mitigation group's work.

During the closing session at the end of the first day, the participants expressed concerns about the incomplete condition of some of the Fact Sheets. Data and information was missing, the information and costs were irrelevant to Belize, and some had dated information.

1.7 Revised Mitigation Technology Selection and MCA Process

In February 2016, the National TNA Coordinator requested a change in Consultants due to inefficient work being carried out by the National TNA consultant. As such, a new TNA consultant was appointed on February 15th, 2016.

Following a request to revise the TNA climate change adaptation and mitigation technologies, conduct a Multi-Criteria Analysis, and proceed to complete the Barrier Analysis and Enabling Framework process of the prioritized technology factsheets, the new Consultants, after consultation with the TNA Coordinator, proceeded to begin consultative meetings with small stakeholder groups in the selected productive Sectors in March through June, 2016. As indicated earlier, the selected sectors for the TNA Climate Change Adaptation technology transfer were: Agriculture, Water, and Marine and Coastal Ecosystems; while for Mitigation the sectors included: Energy, Transport and Land Use Land-use Change and Agroforestry.

A major drawback occurred around mid-June, 2016, when the Mitigation Consultant had not delivered on the proposed mitigation technology factsheets and another Consultant had to be procured who could continue with the consultations for re-selection of the mitigation technologies, and drafting of the corresponding technology factsheets.

1.7.1 Mitigation Factsheets

The new Mitigation Consultant proceeded to conduct the consultative process with small working groups and focus groups of stakeholders in the Energy and Transport Sector during which the following technologies were selected for developing technology factsheets, and prioritized them using the TNA project Multi Criteria Assessment tool. The technologies selected by the stakeholders included:

Energy sector:

1. Solar PV Off-Grid Systems.
2. Gasification Systems.
3. Solar PV On-Grid.
4. Micro-Hydro Electric Power System.

Transport sector:

1. Levying duty on imported motor vehicles based on carbon emission rates.
2. Retrofitting of existing vehicles with Liquid Petroleum Gas (LPG) Systems.
3. Improved Urban/Suburban Public Transport System using more fuel-efficient buses.

Land Use, Land Use Change and Agroforestry sector:

For the Land use, Land-use Change and Agroforestry Sector, the consultants conducted a series of consultative meetings with small groups of stakeholders in the forestry, agriculture, non-governmental organizations (NGOs), and the private sector, to review technology needs and gaps in the sector, and reach an agreement of at least three technologies for factsheet development. In the end, the technologies choses were to establish improved nurseries and reforestation programme to address the degraded pine and broadleaf forests areas of the Mountain Pine Ridge (MPR) and the Chiquibul Forest Reserve, and work with 20 farmers from buffer communities to the Vaca Forest Reserve in integrated landscape forest management. Two technology factsheets were drafted and reviewed, namely:

1. Improved Tropical Hardwood & Pine Caribe Species Nurseries and Reforestation (MPR & Chiquibul Forest Reserves).

2. Integrated Landscape Forest Management: A Management Alternative in the Vaca Forest Reserve.

1.7.2 Consultations for the Mitigation Technologies

The consultation process for the selection of the revised mitigation technologies in Energy and Transport was face-to-face visits and discussions with small groups of stakeholders in the respective sub-sectors. Visits to individual stakeholders to select, discuss and review the draft technology factsheets were carried out on a bi-weekly basis. Meeting with these groups proved difficult at times to organize, as the agreed meeting date and time had to be postponed numerous times due to other commitments by the stakeholders. Nevertheless, the following are the dates in which these sectors were met for consultation sessions regarding the developments of the various factsheets:

- Transport Sector Consultation – June 29th, 2016
    - Attendees
        - Lead TNA Consultant
        - TNA Mitigation Consultant
        - Senior Transport Officer & Acting Operations Officer
        - Transport Warden II
        - Deputy Chief Transport Officer

- Transport Sector Consultation – August 4th, 2016
  - Attendees
    - Lead TNA Consultant
    - Senior Transport Officer & Acting Operations Officer
    - Transport Warden II

- Transport and Energy Sector Consultation – November 25th, 2016
  - Attendees
    - Lead Consultant
    - Assistant Consultant
    - Senior transport Officer & Acting Operations Officer
    - Director of Energy

Table 11 below is a summary of the selected mitigation technology by sector. The updated technology selection was based primarily on feedback from the stakeholders small group consultations and the recommendations from Belize's NDC, Belize's Third National Communication to the UNFCCC, and the National Climate Change Policy, Strategy and Action Plan. From the inception of the deliberations, the selected technologies were related to activities or programmes already being considered or implemented in the public and private sectors. The ten mitigation technology factsheets are contained in Appendix I for reference.

Table 11: Summary list of Mitigation Factsheets

Sector	Sub-sector/ Technology Option	Technology Application	Remarks
		1) *Solar PV Off-Grid Systems*	An off-grid system is a decentralized renewable energy system adopted by homes and small businesses to produce reliable and cost-effective power. In isolated locations, off-grid systems tend to be cheaper than establishing transmission lines in the area, and has the potential of reducing GHG emissions since no power will be provided from the national grid.
		2) *Solar PV On-Grid Systems*	On-Grid Solar PV systems (1 – 5 kW) are installed on residential, commercial or public buildings and generate electricity which is consumed by the customer and the excess is sent/sold to

Energy	Greenhouse Gas Reduction Technology		the grid to be consumed by other users.
		3) *Gasification Systems*	Gasification is the partial oxidation process that uses a carbon source such as coal or biomass to produce carbon monoxide (CO) and hydrogen (H_2), plus carbon dioxide (CO_2) and possibly hydrocarbon molecules such as methane (CH_4) which are otherwise known as ***syngas*** or synthetic gas. The syngas can then be combusted to generate electrical or mechanical energy or as feedstock to manufacture fertilizers, pure hydrogen, methane or liquid transportation fuels. The solids and liquids left behind are called charcoal and tar which are then used for soil augmentation.
		4) *Solar Water Heaters*	Solar Water Heating (SWH) is a proven technology that has been widely applied across residential, commercial and industrial sectors around the world. Solar water heating (SWH) takes advantage of the region's abundant solar resource to provide a simple, cost-effective, and sustainable means of heating water.
		5) *Micro-Hydro System*	Micro Hydropower Run-of-the-River Facility for Douglas D' Silva Forest Station and Tourist Centre, Mountain Pine Ridge, Belize. Micro-hydro power is the small-scale harnessing of energy from falling water, such as steep mountain rivers. Using this renewable, indigenous, non-polluting resource, micro-hydro plants can generate power for homes, hospitals, schools, workshops, environmentally friendly tourist destinations, forest station facility and small farming communities.

Sector	Sub-sector/ Technology Option	Technology Application	Remarks
Transport	Greenhouse Gas Reduction Technology	1) *Levying duty on imported motor vehicles based on carbon emission rates.*	This technology intervention aims to change the way in which duties are charged on motor vehicles being imported into the country of Belize. The main result of this project will be to modernize the way in which duty is charged so that it encourages the country's citizens to import more fuel efficient and less carbon emitting motor vehicles.
		2) *Retrofitting of existing vehicles with Liquid Petroleum Gas (LPG) Systems.*	When LPG is used to fuel internal combustion engines, it is often referred to as auto gas or auto propane – in Belize it is called butane. LPG has been used since the 1940s as a petrol alternative for spark ignition engines. This project seeks to retrofit existing petrol (gasoline) vehicles in Belize to use LPG or butane. The aim of this intervention is to improve fuel efficiency, fuel costs and reduce GHG emissions.
		3) *Improved Urban/Suburban Public Transport System using more fuel-efficient buses.*	This technology intervention seeks to improve the public transportation system through the revamping of the current bus fleet to allow for newer, cleaner and more comfortable buses with reduced carbon dioxide emission rates (CO_2 per mile). An additional spin-off effect would be the increased use of the public transportation system by private vehicle owners on a daily basis, that will reduce vehicle usage and as a consequence further reduce carbon emissions.

Sector	Sub-sector/ Technology Option	Technology Application	Remarks
Land Use, Land Use Change & Agro-Forestry	Greenhouse Gas Reduction Technology	1) *Improved Tropical Hardwood & Pine Caribe Species Nurseries and Reforestation (Mountain Pine Ridge & Chiquibul Forest Reserves*)	The proposed reforestation technology transfer will target about 5,000 acres (2023.6 ha) for rehabilitation over a project time horizon of 5-years, during which the Forest Department and other stakeholders will be institutionally and technically strengthened to sustain and manage the reforestation program. Reforestation would provide carbon sequestration rates of 95 tonnes/ha/year on average.
		2) *Integrated Landscape Forest Management: A Management Alternative in the Vaca Forest Reserve.*	The proposed agroforestry technology is the re-introduction of the Forest Landscape Management approach as an alternative and innovative means of management and conservation of the Reserve. The target group will be 20 farmers from three buffer communities and the coordinating agencies will comprise of the Friends for Conservation and Development and the Forest Department. Other public and private stakeholders will be invited to activate a Vaca Forest Reserve Working Group. The time horizon for the project is five (5) years. The general objective is to reduce emissions arising from land-use and land-use change through a community forestry program incorporating sustainable livelihood strategies and diversifying local economic opportunities.

CHAPTER 2. INSTITUTIONAL ARRANGEMENT FOR THE TNA AND STAKEHOLDER INVOLVEMENT

2.1 Key National Institutions in Climate Change Policy Making and their Role in the TNA

Cognizant that Climate Change is already having negative effects on the socioeconomic fabric of Belize, and recognizing also, that vulnerability to the impacts of Climate Change will be the greatest challenge to sustainable development in the medium and long term, the Government of Belize adopted and implemented the National Climate Change Policy, Strategy and Action Plan (NCCPSAP) which serves as a Road Map for all governmental entities as they seek to develop and implement adaptation and mitigation policies and programme in their respective portfolios.

The effective implementation of the NCCPSAP called for the establishment of a coherent, overarching governance structure with clear policy directives and supported by a strong institutional framework, that can provide direction and coordination of efforts among other agencies and line ministries, in their equitable and critical role in adaptation and mitigation actions (GOB-CCCCC, 2015). The National Climate Change governance structure must be supported by appropriate legislative and regulatory instruments to adopt and implement policies and measures to mitigate the adverse effects of Climate Change and adapt to these changes, as it seeks to build resilience in the development of a low carbon economy. In this regard, it is being recommended that GOB establishes a Climate Change Department (CCD) in the MAFFESD and revise the mandate of the Belize National Climate Change Committee (BNCCC).

The reconfiguration of the governance structure for Climate Change management has financial implications, and the proposed two streams of funding as indicated in the NCCPSAP must be further analysed, while other sources of finance to kick start the process must be identified. Notwithstanding the establishment of a Climate Change Department, GOB has established the National Climate Change Office (NCCO) within the Ministry of Agriculture, Forestry, Fisheries, the Environment, and Sustainable Development (MAFFESD) to coordinate all matter related to Climate Change in the interim. Steps have also been taken to re-configured and streamlined the BNCCC in-keeping with its perceived role of providing policy guidance and facilitating the mainstreaming of Climate Change adaptation and mitigation. The BNCCC consists of a total of eleven (11) members with three sub-committees (Vulnerability Assessment and Adaptation, Mitigation, and Public Education and Outreach).

Key institutions involve in Climate Change policy making include the following:

1. Cabinet of Belize;
2. Ministry of Agriculture, Forestry, Fisheries, the Environment and Sustainable Development;
3. The National Climate Change Office (NCCO) in the MAFFESD*;
4. Ministry of Finance and Economic Development;
5. Ministry of Energy, Science, Technology and Public Utilities;
6. Ministry of Transport and NEMO
7. Ministry of Health
8. Ministry of Labour, Local Government and Rural Development
9. University of Belize
10. Ministry of Tourism, Culture and Civil Aviation
11. Ministry of Works
12. Ministry of Education

* NCCO mandate is to coordinate all matter related to Climate Change, and advise the Minister on climate change related issues and Belize's commitment to the UNFCCC via the National Climate Change Committee.

Figure 22 shows the new governance architecture for Climate Change Administration in Belize as proposed in the NCCPSAP (GOB-CCCCC, 2015).

The Chief Executive Officers of these ministries/institutions, or their nominee, are members of the Belize National Climate Change Committee (BNCCC), the body that advises the Government of Belize on the Convention and matter related thereof.

The Chief Executive Officer of the Ministry of Forestry, Fisheries and Sustainable Development (MFFSD) sits as the chair of the committee, whereas the NCCO functions as the secretariat of the committee. The main task of the committee is to advise the government of its responsibilities under the UNFCCC and the implementation of appropriate policies and strategies to ensure continued sustainable development in Belize.

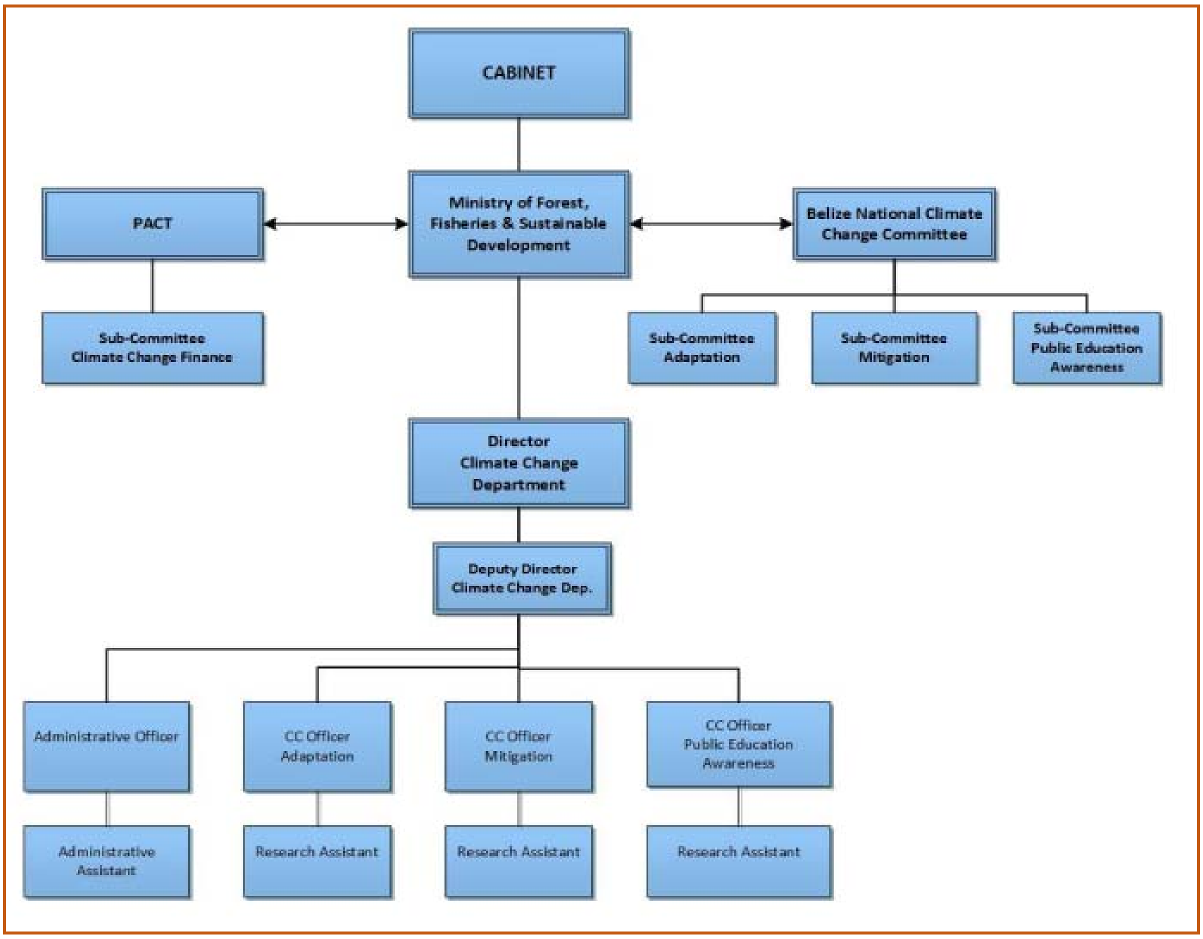


Figure 22: New governance architecture for Climate Change management in Belize

(Source: GOB-CCCCC, 2015)

2.2 National Technology Needs Assessment Team

A schematic of the institutional arrangement for the Technology Needs Assessment Phase II Project in Belize is shown in Figure 23. The NCCO, headed by the National Coordinator, is responsible for the coordination and management of the TNA project.

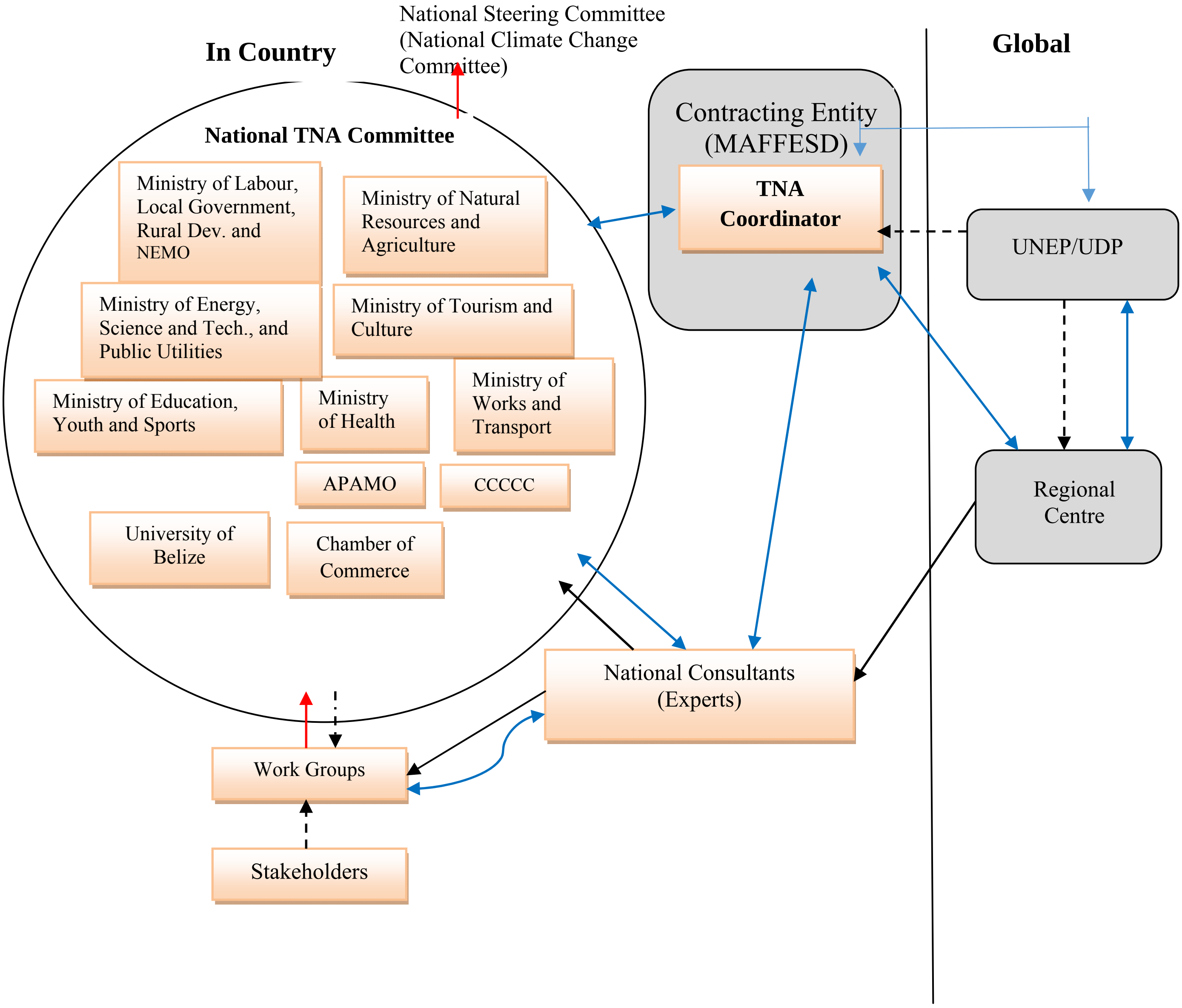


Figure 23: Institutional arrangement for Technology Needs Assessment Phase II, Belize

(Source: Terms of Reference National TNA Consultant, 2016)

The Belize National Climate Change Committee functions as the National TNA Steering Committee for the duration of the project. The National TNA Team comprises the National Climate Change Coordinator and TNA project Coordinator, the TNA Assistant Coordinator, the TNA Sector working groups, the national consultants, and key stakeholders.

2.2.1 The National Climate Change Office

The National Climate Change Office (NCCO) was established in 2015 under the then Ministry of Forestry, Fisheries, and Sustainable Development (MFFSD), now the Ministry of Agriculture, Forestry, Fisheries, the Environment and Sustainable Development (MAFFESD). The NCCO headed by a National Climate Change Coordinator, is the government agency responsible for Climate Change. The main task of the NCCO is to coordinate the country's Climate Change program on behalf of the Government of Belize. The NCCO is the secretariat to and is supported by the Belize National Climate Change Committee (BNCCC), which comprises of eleven members from key line ministries, non-government organizations, the University of Belize, and members of the private sector (GOB-NCCO, 2016).

2.2.2 National TNA Coordinator

The National Climate Change Coordinator, of the National Climate Change Office of Belize is designated as the National TNA Coordinator. The National Coordinator serves as the in-kind contribution of the Government of Belize to the Project. The National Climate Change Coordinator is assisted by the Assistant National TNA Coordinator, who serves as a consultant to the project under the auspices of the National Climate Change Office.

2.2.3 National Project Steering Committee (NPSC)

The Belize National Climate Change Committee functions as the National Project Steering Committee. The CEO in the Ministry of Agriculture, Forestry, Fisheries, Environment and Sustainable Development chairs this committee.

Members of the NPSC include:

1. Ministry of Agriculture, Forestry, Fisheries, the Environment and Sustainable Development — Chair
2. Ministry of Economic Development- Vice Chair
3. Ministry of Natural Resources
4. Ministry of Health
5. Ministry of Works and Transport
6. Ministry of Tourism, Culture and Civil Aviation
7. Ministry of Labour, Local Government, Rural Development and NEMO
8. Ministry of Energy, Science and Technology, and Public Utilities
9. Representative from the Private Sector (Vice Chair)
10. Representative from NGO/CBO Umbrella Group
11. Representative from the University of Belize

2.2.4 The Technology Needs Assessment Consultant and Team

The TNA Consultant selected by the mission is the Lead Consultant or Team Leader. The Lead Consultant is also the Climate Change Adaptation Consultant, and is assisted by a Climate Change Mitigation Consultant. The Team Leader has the responsibility for coordination and assignment of tasks. Team members are encouraged to make contact with stakeholders in the search for data and information. To date, all stakeholder's meetings and workshop preparation have been facilitated by the Team Leader in collaboration and with the support of the Assistant National Coordinator. The team participates in each of the workshops since the National Inception Meeting.

2.2.5 Working Groups for Climate Change Mitigation

Members of the Technology Needs Assessment small working groups are as follows:

(i) Energy

a. Department of Energy
b. Public Utilities Commission
c. Belize Bureau of Standards
d. Industry Stakeholders
e. Rep. Financial Institutions

(ii) Transport

a. Department of Public Transport
b. Department of Energy
c. Private Bus Owners
d. Industry Stakeholders
e. Rep. Financial Institutions

(iii) Land Use, Land-use & Agroforestry

a) Forestry Department
b) Agriculture Department
c) Local NGOs
d) CARDI
e) University of Belize School of Agriculture
f) Representative of Farmers groups

The Working Groups are national stakeholders who participated in the technology selection process by reviewing outputs of the consultant(s), conduction technical evaluation and providing technical advice as needed.

2.3 Technology Needs and Criteria

Technology requirements can change with changes in policy, development objectives and changes in the technologies themselves (UNDP, 2010). It should therefore be cautioned that the technology needs identified 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. The choice of criteria for technology transfer should satisfy the general requirements of: 'Technology Use and Diffusion'; 'Sustainable Development Impacts'; and 'Climate Impacts'. However, as a general requirement the following criteria should also be taken into account:

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

Table 12: 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 & Aquaculture	√		√	√	√			√	√
Human Settlements	√			√				√	√
Human Health		√			√	√			√
Tourism	√		√	√	√	√	√	√	

Identified links among and across the sectors can also aid in maximizing technology choices as illustrated in Table 12. As can be observed, the matrix (Table 12) attempts to illustrate the possible synergy and inter-linkages among sectors. 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 prioritizing technologies that can have multiple or collateral benefits in other sectors. It should be noted that the identified inter-linkages are based on the possible applicable technologies only.

In the Energy sector, for example, the principal strategic elements of Belize's Sustainable Energy Roadmap to 2035 (GOB, 2016c) are:

- Energy efficiency, which involves interventions in: i) appliances and buildings; and ii) transport.

- Renewable energy policy actions aim at shifting the energy matrix away from fossil fuels to alternative renewable energy technologies.
- Clean production policy actions aim to upgrade production systems in agriculture and forestry to use less energy and other raw materials, increase productivity, better waste management practices that may co-produce or generate energy, including bio-fuels and/or electricity.
- Modernizing the energy infrastructure such as a smarter, more unified and integrated electric grid.
- Universal access to modern energy services is an essential pillar of Belize's energy strategy. Universal access to electricity is critical for the socio-economic development of the nation, and is fundamental to lifting the living standards of the people of Belize.

CHAPTER 3: TECHNOLOGY PRIORITIZATION FOR THE ENERGY SECTOR

3.1 Energy Production and GHG emissions in the Energy Sector

The Government of Belize is committed to develop, adopt and implement policies and measures to reduce its carbon footprint, and increase the country's resilience to the adverse effects of Climate Change (GOB-NCCO, 2016). Climate Change mitigation potential of Belize according to the NDC (2016), is action-based among multiple sectors, namely: forestry, energy (electricity), waste and transport.

Energy production in Belize (MESTPU, 2016) comes from various sources.

- Wood (10.09%);
- Petroleum gas (0.86%);
- Hydroelectric plants (10.10%);
- Biomass (35.36%); and,
- Crude oil (43.56%).

3.1.1 Crude Oil

The Belize Natural Energy (BNE) is the only entity that has been successful in exploration and production of crude oil in Belize. In 2005, BNE discovered commercial quantities of crude oil. Currently, BNE produces approximately 1,800 barrels of crude oil per day, and 1,800 gallons of Liquefied Petroleum Gas (LPG – sold locally)

Since operation began, BNE has:

- Discovered and developed Belize's only two commercial oil fields;
- Produced 10 million barrels (bbl.) of crude oil;
- Sold 10% of crude production to local industries;
- Contributed in excess of USD 240 million in Government Revenues; and
- In the process of diversifying in energy production (e.g. RE, etc.) as crude oil resource decreases.

3.1.2 Hydro-Electricity

Four (4) hydro power plants, three (3) on the Macal River (Cayo District) and one on the Columbia River (Toledo District), supply power to the local electricity grid. These are the Mollejon Run-of-river Hydroelectric Plant, Chalillo Hydroelectric dam and reservoir, Vaca Run-of-river Hydroelectric Plant, and Hydro Maya Limited (HML), respectively. In total, these plants produce approximately 52 Mega Watts of electricity at peak capacity (rainy season).

3.1.3 Biomass and Wood

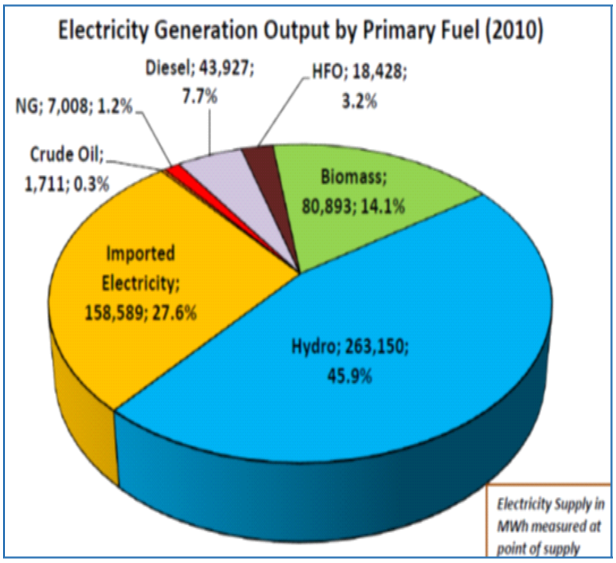
Belize Co-Generation (BELCOGEN, ASR/BSI) uses the trash from sugar production to generate electricity; approximately 13 MW seasonally from December to July each year. Wood is used by local families and other entities to produce charcoal for consumption by households and small scale commercial and industrial entities, such as white lime production.

3.1.4 Petroleum Products and Electricity Generation

Belize also imports petroleum products mainly for the transport and commercial sectors and electricity from Mexico. Products such as liquefied petroleum gas (LPG), gasoline, kerosene, light fuel oils and diesel oil are the majority of the petroleum products imported. Currently, petroleum is imported from Venezuela under the Petro-Caribe Agreement.

Primary Fuel Type for Electricity Generation in Belize, 2010	MWh	Percentage
Hydro	263,150	45.9
Biomass	80,893	14.1
Imported Electricity	158,589	27.6
Diesel	43,927	7.7
Heavy Fuel Oil (HFO)	18,428	3.2
Natural Gas (NG)	7,008	1.2
Crude Oil	1,711	0.3
Total	**573,706**	**100**

a. *Primary fuel type for Electricity*



b. *Electricity generation output (MWh)*

Figure 24: Primary fuel type for electricity in Belize in 2010
(Source: Tillett, A., Locke, J., Mencias, J., 2012)

Figure 24 shows a breakdown of the actual electricity (measured in MWhs) generated from the primary fuel inputs in 2010. This energy supply profile has not changed significantly from 2010 to 2016.

Approximately 60% of electricity was generated from renewable energy sources, and 27.6% was imported from Mexico. Interestingly, nearly 16% of the total electricity was generated from local sources (Biomass, Natural Gas and Crude) and for own use, with the remainder provided by utility sources. As can be observed, energy derived from hydro power contributes almost 46% of the total, followed closely by imported, fossil-based electricity sourced from Comisión Federal de Energía of Mexico or the Federal Energy Commission of Quintana Roo, Mexico (CFE) which was 27.6%. In third place was energy derived from biomass (mostly Cogeneration from the Belize Sugar Industry), contributing about 14.1%. Electricity derived from imported diesel and heavy fuel oil topped off the remainder.

Note that in 2014, 36.82% of the electricity generation output was imported from CFE (GOB-NCCO, 2016).

Emissions

According to the second GHG emission inventory report (see Table 13), total emissions in 2000 were 13,482.7769 Gg CO2 equivalent or 13.5 Mt. The Energy Sector's contribution the 2000 total emission was 8%, which was less than the 13% and 22% contributions in 1997 and 1994, respectively.

Table 13: Total and proportions of GHG emissions for Belize in 1994, 1997 & 2000

Total Volume of GHG Emissions by Sectors (Gg) for Reference Years 1994, 1997 & 2000			
Sector	**1994**	**1997**	**2000**
Energy	617.5280	1,026.7511	1,127.2995
Industrial Processes & Solvents	1.7350	1.8001	2.1972
Agriculture	46.4146	1.5846	2.0825
Land Use Change & Forestry	2,056.3650	7,117.1762	12,349. 2819
Waste	104.7000	1.5141	1.9158
Total	**2,826.7426**	**8,148. 8262**	**13,482.7769**
Proportion of GHG Emissions by Sectors for Reference Years 1994, 1997 & 2000			
Sector	**% of Total**	**% of Total**	**% of Total**
Energy	22	13	8
Industrial Processes & Solvents	0	0	< 1
Agriculture	2	0	< 1
Land Use Change & Forestry	73	87	91
Waste	4	0	< 1
Total	100	100	100

(Source: Belize's Second National Communications to the UNFCCC, 2011). *1 Gg is 1000 tonnes*

The Energy Sub-Sector emissions for the baseline years 2003, 2006 and 2009, as reported in Belize's Third National Communication (TNC) 2016, is summarized in Table 14 below. Total, higher emissions were registered from diesel and gas in 2003 and 2006; with increased contribution from crude in 2009, as crude production in the Spanish Lookout field was on the rise.

Table 14: Estimated Sub-Sector Energy emissions (tonnes CO_2 for 2003, 2006, & 2009)

Emissions in tonnes, Belize, C. A.	2003				2006				2009			
	Gas	Diesel	LPG	Crude	Gas	Diesel	LPG	Crude	Gas	Diesel	LPG	Crude
Energy		26.18				13.37		1.55		5.66		5.00
Manufacture - autogen		1.20	0.00			1.18		1.85		1.70	0.00	3.44
Manufacture-process heat		11.90	1.60			11.82	2.05	1.85		6.41	1.76	9.64
Transport - aviation	2.43				2.30				2.44			
Road	47.47	36.12	1.06		35.9	37.40	1.25		39.6	33.53	1.18	
National marine	2.21				1.38				1.46			
Commercial autogen		0.80				0.79				0.57		
Commercial process heat		0.40	4.64			0.39	5.06			0.35		
Residential	0.00	0.30	5.30			0.63	5.87			0.28		
Agriculture	3.28	8.88	0.66		2.30	11.06	0.44	4.26	3.27	8.22	0.44	6.02
TOTALS	55.4	85.8	13.3	0	41.9	76.6	14.7	9.51	47.3	56.7	14.7	24.1
Grand Total	**154.5 tonnes**				**142.71 tonnes**				**142.80 tonnes**			

(Source: Belize's Third National Communications, GOB-NCCO, 2016)

Electricity Consumption

Table 15 and Figure 25 show the historic electricity consumption per capita (kWh per person) for the period 2000 to 2014. The per capita consumption of electricity almost triple from 2012 – 2013, and remained above 1,800 kWh in 2014, compared to the 612 kWh per person or lower consumption during and prior to 2012. The sharp increase in electric energy demand may be attributed to an increase in services and households, and improved metering, among other reasons.

Table 15: Electricity consumption in kWh per capita

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Belize	654.14	672.1	678.94	696.37	679.62	389.33	387.86	553.02	641.62	627.8	631.12	618.16	611.5	1,884.55	1,848.35

(Source: CIA World Factbook retrieved from http://www.indexmundi.com/g/g.aspx July, 2017)

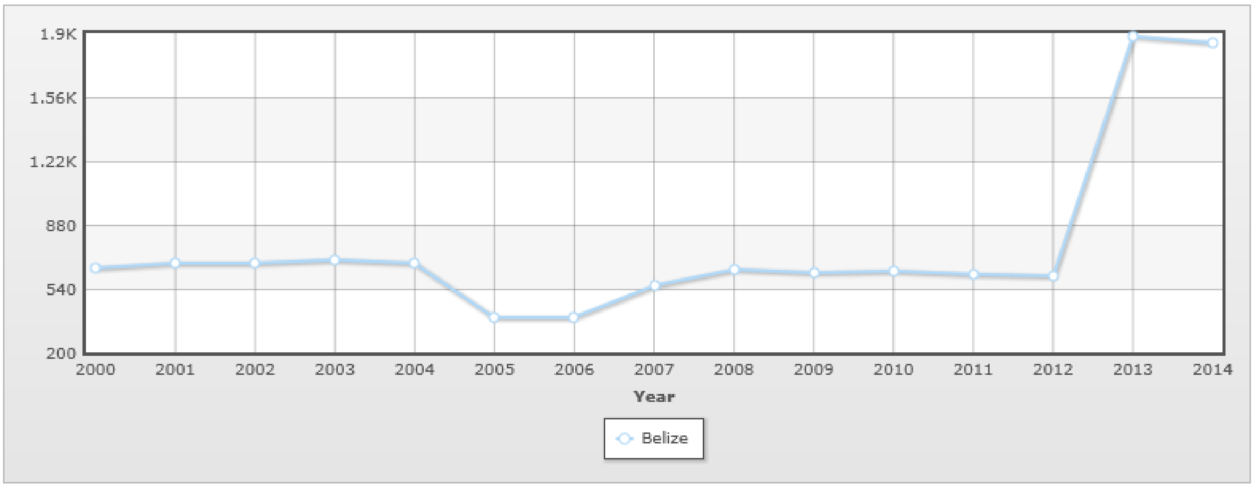


Figure 25: Electricity consumption per capita (kWh per person) in Belize

(Source: CIA World Factbook retrieved from http://www.indexmundi.com/g/g.aspx July, 2017)

3.2 Energy Sector and Climate Change

In order for Belize to become a low carbon economy by 2033, one sustainable energy strategy includes the development of Renewable Energy (RE) to shift the energy matrix away from fossil-fuels (especially oil) to alternative renewable energy technologies (GOB-NCCO, 2016). To realize the country's medium and long-term energy strategy, it is necessary to develop a local electricity micro-generation market, where small producers, such as individual households, communities, commercial establishments and even small industrial entities, can sell electricity for local distributions systems and the national grid. Hence, the need to develop and seek funding/investments for RE packages including: solar photovoltaic on-grid and off-grid systems, micro-hydro power, wind, biomass, etc. (Cocco, *et.al.*, 2014).

3.2.1 Decision Context

The demand for electricity will increase in Belize, but a shift towards renewable and more efficient energy source will moderate the ever-growing demand. Based on a report from Castalia Limited in 2014, Belize has unrealized sustainable energy potential, but to tap into this potential requires approximately BZD 500 million. This would make the renewable energy source contribute almost 90% of the county's electricity needs by 2033. The report states that a focus on biomass, solar and hydropower are key to realizing this goal.

Section six (6) of the Third National Communication report highlights the gaps, constraints, financial and technical needs of each sector in order to achieve the Climate Change goals set out in the National Climate Change Policy, Strategy and Action Plan (NCCPSAP). The following areas were identified as most relevant to climate change mitigation in the Energy Sector:

a) Improve energy efficiency to dramatically lower energy intensities across key economic sectors such as Transport, Industry, Buildings (Commercial & Residential), Public lighting and Agriculture. Actions include:

   - Improve energy efficiency in buildings and appliances.
   - Promote transition to sustainable transportation.
   - Develop appropriate financial and market-based mechanisms that support energy efficiency and renewable energy.

b) Develop renewable energy to shift the energy matrix away from fossil fuels (especially oil) to alternative renewable energy technologies. The main action is:

   - Develop Belize's human, technological and institutional capacity to accelerate the uptake of appropriate clean energy and clean production technologies.

c) Promote and facilitate Clean Production systems in the processing of Agriculture and Forestry outputs to co-produce bio-fuels and/or electricity.

3.3 Technology Options in the Energy Sector and their other Co-benefits

3.3.1 Solar PV Off-Grid

An off-grid system is a decentralized renewable energy system adopted by homes and small businesses to produce reliable and cost-effective power. In isolated locations, off-grid systems tend to be cheaper than establishing transmission lines in the area.

In order to set-up an off-grid solar system, apart from purchasing the solar PV system you will need to invest in energy storage systems, as off-grid solar power systems without storage will not be able to supply power when there's no sunshine. The main components of an off-grid system are the PV array, charge controller, battery bank and DC-AC converter. [DC–Direct Current, AC – Alternating Current]

Typically off grid systems require a larger up-front investment than grid tied systems due to additional charge controller and batteries that are employed in the system.

The power that is generated by the renewable energy source initially charges the batteries through the charge controller. The inverter helps to regulate the voltage and in most cases, converts the DC power to AC (what normal home appliances require).

The system to be installed is a DC system that is able to power a few lights, a small radio and a fan. The components are as follows:

- 60-W Solar Panel
- Sealed 'No Maintenance' Solar Battery (12v/30Ah)
- Battery Enclosure
- Battery Capacity meter
- Dual Position (Lighter-Style) 12V charging outlet

- 13 W Florescent Light Bulbs
- DC 3-speed Ventilation Standing Fan
- Solar Charge Controller
- System Wiring and Mounting Hardware

Economic benefits include job creation for local technicians for the installation and maintenance of PV systems. This would require technical and manual labour, which would increase the workforce of Belize. Stand-alone and Mini-grid systems would require personnel to monitor, maintain, and evaluate installations. Even tertiary institutions can benefit from offering technical programs relating to Solar PV systems. Cost savings may be realized from establishment of community micro grid of Solar PV; reducing the need for expensive transmission lines and accessories for national grid linkup of far flung communities, and the need to imports more electricity and petroleum products, as demands in rural Belize increase in the near future.

Some of the potential social impacts include:

i. Increased income due to investment in Solar PV systems, employment through installation, maintenance, evaluation and monitoring of systems, and even training programs.
ii. Capacity development of locals through training and capacity building in the use and maintenance of solar technologies.
iii. Improvement in health, education and general livelihood of populations not served by the national grid.

Some of the environmental impacts are:

i. Off-grid PV systems that are roof- mounted and do not require additional land usage to for its installation.
ii. Solar PV systems are considered closed systems and hence require no fuel or any inputs during operation and electricity production. It also does not contaminate water.
iii. Solar PV systems cause no noise or vibration and hence considered environmentally friendly.
iv. Predictions are that upwards of 80% of the bulk material in solar panels will be recyclable; recycling of solar panels and batteries is already economically viable.

3.3.2 Gasification

Gasification is the partial oxidation process that uses a carbon source such as coal or biomass to produce carbon monoxide (CO) and hydrogen (H_2), plus carbon dioxide (CO_2) and possibly hydrocarbon molecules such as methane (CH_4) which are otherwise known as syngas or synthetic gas.

This technology is based on biomass gasification to produce electricity using small modular gasifiers ─ such as the APL Power Pallet PP20 unit. This unit integrates a gasifier, an internal combustion engine and an electricity generator. This TNA intervention seeks to install two (2) gasification units at separate locations. Preferably at establishments/companies that produce biomass waste such as coconut water processing and/or oil processing facilities. The units will be installed and used as either the primary or backup energy source.

The intent is for these systems to be installed at agro-processing establishments, where there is a suitable biomass waste stream. The unit will be used to produce electricity for emergency situations such as power outages. Establishments that currently produce coconut water and oil are of particular interest. Coconut husks are a good biomass source, sugar cane bagasse, citrus waste and others.

Gasification is a series of chemical reactions, which take place in the controlled environment of a gasifier. There are multiple types of gasifiers and the model chosen is dependent on the feedstock to be gasified. The normal process of gasification can be broken down into various stages, such as:

1. Biomass fuel is heated in a reduced oxygen gasifier chamber to about 100 °C under high pressure (about 1000 lb. per sq. inch) so that drying occurs.
2. Pyrolysis follows at 200 – 300 °C. During pyrolysis, volatiles in the form of gas and liquids are off gassed and solid char rich in carbon is left behind. It is this char that will undergo gasification reactions.
3. Combustion occurs as the previously produced volatiles, along with some of the char, reacts with limited amounts of oxygen. This creates carbon dioxide and small amounts of carbon monoxide. The combustion provides heat for the subsequent gasification process to occur.
4. Gasification happens once the char starts to react with carbon and steam to generate carbon monoxide and hydrogen. It is this mixture of carbon monoxide and hydrogen, which comprises syngas. Whatever parts of the fuel are not converted, are reduced into charcoal and tar and fall into an ash bin.

The syngas can then be combusted to generate electrical or mechanical energy or as feedstock to manufacture fertilizers, pure hydrogen, methane or liquid transportation fuels. The solids and liquids left behind are called charcoal and tar which are then used for soil augmentation.

The viability of this unit is heavily weighted on the availability and cost of appropriate feedstock. Based on the feedstock options presented in the above table, Belize's most abundant feedstock would be softwood and hardwood chips as well as coconut shells or palm kernel shells. The following compares the operating costs in USD of fossil fuels versus gasified biomass.

- Diesel/LPG $0.40 - $0.75/kWh
- Gasoline $0.50 - $1.00/kWh
- Gasified Biomass $0.00 - $0.20/kWh

(Note that these are in US dollars and calculated when the world market price for crude oil was at USD 50 per barrel.)

Socially, the potential is there for earnings to be generated from the sale of electricity. This can in turn, be used to purchase of feedstock from local farmers. Additionally, there will be a need to train individuals to properly operate the gasifier. A possible negative impact comes in the form of potential negative health effects for the operators of these systems. Health issues as it relates to the operation of the gasifier will be mitigated with the training that must be received from the equipment supplier and properly equipping operators with the correct safety gears.

Some gasification units are recognized as carbon negative units. That is, at the end of the process cycle, the unit has the ability to remove carbon from the atmosphere. It should be noted that the carbon emissions from the peripheral activities such as wood chipping and transportation are not being accounted for.

3.3.3 Solar PV On-Grid

On-Grid solar PV systems or Grid-connected systems are solar powered systems that are connected to the national power grid. Grid-connected PV systems does not require energy storage but instead use an inverter to convert electricity from direct current (DC) to alternating current (AC), and the generated electricity is then supplied through the distribution network to consumers. Grid connected PV systems are further classified into two types of applications – distributed and centralized. Grid-connected distributed PV systems are installed on residential, commercial or public buildings and generate electricity which is consumed by the customer and the excess is sent/sold to the grid to be consumed by other users. Most distributed systems range between 1-5 kW in power generation. The centralized systems are usually larger and not necessarily on building rooftops but can be designed as solar 'farms', ranging from 10 kW up to a few MW in generating capacity. An example of a centralized Solar PV On Grid system is the small farm, pilot Solar PV system set through the Japan International Cooperation Agency (JICA) and the Government of Belize (2010) at the University of Belize main campus that feeds into the national grid.

Some of the economic benefits for Belize triggered by an increased Grid-connected Solar PV uptake would include:

(i) Direct job creation- Installation and maintenance of PV systems would require technical and manual labour, which would increase the workforce for Belize. The utility and regulator would need more technical personnel as well, to monitor and evaluate installations. Even tertiary institutions can benefit from offering technical programs in Solar PV systems
(ii) Energy security. It is crucial to diversify energy sources for electricity production, especially since a substantial percentage of Belize's electricity needs is sourced from Mexico, and may become insecure in the future. Also, a high portion of Belize's electricity is generated through hydropower. Solar PV can complement hydropower during extended dry periods when hydropower generation is generally lower.
(iii) National Cost savings. Due to reduced imports of total petroleum products Belize would retain an otherwise outflow of currency.
(iv) Reduced Grid Electricity Losses. Grid-connected distributed PV systems allow for reduced losses in the electricity network since the system is installed at the point of use and costs are reduced if mounted on existing infra-structure.
(v) Customers with on-grid distributed systems can benefit from a reduced electricity bill or in some cases make a profit by selling back excess power to the grid.
(vi) The local energy distributor (BEL) would benefit financially.

Socially, the Growth and Sustainable Development Strategy 2014 – 2017 adopts an integrated, systemic approach for sustainable development and encompasses medium-term economic development, poverty reduction and longer-term sustainable development issues. It is focused on the country's development priorities which creates an enabling environment for investment in technologies required to achieve this goal.

Some Social Benefits of an increased Solar PV market include:

(i) Increased income due to investment in Solar PV systems, employment through installation, maintenance, evaluation and monitoring of systems, and even training programs.
(ii) Capacity development of locals through training and capacity building in the installation, use and maintenance of solar technologies.

Solar PV is a clean technology and has the following additional environmental benefits:

(i) Grid connected-distributed PV systems that are roof-mounted and do not require additional land usage to for its installation.
(ii) Solar PV systems are considered closed systems and hence require no fuel or any inputs during operation and electricity production. It also does not contaminate water.
(iii) Solar PV systems cause no noise or vibration and hence considered environmentally friendly.
(iv) Predictions are that upwards of 80% of the bulk material in solar panels will be recyclable; recycling of solar panels is already economically viable.

3.3.3.1 Pilot Solar PV On Grid installation at the University of Belize

In November 1, 2010 the GOB, with funding and technical assistant from the Japan International Cooperation Agency (JICA), installed a pilot Solar PV On Grid system on 2.04 acres of land on the University of Belize main campus in Belmopan. The objective of the pilot project was to introduce clean energy by solar electricity generation using photovoltaic panels and to evaluate the feasibility of uploading and selling solar electricity to Belize Electricity Limited (BEL), the national electricity distributor.

The main components of the system were:

- Array of PV panels;
- Underground cables (22 kV and 600 v) including communication cables;
- Power transformers and 11 kV metal enclosed cubicle;
- Control house;
- Warehouse for spare parts.

After 10 years, the system will be handed over to the University of Belize (UB) to maintain, operate and sell energy. Figure 26 shows the GOB/JICA Solar PV On Grid system electricity generation system display, and a portion of the PV panels array.

Figure 26: Solar PV On Grid system at the University of Belize central campus

(GOB/JICA project, installed in Nov. 2010)

3.3.4 Micro Hydropower Run-of-the-River Facility for Douglas D' Silva Forest Station

Micro-hydro power is the small-scale harnessing of energy from falling water, such as steep mountain rivers. Using this renewable, indigenous, non-polluting resource, micro-hydro plants can generate power for homes, hospitals, schools, workshops, environmentally friendly tourist destinations, forest station facility and small farming communities.

A "Run-of-the-river" system does not require a dam or storage facility to be constructed. Instead water is diverted from the stream or river, channelled into a valley and drop through a turbine via a pipeline called a penstock.

The turbine in the power house drives a generator that provides the electricity to the local community. By not requiring an expensive dam for water storage, run-of-the-river systems are a low-cost way to produce power. They also avoid the damaging environmental and social effects that larger hydroelectric schemes cause, including a risk of flooding. Water from the river is channelled through a settling basin, which helps to remove sediment that could harm the turbine. The water then flows into the Forebay Tank where it is directed downhill through the penstock. When the water reaches the bottom, it drives a specially designed turbine to produce the electricity. Water is then sent back into the stream. The diagram in Figure 27 illustrates this run-of-river micro-hydro technology.

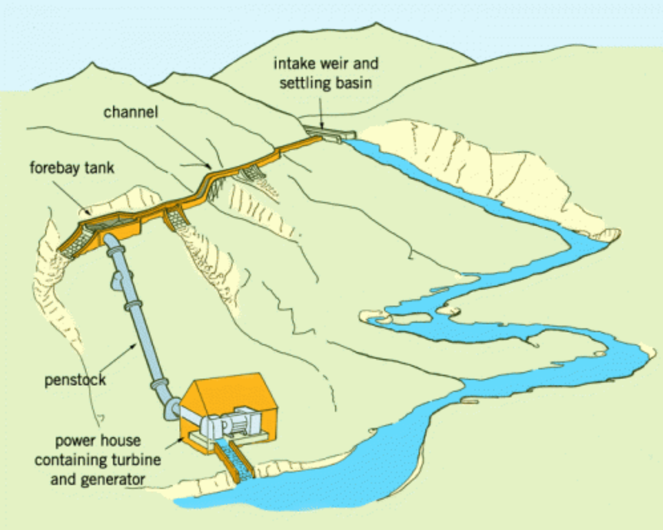


Figure 27: Illustration of micro-hydro run-of-river system

One of the greatest limiting factors in the transformation of the Douglas D'Silva Station into an Eco-Tourism, Research and Education Facility is the unreliable source of electrical energy produced by an old Lister diesel generator. Energy is intermittently provided for a three to four-hour period. For the station to be converted into a tourist resort and education/research centre, it would require that the system be upgraded requiring greater output than can be provided by the present generator, and a more reliable source of energy. An assessment of the available alternative sources of energy indicate that the facility's needs could best be met through a small hydroelectric plant.

The hydrology and topography of the area, with its abundance of creeks and tributaries of the Macal River, provides a suitable environment for the use of this technology.

The Mountain Pine Ridge Micro-Hydroelectric project is projected to generate electric power of 110/220 V, utilizing the waters of the Rio On River by means of a micro hydroelectric power station with a total installed capacity of 75 -100 kW. The aim is to improve the supply and quality of the electric service in the Douglas D'Silva Forest Station (DDSFS) and the proposed plans to convert the DDSFS into a model Eco-Tourism, Education and Research facility (Tunich Nah, 2004). It is expected that this improvement in providing a reliable source of affordable electricity will allow the transformation of the Station into an Eco-Tourism, Research and Education Centre.

The transformation of the DDSFS into a model Eco-Tourism, Education and Research Facility in accordance to the MPRFR Master Plan will provide and create new job opportunities for members of nearby communities of San Antonio, Cristo Rey, Seven Miles Village and San Ignacio (De Veries, 2004). The MPRFR Visitor Use Master Plan calls for Public-Private administration of the proposed Eco-Tourism Education and Research Facility. However, the installation and operations of the micro hydroelectric plant will be the responsibility of the Forest Department in the Ministry of Agriculture, Forestry, Fisheries, the Environment and Sustainable Development, which manages the reserve within which the forest station and the project site area are located.

The market potential of the micro hydroelectric facility will indirectly stimulate the local tourism market, enhance sustainable forest management and research. The technology itself can be replicated or adopted in other tourist/forestry /agriculture enterprise, that may benefit from the economic and environmental spin off of an 'eco-tourism/green technology label'.

3.4 Criteria and process of technology prioritisation for the Energy Sector

3.4.1 Multi-Criteria Analysis (MCA) Process Results

Once stakeholders had reviewed the selected mitigation technologies and the draft factsheets, the Multi-Criteria Analysis (MCA) was conducted. For the sake of expediting the MCA process a combined session was called on February 7th, 2017. This session sought to conduct the MCA session in a workshop environment for the mitigation technologies (Energy, Transport and Agro-Forestry).

Factsheets that were analysed in the MCA process for the Energy Sector were: -

a) Solar PV Off-Grid Systems
b) Solar PV On-Grid Systems
c) Solar Water Heaters
d) Gasification Systems
e) Micro-Hydro System

MCA Criterion and Category

After extended discussions, the criteria selected for prioritizing the Energy technology factsheets were based on three general properties, namely:

a) Technology use and diffusion; b) Sustainable development impacts, c) Climate change impacts.

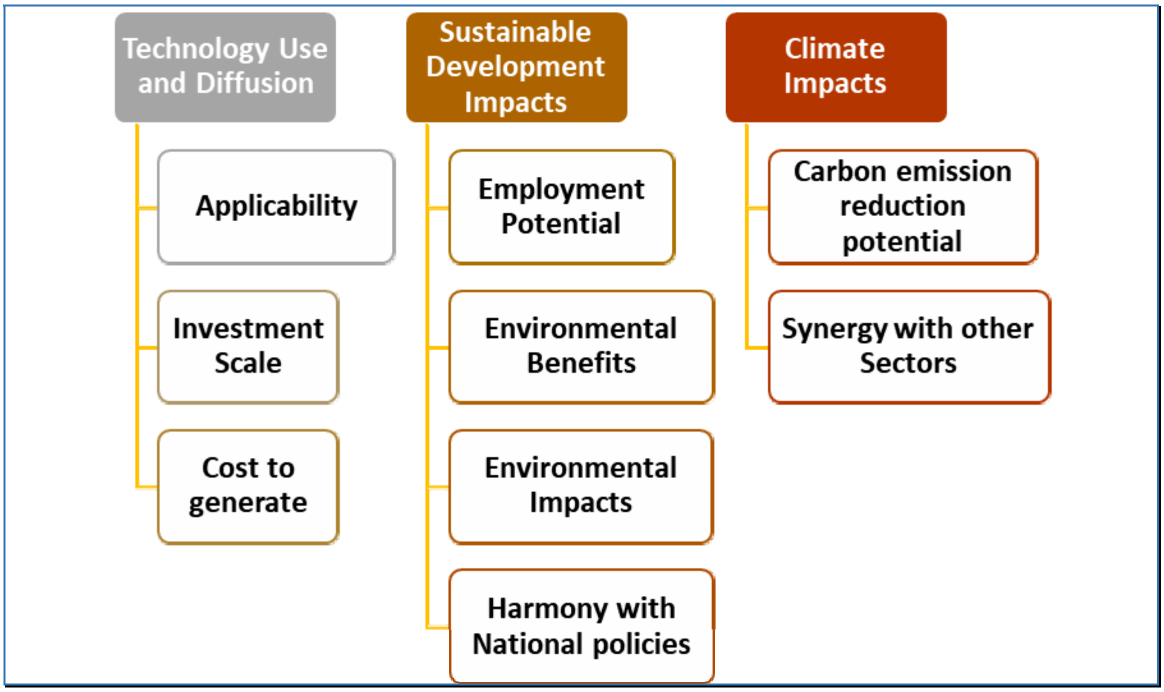


Figure 28: Energy Technology Criteria Properties and Categories for the MCA

Most of the selected criteria categories corresponded to properties or characteristics of the three, desired properties for each technology as illustrated in Figure 28. These are 'Technology Use and Diffusion', 'Sustainable Development Impacts', and 'Climate Impacts'.

The MCA for Energy and Agro-Forestry were completed successfully in the session. However, since there were no representatives from the transport working group, the Transport technology factsheets MCA had to be rescheduled to a later date on February 23rd, 2017. The three drafted Transport sector technology factsheets were eventually prioritized during a small group meeting with representatives of the Transport Department, Bureau of Standards, Bus Owners representative, the Lead Consultant and Mitigation Consultant, and the National Climate Change Office TNA Assistant Coordinator, on February 23, 2017. Table 16 and Table 17 list the technologies criteria category and weighting, respectively.

Table 16 : Criteria Category, Units and Value Preferred

Criterion	Criteria category	Unit Chosen	Value Preferred (High, Low)
Capital Cost	Cost	low to high	Low
O&M	Cost	low to high	Low
Job Creation	Economic Impact	low to high	High
Energy Independence	Economic Impact	low to high	High
Skill and Capacity Dev.	Social Impact	low to high	High
Energy Security (HH Level)	Social Impact	low to high	High
Cost per ton GHG	Environmental Impact	low to high	Low
Local Environment Benefit	Environmental Impact	low to high	High
Use of Local Resources	Environmental Impact	low to high	High
Adoption Rate	Social Impact	low to high	High

Table 17: Weighting Criteria for Energy Technologies

Criterion	Allocation of budget (total = 100)	Weight, %
Capital Cost	20	20%
O&M	15	15%
Job Creation	10	10%
Energy Independence	9	9%
Skill and Capacity Dev.	5	5%
Energy Security (HH Level)	3	3%
Cost per ton GHG	10	10%
Local Environment Benefit	10	10%
Use of Local Resources	3	3%
Adoption Rate	15	15%
Total allocated	100	
Budget usage	OK	

3.5 Results of Technology Prioritisation for the Energy Sector

Results of the prioritized Energy sector mitigation technology factsheets is illustrated in Table 18 below. The three technology factsheets prioritized in order of score attained were:

1. Solar PV Off Grid
2. Gasification, and
3. On-grid Solar PV

The factsheets for the Micro-hydro and Solar Water Heaters technologies garnered the least scores in the MCA process. The result of the MCA process was later discussed with stakeholders during a subsequent, small group meeting held at the NCCO Office in July, 2017. The micro-hydro technology was considered for further evaluation in the Barrier Analysis and Enabling Framework phase although it was not prioritized, but the proponents did not fervently pursue the matter; thus the Consultants withdrew this technology from the prioritized list.

Consequently, the three prioritized technologies as listed in Table 18 will be taken forward to the Barrier Analysis and Enabling Framework phase of the TNA process for Belize.

Table 18: Prioritized Energy Sector Mitigation Technologies

Rank	Option	Weighted Score
1	Solar PV Off Grid	65.1
2	Gasification	63.9
3	On-grid Solar PV	52.6
4	Micro-Hydro	33.0
5	Solar Water Heaters	32.5

CHAPTER 4. TECHNOLOGY PRIORITIZATION FOR THE TRANSPORT SECTOR

4.1 GHG Emissions and Existing Technologies in the Transport Sector

4.1.1 Status of the Transport Sector

Belize's road network consists of 4,490 km of roads, of which 600 km are arterial roads or "highways", 778 km are secondary roads and 3,110 km are rural roads. Only 17.6% of the road network is paved (GOB-CRIP, 2014). The existing network of roads and bridges is severely impacted by recurrent flooding. Insufficient maintenance coupled with poorly designed road alignments are contributing to both high internal freight costs and to one of the highest road fatality rates in the Latin American region.

Problems identified in the Belize Transport sector during the recent survey conducted in preparation of a Comprehensive National Transportation Master Plan (Bonilla *et al.,* 2017) were:

- Deficiencies in the road maintenance system. In Belize's Primary Highway Network, 27% of the surface is in bad conditions; 69% in fair conditions; and only 4% in good conditions. The deficiency results from: a) Insufficient budget; b) Outdated construction methods; c) Lack of control of vehicle weights and overloads.
- Road Safety. There are more road accidents in Belize than the average for other Central American countries. The reasons may be: a) Infrastructure, e.g. lack of vertical and horizontal signalling; b) narrow bridges in poor conditions and, c) insufficient shoulder width.
    - Behaviour of drivers. Speeding on the road network is a major problem. This was brought to light during a road survey conducted in November, 2011.
    - Vehicles. There is no technical inspection to assess the road worthiness of motor vehicles.
- Below average quality of the road network. The quality of Belizean roads is below the average considering they have been qualified as poor (grade 3.0) compared to the rest of the countries in the region (grade 3.7).
- Insufficiency of redundancies in the road network.
- Lack of capacity in the road transport sector.

a. On the part of the Ministry of Works, the following shortcomings have been identified:

i. The technical staff has been decreasing as the private sector proposes better financial conditions and engineers tend to quit the Ministry as they have gained enough experience to become consultants.

ii. There is a real lack of skills in certain disciplines such as transport economics /planning, legal/contractual issues, hydrology.

iii. The monitoring process requested by International Financing Institutions (IFIs) tend to be pretty demanding, in some cases with high amounts of bureaucracy and low flexibility.

iv. Trainings are not really effective as often the staff is not available or cannot focus enough on the issue which hinders the improvement of capacity.

b. Private sector. The main weaknesses are as follows:

i. Low size of companies, and low number of competent contractors.

ii. Lack of knowledge of newer methods.

iii. As the construction tends to be a protected market, programmes funded by IFIs tend to divide the roads in very small road sections so the local contractors are eligible. This has a double consequence: it reduces the attraction of those contracts for international countries that could transfer knowledge, and it increases the bureaucracy and the monitoring efforts as the number of contracts is higher.

iv. In terms of works supervision, local consultants have difficulties to align to IFIs procedure.

4.1.2 Public Transport

The main challenges identified in the transport sector were:

- Lack of vehicle and license database.
- Inappropriate intercity bus stop infrastructure which increases road safety risks and hinders proper bus operations as drivers tend to stop arbitrary.
- Insufficient bus termini infrastructure for national and international services, especially in Belize City, but also applicable to several cities of the country.
- Inefficient organization and operations of the bus transport system.

The shortcomings in this area are very important and include:

a. Evidence of low level of professionalism in the profession, with very few legally constituted companies.
b. Extremely old fleet (average age 25 years).
c. Inadequacy of supply and demand, with significant oversupply for many

routes.

d. Duration of route permits very low (2 years).

e. Difficulties to generate revenue for the operators and to obtain funding which partially explains the age of the fleet.

f. Unclear policy for issuing route permits.

g. Low level of requirements to obtain a permit (easy access to the sector with impact on the quality of service.

h. Presence of monopolies or lack of minimum services (no bus services to the airport, monopoly for taxis, and so no public transport).

The Government of Belize will have to address these pressing challenges if it aims to revamp the Transport sector in Belize.

Fuel Sub-sector

Considering Belize's sustainable development goals as well as the sustainable energy goals pursued as part of the National Energy Policy (GOB-MESTPU, 2012; GOB-CCCCC 2015), there is an urgent need to make interventions in the Fuel sub-sector, specifically:

(i) Formulate and implement a Sustainable Transport policy to reduce economy-wide fuel intensity, and

(ii) Implement a bio-fuels policy within an overarching upgrading of the regulatory and business environment for fuel production, delivery, storage and end-use.

In the absence of a transport policy (GOB-CCCCC 2015), it is imperative that a vulnerability assessment is undertaken with greater emphasis on assessing the vulnerability of the transport infrastructure, particularly in urban areas and other areas which are critical in sustaining the country's productive sectors (tourism, agriculture, commerce and ports). An improved and energy efficient transport sector will not only reduce the country vulnerability to storm surges and floods, but also assist in reducing GHG emission.

It is therefore necessary to promote energy efficiency in the transport sector through appropriate policies and investments: These improvements should include:

a. Undertaking a traffic management study aimed at reducing traffic congestion in urban areas and along the Philip Goldson Highway into Belize City;
b. Improve public transportation;
c. Upgrade maintenance of bus fleet;
d. Improve management and scheduling;
e. Upgrade the country's industrial fleet
f. Promote the use of bio-fuels

Emissions

Assessments of GHG emissions and sinks for the National Communications to the UNFCCC, captures emissions for the Transport sector as an aggregate of emissions in the Energy sector.

According to the Belize Second National Communication (GOB, 2011b), two main energy sources were identified for emissions: fossil fuels, which are imported; and biomass which includes the burning of bagasse in the sugar industry, and consumption of fuel wood for domestic use, as well as for the production of white lime.

The results of this study show that there was a small increase in emissions within the energy sector between 1997 levels at 1,026.751153 Gg and 2000 at 1,127.2995 Gg. Considering emissions for 1994 of 617.53 Gg (recalculated), the trend shows a steady increase in emissions, but the study also revealed that these emissions were from the same sources. No new sources were identified in any of the two reference years considered in the study.

Emissions classified as International Bunkers stood at 41.27 Gg for 1994, 276.02 Gg for 1997 and 94.35 Gg for 2000. Data indicated that this was primarily due to trade within the Commercial Free Zone (CFZ) in the Corozal District, which peaked in 1998. Activities that resulted in GHG emissions within the energy sector included electrical energy generation, manufacturing, road transportation, marine transportation (National Navigation) and local flights (Domestic Aviation). Residential outputs and the fishing industry also contributed to those emissions. Consumption of gasoline and the resulting emissions increased considerably from 1994 to 1997, but dropped to a lower level by 2000.

The combination of gasoline and diesel showed similar behaviour, this probably being attributed to more vehicles being on the roads. The expansion of new-vehicle dealerships may also be a factor in this sub-sector.

The principal contributor to CO_2 emissions within the energy sector came from road transportation (GOB, 2011b). Emissions from this activity were 263.58, 275.94 and 330.55 Gg CO_2 for 1994, 1997 and 2000 respectively, accounting for 44.2%, 44.6% and 51.4% of all energy-related activities countrywide. Carbon dioxide emissions from the transportation sub-sector (within the Energy Sector) accounted for the third highest level of GHG emissions in 2000.

Meanwhile, the Third National Communication (GOB-NCCO, 2016 b) emission estimates for the Energy Sector show an overall decrease in emissions of carbon dioxide (CO_2) for the reference period 2003, 2006 and 2009. Table 14 (Section 3.1.4) is a summary of the most recent estimates of sub-sector's carbon emissions from different energy sources for the Energy sector of Belize. The contributions of the sources showed a decline from liquid fuels and a major increase in biomass use and the supplies of hydroelectricity.

4.1.3 Climate Change Vulnerabilities

Currently, Belize imports all of its petroleum products. The majority is imported from Venezuela through the Petro-Caribe initiative. Belize imports approximately 40 million gallons of fuel product annually (20 million gallons in diesel and 20 million gallons in gasoline).

Table 19: Belize GHG emissions for 2003, 2006 and 2998 in tonnes

Greenhouse Gas Emissions (tonnes)			
Sector	**2003**	**2006**	**2009**
Road Transportation	84.65	74.55	74.31
Agriculture	12.82	18.06	17.95
Electricity Production	26.18	14.95	10.66

According to the second GHG emission inventory report, total emissions in 2000 were 13,482.7769 Gg CO2 equivalent or 13.5 Mt. Note that 1 Gg is 1000 tonnes.

The Third National Communication states that the transport sector is the biggest consumer of energy in Belize, accounting for 46.8% of total consumption in 2010 (GOB, 2016b). The Third National Greenhouse Gas Inventory Report (2015) also shows that transportation, in particular road transportation accounts for a significant amount of GHG when compared to other sectors, as shown in the Table 19.

4.2 Decision Context

Section six (6) of the Third National Communication report highlights the gaps, constraints, financial and technical needs of each sector in order to achieve the Climate Change goals set out in the National Climate Change Policy, Strategy and Action Plan (GOB-CCCCC, 2015). For the Transport Sector, the following areas were identified that are most relevant to Climate Change mitigation:

Resources included estimated cost for the following planned activities:

- Comprehensive assessment of transportation/communications infrastructure and their vulnerability to storm surges, floods and other forms of natural disasters, especially in relation to the major productive (tourism, agriculture, etc.) sectors.
- Review and update standards for construction and maintenance of transportation infrastructure to include an additional protective margin for the expected risks associated with climate Change.

- Develop risk assessments and response plans, including mapping and identification of high-risk and critical infrastructure (related to the productive sectors), and implementing key infrastructure reinforcements and relocations.
- Promote energy efficiency in the transport sector through appropriate policies and investments: These improvements should include:

  a. Undertaking a traffic management study aimed at reducing traffic congestion in urban areas and along the Philip Goldson Highway into Belize City
  b. Improving public transportation
  c. Upgrading maintenance of bus fleet
  d. Improving scheduling
  e. Upgrading the industrial fleet
  f. Promoting the use of bio-fuels

4.3 Mitigation Technology Options in the Transport Sector and their other Co-benefits

4.3.1 Levying duties on imported vehicles based on carbon emissions

This technology intervention aims to change the way in which duties are charged on motor vehicles being imported into the country of Belize. The main result of this project will be to modernize the way in which duty is charged so that it encourages the country's citizens to import more fuel-efficient motor vehicles.

It is the intention of this technology intervention to formulate a system (Vehicle Emission Duty - VED) that charges duties on an imported vehicle not by the number of cylinders it has, but by the amount of CO_2 it emits per unit distance travelled (gCO_2/mile). Note that the factsheet does not propose a VED system to replace the current import duty tariffs, but rather that imported vehicles with low or acceptable emission rates will enjoy a reduction in the import duty cost. The factsheet will be used to initiate the consultative exercise for the development of such a system. The project will be carried out by a team of experts knowledgeable in the fields of customs and excise regulations, automotive systems and legislation.

The ultimate goal is to produce a comprehensive monitoring and evaluation of a VED pilot project, and an accompanying report to be presented to the relevant stakeholders (government and non-government) for review and approval.

Economically, this system has the potential of reducing the country's fuel bill through a more efficient use of fuel in the near future. The indirect outcome is to have more money for other areas of the economy such as health care and education.

4.3.2 Retrofitting vehicles with LPG fuel systems

When LPG is used to fuel internal combustion engines, it is often referred to as auto gas or auto propane – in Belize it is called butane. LPG has been used since the 1940s as a petrol alternative for spark ignition engines. Research carried out in 2013 by Atlantic Consulting compared results for 1251 models of bi-fuel vehicles and concluded that there was an average 11% CO_2 reduction when running on LPG compared to the identical cars running on petrol.

The research also indicates that LPG cars produce less nitrous oxide (NOx) than both petrol and diesel ones. In fact, when compared to diesel, five times less NOx is emitted. LPG vehicles are significantly lower on particle emissions as well. Extensive independent tests showed that one diesel vehicle emits 120 times the number of fine particles as the equivalent LPG vehicle. It takes 20 LPG vehicles to emit the same amount of NOx as one diesel vehicle.

This technology intervention seeks retrofit existing petrol (gasoline) vehicles in Belize to use LPG or butane as it’s called in Belize. The aim of this initiative is to both improve fuel efficiency and reduce GHG emissions.

There are no statistics on the number of vehicles in Belize that have already converted to Butane. However, a proposed initiative to convert 15-25 % of existing vehicles to LPG would create jobs for people to install and maintain these LPG systems. Other areas of potential economic benefits would come from the need to build more LPG refuelling stations.

Lower operating costs would be beneficial to both the private and commercial sectors. See Table 20 below. Note that the Premium fuel & LPG fuel cost are July, 2017 rates, obtained from TOMZA Ltd. Belize.

Table 20: Comparison of LPG - Gasoline/Diesel cost savings

LPG Cost Saving		
	Fuel (Gasoline / Diesel)	**LPG**
Annual Mileage	20,000	20,000
mpg	34 mpg	28 mpg
Fuel Price	BZD 10.50/gallon	BZD 4.50/gallon
Fuel Cost p.a.	BZD 6,176.47	BZD 3214.29
Saving in fuel cost alone BZD: 2,962.18 per annum		

(Source: Original example derived from http://tinley.com.uk/)

According to the second GHG emission inventory report, total emissions in 2000 were 13,482.7769 Gg CO2 equivalent or 13.5 Mt. Note that 1 Gg is 1000 tonnes.

The Third National Communication states that the transport sector is the biggest consumer of energy in Belize, accounting for 46.8% of total consumption in 2010 (GOB, 2016b). The Third

National Greenhouse Gas Inventory Report (2015) also shows that transportation, in particular road transportation accounts for a significant amount of GHG when compared to other sectors, as shown in the Table 19.

In Belize, LPG is closer to 45 % the cost of petrol in July 2017 (Table 20). As such the savings per annum is significant for working-class clients such as taxi drivers and freight delivery service operators. Also, national cost savings – arising from the reduced imports of higher priced petroleum products, would retain more foreign currency in country.

Some social benefits would include:

(i) Increased income due to investment in LPG systems, and job creation through installation and maintenance.
(ii) Capacity development of locals through training and capacity building in the use and maintenance of LPG systems.
(iii) A better quality of life stemming from more financial freedom based on the lower operating cost of private or commercial vehicles.

According to the United Nations, road transport is the largest GHG emitter per kt in the energy sector for Belize, and related emissions were 263.58, 275.94 and 330.55 kt CO2 for the years 1994, 1997 and 2000, respectively. Road transport accounted for 44.2%, 44.6% and 51.4% of all energy-related activities countrywide, in the same reference years. Vehicles converted to LPG will emit up to 11% less carbon than a similarly sized petrol vehicle.

4.3.3 Improved Public Transport system using more fuel-efficient buses

Belize’s public transportation service is currently regulated by the Transport Department under the Ministry of Works and Transport. For both inter and intra municipality operations, bus routes are licensed to private entities (companies and individuals). The main type of buses being used currently are used school buses imported form the United Sates. These buses have an average carrying capacity of 50-55 persons, and use large diesel engines with total displacements sometimes in excess of 8.0 litres and averaging 5–8 miles per gallon (2.1–3.4 kilometres per litre).

The level of bus service provided to the public is best described as poor to average. The main issues being faced by passengers are lateness, overcrowding, unreliable buses (frequent breakdowns), and the unacceptable condition of many buses, such as uncomfortable seats and holes in the floor board – just to name a few. This technology intervention seeks to improve the public transportation system through the revamping of the current bus fleet to allow for newer, cleaner and more comfortable buses with reduced carbon dioxide emission rates (CO_2 per mile). An additional spin-off effect would be the increased use of the public transportation system by private vehicle owners on a daily basis that will reduce vehicle usage and as a consequence further reduce carbon emissions.

The technology intervention will initially take the form of a pilot project. This pilot will see the purchasing and application of the desired buses on a particular route. Discussions with the Transport Department suggests the route between Belize City and Benque Viejo del Carmen, in the west, is best suited for this pilot as it is a main bus route, and the department has some data (bus owners, bus runs, etc.) for this route.

The aim of this pilot project will be to study the applicability of smaller buses along the major bus routes (inter-district). The study should determine their usefulness, fuel efficiency, operating cost and convenience to the travelling public.

Current Bus Fleet

Currently there are 46 bus runs daily between the municipalities of Belize City and Benque Viejo del Carmen. That is a total of 3,726 miles [5,960 km] run per day. Online documentation as well as bus owners state that these buses average between 6 to 7 miles per gallon (2.55 – 2.97 km/litre). The current

buses use an average of 6.5 mpg (2.76 km/l), these buses on the Belize City to Benque run use a total of 573 gallons (2,169 litres) of diesel fuel per day. And at an emission rate of 22.2 lb. CO_2 /gallon of diesel (2.67 kg CO_2/litre), these buses emit a total of 11,900 lb. CO_2/daily (5,400 kgCO_2) – or approximately 4.3 Million lb. (1950 tonnes CO_2) annually.

Table 21: Public Bus carbon emission comparison for Belize City-Benque Viejo run

Belize City to Benque Viejo del Carmen Bus Route (81 miles/130 km)		
Public Bus Carbon Emission Comparison		
Description	Existing Fleet	Proposed Fleet
Bus Runs	46	92
Distance Travelled miles[km]	3726 [5961]	7452[11923]
Bus Type	Used Bluebird/Thomas Buses (55 seater)	New Toyota Coaster or equivalent Buses (28 seater)
Est. Fuel Economy mpg[km/l]	6.5[2.76]	16[6.80]
Fuel Used gallons[litres]	573[2169]	465[1760]
% Reduction in fuel use	-	19%
Carbon Emission lbs[kg] of CO2	22.2[2.67]	22.2[2.67]
Carbon Emission Annually lbs[tonnes]	4.34 million [1970]	3.77 million [1715]
Total Reduction		Less 255 metric tonnes per day [~93,000 mt CO_2 per annum]
% Reduction in Carbon Emission		13%

Proposed Bus Fleet

For a fair comparison of the two bus types, it will be necessary to double the number of runs to 92 to ensure the same carrying capacity. The new buses will use an average of 16 mpg [6.8 km/l], these buses on the Belize City to Benque run would use a total of 465 gallons (1760 litres) of diesel fuel per day. And at an emission rate of 22.2 lb. CO_2 /gallon of diesel (2.67 kgCO_2/litre), these buses will emit a total of 10,340 lb. CO_2/daily (4,700 kgCO_2); or approximately 3.77 Million lb. (1,715 tonnes CO_2) annually.

See a summary of the comparison in Table 21.

The economical cost to bus operators will be great. However, once the terms and conditions of the Public-Private Partnership (PPP) between GOB and bus owners are reasonable, these additional costs can be manageable. Additionally, more information will be gathered during the pilot test phase. Once fully developed, this project will see additional employment for drivers and conductors, as the number of buses will essentially double.

The social impact will be extensive. The public will now be able to travel in relative comfort and be free of the fear and effects of frequent bus breakdowns. Passengers will be less stressed and anxious about using the public transport system.

It is envisioned that this proposed bus service will see an increase in usage by private car owners. This is will result in a decrease in fuel usage and carbon emissions on a national level.

4.4 Criteria and Process of Technology Prioritisation for the Transport Sector

Factsheets that were analysed in the MCA process for the Transport Sector were:

a) Levying duty on imported motor vehicles based on carbon emission rates.
b) Retrofitting of existing vehicles with Liquid Petroleum Gas (LPG) Systems.
c) Improved Urban/Suburban Public Transport System using more fuel-efficient buses.

The criteria category, units and preferred value for the technology factsheets are listed in Table 22. The agreed weighting of the criteria for the technology factsheets are listed in Table 23.

Table 22: MCA criterion and category for the Transport sector technology factsheets

Criterion	Criteria category	Unit Chosen	Value Preferred (High, Low)
capital cost	economic	BZE dollars	Low
operating cost	economic	Likert scale	Low
job creation	economic	Likert scale	High
cost of transportation	economic	Likert scale	Low
customer satisfaction	social	Likert scale	High
living standard	social	Likert scale	High
GHG emission reduction	environmental	Likert scale	High
improved air quality	environmental	Likert scale	High
sustainability	economic	Likert scale	High
replicability	economic	Likert scale	High

Table 23: Weighting of the Criteria for the Transport sector technology factsheets

Criterion	Allocation of budget (total = 100)	Weight, %
capital cost	13	13%
operating cost	12	12%
job creation	8	8%
cost of transportation	10	10%
customer satisfaction	8	8%
living standard	10	10%
GHG emission reduction	15	15%
improved air quality	8	8%
sustainability	10	10%
replicability	6	6%
Total allocated	100	
Budget usage	OK	

4.5 Results of Technology Prioritisation for the Transport Sector

Table 24 below shows the two factsheets that were prioritised in the MCA process for the Transport Sector as highlight in green. These two technologies will therefore be carried forward for the Barrier Analysis and Enabling Framework phase of the TNA process.

Table 24: Results for prioritized Transport Sector technology factsheets

Ranking of Options		
Rank	Option	Weighted Score
1	Levying duty on imported motor vehicles based on carbon emission rates	50.0
2	Retrofitting of existing vehicles with Liquid Petroleum Gas (LPG) Systems	47.0
3	Improved Urban/Suburban Public Transport System using more fuel-efficient buses	37.6

CHAPTER 5. TECHNOLOGY PRIORITIZATION FOR THE LAND USE, LAND-USE CHANGE AND AGROFORESTRY SECTOR

5.1 GHG Emissions and Existing Technologies of the Land Use, Land-use Change and Agroforestry

The Bali Action Plan (2007) called for "policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the roles of conservation, sustainable management of forests and enhancement of forest carbon stocks…" The emerging financial mechanism from this was, "reducing emissions from deforestation and degradation (REDD+) (GOB-CCCCC, 2011).

Mitigation of Climate Change through sustainable forest management (SFM)

Currently, forests store about half of the global terrestrial carbon pool (FAO, 2014), while deforestation and forest degradation are estimated to account for about 17.4 percent of global emissions of GHG. Forests can be net sinks or net sources of carbon, depending on their age, health, and vulnerability to wildfires and other disturbances (e.g. bark beetle infestation, tropical cyclone impacts etc.), and on how they are managed. When managed sustainably, forests can serve as a means to mitigate and adapt to climate change by increasing the vegetative cover and enhance the terrestrial carbon pool. Forest management practices that increase carbon sequestration from the atmosphere are:

- Afforestation, reforestation and the restoration of degraded forests;
- Increasing tree cover through agroforestry, urban forestry and tree-planting in rural landscapes; and
- Enhancing existing forest carbon stocks in forest biomass above and below ground, and in leaf litter and soils, through certain silviculture practices, selection and planting of fast-growing species, lengthening the harvesting cycle, fertilization, etc.;
- Preventing or minimizing forest degradation to reduce GHG emissions.

Agroforestry or agro-silviculture

Agroforestry is a land use management system where trees or shrubs are grown around crops or pastureland. Trees and shrubs are grown using agriculture and forestry technologies to create a more diverse, productive, profitable, healthy, ecologically sound and sustainable land-use system (NAC, 2014; Wikipedia.org, 2017).

In buffer, farming communities next to forest reserves, agroforestry is recommended, so small and medium-size farmers improve their productive system, and at the same time help manage the forest reserve and preserve the ecological services such reserves provide for the benefit of the majority.

Some impacts of agroforestry include:

- Reducing poverty through increased production of wood and other tree products for subsistence and sale.
- Contributing to food security by restoring soil fertility for food crops.
- Cleaner water through reduced nutrient and soil runoff.
- Countering global warming and the risk of hunger by increasing the number of drought-resistant trees and the production of fruits, nuts and edible oils.
- Reducing deforestation/agriculture frontier and the pressure on woodlands/forest reserves by providing farm-grown fuelwood.
- Reducing or eliminating the need for toxic chemicals
- Improve human nutrients through more diverse farm outputs.
- Providing growing spaces for the cultivation of medicinal plants.
- Increased crop stability.
- Minimizing malfunctional land-use (i.e. crop production and animal grazing that deplete the fertility of the land and increase erosion and sedimentation).
- Agroforestry systems are more drought resistant.
- Stabilizes depleted soils from erosion.
- Bioremediation.

Agroforestry also enhances other environmental goals, such as:

i. Carbon sequestration;
ii. Odour, dust, and noise reduction; cleaner air;
iii. Green spaces and visual aesthetics;
iv. Conservation and maintenance of wildlife habitat.

Land Use, Land-use Change

The UNFCCC (Iversen *et al*., 2014) identifies six categories of land use, namely: forest land, crop land, grassland, wetlands, settlements and other lands (e.g. bare soil, rock, ice, etc.). The corresponding carbon pools are: living biomass, dead organic matter, soil organic carbon, and harvested wood products. While, agricultural practices on farmland such as burning of crop residues, fertilizer applications, rice cultivation, and livestock production produce emissions, mainly methane and nitrous oxide.

Area of forest and other wooded land in Belize

Table 25 below is a summary of categories of land cover in Belize for the period 1990 to 2015.

Table 25: Area of forests, other wooded land and inland water bodies

Categories	Area ('000 hectares)				
	1990	**2000**	**2005**	**2010**	**2015**
Forest	1,616.027	1,459.301	1,416.53	1,391.391	1,366.3
Other wooded land	75	94	104	113	200
Other land	589.973	727.699	760.47	776.609	714.7
Inland water bodies	16	16	16	16	16
TOTAL	2,297.00	2,297.00	2,297.00	2,297.00	2,297.00

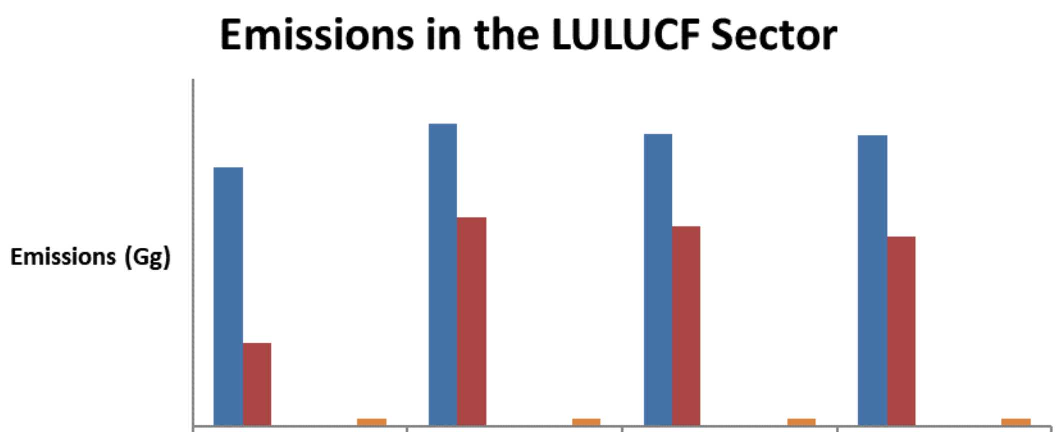
(Source: FAO - Country Report Belize 2016, www.fao.org)

Over the period 1990 to 2015 forest cover decreased by 249.727 thousand ha, or approximately 15%. This land use change was primarily for agricultural expansion, settlements and pastures.

Emissions

Like most countries in the Central American region, the inventories of GHG emission shows that increase rates of emissions in Belize are related to deforestation activities. The continued reduction in areas under forest coverage will diminish the country's capacity to offset emissions (GOB-NCCO, 2016). The increases in land degradation coupled with increased utilization of land with less productive potential, and population increase, will very likely contribute to greater non-sustainable forest conversion.

According to Belize's Third National Communication (GOB-NCCO, 2016), there was a progressively small increase in net CO_2 emissions in the LULUCF sector for the base years 2003, 2006 and 2009. The 2000 net emission (8088.0 Gg) was almost double the mean for the base years 2003, 2006 and 2009 (4415.67 Gg). See Figure 30 below for more detail. It is concluded that the progressive increase in net emissions from the LULUCF sector was linked to higher rates of deforestation and decreasing areas of forest being managed for long-term timber production.



	2000	2003	2006	2009
CO2 emissions	11950	13949	13501	13449
CO2 Removals	3862	9666	9208	8778
CH 4(Gg)	40	43	41	40
N2O (Gg)	0	0	0	0
Nox	10	11	10	10
Co (Gg)	349	376	361	346

Figure 29: Emissions in the LULUCF Sector for the period 2000-2009

5.2 Decision Context

In the GHG inventory, forests are classified as mature, natural and broadleaf forest. Other forest ecosystems in Belize are the Pine forest, Mangroves and Littoral forests. Tropical forests ecosystems are considered to be among the most diverse and productive ecosystems on earth (Montagnini and Jordan, 2005), offering environmental, social and economic benefits, and hence must be protected. Economically, tropical forests contribute the timber and eco-tourism industries, and the trade in non-timber products. In some countries, these forests contribute to the informal economy such as fuelwood, medicinal material and other non-timber forest products used by locals, and also game meat.

Tropical forests provide multiple environmental services such as recharge areas for surface and ground water resources, soil conservation, biological corridor as habitat for wild life, carbon sink, to name a few. On the social front, forests provide fuel and build material and medicinal products for buffer communities, employment, and a multitude of other environmental services that benefit society.

In TNA process, two technologies are considered that are aligned in improved forest management with reforestation components, as actions to enhance the carbon sequestration potential of degraded forest areas of the Mountain Pine Ridge/Chiquibul, and Vaca Forest Reserves.

5.3 Mitigation Technology Options in the Land Use, Land-use Change & Agroforestry Sector and their Co-benefits

For the Land use, Land-use Change and Agroforestry sector, the consultants conducted a series of consultative meetings with small groups of stakeholders in the forestry, agriculture, non-governmental organizations (NGOs), and the private sector, to review technology needs and gaps in the sector, and reach an agreement of at least three technologies for factsheet development. In the end, the technologies chosen were to establish improved nurseries and reforestation programme to address the degraded pine and broadleaf forest areas of the Mountain Pine Ridge (MPR) and the Chiquibul Forest Reserves, and work with some 20 farmers from buffer communities to the Vaca Forest Reserve in integrated landscape forest management. Two technology factsheets were drafted and reviewed, namely:

1. Improved Tropical Hardwood & Pine Caribe Species Nurseries and Reforestation (MPR & Chiquibul Forest Reserves)
2. Integrated Landscape Forest Management: A Management Alternative in the Vaca Forest Reserve

These factsheets, along with another three technology factsheets for the Transport sector and five for the Energy sectors are included in Annex I of this report.

5.4 Criteria and Process of Technology Prioritisation for the LULUC and Agroforestry Sector

The mitigation technology factsheets that were analysed in the MCA process for the Land Use, Land-use Change and Agroforestry sector were:

a) Improved Tropical Hardwood & Pine Caribe Species Nurseries and Reforestation (MPR & Chiquibul Forest Reserves);
b) Integrated Landscape Forest Management: A Management Alternative in the Vaca Forest Reserve.

The criteria selected for the MCA exercise to prioritize these technology factsheets were considered under the general headings or properties as illustrated in Figure 30 and summarised in Table 26.

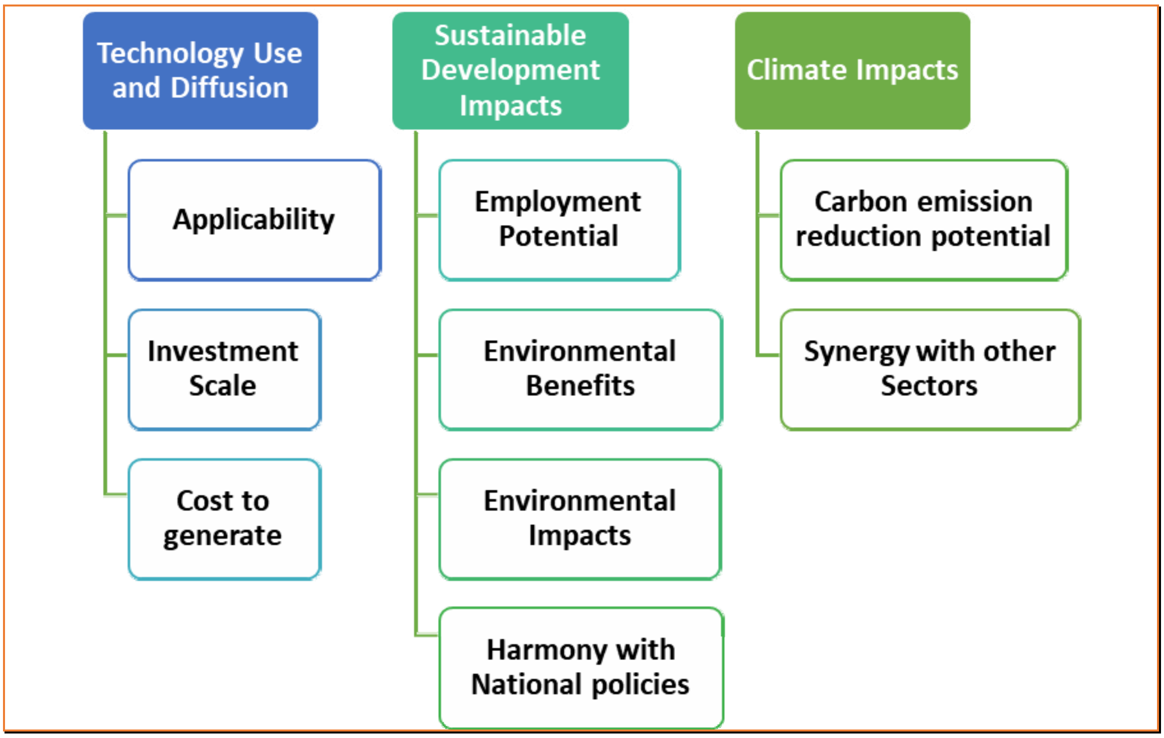


Figure 30: Land Use, Land-use Change & Agroforestry Technologies Properties and Criteria

Table 26: LULUCF mitigation technology properties and criteria for the MCA process

Use and Diffusion	Sustainable development impacts	Climate impacts
Applicability - Community involvement - Replicability, preferably high	**Employment potential** - Employment for locals (farmers, extension personnel, food processors, vendors)	**Carbon emission reduction potential** - Mitigation potential – CO_2 emission reduction -Land degradation reduction
Investment scale - Capital cost, preferably low Investment cost can be sought from local, regional and/or international sources.	**Environmental benefits** - Land degradation reduction - Enhance environmental services	**Synergy with other sectors** - Country priority (Tourism, Water, Local Government, Agriculture, Commercial sector, etc.)
Cost to generate - Operating costs, preferably low - Sustainability – in kind contributions (GOB), marketing of farm/forest products and services	**Environmental impacts** - Negative environmental impacts preferably low or none -	
	Harmony with National policies - Improving living standards - Carbon emission reduction (NCCPSAP & REDD+)	

The MCA criterion and categories are summarized in Table 27, while the agreed weightings of the criteria by the LULUC & Agroforestry sector, stakeholder small group are listed in Table 28. In this case, the highest weightings were attributed to 'Capital Cost' and 'Mitigation Potential'.

Table 27: MCA Criterion and Category

Criterion	Criteria category	Unit Chosen	Value Preferred (High, Low)
Capital Cost	Economic	US Dollars	Low
Operating cost	Economic	US Dollars	Low
Mitigation potential	Environmental	likert	High
Negative environmental impa	Environmental	likert	Low
Employment	Economic	likert	High
Living standard	socio-economic	likert	High
Replicability	Economic	likert	High
Sustainability	Economic	likert	High
Country priority	political	likert	High
Community involvement	social	likert	High

Table 28: Weighting of Criteria

Criterion	Allocation of budget (total = 100)	Weight, %
Capital Cost	15	15%
Operating cost	10	10%
Mitigation potential	15	15%
Negative environmental impact	8	8%
Employment	10	10%
Living standard	10	10%
Replicability	8	8%
Sustainability	10	10%
Country priority	6	6%
Community involvement	8	8%
Total allocated	100	
Budget usage	OK	

5.5 Results of Technology Prioritisation for the Land Use, Land-use Change and Agroforestry Sector

The result of the MCA exercise for the LULUCF/Agroforestry sector showed that the "Integrated Landscape Forest Management: A Management Alternative in the Vaca Forest Reserve" technology factsheet garnered a higher, weighted score than the "Improved Tropical Hardwood & Pine Caribe Species Nurseries and Reforestation (MPR & Chiquibul Forest Reserves)", technology factsheet. The key stakeholders connected with the Vaca Forest Reserve Management plan, namely: Friends for Conservation, Forestry Department, CARDI, Agriculture Department, and farmers representatives were updated on the way forward, following the completion of the MCA process. The MCA prioritized Land Use, Land-use Change and Agroforestry sector technology is highlighted in Table 29.

Consequently, the technology "Integrated Landscape Forest Management: A Management Alternative in the Vaca Forest Reserve", will be considered for the second phase or the Barrier Analysis and Enabling Framework phase of the TNA project for Belize.

Table 29: Prioritized mitigation technology for Land Use, Land-use Change and Agroforestry Sector

Ranking of Options		
Rank	**Option**	**Weighted Score**
1	**Integrated Landscape Forest Management: A Management Alternative in the Vaca Forest Reserve**	**59**
2	Improved Tropical Hardwood & Pine Caribe Species Nurseries and Reforestation (MPR & Chiquibul)*	**33**

*MPR: Mountain Pine Ridge Forest Reserve; Chiquibul National Park.

CHAPTER 6. TECHNOLOGY NEEDS ASSESSMENT CONCLUSION AND RECOMMENDATIONS

6.1 Summary and Conclusion

6.1.1 Summary of the Prioritized Mitigation Technologies

A summary of all six (6) prioritized climate change mitigation technologies is listed in Table 30. Those technology factsheets that were not prioritized will not be discarded but rather, stakeholders from each sector will have the option to use these technology factsheets to draft project concept papers to seek funding from diverse sources. The prioritized technologies will all be investigated further via the Barrier Analysis and Enabling Framework protocol of the TNA process, the results of which will be used to develop a Technology Action Plan or TAP, (a strategic roadmap or portfolio) of technology concept projects ready for funding.

All the prioritized mitigation technologies reviewed in this report are in harmony with the medium and long-term strategy of the government of Belize to develop, adopt and implement policies and measures/actions to reduce its carbon footprint, transition its development pathway from a fossil-based economy to cleaner, renewable energy use, and increase the country's resilience to the adverse effects of Climate Change. At the same time, the implementation of these technologies will contribute to the over-arching goal of the Growth and Sustainable Development Strategy (GSDS), which integrate medium-term economic development, poverty reduction, and longer-term sustainable development. The GSDS is the country's primary development blueprint, and outlines four critical success factors for national development and a better way of life for its citizens today and in the future.

Table 30: List of prioritized climate change mitigation technologies

Rank	Option	Weighted Score
Energy –		
1	**Solar PV Off Grid**	**65.1**
2	**Gasification**	**63.1**
3	**On-grid Solar PV**	**52.6**
4	**Micro-Hydro***	**33.0**
5	**Solar Water Heaters**	**32.5**

Transport – **1**	**Levying duty on imported motor vehicles based on vehicle fuel efficiency**	**50.0**
2	**Retrofitting of existing vehicles with LPG Systems**	**47.0**
3	**Improved Urban/Suburban Public Transport System using more fuel-efficient buses***	**37.6**
Land use, Land-use Change & Agroforestry – **1**	**Integrated Landscape Forest Management: A Management Alternative in the Vaca Forest Reserve**	**59**
2	Improved Tropical Hardwood & Pine Caribe Species Nurseries and Reforestation (MPR & the Chiquibul)	**33**

6.2 Recommendations

6.2.1 Energy Sector

Some recommendations for the Energy sector, as outlined in the TNC and the NCCPSAP (GOB-NCCO, 2016; GOB-CCCCC, 2015) to support the sustainable development of Belize are:

- Improve energy efficiency to dramatically lower energy intensities across key economic sectors. Some actions may include:
  - Improve energy efficiency in buildings and appliances.
  - Promote transition to sustainable transportation.
  - Develop appropriate financial and market-based mechanisms that support energy efficiency and renewable energy.

- Develop renewable energy to shift the energy matrix away from fossil fuels (especially oil) to alternative renewable energy technologies. The main action is:

  - Develop Belize's human, technological and institutional capacity to accelerate the uptake of appropriate clean energy and clean production technologies.

- Promote and facilitate clean production systems in the processing of Agriculture, Forestry and other industrial outputs/products to co-produce bio-fuels and/or electricity from RE sources.

6.2.2 Transport Sector

The Transport Sector of Belize is in a transformational phase with the drafting and adoption of the National Transportation Master Plan. Some recommendation for the Transport sector with regards to the prioritized mitigation technologies under the TNA project are:

- Upgrade the road maintenance system countrywide.
- Improve road safety ─ road infrastructure, bridges and stream-crossings, behaviour of drivers and road worthiness of motor vehicles, to name a few areas for improvement.
- Formulate and implement a Sustainable Transport policy to reduce economy-wide fuel intensity.
- Implement a bio-fuels policy within an overarching upgrading of the regulatory and business environment for fuel production, delivery, storage and end-use.
- Promote energy efficiency in the transport sector through appropriate policies and investments. These improvements should include:

  g. Undertaking a traffic management study aimed at reducing traffic congestion in urban areas and along the Philip Goldson Highway into Belize City
  h. Improving public transportation
  i. Upgrading maintenance of bus fleet
  j. Improving scheduling
  k. Upgrading the industrial fleet

6.2.3 Land Use, Land-Use and Agroforestry

The general objective in the Land Use, Land-use Change and Agroforestry sector is a national land use strategy that promotes minimal impact of land use on the country's forest ecosystems and services, and the enhances Belize's forests carbon sequestration capacity in the medium and long-term. Some recommendations to this end include:

- Increase public budget allocation for reforestation and restoration of degraded forests.
- Upgrade the institutional capacity of the Forest and Agriculture Departments to promulgate agroforestry and forest management across Belize.
- Enhance the synergies between line ministries and the private sector to increase tree cover through agroforestry, urban forestry and tree planting in the rural landscape.

- Ensure the compliance with the 66-ft. riparian buffer along streams, rivers and other water bodies to diminish sedimentation and improve water quality, and at the same time increasing the national forest cover.

- Enhance existing forest carbon stocks in forest biomass above and below ground, and in leaf litter and soils, through certain silviculture practices, selection and planting of fast-growing species, lengthening the harvesting cycle, fertilization and other good practices.

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ANNEXES

Annex I: Climate Change Mitigation Factsheets

ENERGY SECTOR

1. **Solar PV On Grid**

<table>
<tr><td colspan="2">SECTOR: ENERGY</td></tr>
<tr><td colspan="2">TECHNOLOGY: Solar PV On Grid</td></tr>
<tr><td>Introduction</td><td>
In order for Belize to become a low carbon economy by 2033, one sustainable energy strategy includes the development of Renewable Energy (RE) to shift the energy matrix away from fossil-fuels (especially oil) to alternative renewable energy technologies (GOB-NCCO, 2016).
In order to achieve some of the energy strategies, it is necessary to develop local electricity micro-generation market where small producers, such as individual households, communities, commercial establishments and even small industrial participants, can sell electricity into local distributions systems and the national grid. Hence, the need to develop the solar photovoltaic on-grid systems for the country.
Table A1: Electricity Generation Output by Primary Fuel (2010) in Belize
<table>
<tr><th>Primary Fuel Type</th><th>MWh</th><th>Percentage</th></tr>
<tr><td>Hydro</td><td>263,150</td><td>45.9</td></tr>
<tr><td>Biomass</td><td>80,893</td><td>14.1</td></tr>
<tr><td>Imported Electricity</td><td>158,589</td><td>27.6</td></tr>
<tr><td>Diesel</td><td>43,927</td><td>7.7</td></tr>
<tr><td>Heavy Fuel Oil (HFO)</td><td>18,428</td><td>3.2</td></tr>
<tr><td>Natural Gas (NG)</td><td>7,008</td><td>1.2</td></tr>
<tr><td>Crude Oil</td><td>1,711</td><td>0.3</td></tr>
<tr><td>Total</td><td>573,706</td><td>100</td></tr>
</table>
(Source: Tillett, A., Locke, J., Mencias, J., 2012)
Table A1 provides a breakdown of the actual electricity (measured in MWhs) generated from the primary fuel inputs. Approximately 60% of electricity was generated from renewable energy sources, and 27.6% was imported from Mexico. Interestingly, nearly 16% of the total electricity was generated for own use, with the remainder provided by utility sources.
Solar PV has enormous energy potential in many countries in Central America and the Caribbean, and likewise in Belize. Most of Belize, especially the central and northern areas, receives medium to high solar intensity (4.5-5 $kWh/m^2/day$) that can sustain a reasonably good power generation throughout most of the year (Tillett, et al. 2012); GOB-MESTPU, 2015).
</td></tr>
</table>

Technology characteristics	Solar photovoltaic, or simply photovoltaic (SPV or PV), refers to the technology of using solar cells to convert solar radiation directly into electricity. A solar cell works based on the photovoltaic effect. The photovoltaic effect can be briefly summarized as sunlight striking a semiconductor and causing electrons to be excited due to energy in the sunlight (photons). [1] Solar PV systems can also be classified into two types: (i) On-grid or Grid-connected, which includes those connected to the traditional power grid (ii) Off-grid, those not connected to the grid. Off-grid PV systems can service areas without electricity access, especially in rural settings such as villages or small communities. These systems need storage such as a battery bank and an optional backup generator. Off-grid PV may also be established in a hybrid configuration with other renewal energy technology such as wind and micro-hydropower. Grid-connected PV systems do not require energy storage but instead use an inverter to convert electricity from direct current (DC) to alternating current (AC) and the generated electricity is then fed grid distribution network to consumers. Grid connected PV systems are further classified into two types of applications ─ distributed and centralized. Grid-connected distributed PV systems are installed on residential, commercial or public buildings and generate electricity which is consumed by the customer and the excess is sent/sold to the grid to be consumed by other users. Most distributed systems range between 1-5 kW in power generation. The centralized systems are usually larger and not necessarily on building rooftops but can be designed as solar 'farms', ranging from 10 kW up to a few MW in generating capacity.
Costs, including cost to implement mitigation option	Based on the two major Solar PV companies in Belize, the current price for on-grid Solar PV, including installation range from BZD 4.5-7.0 per Watt. Annual maintenance costs for on-grid systems is approximately 2-5% of system cost. Projected approximate cost to supply and install a unit on-grid residential system is as follows: 2.6 kW On-Grid system: BZ$ 17,500.00 3.13 kW On-Grid system: BZ$ 19,600.00 3.9 kW On-Grid system: BZ$ 23,450.00 4.2 kW On-Grid system: BZ$ 26,600.00 5.2 kW On-Grid system: BZ$ 30,400.00 The above specifications and costs were taken from: http://www.wholesalesolar.com Costs do not include applicable importation taxes of mark-up. It is being recommended that a pilot project be instituted for the installation of ten (10) on-grid solar systems country-wide. The chosen participants will need to show a three (3) year history of monthly electricity bills. The pilot project will seek to compare past electricity bills with ones after the on-grid solar systems are installed.

Cost of not modifying the project	The cost of not doing anything would result in a gradual increase in energy production from non-renewable sources. Note that there is great potential for Solar PV to increase its share in the energy mix and impact on GHG reduction. If the expected Solar PV target of 5 MW (3.4%) to the electricity grid is realized within the next 15 years, and assuming an emissions factor of 0.22 tCO_2 per MWh from CFE (Comisión Federal de Electricidad), this would contribute to a reduction of over 30,000 metric tons of CO_2 annually.
Potential development impacts, benefits	
Economic	Some of the economic benefits for Belize triggered by an increased Grid-connected Solar PV uptake would include: Direct job creation- Installation and maintenance of PV systems would require technical and manual labour, which would increase the workforce for Belize. The utility and regulator would need more technical personnel as well, to monitor and evaluate installations. Even tertiary institutions can benefit from offering technical programs in Solar PV systems Energy security – It is crucial to diversify energy sources for electricity production, especially since a large portion of electricity is obtained from Mexico and may become insecure in the future. Also, a high portion of Belize's electricity is generated through hydropower, which can be compromised from projected increased in extreme drought conditions due to climate change. Solar PV can strategically complement hydropower during dry periods when hydropower generation is generally lower. National Cost savings ─ resulting from reduced imports of total petroleum products and electricity purchases. Reduced Grid Electricity Losses - Grid-connected distributed PV systems allow for reduced losses in the electricity network since the system is installed at the point of use and costs are reduced if mounted on existing structures. Customers with on-grid distributed systems can benefit from a reduced electricity bill or in some cases make a profit by selling back excess power to the grid.
Social	The Growth and Sustainable Development Strategy 2014 – 2017 adopts an integrated, systemic approach for sustainable development and encompasses medium-term economic development, poverty reduction and longer-term sustainable development issues. It is focused on the country's development priorities which creates an enabling environment for investment in technologies required to achieve this goal. Some Social Benefits of an increased Solar PV market include: (i) Increased income due to investment in Solar PV systems, employment through installation, maintenance, evaluation and monitoring of systems, and even training programs. (ii) Capacity development of locals through training and capacity building in the

	installation, use and maintenance of solar technologies.
Environmental	Solar PV is a clean technology and has the following additional environmental benefits: (i) Grid connected-distributed PV systems that are roof-mounted and do not require additional land usage for its installation. (ii) Solar PV systems are considered 'closed' systems and hence require no fuel or any inputs during operation and electricity production. It also does not contaminate water. (iii) Solar PV systems cause no noise or vibration and hence considered environmentally friendly. (iv) Predictions are that upwards of 80% of the bulk material in solar panels will be recyclable; recycling of solar panels is already economically viable.
Current Status	According to a 2013 initial draft proposal by the Public Utilities Commission (PUC), the CAP for Non-firm Renewable generation sources will probably be about 10% of peak demand, so using 2012 as a baseline, this would be about 8.2 MW for wind and solar power generation combined. Given that the total allowed is 8.2 MW (2012), then a possible allocation could be affected as follows: Solar Home Systems/Distributed Domestic – 1.5 MW (0 to 5 kW_p); Distributed Commercial Systems – 1.7 MW (5 to 75 kW_p); Others – 5 MW (75 kW_p systems and greater). As electricity demand increase, these allocations would certainly expand. On implementation of the Caps it would mean that developer installations would be approved on a first come first serve basis, with time limits being imposed for System installations for implementation. Net-metering and Distributed Generation can commence as soon as regulations are in effect. [2] Currently, Belize is seeing a rise in the purchase and use of Solar PV systems, for both grid-connected and off-grid use. Two major Solar PV companies in the central corridor of Belize have installed an average of 140 kW annually over the past three years, almost equally split between on-grid and off-grid. One company has done over 40 installations with most installations averaging 5 kW for each system, mostly off-grid, while the other has done twice as much on-grid installations as off-grid. Belize also boasts a 480 kW solar farm located in the capital Belmopan at the University of Belize (UB) campus, courtesy of the Japanese government (JICA). This system has been producing approximately 590 MWh of electricity annually since 2012 and the system is tied to the grid.
Barriers	Based on the Castalia Consultant report on Belize Renewable Energy (RE) and Electricity (EE) Sustainable Energy study, some of the barriers of Solar PV on-grid uptake include:

	- Information Barriers-lack of investment-grade resources and information so that customers can be convinced that this is a viable investment. - Regulatory Barriers-regulations concerning sale of excess electricity to the grid (net-metering) still unresolved. - Financial Barriers-limited investment interest leading to high interest rates, few financial incentives such as lower taxes and import duty. - Technical Barriers-Few skilled persons can install and maintain Solar PV systems, limited familiarity with grid interconnection of intermittent RE. Additionally, the current stock of meters used in Belize cannot support net-metering. - No net meter legislation for Solar PV On-grid electricity generation and purchase. - Sole electricity distributor in Belize not keen on having their profit margin reduced because some customers will accumulate credits from solar PV On-grid electricity generation. - Initial or capital costs
Acceptability to local stakeholders	Private and commercial stakeholders are willing to implement this technology – especially since it promises a reduction in monthly electricity bills.
Endorsement by experts	The Public Utilities Commission (PUC) requested proposals to establish electricity generation and/or supply facilities that will satisfy public demand for electricity in Belize for the next 15 years. Through this process the PUC, with the support of the utility company Belize Electricity Limited (BEL) and GOB, aim to add up to 60 MW of dispatch able capacity, and 15 MW of variable capacity to the National Electricity System, over the next 15 years. According to Ministry of Energy and PUC sources, it is anticipated that approximately 5 MW of variable capacity will be reserved or allocated for Solar energy generation. Belize' s 2020 target is to achieve at least 80% electricity production from renewable sources and to become a net exporter of electricity by the end of the decade.
Timeframe	Time frame to install – 3 months. Time frame for pilot test is 12 months.
Institutional capacity	For the pilot tests, the required institutional capacity can be met by the existing local solar companies. However, as solar grows, there will be need for increased institutional capacity in the form of trained personnel to install and maintain. Since 2010 in the United States, the number of people working in the solar industry more than doubled and the cost of solar systems fell by 70%. [1]
Adequacy for current climate	Without the net metering legislation in place, the suitability of on-grid solar systems in minimal. Additionally, the following elements are required: Acceptance by the public and private sector that Solar PV is a proven technology and that it is a financially viable alternative. Policies formulated and promulgated by GOB and PUC allowing for net-metering.

	Reduction in procurement costs of the components via lower import duties and other taxes. Greater numbers of technicians with the capacity to assess, provide advice, and install the systems. Willingness on the part of BEL to purchase power from private suppliers.
Size of beneficiaries group	On-Grid solar systems can provide significant benefits to large cross section of the population. Opportunity for the private sector to become net suppliers of renewable energy to the national grid.

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http://www.climatetechwiki.org/technology/pv

Net Metering Options Draft Proposal – PUC

www.prosolarltd.com

2. Solar PV Off Grid

SECTOR: **ENERGY**	
TECHNOLOGY: Solar PV Off Grid	
Introduction	According to the Belize 2010 census, it was estimated that there was a total of 48 villages without access to electricity, most of them in the Toledo district, where only 50% of the households were connected to the grid. The census provides data for about 30 of these 'unserved' villages. In 2010, these 30 villages accounted for a total of 18,942 people or 5.9% of the country's population. In terms of households, there were a total of 3,414 households in the 30 villages, which accounted for 4.3% of the country's household total. The proposed technology transfer will consist of a pilot project to install 75 small scale Solar PV off-grid systems in three (3) villages in the Toledo district, namely Conejo Creek (pop. 210), Sunday Wood (pop. 285) and Crique Sarco (pop. 328). Note that these population figures were taken from the 2010 Census.
Technology characteristics	An off-grid system is a decentralized renewable energy system adopted by homes and small businesses to produce reliable and cost-effective power. In isolated locations, off-grid systems tend to be cheaper than establishing transmission lines in the area. [1] Apart from investing in the solar PV system itself, it is necessary to invest in energy storage, such as a bank of deep cycle batteries. Without storage the system will not be able to supply power when there's no sunshine. The main components of a solar PV off-grid system are: the photo voltaic array, charge controller, battery bank, and direct current to alternating current (DC-AC) converter. Typically, off grid systems require a larger up-front investment than grid tied systems due to additional charge controller and batteries that are employed in the former. The power that is generated by the renewable energy source initially charges the batteries through the charge controller. The inverter helps to regulate the voltage and in most cases, converts the DC power to AC power, which is the normal requirement for home appliances. [2]

<table>
<tr><td>Costs, including cost to implement adaptation options</td><td>The system to be installed is a DC supply for small households that will be able to power a few lights, a small radio or TV, and a couple fans. The components are as follow:
• 60-W Solar Panel
• Sealed 'No Maintenance' Solar Battery (12 v/30 Ah)
• Battery Enclosure
• Battery Capacity meter
• Dual Position (Lighter-Style) 12 V charging outlet
• 13 W Florescent Light Bulbs
• DC 3-speed Ventilation Standing Fan
• Solar Charge Controller
• AM/FM radio
• System Wiring and Mounting Hardware
The cost the above system is approximately BZD 1,500.00. This does not include installation which is approximately $500.00 per system.</td></tr>
<tr><td>Cost of not modifying the project</td><td>The cost of not implementing this off-grid solar is unknown.</td></tr>
<tr><td colspan="2">Potential development impacts, benefits</td></tr>
<tr><td>Economic</td><td>Direct job creation for locals. Installation and maintenance of PV systems requires technical and manual labour, which would add to the employment figure for Belize. Stand-alone and Mini-grid systems would require personnel to monitor and evaluate installations. Even tertiary institutions can benefit from offering technical programs in Solar PV systems and installation.
National Cost savings resulting from reduced imports of total petroleum products. Dollars would remain at home Belize.</td></tr>
<tr><td>Social</td><td>(i) Increased income due to investment in Solar PV systems, employment through installation, maintenance, evaluation and monitoring of systems, and even training programs.
(ii) Capacity development of locals through training and capacity building in the use and maintenance of solar technologies.
(iii) Improvement in health, education and general livelihood of populations not served by the national grid.</td></tr>
<tr><td>Environmental</td><td>(i) Off-grid PV systems that are roof- mounted and do not require additional land usage to for its installation.</td></tr>
</table>

	(ii) Solar PV systems are considered closed systems and hence require no fuel or any inputs during operation and electricity production. It also does not contaminate the environment. (iii) Solar PV systems cause no noise or vibration and hence considered environmentally friendly. (iv) Predictions are that upwards of 80% of the bulk material in solar panels will be recyclable; recycling of solar panels is already economically viable.
Status	There have been numerous Solar PV Off-grid social projects implemented in Belize, mostly in the Toledo District. Some of these projects include: San Jose, Toledo - Micro-grid 2013; San Antonio and Laguna, Toledo – IT and Education Centre 2009; San Benito Poite, Toledo – Internet Cafe 2009; Solar Home Systems for Toledo Villages (Conejo Creek, Dolores, Corazon) in 2006 and 2007; Solar Systems for Five Toledo Primary Schools (SIF) 2009; Solar Systems for four Toledo Primary Schools (US Capital) 2015; and Solar System for Corazon Creek high school in 2013. Some of these projects have failed due to varying degrees of social, technical, economic, and/or environmental sustainability. In many cases, as soon as the battery/storage expired, the whole system and project collapsed. Either due to a lack of ownership, just plain financial difficulties, or lack of technical capacity — the systems were not maintained which led to the collapse of the projects.
Barriers	Some of the major barriers in implementing such a project include: ➢ Internal and external village politics. Who gets what? This will be a significant hurdle that needs careful consideration, planning and execution to avert strife and tension within the project areas. ➢ Lack of investment-grade resources and information so that customers can be convinced that this is a viable investment. ➢ Limited investment interest leading to high interest rates, few financial incentives such as lower taxes and import duty, lack of finance for maintenance of off-grid system components. ➢ Few skilled persons can install and maintain Solar PV systems; limited familiarity with grid interconnection of intermittent RE ➢ Lack of recycling mechanisms for discarded parts, especially batteries. ➢ Limited supply and demand chain for expansion and lucrative investment ➢ Regulatory and standards framework
Acceptability to local stakeholders	It would be safe to assume that all stakeholders involved would have a positive reaction towards such a project. However, as part of the planning stage, rigorous consultations must be executed and assessed to ensure all parties are in favour

	and willing to participate during the installation and maintain their solar systems.
Endorsement by experts	The Public Utilities Commission (PUC) requested proposals to establish electricity generation and/or supply facilities that will satisfy public demand for electricity in Belize for the next 15 years. Through this process the PUC, with the support of the utility company Belize Electricity Limited (BEL) and GOB, aim to add up to 60 MW of dispatch able capacity, and 15 MW of variable capacity to the National Electricity System, over the next 15 years. According to Ministry of Energy and PUC sources, it is anticipated that approximately 5 MW of variable capacity will be reserved or allocated for Solar energy generation. Belize' s 2020 target is to achieve at least 80% electricity production from renewable sources and to become a net exporter of electricity by the end of the decade.
Timeframe	The project should commence installation of the 75 Off-grid solar systems within six months of approval, and run for one year. During this year, monthly visits will be conducted to assess each system to get feedback on its operation, usefulness and to troubleshoot any technical issues.
Institutional capacity	Fortunately, there are a few private companies in Belize that offer these types of solar systems. Lack of local capacity in the rural areas for maintenance of the system.
Adequacy for current climate	An enabling environment for the rollout of this technology across Belize would depend on conditions such as: o Sustainability needs to be an important component of any social project. Social aspects need to be addressed as a component of any project. For instance, ownership of the project, equipment and facilities need to be planned properly for sustainability. o Equity and fairness for the benefactors need to be carefully decided. Sometimes only a small portion of the community benefit and thereafter, the rest of the community lose sense of ownership and support for the project declines. o Further financial and technical support needs to be planned after the completion of project. Many projects end with the installation of the system. Monitoring and evaluation after the project expires is crucial so that projects that follow have some guidance as to what worked and what did not work. o Local people need to be trained as technicians with the capacity to assess, provide advice, and install the systems. o Social projects to supply solar PV Off-grid technology to under privileged communities can be enhanced if technology is marketable, and helps stimulate the local and national economy by attracting other potential clients who are

	willing to pay.
Size of beneficiaries group	This pilot project seeks to benefit 75 homes. At a rate of 5 persons per household, the total number of people expected to benefit will be 375 plus.

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http://www.solarmango.com/dictionary/off-grid

https://www.civicsolar.com/support/installer/articles/components-grid-systems

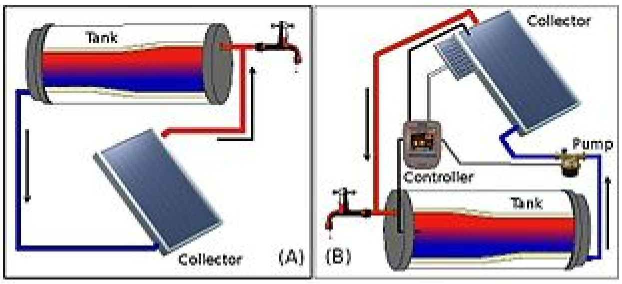
3. Solar Water Heater

<table>
<tr><td colspan="2">SECTOR: ENERGY
CATEGORY: Solar Thermal (Domestic and Commercial water heating)</td></tr>
<tr><td colspan="2">TECHNOLOGY: Solar Water Heater</td></tr>
<tr><td>Introduction</td><td>Solar Water Heating (SWH) is a proven technology that has been widely applied across residential, commercial and industrial sectors around the world (REN21, 2009). China and northern Europe have led the global SWH market in terms of total installed capacity, although island jurisdictions such as Barbados and Cyprus have some of the highest penetrations of SWH on a per capita basis. Solar water heating (SWH) takes advantage of the region’s abundant solar resource to provide a simple, cost-effective, and sustainable means of heating water

Solar water heating is a very recent technology for Belize but the country currently has poor incentives, information and awareness promoting solar thermal technologies for heating water. Also, there is no direct financing scheme or low-interest loan facility for solar water heater purchase in Belize, and end-users must either pay up-front or access traditional commercial loans in order to meet the investment cost of SWH.

This technology transfer initiative under the TNA project will seek to install twenty-four (24) SWH in four municipalities across the country. Namely, Corozal Town, Belize City, Belmopan and Dangriga. The electricity bills for participants in this pilot project will be monitored over a 12-month period. Electricity consumption pre- and post-installation of the SWH will be compared to determine the real financial and environmental benefits and savings.</td></tr>
<tr><td>Technology characteristics</td><td>Solar water heating (SWH) is the conversion of sunlight into renewable energy for water heating using a solar thermal collector. [1]

Solar water heating collectors capture and retain sensible heat from the sun and transfer this heat to a liquid. Solar thermal heat is trapped in a way similar to the “greenhouse effect”; but in this case, it is the ability of a reflective surface to transmit short wave radiation and reflect long wave radiation. Heat and infrared radiation (IR) are produced when short wave radiation light hits a collector’s absorber, which is then trapped inside the collector. Fluid, usually water, in contact with the absorber collects the trapped, sensible heat and transfer it to storage. [2]



Direct systems: (A) Passive CHS system with tank above collector. (B) Active system with pump and controller driven by a photovoltaic panel [2]

(Source: (Wikipedia 2016) [2]</td></tr>
</table>

	Heat transfer *Direct* *Direct* or *open loop* systems circulate potable water through the collectors. They are relatively cheap. I*ndirect* *Indirect* or *closed loop* systems use a heat exchanger to transfer heat from the "heat-transfer fluid" (HTF) fluid to the potable water. **Propulsion** *Passive* *Passive* systems rely on heat-driven convection or heat pipes to circulate the working fluid. Passive systems cost less and require low or no maintenance, but are less efficient. Overheating and freezing are major concerns. *Active* *Active* systems use one or more pumps to circulate water and/or heating fluid. This permits a much wider range of system configurations. Pumped systems are more expensive to purchase and to operate. Active systems operate at higher efficiency that can be more easily controlled. Do it Yourself (DIY) SWH systems are usually cheaper than commercial ones, and they are used both in the developed and developing world.
Costs, including	
Cost to implement adaptation options	Based on the three major SWH vendors in Belize, prices range from BZ$ 2,000 to BZ$ 4,000. The price varies depending on storage capacity and whether it is vacuum tubes or flat panel models being used.
Operational Cost	There are very few persons trained to install SWH in Belize. Most current installations are done by plumbers or even electricians. Installation costs about BZ$ 500, with a team of two persons and installation usually takes about half-a-day. Maintenance is minimal and mainly requires the cleaning of the glazed panel or tubes to ensure efficiencies are maintained. Maintenance also includes regular checks for leaks on the plumbing and occasional flushing of the system. Encapsulated tubes need to be replaced whenever they break or are damaged. According to one vendor's statistics, sales of vacuum tubes have been about 8 every year for every sale of 30 SWH unit, so a typical unit requires a single tube replacement every three year. Each tube costs about BZ$ 35.
Cost of not modifying the project	The cost of not implementing this project will see the gradual increase and reliance on non-renewable sources of energy for heating water.
Potential development impacts,	Most of Belize, especially the central and northern areas, receives medium to high solar intensity (4.5-5 kWh/m^2/day) that can sustain a reasonably good

benefits	power generation throughout most of the year. With 20% of Belize's households converting to SWH (approximately 17,060 SWH units) – the average use is equivalent to 119 MWh/day of thermal energy. Assuming that these would replace existing traditional electric water heaters, this would represent a 23,900 tCO_2 reduction per annum. Similarly, in the commercial sector (hotels) 9,889 KWh/day or 1,412 solar water heaters would reduce GHG emissions by 1,980 tons of CO2 per year.
Economic	Some of the economic benefits for Belize triggered by an increased uptake of SWH would include: i) Direct job creation for locals: Installation and maintenance of SWH systems would require technical and manual labour, which would increase the workforce for Belize. ii) Replacing existing electric or LPG water heaters with SWH would reduce the energy intensity and hence save money. Both domestic and commercial sectors can benefit from this, but hotels and resorts would be the biggest winners in SWH investments. iii) National Cost savings - due to reduced imports of total petroleum products Belize would retain currency. iv) Hotels and Resorts can benefit economically by promoting their regional or global green/environmental certifications.
Social	*Income, education, health, other* Electricity expenses make up a significant portion of operating expenses in the tourism industry, especially those providing accommodations, such as hotels and resorts. Solar water heaters can replace conventional thermal systems and drive down operating costs. Note that payback time on investments can be short term, as indicated by a recent study conducted by the International Renewable Energy Agency (IRENA) which states that the estimated payback period for SHW systems for hotels in the Caribbean can be as short as one year. The widespread adoption of renewable energy resources in the hotel sector of Belize can lead to increased demand for local trained personnel in installation, operation, and maintenance of SWH systems. An increase in investment in SWH can simultaneously benefit the environment and stimulate the local economy.
Environmental	*Local pollution, GHG emissions, other* Besides the reduction of GHG as mentioned earlier in the document, SWH is a clean technology and has the following additional environmental benefits: i. Solar water heating systems require no fuel or any inputs during operation and electricity production and does not contaminate any water since there are no waste products. ii. SWH systems are noise and vibration free which can be considered environmentally friendly. iii. SWH systems have a service life of over 20 years with minimal

	maintenance, and most parts can be recycled.
Status	Despite the favourable economic and climatic conditions, the SWH market in the Caribbean is still emerging. Average per capita deployment is relatively low, estimated at 48.9 kW_{th}/1000 people compared to the market leader of Austria at 430 kW_{th}/1,000 people (CREDP, 2013; Gardner, 2012; Mauthner & Weiss, 2015). However, this regional average is skewed by the high levels of SWH deployment in Barbados (319 kW_{th}/1000 people), Saint Lucia (111.4 kW_{th}/1000 people), and Grenada (80.0 kW_{th}/1000 people) (Gray *et al.*, 2015). In Belize, SWH investment has the potential to reduce energy costs, stimulate local markets for clean energy technologies, mitigate GHG if the technology will replace electric and gas water heaters and hence improve the environmental performance of the tourism sector. Belize, in general, does not offer tax exemptions on solar water heater purchase. As is the case in many other CARICOM states, domestic hot water is not a priority in Belize households and focus on the application of renewable energy technologies have been largely centred on electricity-generation devices.
Barriers	Most Caribbean countries face significant barriers to SHW technology and these are: - • **Financial Barriers** Despite the fact that a SWH investment has a short payback period of as little as 15 months and a generally high net present value, initial investments are very high, as much as US$ 1000 for a 40-gal unit. High upfront costs will discourage many homeowners from making this investment. • **Organizational/regulatory Barriers** Many organizations including hospitals, public facilities and government departments still do not see energy efficiency and energy management as priority and in many cases, see energy expenses as a fixed cost. Motivation to invest in SWH may be triggered by occasional increases in fuel or electricity cost and then shortly after, this drive to save energy dies off. Other barriers identified that can restrict the mainstreaming of this technology are: - Weak Enabling policy environments for SWH - Incumbent Technology - Information Barriers - Technical Barriers
Acceptability to local stakeholders	According to Belize's 2010 census, Belize had 79,492 households with an average of 4.1 persons per household. There is no data on how many of these households have access to hot water systems. In 2012 the estimated solar water heating technology installed capacity for Belize was estimated at 6.3 kW_{th} per 1,000 inhabitants and well below the regional average of 48.9 kW_{th} per 1,000 inhabitants [3]. The mid-year population estimate for Belize in 2013 was 349,728 with an estimated 85,300 households, so the estimated installed SWH capacity in 2013 was 2,205 kW_{th} or

	the equivalent of 315 SWH units of 80-gal capacity each. If Belize were to attain technology penetration level at least similar to the Caribbean region, the SWH installed capacity would be a total of 17.1 MW_{th}. Based on a typical Belizean household solar thermal requirement of 7 kWh/day per household [4], would represent about 2,445 households (2.9% of the households) or 2,445 solar water heater units of 80 gallons capacity each. On the commercial side, in 2010 Belize had 664 hotels with 6,849 rooms but this increased to 757 hotels with 7,377 rooms by 2013 with an average of 10 rooms per hotel [5]. The average hotel occupancy rate was 38.3% for the period of 2007-2010 [6]. Assuming a 38.3% occupancy rate this reflects 2,825 rooms, and assuming a two-person per room occupancy, this would represent a total water heating demand of 9,889 kWh/day or 1,412 solar water heaters of 80 gallons capacity each.
Endorsement by experts	Solar thermal energy can cover a substantial part of the world's energy use in a cost effective and sustainable way. Any long-term vision for economic development must include solar thermal technologies to save finite energy sources. Key to solar' s growth is the willingness by governments, industry and all Belizean for the transition from fossil fuels to renewables. [7]
Timeframe	Six (6) months to acquire and install all 24 systems. Assessment will take place over a 12-month period.
Institutional capacity	For the pilot tests, the required institutional capacity can be met by the existing local solar companies. However, as the need for SWH grows, there will be need for more institutional capacity in the form of trained personnel to install and maintain.
Adequacy for current climate	Solar PV has enormous energy potential in many countries in Central America and the Caribbean, and likewise in Belize. Most of Belize, especially the central and northern areas, receives medium to high solar intensity (4.5-5 kWh/m^2/day) that can sustain a reasonably good power generation throughout most of the year. Assuming that these would replace existing traditional electric water heaters, this would represent a 23,900 tCO_2 reduction per annum. It is possible to estimate that each m^2 of solar thermal collector surface in a properly sized residential solar water heating system in the Caribbean region would displace about 0.8 tons of CO_2 per year, as a rough approximation.
Size of beneficiaries group	The pilot project will benefit 24 households (six persons per household) evenly distributed among four municipalities in Belize.

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4. Gasification

SECTOR:	ENERGY
TECHNOLOGY:	Gasification
Introduction	The Central American country of Belize has an area of 8,867 square miles (22,960 km²) and approximately 330,000 people (2010 census). This results in one of the lowest population densities in the world and as such, there are a number of isolated communities that are not connected to the national power grid. There are also several entities such as eco-hotels that rely on electricity generated from non-renewable fossil fuels. Gasification is the partial oxidation process that uses a carbon source such as coal or biomass to produce carbon monoxide (CO) and hydrogen (H_2), plus carbon dioxide (CO_2) and possibly hydrocarbon molecules such as methane (CH_4) which are otherwise known as syngas or synthetic gas. This factsheet will focus on biomass gasification to produce electricity using small modular gasifiers – in particular the APL Power Pallet PP 20 unit. This unit integrates a gasifier, an internal combustion engine and a electricity generator.
Technology characteristics	Gasification is a series of chemical reactions, which take place in the controlled environment of a gasifier. There are multiple types of gasifiers and the model chosen is dependent on the feedstock to be gasified. The normal process of gasification can be broken down into various stages: i. Biomass fuel is heated in a reduced oxygen gasifier chamber to about 100 °C under high pressure (about 1000 lbs. per sq. in.) so that drying occurs. ii. Pyrolysis follows at 200-300 °C. During pyrolysis, volatiles in the form of gas and liquids are off gassed and solid char rich in carbon is left behind. It is this char that will undergo gasification reactions. iii. Combustion occurs as the previously produced volatiles, along with some of the char, reacts with limited amounts of oxygen. This creates carbon dioxide and small amounts of carbon monoxide. The combustion provides heat for the subsequent gasification process to occur. iv. Gasification happens once the char starts to react with carbon and steam to generate carbon monoxide and hydrogen. It is this mixture of carbon monoxide and hydrogen, which comprises syngas. Whatever parts of the fuel are not converted, are reduced into charcoal and tar, and fall into an ash bin. The syngas can then be combusted to generate electrical or mechanical energy or as feedstock to manufacture fertilizers, pure hydrogen, methane or liquid transportation fuels. The solids and liquids left behind are called charcoal and

<table>
<tr>
<td></td>
<td>tar which are then used for soil augmentation.

The APL Power Pallet PP 20 is a complete biomass power generation solution that converts woody biomass into electricity. The APL PP 20 is a compact and fully automated system - from biomass to electricity generation. The following are the main performance characteristics of the Power Pallet PP 20:
<table>
<tr><td>Continuous Power Rating:</td><td>18 kW @ 60 Hz 120/240 VAC</td></tr>
<tr><td>Biomass Consumption:</td><td>1.2 kg/kWh, 2.5 lbs/kWh</td></tr>
<tr><td>Run Time per Hopper Fill: approximate @ 250 kg/m^3 fuel density</td><td>5 kW: 10 hrs
10 kW: 5 hrs
15 kW: 3 hrs</td></tr>
<tr><td>Max. Continuous Operation:</td><td>>12 hours</td></tr>
<tr><td>Start Up Time:</td><td>10-20 min.</td></tr>
<tr><td>Installed Footprint:</td><td>1.36 x 1.36 m
53.5 x 53.5 inches</td></tr>
</table>
The Power Pallet uses agricultural and forestry waste materials that can be readily sourced very near the point of generation. The following are the feedstock (biomass) characteristics:
<table>
<tr><td>Feedstock Size:</td><td>12-40 mm/0.5-1.5 in.</td></tr>
<tr><td>Moisture Content:</td><td>5-30% dry basis</td></tr>
<tr><td>Approved and Tested
w/ normal operating procedures</td><td>Nut Shells (e.g. Walnut, Hazelnut)
Softwood Chips (e.g. Fir, Pine)
Hardwood Chips (e.g. Oak, Ash)</td></tr>
<tr><td>Approved and Tested
w/ increased operating effort</td><td>Corn Cobs
Coconut Shells
Palm Kernel Shells</td></tr>
<tr><td>Not Approved
dangerous & voids warranty</td><td>Coal
Tires
Plastic
Municipal Solid Waste</td></tr>
</table>
</td>
</tr>
<tr>
<td>Costs, including cost to implement mitigation options</td>
<td>The APL Power Pallet PP 20’s acquisition cost is approximately US$ 25,000. Additional costs will be incurred to ship, import and install the unit which is estimated to be US$ 10,000.</td>
</tr>
<tr>
<td>Cost of not modifying the project</td>
<td>To generate 20 kW from a conventional fossil fuel (diesel) burning generator. The cost of this type of generator installed is approximately US$ 20,000.00. Over an entire year of operation at an average of 12 hours per day, equates to approximately 7000 gallons of fuel. And at an emission rate of 22.2 lbs./gallon of diesel. This plant will emit approximately 154,000 pounds of CO_2 per annum. Coupled with the cost of the fuel at US$ 4.00 per gallon. The annual</td>
</tr>
</table>

	operating cost will be about US$ 20,000.00 in fuel and maintenance costs.
Potential development impacts, benefits	
Economic	*Costs, employment, investment, other*: The viability of this unit is heavily weighted on the availability and cost of appropriate feedstock. Based on the feedstock options presented in the above table, Belize's most abundant feedstock would be softwood and hardwood chips as well as coconut shell and palm kernel shells. The following table compares the operating costs of fossil fuels versus gasified biomass: Diesel/LPG: US$ 0.40 - US$ 0.75/kWh Gasoline: US$ 0.50 - US$ 1.00/kWh Gasified Biomass: US$ 0.00 - US$ 0.20/kWh Note that these are in US dollars and calculated when the world market price for crude oil was at US$ 50 per barrel. Note that the feedstock should be of a certain size, 0.5 in to 1.5 in – as such some pre-processing must occur. Depending on the feedstock shredders and wood chipper range in price from US$ 300 for small unit that can handle trees up to 3 inches in diameter. The cost for larger units that can handle 12-inch diameter trees is approximately US$ 20,000. The employment potential for this unit will vary greatly. It will depend on its location, if it will be used to generate electricity for a remote resort or community. Locals can be hired to provide biomass fuel for the system on a regular basis.
Social	*Income, education, health, other:* Income generation for this technology in unknown. Note however, that the potential is there for earnings to be generated from the sale of electricity. This can in term be passed on for the purchase of feedstock from local farmers. Education will have to come in the form of training of operators of the system. Much like training of operators for water systems. Health issues as it relates to the operation of the gasifier will be mitigated with the training that must be received form the equipment supplier.
Environmental	*Local pollution, GHG emissions, other.* Gasification units such as the Power Pallet PP 20 are recognized as carbon negative units. Here are the specifics of the accounting for a Power Pallet PP 20 running for 3,500 hours per year at 15 kW electrical output, and consuming 1.2 kg/kWh of fuel: Output 53 megawatt hours per year (MWh/yr) of electricity (secondary energy)

	Consume 63 metric tons per year (tonnes/yr.) of biomass Sequester 3 tonnes carbon/yr. or 11 tonnes CO_2 /yr. (assuming 5% by input mass carbon sequestration) Offset from 15-93 tonnes CO_2 /yr. compared to use of fossil fuel for electrical generation. It should be noted that the carbon emissions from the peripheral activities such as wood chipping and transportation were not accounted for. For example, the average Caribbean pine tree with a height of 20 m and diameter of 0.3 m, can provide the gasifier with an output of 15 kW for 8 days @ 12 hour runs per day.
Status	There are no known gasifiers in the country of Belize presently.
Barriers	- *include barriers to implementation and issues such as the need to adjust other policies to accommodate the adaptation option* The main barriers to the implementation of this mitigation technology include i. Capital cost of gasification unit and peripheral machines (wood chipper). ii. Sourcing large quantities of cheap and appropriate biomass. iii. The work required to find, cut, and process the biomass so that it becomes suitable for use. iv. This technology is quite specific, not known locally and not well known internationally. It will require extensive training of stakeholders from specialized trainers. v. A possible negative social and environmental outlook on the technology for the need to cut trees to supply the plant.
Acceptability to local stakeholders	*Not all adaptations technologies will be equally attractive to all stakeholders for political, economic, social, or, a cultural reason.* The acceptability will vary depending on the stakeholder. It is believed that the main issue will come from the fact that trees will be used to power the unit. To counter these negative views, it is being suggested that any community/entity that implements this technology, also commence a tree replanting programme, where for each tree that is cut down, five trees are planted in its place. This will provide additional employment for local communities and stimulate the local economy.
Endorsement by experts	*In some countries decision-makers will partly base their selection on consistency of proposed mitigation options with international best practices.* There are currently no endorsements for this technology. However, the Ministry of Energy has expressed interest in gasification technology, and can help

	promulgate it among potential stakeholders.
Timeframe	*Specify timeframe for implementing the technology* The specific timeframe for implementation of this technology would be 6 – 8 months. However, monitoring and evaluation should extend for a year or two to assess its sustainability.
Institutional capacity	*How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented* Training for the implementation will need to come from the supplier of this technology, namely the suppliers of the Power Pallet PP20, in coordination with the Ministry of Energy, Technology, Science and Public Utilities.
Adequacy for current climate	*Are there negative consequences of the mitigation option in current climate?* Villages that are not connected to the national power grid, but use a diesel generator set to power its water system can use this technology. Small remote hotels and military outposts that are not connected to the national grid can use this technology to supplement their current energy system (including charging and maintenance of solar PV battery pack).
Size of beneficiaries group	*Mitigation technologies which provide small benefits to large numbers of people will often be favoured over those that provide larger benefits, but to fewer people.* The size of beneficiary groups includes the villages of: San Benito Poite, population 550; Jalacte, population 780; Pueblo Viejo, population 450. Also, proprietors and workers of small industrial establishments, hospital and eco-tourism resorts and hotels.

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5. Micro-Hydro

Sector: ENERGY
Sub-Sector/Technology Option: Micro-hydro power
Technology Application: Micro Hydropower Run-of-the-River Facility for Douglas D' Silva Forest Station and Tourist Centre, Mountain Pine Ridge, Belize

Introduction

Micro-hydro power is the small-scale harnessing of energy from falling water, such as steep mountain streams or small rivers. Using this renewable, indigenous, non-polluting resource, micro-hydro plants can generate power for homes, hospitals, schools, workshops, environmentally friendly tourist destinations, forest station facility and small farming communities.

Small-scale hydro schemes can generate up to 500 kilowatts of power. The micro-hydro power station, which converts the energy of flowing water into electricity, provides poor communities in many rural areas around the world with an affordable, easy to maintain and long-term solution to their energy needs (Practical Action, 2016).

Micro-hydro: How it Works

"Run-of-the-river" systems do not require a dam or storage facility to be constructed. Instead water is diverted from the stream or river, channelled into a valley and drop through a turbine via a pipeline called a penstock (See Figure 1).

The turbine in the power house drives a generator that provides the electricity to the local community. By not requiring an expensive dam for water storage, run-of-the-river systems are a low-cost way to produce power. They also avoid the damaging environmental and social effects that larger hydroelectric schemes cause, including a risk of flooding. Water from the river is channelled through a settling basin, which helps to remove sediment that could harm the turbine. The water then flows into the Forebay Tank where it is directed downhill through the penstock. When the water reaches the bottom, it drives a specially designed turbine to produce the electricity.

Micro-hydro power systems are designed to operate for a minimum of 20 years. It is a low-cost way to produce electricity by barrowing the water from the river and returning it safely back farther downstream. Micro-hydro power is entirely renewable energy and is an alternative climate change mitigation technology that can transform the life of rural communities, who are generally the first and worst that are being impacted by climate extremes connected with climate change.

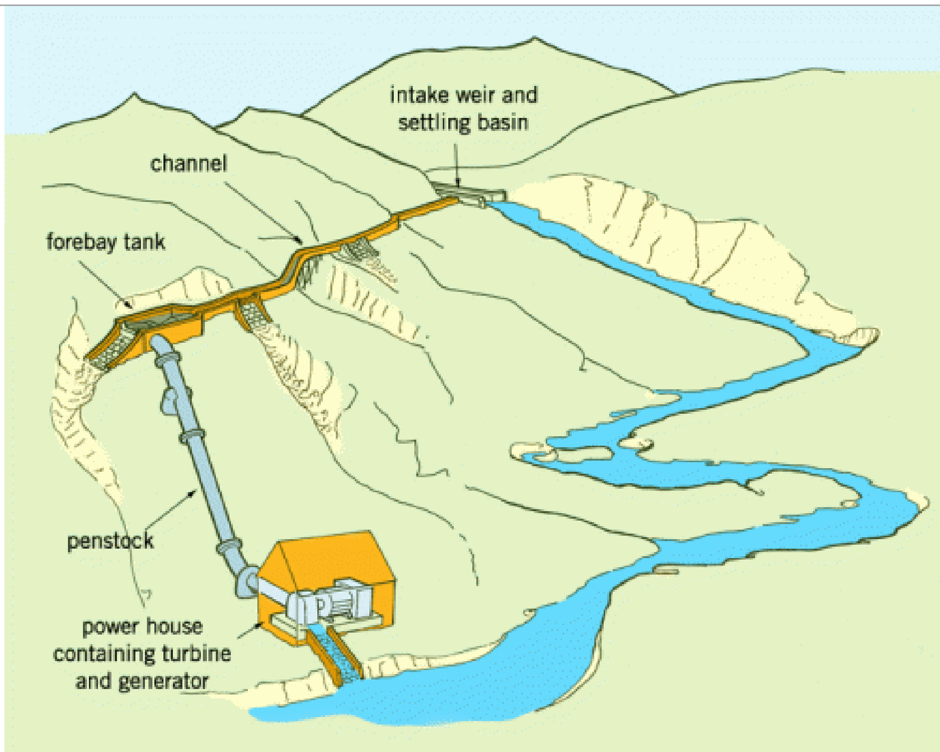

Figure 1. Schematic of a micro hydroelectric power system.

(Source: Practical Action, 2016)

What's the environmental impact?

In contrast to traditional power stations that use fossil fuels, micro-hydro power generators have practically little no effect on the environment. Also, because micro-hydro power facilities do not depend on dams to store and direct water, they have minimal, negative environmental impacts compare to large-scale hydro-electric stations.

Additionally, by reducing the need to cut down trees for firewood and contributing to increase farming efficiency and other small-scale economic enterprises in rural settings, micro-hydro power has a positive effect on the local environment, and is an effective climate change mitigation technology.

Technology Characteristics	
Features	One of the greatest limiting factors in the transformation of the Douglas D'Silva Station into an Eco-Tourism, Research and Education Facility is the unreliable source of electrical energy produced by an old Lister diesel generator. Energy is intermittently provided for a three to four-hour period. For the station to be converted into a tourist resort and education/research centre, it would require that the system be upgraded requiring greater output than can be provided by the present generator, and a more reliable source of energy. An assessment of the available alternatives sources of energy indicate that the facility's needs could best be met through a small hydroelectric plant. The hydrology and topography of the

	area, with its abundance of creeks and tributaries of the Macal River, is suitable for this renewable technology of minimal environmental impacts. The Mountain Pine Ridge Micro-Hydroelectric project is projected to generate electric power of 110/220 V, utilizing the waters of the Rio On river by means of a micro hydroelectric power station with a total installed capacity of 75 -100 kW. The aim is to improve the supply and quality of the electric service in the Douglas D'Silva Forest Station (DDSFS) and the proposed plans to convert the DDSFS into a model Eco-Tourism, Education and Research facility (Tunich Nah, 2004). It is expected that this improvement in providing a reliable source of affordable electricity will allow the transformation of the Station into an Eco-Tourism, Research and Education Centre. The DDSFS, also known as Augustine Forest Station, is the administrative centre for all operations within the MPRFR, the Eligio Panti National Park, the Chiquibul Forest Reserve, the Chiquibul National Park and the Thousand Foot Falls Natural Monument. The activities currently being carried out at the station include sustainable forest management, minor reforestation programs, watershed protection, eco-tourism development, development of two recreational sites and facilities, research, education, Southern Pine Bark Beetle monitoring and control, forest fire management among others. However, budget allocation for all these activities is limited, and hence is a major constraint to realize the fundamental objectives of sustainable forest management, carbon emission reduction through reforestation, and generation/utilization of renewable energy.
Capital Investment Cost	The total cost of the project including the items previously described and utilizing **3 x 25 kw turbines costing** **US$ 396,470.00**. The cost breakdown is presented in **Table 1 below** **Total cost of Douglas D'Silva Forest Station project** Description Cost (US$) Civil works $ 174,475 Roads and access $ 15,000 Electro-mechanic equipment $ 162,975 Construction Phase interest $ 10,275 Project supervision $ 33,745 **TOTAL $ 396,470**
Operating Cost	Operational cost for the 3-year project cycle is US

	$30,000.00 per year
Maturity	Micro hydroelectric generation technology has been in used from the 1970s.
Country Specific Applicability and Potential	
Status of technology in country	Blue Creek village micro hydroelectric power facility on the Rio Bravo became operational in the 1980s. This system was generating, at its production peak period, about 100 – 250 kW. This facility became redundant and was decommissioned after the area was connected to the national grid in 1992.
Market potential	The transformation of the DDSFS into a model Eco-Tourism, Education and Research Facility in accordance to the MPRFR Master Plan will provide and create new job opportunities for members of nearby communities of San Antonio, Cristo Rey, Seven Miles Village and San Ignacio (De Veries, 2004). The MPRFR Visitor Use Master Plan calls for Public-Private administration of the proposed Eco-Tourism Education and Research Facility. However, the installation and operations of the micro hydroelectric plant will be the responsibility of the Forest Department in the Ministry of Agriculture, Forestry, Fisheries, the Environment and Sustainable Development, which manages the reserve within which the forest station and the project site area are located. The market potential of the micro hydroelectric facility will indirectly stimulate the local tourism market, enhance sustainable forest management and research. The technology itself can be replicated or adopted in other tourist/forestry /agriculture enterprise, that may benefit from the economic and environmental spin off of an 'eco-tourism/green technology label'.
Scale of application and time horizon	The micro hydroelectric facility technology transfer under the TNA initiative will be sited locally in the DDSFR Eco-Tourism, Education and Research Facility, serving the wider operations and sustainable forest management of the Mountain Pine Ridge Forest Reserve (MPRFR). The time horizon for the micro hydroelectric facility will be 25 years.
Institutional and Organizational requirements	The Forest Department in the Ministry of Agriculture, Fisheries, Forestry, Environment, and Sustainable Development, will be the governmental body directly responsible for the installation, operation and maintenance of the MPRFR micro-hydroelectric facility on the Rio On. Other governmental and quasi-governmental agencies who will have a stake in this development include: Ministry of Tourism, Ministry of Natural Resources, and Ministry of Defence. Statutory

	bodies include the Protected Areas Conservation Trust, the Belize Tourism Board, and the Institute of Archaeology.
Operation and maintenance	The Administration, operation and maintenance of the Douglas D'Silva Forest Station micro hydroelectric plant will be the direct responsibility of the Forest Department.
Scale/size of beneficiary group	The average, annual number of visitors (Belizean and non-Belizean) to the Mountain Pine Ridge Forest Reserve tourist destinations and trails between 1995 and 2002 was near 150,000 (Tunich, 2016). The figures showed that in 2002, about 38 % of the total number of visitors were Belizeans, and 62 % were of other nationalities. In 2015, the total number of visitors was . Visitors include tourists, foreign student research groups, non-national researchers, Belizeans and Belizean students, family groups, governmental and private sector officials and workers, tour guide agency representatives, and others. An upgraded DDSFS Eco-tourism, Education and Research Centre will attract even more visitors with the increasing number of tourists travelling to Belize.
Acceptability to local stakeholders	An improved and reliable, renewable, electric power supply system produced by the proposed micro hydroelectric facility on the Rio On is a recommendation proposed in the Mountain Pine Ridge Forest Reserve Visitor Use Master Plan (De Vries, 2004). Local stakeholder's consultations on the Plan fully support the improved electrification of the Douglas D'Silva Forest Stations Tourist and Education Centre.
Endorsement by experts	All the experts in forest management, tourism and other productive sectors in the area of the Mountain Pine Ridge Forest Reserve, including policymakers in related sectors endorse the micro hydroelectric energy facility for the DDSFR Tourist centre.
Barriers and Disadvantages	Some barriers and disadvantages to the procurement, installation and operation of the proposed 100 – 150 kW micro hydroelectric system for the Mountain Pine Ridge Forest Reserve visitors centre include: initial cost, reliability of the system under extreme conditions, capacity for maintenance, high cost of spares and equipment, life of technology may be too short, technology may become obsolete and need for replacement before projected time horizon, sustainability after 4-year of project cycle, insufficient flow during drought years, tropical cyclone impacts, forest fire damage to 2.5 km transmission lines
Climate change mitigation Benefits: Hydroelectric power systems is a renewable or clean form of energy that have almost zero emissions, except for those larger facilities with large	

reservoirs inundating vast, vegetative zones. Smaller, run-of-the-river micro hydroelectric systems have proven to be more efficient and cause less impacts to the environment.	
Mitigation potential: The mitigation potential of a 75 – 100 kW renewable energy generator is in the order of approximately 134.1 lb. of Carbon offset for 100 kWh of generated electricity, or 0.0608 tonnes CO_2 **(source: www.better-world-energy.com).**	
Potential Development Benefits: Economic, Social, Environmental	
Economic benefits	The economic benefits of a reliable and renewable energy supply for the DDSFR Eco-Tourism, Education and Research Facility will prove to be far-reaching across various productive and recreational-based sectors. Main income sources will be from Entrance, Rentals and Activities. Preliminary estimates have this figure at US $ 104,257.5 annually, using a middle-earning estimate for selected activities and a wide split entrance rate of US $1.50 for Belizeans and US $ 5.00 for non- Belizean (De Vries, 2004). The Forest Department will need to hire at least four full-time, certified, micro hydroelectric technicians, and four certified electricians. An additional 5 labourers will need to be hired for the construction and installation phase of the hydroelectric plant.
Social benefits	The establishment of the DDSFR Tourist Centre will require joint administration by the Forest Department and Private Sector partners. Once the micro hydroelectric plant is up and operational, this will stimulate the local economy and provide much need jobs for persons from most of the buffer communities, and other communities in the Cayo District.
Environmental benefits	Compared with other forms of electric power generation for small enterprise like the proposed Douglas D'Silva Forest Station Eco-Tourism, Education and Research Facility, a micro hydroelectric power facility is one of the better options, with insignificant environmental impacts.

References:

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TRANSPORT SECTOR

6. Improved Urban/Suburban Public Transport System using LPG Buses

SECTOR: TRANSPORT	
TECHNOLOGY: Improved Urban/Suburban Public Transport System using LPG buses	
Introduction	Belize's public transportation service is currently regulated by the Transport Department under the Ministry of Works and Transport. For both inter and intra municipality operations, bus routes are licensed to private entities (companies and individuals). The main type of buses being used currently are used school busses imported form the United States. These buses have an average carrying capacity of 50 - 55 persons, and use large diesel engines with total displacements sometimes in excess of 8.0 litres. These buses average 5 – 8 miles per gallon [2.1 – 3.4 kilometres per litre]. The level of bus service provided to the public is best described as poor to average. The main issues faced by passengers are lateness, overcrowding, unreliable buses (frequent breakdowns), and unacceptable condition of many buses, such as uncomfortable seats and holes in the floor board – just to name a few. This technology intervention seeks to improve the public transportation system through the revamping of the current bus fleet to allow for newer, cleaner and more comfortable buses with reduced carbon dioxide emission rates (CO_2 per mile). An additional spin-off effect would be the increased use of an upgraded, public transportation on a daily basis by private citizens who own vehicles, but choose to use the public transport system for one reason or another. This should contribute to the reduction in private vehicle usage, and consequently carbon emissions. The technology intervention will initially take the form of a pilot project. This pilot will see the purchasing and operational use of the desired buses on specific bus routes. Discussions with the Transport Department suggests the route between Belize City and Banque Viejo del Carmen is best suited for this pilot as it's a main bus route, and the department has some data (bus owners, bus runs, etc.) for this route.
Technology characteristics	The explanation for using this technology is quite simple. On a phased basis, replace the existing bus fleet with more reliable and fuel-efficient buses. Currently there are 46 daily bus runs between Belize City and Benque Viejo del Carmen. That is a total of 3,726 miles [5,960 km] per day. Online documentation as well as bus owners states that these busses average between 6 to 7 miles per gallon [2.55 – 2.97 km/litre].

Using an average of 6.5 mpg [2.76 km/l], these buses on the Belize City – Benque Viejo run use a total of 573 gallons [2,169 litres] of diesel fuel per day. At an emission rate of 22.2 lb. CO_2 /gallon of diesel [2.67 kg CO_2/litre], these buses emit a total of 12,720.6 lb. CO_2/daily [5,770 kg CO_2] – or approximately 4.64 Million lb. [2106.04 tonnes CO_2] annually.

To replace these busses, it will be necessary to double the number of runs to 92 to ensure the same carrying capacity.

Using an average of 16 mpg [6.8 km/l], these buses on the Belize City to Benque run use a total of 465 gallons [1,760 litres] of diesel fuel per day. At an emission rate of 22.2 lb. CO_2 /gallon of diesel [2.67 kg CO_2/litre], these buses will emit a total of 10,340 lb. CO_2/daily [4,700 kg CO_2]. Or approximately 3.77 Million lb. [1,715 tonnes CO_2] annually. See comparison table below.

Table 1. Carbon dioxide emission comparison for current and proposed bus fleet

Belize City to Benque Viejo del Carmen Bus Route (81 miles/130 km)		
Public Bus Carbon Emission Comparison		
Description	Existing Fleet	Proposed Fleet
Bus Runs	46	92
Distance Travelled miles[km]	3726 [5961]	7452[11923]
Bus Type	Used Bluebird/Thomas Buses (55 seater)	New Toyota Coaster Buses (28 seater)
Est. Fuel Economy mpg[km/l]	6.5[2.76]	16[6.80]
Fuel Used gallons[litres]	573[2169]	465[1760]
% Reduction in fuel use	-	19%
Carbon Emission lb. [kg] of CO_2	22.2[2.67]	22.2[2.67]
Carbon Emission Annually lb. [tonnes]	4.64 million [1970]	3.77 million [1715]
% Reduction in Carbon Emission		18.75%

Costs, including cost to implement adaptation options

Currently, the bus system is privately owned by numerous bus companies that are given licenses to run buses along designated routes. The Government's only role is to regulate.

This proposal calls for a Public Private Partnership (PPP) between the Government and the private bus operators. As the regulatory body, the Government through the Department of Transport and would mandate that buses over a certain age should be phased out of the system over period (2 - 5 years) and replaced with new and more efficient buses. To assist operators with purchasing – the Government would then grant tax waivers for bus imports and also facilitate low interest loans.

	The 2017 market price for a Toyota Coaster is BZD 118,000 (duty free). If the General Sales Tax (GST) were to also be removed, the price for each bus would fall to approximately BZD 105,000. The terms and conditions of the partnership are to be worked out between the Government and bus operators. To test the proposal, a pilot project involving two (2) buses should be implemented. These buses will run between Belize City and Benque Viejo del Carmen. One bus will execute the "express" return, run ─ meaning it only stops in San Ignacio and Belmopan, on its way to its destination in Benque Viejo, and back. While the other will execute the "regular" run, with regular stops as required by passengers. The parameters of passenger volume, fuel usage, maintenance requirements, financial viability will all be assessed during the proposed 1-year pilot project. A monitoring and evaluation program will be instituted for the duration of the pilot. An evaluation report shall be drafted and submitted to the relevant authority for their assessment and action. Preliminary cost breakdown: i. Purchase of two new buses @ BZD 118,000/bus = 236,000 ii. License and Insurance for two buses @ BZD 500/bus = 1,000 iii. M & E including hiring and training two Traffic Officers = 60,000 iv. Contingency including equipment, travel & subsistent = 25,000 **Total BZD = 322,000** **USD = 161,000**
cost of not modifying the project	The status quo would remain as is with the use of unreliable, inefficient and uncomfortable buses. Carbon emissions from the Transport Sector will increase, as demands for public service transportation increases, and bus owners continue to import, inefficient and emission-control defective buses for their fleet.
Potential development impacts, benefits	
Economic	The economic cost to bus operators will be high, initially. However, once the terms and conditions of the PPP are reasonable, these additional costs can be manageable. Additionally, more information will be gathered during the pilot test phase. Once fully developed, this project will see additional employment for drivers and conductors. As the number of buses will essentially double.
Social	The social impact will be extensive. The public will now be able to travel in relative comfort and be free of the fear and effects of frequent bus breakdowns.

	Passengers will be less stressed and anxious about using the public transport system.
Environmental	It is envisioned that this proposed bus service will see an increase in usage by private car owners. This will result in a reduction in fuel usage and carbon emissions at the national level.
Status	Currently, there is an initiative by the Government to conduct a feasibility study on the transport system on a national level (National Transportation Master Plan). To date the project is still in the tendering phase.
Barriers	1) Political will; 2) Legislative modification to improve regulations; 3) Cultural shift in thinking by the Government and general public; 4) Infrastructure improvement in the form of providing better and more intra and inter-district bus terminals, upgraded road infrastructure including alternating bust stops at key localities along the right-of-way (ROW) of highways.
Acceptability to local stakeholders	Acceptability by the major stakeholders (bus operators) will be a challenge. The major issue will require them to spend money for new buses.
Endorsement by experts	Members of the National Transport Authority (NTA) were consulted on this matter. They are in full agreement with such a proposal in its current form.
Timeframe	Pilot project should be implemented over a period of 8 – 12 months.
Institutional capacity	The pilot project will require institutional strengthening in the form of personnel. Bus drivers and conductors and office staff stationed at the current NTA offices.
Adequacy for current climate	This mitigation measure is suitable for the current situation. What will be required is effective dialog between Government and the bus operators, informing them of the intent and purpose of this pilot exercise.
Size of beneficiaries group	The pilot study will benefit approximately 120 persons on a daily basis – two runs per day for each bus, at 30 persons per run. Employment will include two bus operators, four conductors and two additional Traffic officers to coordinate and manage the pilot project.

References:

Consultation Session: Mr. Paul Schmidt – Snr transport Officer & Acting Operations Officer & Mr. Peter Williams – Transport Warden 2. National Transport Authority. July 1st, 2016.

Source: U.S. Environmental Protection Agency. Emission Facts: Average Carbon Dioxide Emissions Resulting from Gasoline and Diesel Fuel. http://www.epa.gov/otaq/climate/420f05001.htm#calculating

Belize Diesel Co. Ltd. - http://www.belizediesel.com

7. Reduce carbon emissions and cost of vehicle operation through the retrofitting of existing vehicles with Liquid Petroleum Gas (LPG) Systems.

SECTOR: TRANSPORT	
TECHNOLOGY: Reduce carbon emissions and cost of vehicle operation through the retrofitting of existing vehicles with Liquid Petroleum Gas (LPG) Systems.	
Introduction	When LPG is used to fuel internal combustion engines, it is often referred to as auto gas or auto propane. In Belize, it is called 'butane'. LPG has been used since the 1940s as a petrol alternative for spark ignition engines. Research carried out in 2013 by Atlantic Consulting compared results for 1,251 models of bi-fuel vehicles and concluded that there was an average 11% CO_2 reduction when running on LPG compared to the identical cars running on petrol. [1] The research also indicates that LPG cars produce less Nitrogen Oxides (NOx) than both petrol and diesel ones. In fact, when compared to diesel, five times less NOx is emitted. LPG vehicles are significantly lower on particle emissions as well. Extensive independent tests showed that one diesel vehicle emits 120 times the number of fine particles as the equivalent LPG vehicle. It takes 20 LPG vehicles to emit the same amount of NOx as one diesel vehicle. The above figures are sourced from the European Fuel Quality Directive which places LPG as part of the solution to decarbonizing the transport sector in Europe. [2] LPG has a lower energy density than either petrol or diesel, so the equivalent fuel consumption is higher but is one third the cost of regular petrol. This technology transfer intervention seeks to retrofit existing petrol (gasoline) vehicles in Belize to use LPG or butane, as it is called in Belize. The pilot will install butane kits on twelve (12) vehicles with V8 engines and twelve (12) vehicles with V6 engines. During the 12-month test, data on ease of use (convenience), fuel economy and vehicle performance will be collected and analysed.
Technology characteristics	LPG, also known as propane and auto gas, is a by-product of crude oil extraction and the refining process. Many people who consider LPG as an alternative to petrol do so because they believe that the combustion of propane results in lower CO_2 emissions. LPG burns cleaner than petrol and therefore emissions of particulates is very low. Moreover, LPG is non-toxic, non-corrosive and free of tetra-ethyl lead and additives. It also has a high-octane rating (The octane rating is a measure of how likely a gasoline or liquid petroleum fuel is to self ignite. The higher the number, the less likely an engine is to pre-ignite and suffer damage).

	Butane kits in Belize are currently offered in either manual or electronic type. The manual type as the name suggests – the user manually switches between using butane or regular fuel. The electronic type does the switching automatically. Note that the latter is more suited for late model vehicles that possess more electrical control engine management systems. [3] The kits include all necessary components including tubes, brackets, and storage tank, along with controllers and injectors. [3]
Costs, including cost to implement adaptation options	Currently the approximate cost to supply and install are as follows: Electronic Kit: BZ$ 3,000.00 per vehicle Manual Kit: BZ$ 2,500.00 per vehicle. Therefore, it will cost over BZ$ 70,000 (US$ 35,000) to install butane kits on the 24 vehicles to be placed under this pilot project.
Cost of not modifying the project	Continued use of petrol and diesel that emit at least 11% more carbon than when LPG is used.
Potential development impacts, benefits	Based on a 2008 statistic, there are approximately 175 vehicles per 1,000 populations. This translates to some 52,000 vehicles currently in operation in Belize. [4]
Economic	There are no statistics on the number of vehicles in Belize that have already converted to Butane. However, a proposed initiative to convert 15-25% of existing vehicles to LPG would create jobs for people to install and maintain these LPG systems. Other areas of potential economic benefits would come from the need to build more LPG refuelling stations. Lower operating costs would be beneficial to both the private and commercial sectors. See Table I below [6]. Note that from Table I, LPG is about 50% the cost of petrol [6]. Note that in Belize, LPG is closer to 45% the cost of petrol. As such the savings per annum in Belize is significant. Also, national cost savings arising from reduced imports of higher priced petroleum products would enable Belize to retain more foreign currency.

<table>
<tr><td></td><td>
Table I: Example of LPG conversion cost savings (http://tinleytech.co.uk)

LPG Cost Savings

A vehicle running on LPG will return slightly fewer miles per gallon than when running on petrol. However, the cost of running a vehicle on LPG will be about 40% less than the cost of running it on gasoline or diesel. Conversion costs can vary depending on vehicle type and tank arrangement required. Kit costs can be recouped in as little as 4,000 miles in fuel saving alone (based on Land Rover 2.25) [6].

<table>
<tr><th colspan="3">LPG Cost Savings Example</th></tr>
<tr><th></th><th>Fuel (Gasoline / Diesel)</th><th>LPG</th></tr>
<tr><td>Annual Mileage</td><td>20,000</td><td>20,000</td></tr>
<tr><td>mpg</td><td>34 mph</td><td>28 mph</td></tr>
<tr><td>Fuel Price</td><td>BZD 10.50/gallon</td><td>BZD 4.50/gallon</td></tr>
<tr><td>Fuel Cost p.a.</td><td>BZD 6,176.47</td><td>BZD 3,214.29</td></tr>
<tr><td colspan="3">Saving in fuel cost alone BZD 2,962.18 per annum</td></tr>
</table>

(Source: Original cost savings example derived from http://tinley.com.uk/; TOMZA Ltd. LPG Converters, personal comm. Plant Director.)

Premium fuel and LGP fuel cost per gallon are July, 2017 rates in Belize.
</td></tr>
<tr><td>Social</td><td>
(i) Increased income due to investment in LPG systems, employment through installation and maintenance.

(ii) Capacity development of locals through training and capacity building in the use and maintenance of LPG systems.

(iii) A better quality of life stemming from more financial freedom based on the lower operating cost of a private or commercial vehicle.
</td></tr>
<tr><td>Environmental</td><td>
According to the United Nations, road transport is the largest GHG emitter per kt[1] in the energy sector for Belize, and related emissions were 263.58, 275.94 and 330.55 kt CO2 for the years 1994, 1997 and 2000, respectively. Road transport accounted for 44.2%, 44.6% and 51.4% of all energy-related activities countrywide, in the same reference years (May, 2007). [5] [7].

Vehicles converted to LPG will emit up to 11% less carbon than a similarly sized petrol vehicle. [1]; [6].
</td></tr>
</table>

[1] Kt kiloton

Status	The technology and expertise currently exist in the country, but only on a limited scale. There are only two (2) known suppliers and installer of LPG conversion system. These are: LPG Gas from Spanish Lookout, Cayo District, and an unknown supplier/installer out of Shipyard Village in the Orange Walk District, northern Belize.
Barriers	i. Initial cost of the system. At a minimum of BZ$ 2,500 per kit; this is outside the budget of many individuals. ii. A general negative public perception of using LPG. The fear of transporting a pressurized container with explosive contents. iii. Public ignorance about the potential cost savings from converting to LPG and fear of the damage it might do to their engines. iv. No national standards for installation and maintenance of LPG kits. v. Limited number of refuelling stations countrywide makes it inconvenient for the average customer.
Acceptability to local stakeholders	The main advantages of converting a vehicle to LPG are that they would emit less GHG, and are cheaper to operate and maintain. The technology's acceptability will be determined by the pilot project and promotion of the technology. It will also depend on whether the potential savings outweigh the innate fear of using LPG as stated previously. The LGP Vehicle Conversion market has great potential in Belize because of the high cost of fuel, vehicle parts and the transport sector high carbon emissions.
Endorsement by experts	There are no known local experts that have endorsed this technology. However, international endorsements are evident from many sources, including: http://www.aegpl.eu/media/21020/atlantic%20consulting%20scientific%20review%20carbon%20footprint,%20ed.%202009.pdf http://tinleytech.co.uk/ http://www.go-lpg.co.uk/ http://www.drivelpg.co.uk/
Timeframe	The pilot project to install 24 butane (LPG) conversion kits would should be done within a 3-month timeframe and run for a minimum of 12 months. During these months data on ease of use (convenience), fuel economy (cost) and vehicle performance (power, maintenance) will be collected and analysed.
Institutional capacity	As stated previously, only two known suppliers and installers of such systems are presently known. While they may be enough to conduct the pilot project, there will be a need to encourage investments in the LPG engine conversion market.
Adequacy for current	Converting more petrol cars to use LPG will benefit Belize economically and environmentally. There would a reduction in the country's annual fuel bill and there

climate	would be a reduction in carbon emissions for these converted vehicles. However, the current investment climate needs addressing in the form of promotion and education about LPG conversion by relevant agencies such as CCCCC, Department of the Environment, and NGOs. More safety standards are recommended to put in place to ensure installations meet prescribed international standards. There should also be consideration for tax breaks and other incentives given to vehicle owners and companies that invest in an LPG conversion kit for their motor vehicles.
Size of beneficiaries group	Under the pilot project there will be 24 beneficiaries. The proposed LPG Conversion technology intervention will have benefits to 24 vehicle owners who are willing to participate in the pilot project, along with at least two LPG conversion/installation companies operating in Belize. Other beneficiaries could be one or two more companies that are will to invest in LPG Conversion market.

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8. Production of performance based (CO2 emission) import duties on motor vehicles. [VED – Vehicle Emission Duty]

SECTOR: TRANSPORT

TECHNOLOGY: Production of performance based (CO2 emission) import duties on motor vehicles. [VED – Vehicle Emission Duty]

Introduction

This technology intervention aims to change the way in which duties are charged on motor vehicles being imported into the country of Belize. The main result of this project will be to modernize the way vehicular import duties are charged, so that it encourages the country's citizens to import more fuel-efficient motor vehicles. The intervention will complement the objectives of the Belize National Transportation Master Plan, which is currently being drafted for adoption, and which will endeavour to regulate every facet of transportation in Belize, including land, air, and sea transport (Bonilla, *et al.*, 2017).

Currently duties are applied as shown in the table below. The rate of duty applicable to Motor Vehicles is according to the engine capacity in Motor Cars/SUVs; according to the weight for Trucks, and according to the seating capacity in Vans and Busses for Public Transport.

Duty Rate for Imported Vehicles into Belize

Type of Vehicle	Cylinders	Litres	ID	RRD	ET	GST	Total %
Pickups	4	up to 3.0	10%		2%	12.5%	26.00%
Cargo Van	6 & 8		10%	15%	5%	12.5%	47.94%
Cars, SUVs	4	up to 3.0	45%		2%	12.5%	65.38%
& minivans	6 & 8		45%	5%	5%	12.5%	76.91%
Motor cycle		Less than 50 cc			2%	12.5%	14.75%
		Above 50 cc	20%		2%	12.5%	37.25%
Vans & Buses	4	10 to 20 passengers	10%		2%	12.5%	26.00
	6 & 8	20 passengers	10%	5%	5%	12.5%	35.56%
Buses		21 passengers+	10%		5%	12.5%	29.38%
Trucks		5 tonnes^{+}	10%	10%	5%	12.5%	41.75%
Tractor trucks			5%	10%	5%	12.5%	35.56%

It is the intention of this technology intervention to formulate a system (Vehicle Emission Duty - VED) that charges duties on an imported vehicle not by the number of cylinders it has, but by the amount of Carbon Dioxide (CO_2) it emits per unit distance travelled (g CO_2/mile). The benefits will be a reduction in the transport sector carbon emissions, reduced air pollution and health risks, and a mode of assessing fuel quality.

Note that this technology factsheet does not propose a VED system, although an example is given in the following section. This factsheet will be used to initiate the consultative exercise in developing this VED system. The project

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will be carried out by a team of experts knowledgeable in the fields of customs and excise regulations, automotive systems and legislation.
The ultimate goal is to produce a document of this VED system to be presented to the relevant stakeholders (government and non-government) for approval, and later, implementation.
</td>
</tr>
<tr>
<td>Technology characteristics</td>
<td>
The proposed VED system will use the manufacture’s data of emissions rates to calculate the percentage duty to be charge. It is envisioned that the system will comprise of categories designated by the vehicle emission rates – and duty percentage is assigned to each category.
Table I below is a theoretical example of what the basic VED would look like.
Table I: Proposed Vehicle Emission Duty
<table>
<tr><th>Category of Vehicles</th><th>Vehicle Emission g CO_2/mile</th><th>Import Duty on Purchase Price</th></tr>
<tr><td>Electric</td><td>0</td><td>10%</td></tr>
<tr><td>A</td><td>1 - 100</td><td>25%</td></tr>
<tr><td>B</td><td>101 - 150</td><td>35%</td></tr>
<tr><td>C</td><td>151 - 200</td><td>45%</td></tr>
<tr><td>D</td><td>201 - 250</td><td>65%</td></tr>
<tr><td>E</td><td>250 - 350 +</td><td>85%</td></tr>
</table>
Note that the table above is an example. The real system will need to be more complex and inclusive to ensure that all vehicle types are covered such as buses, trucks, tractors, etc. There will be the need for clauses that deal with vehicles in which the CO2 emission rates are not available from the manufacturer.
Vehicle Emission Technology
Motor vehicle exhaust emissions are a significant source of pollution, including carbon monoxide, nitrogen oxides and hydrocarbons (US EPA, 1994; EPA Illinois; [3]). These pollutants can be harmful to human health and the environment and lead to the formation of ground level ozone (smog). Exhaust emissions from cars and trucks are one of the single greatest sources of air pollution and CO_2 emission. Table II below.
</td>
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</table>

Table II: Estimates of average passenger car emissions in the US for April 2000

U.S. Environmental Protection Agency estimates of average passenger car emissions in the United States for April 2000 [3]		
Component	**Emission Rate**	**Annual pollution emitted**
Hydrocarbons	2.80 grams/mile (1.75 g/km)	77.1 pounds (35.0 kg)
Carbon monoxide	20.9 grams/mile (13.06 g/km)	575 pounds (261 kg)
NO_x	1.39 grams/mile (0.87 g/km)	38.2 pounds (17.3 kg)
Carbon dioxide - greenhouse gas	415 grams/mile (258 g/km)	11,450 pounds (5,190 kg)

Hydrocarbons, carbon monoxide and oxides of nitrogen are created during the combustion process and are emitted into the atmosphere through the tail pipe. Hydrocarbons are also emitted as a result of vaporization of gasoline from the tank and crankcase of the automobile. The US Clean Air Act of 1977 set limits as to the amount of each of these pollutants that are emitted from automobiles. Some of the more popular emission control devices installed on automobiles are: EGA valve, Catalytic Converter, Air Pump, PCV valve, and Charcoal Canister.

Table III: US Exhaust Emission Standards

United States Light-Duty Vehicle, Light-Duty Truck, and Medium-Duty Passenger Vehicle—Tier 2 Exhaust Emission Standards (for Bin 5)		
Component	Emission Rate	Annual pollution emitted
NMOG (Volatile organic compounds)	0.075 grams/mile (0.046 g/km)	2.1 pounds (0.95 kg)
Carbon Monoxide	3.4 grams/mile (2.1 g/km)	94 pounds (43 kg)
NO_x	0.05 grams/mile (0.0305 g/km)	1.4 pounds (0.64 kg)
Formaldehyde	0.015 grams/mile (0.0092 g/km)	0.41 pounds (0.19 kg)

(Source: epa.gov, 2000).

<table>
<tr><td></td><td>In 2000, the United States Environmental Protection Agency initiated a more stringent emissions standard for light duty vehicles. The requirements were phased in with 2004 vehicles and all new cars and light trucks were required to meet the updated standards by the end of 2007 [3]. These Standards may likely be adopted in Belize with some minor adjustments.

Proposed Vehicle Emission Duty Concept

The main requirement for this technology transfer (i.e. VED Concept) will be the choice of a reliable and consistent vehicle emission testing protocol. Two systems that can be used are:
1) A laboratory emission testing facility;
2) Portable emissions measurement system.

A Laboratory Emission Testing facility is a major infrastructure and institutional investment that requires planning and institutional capacity. The cost – benefits has to be closely evaluated.

A portable emissions measurement system (PEMS) is a lightweight 'laboratory' that is used to test and/or assess mobile source emissions (i.e. cars, trucks, buses, construction equipment, generators, trains, cranes, etc.) for the purposes of compliance, regulation, or decision-making [3]. The PEMS technology for emission testing has its advantages and advantages, but the technology is being improved,

The VED proposal will have to investigate these and other vehicle emissions measurement systems and protocols, and make recommendations to the government on the most appropriate systems that can be used to achieve the goals carbon emission reduction in the transport industry and reduce the health risks to Belizean.</td></tr>
<tr><td>Costs, including

cost to implement mitigation options</td><td>This vehicle performance based system will require a minimum of eight (8) months of work by a consulting firm to formulate the system, and another six (6) months for vetting and adoption. The approximate cost of USD 100,000.00. The cost breakdown is a follow:

Eight months Literature review, consultation (workshops), draft the proposal, presentation, and draft review.

20 day-work/month @ USD 500/day = 80,000

Travel to and from Belize Three return trips @USD 1500/trip = 4,500

Contingency: 15 % = <u>15,500</u>

Total USD 100,000</td></tr>
<tr><td>cost of not modifying the project</td><td>Continuing with this archaic system that does not encourage the importation of more efficient vehicles such as hybrids and electrics.</td></tr>
<tr><td colspan="2">Potential development impacts, benefits</td></tr>
</table>

Economic	Country will spend less money on fuel. Hence it will have more for other areas of the economy.
Social	More money can go towards more essential functions such as health care and education.
Environmental	GHG emissions will be lowered
Status	No mention of this type of change is seen on the Belize Customs and Excise Department.
Barriers	- Cultural change. Urgent need of a cultural shift as a society to driving smaller, more fuel-efficient vehicles; - lack of political will-power to implement this carbon emission based vehicle duty system if it results in lower revenues
Endorsement by experts	- The Department of Energy has expressed some interest in such a venture. - The National Determined Contribution (NDC) for Belize expresses the need for the development of a domestic transportation policy and a National Transportation Master Plan. Note that this Master Plan is currently being executed by a team of consultants. The main aim of the plan should be to achieve a 20% reduction in conventional transportation fuel use by 2030 and promote energy efficiency in the transport sector through appropriate polices and investments.
Timeframe	Within a year to implement.
Institutional capacity	There is enough in-country capacity to conduct this exercise. Lawyers, Engineers etc.

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LAND USE, LAND-USE CHANGE AND AGROFORESTRY SECTOR

9 Improved Tropical Hardwood & Pine Caribe Species Nurseries and Reforestation (Mountain Pine Ridge & Chiquibul Forest Reserves)

Sector: **Land use, Land-use Change and Agroforestry**	
Sub-Sector/Technology Option: Agroforestry	
Technology: *Improved Tropical Hardwood & Pine Caribe Species Nurseries and Reforestation (MPR & Chiquibul Forest Reserves)*	
Introduction	*Brief introduction to the technology* Agricultural lands and degraded forests are believed to be a major potential sink and could absorb large quantities of Carbon if trees are reintroduced to these systems and judiciously managed (Albretch and Kandji, 2003). Carbon sequestration potential of tropical agroforestry systems produce a median sequestration value of 95 metric tonnes/ha/yr (Albrecht & Kandji, 2003). Considering variables of location, soil type, rainfall and species it can be as high as 228 metric tons per hectare. Assuming a median of 95,000 kg divided by 1,250 trees per hectare one would get 76 kg (167 lbs) per tree. In a managed plantation trees are culled back to about 600 trees per hectare, which would result in 158 kg (348 lbs) per tree per year (Albrecht & Kanji, 2003). Managed plantation generally produce 20 to 30 times more wood than do natural forests, resulting in higher sequestration rates per hectare (Dombro, 2015). The Mountain Pine Ridge Forest Reserve (MPRFR) Visitor Master Plan (De Vires, 2004) calls for a Nursery and Agroforestry Park to educate visitors about tropical agroforestry techniques, reforestation of degraded areas of the Mountain Pine Ridge and the Chiquibul National Park, and the growing and harvesting of live plants for activities to be carried out through the Visitor Use Master Plan, including construction material and food. The climate change mitigation technology, namely: "Improved tropical hardwood and Pine species nurseries and reforestation for the Mountain Pine Ridge and Chiquibul National Park", is a response to the MPRFR Master Plan, as well as a means of generating badly needed income for the sustainability of the Douglas D'Silva Forest Station (DDFS) Eco-Tourism, Research and Education Facility. Visitors, students and the public at large will be invited to participate by planting their own tropical tree in Belize in pre-selected areas of degraded forest for a minimal fee, thus enhancing the carbon sink in this region of the country, and contributing to the goal of a carbon neutral tourist destination in Belize.

Technology characteristics	The Forest Department of Belize identifies over 10,000 acres (4046.9 ha) of degraded forests in the greater Mountain Pine Ridge Forest Reserve (MPRFR) and the Chiquibul National Park, resulting from the persistent, devastating effects of the Southern Bark Beetle infestation of 2000-2004, inadequate fire management, uncontrolled wildfires, and illegal logging (personal comm. Officials of the Forest Dep., 2016). The key assumption in an earlier reforestation project for the MPFR through the Clean Development Mechanism (CDM) was that in the absence of a CDM financing (Carbon Credits), there would be no need to protect the area from wildfires, and consequently the ecosystem would transition to grassland (Silviculture Belize Ltd, 2004). The proposed reforestation technology transfer under the TNA initiative will target about 5,000 acres (2023.6 ha) for rehabilitation over a project time horizon of 5-years, during which the Forest Department and other stakeholders such as the DDFS Eco-Tourism, Research and Education Facility authorities, will be institutionally and technically strengthened to sustain and manage the reforestation program as a vital part of their enterprise. Reforestation of degraded tropical forest begins at the nurseries where indigenous, tolerant and suitable seeds are harvested from healthy trees in their natural environment in Belize. In the case of *Pinus caribaea var. Hondurensis* and *Pinus Ocarpa(patula)* of the original MPRFR provenance; seeds can be imported from tropical tree seeds centres, such as the Pine Seed Bank of the Queensland Forestry Research Institute, Department of Primary Industries, Government of Queensland, where the Belize *Pinus Caribaea var Hondurensis* provenance has been preserved as a source of seed for the Queensland forest industry (Global Forest Nursery Development Inc., 2002). Pine seeds of this variety and others can also be collected locally from small, robust stands in the MPRFR. Forest technicians will supervise the collection of tropical timber species such as Mahogany, Cedar, Santa Maria, Ramon (indigenous edible fruit timber species), Nargusta, and Granadia. Seed harvesting can be done twice per year, i.e., April - June and September – November. Sowing in seed beds can be carried out in July – August and October – January, after seeds have been carefully selected. Planting will be staggered so there will always be seedling/trees for the field planting programme. Nurseries will be constructed with local material, with a netting-roof and open-side design. Other nursery material such as the drip irrigation/fertigation systems, and agro chemicals such as lanate and other mild pesticides will be procured as needed. Four nurseries will be established: two for the broad leaf timber species, and two for pine varieties. Water for the drip irrigation will be abstracted from a small reservoir in a nearby stream. The technology transfer will incorporate the following:

	1) Seed collection and procurement in country or abroad, and technology transfer (know how) in advanced reforestation nursery installation and operations. (*Duploys Botanical Garden as potential source, Bullridge Limited).* 2) Silviculture training for forest officers and 10 labourers to be conducted at the onset of the programme, and repeated on a yearly basis for new recruits during project cycle. 3) Forest management work plan and activities will be prepared and executed to care for the reforested zones. 4) Management and Planning strategy will be implemented for forest officers and some Eco-tourism Centre staff who will deal with the tourists and visitors, and supervise replanting programme. 5) Public awareness/education programmes on climate change and mitigation technologies for carbon sink and emission reduction (e.g. reforestation/afforestation) will be conducted for visitors, tourists, students and others. Equipped Welcome Lecture Centre for visitors/training.
Costs, including cost to implement mitigation options	Capital cost for the Reforestation Technology programme for the MPRFR and Chiquibul National Park is of the order of US $36,000 per year for the first three years and US $24,000.00 per year for the last two. **Capital cost: US $156,000.00**
Operational Costs	1) Forest management work plan and activities will be prepared and executed to care for the reforested zones. (CSFI & Ya'axche) 2) Spares and equipment 3) Public Awareness and education programme. **US $20,800.00 per year or US $104,000.00 for five years**
Cost of not modifying the project	The no action alternative (doing nothing, accepting the status quo) is further transformation of degraded forest to savannah, weak forest management, increased impacts of climate change (threatened watershed, droughts and uncontrolled bushfires).
Potential development impacts, benefits	Potential development impacts will be the gradual establishment of the Douglas D'Silva Forest Station Eco-Tourism, Research and Education Facility in the MPRFR, income generation for private sector partners/tour guide companies and the GOB (Forest Department) operating at the Eco-Tourism Facility and nature attractions in the area, employment for people in the buffer communities, improved forest management and reforestation in the MPRFR and the Chiquibul National Park.
Economic	*Costs, employment, investment, others...* Increase employment for villagers in buffer communities, stimulation of local economy in the tourism trade, encouraging participations of locals in the food, beverage and fruit sales, etc.

Social	*Income, education, health, other* Increased job opportunities for men and women in buffer communities, improved livelihood security (food, education, health, recreation, self-employment for tourist industry, etc.)
Environmental	*Local pollution, GHG emissions, other* Visitors and tourist-oriented reforestation and education programme will be managed in an eco-friendly and best-practice standard that will have the lest impacts on the environment. GHG emissions will be kept at a minimum in daily operations of the facility. Carbon sequestration benefits from one hectare of actively growing *Pinus caribaea var. Hondurensis* is: 42 - 69 metric tons per ha per year (Duca de Lima, et al. 2016). Meanwhile the Carbon sequestration potential from one hectare of well-managed *broad leave tropical species* such as mahogany or Cedar is about: 95 metric tons/ha/year (Albrecht & Kandji, 2003). Transplanting of timber seedlings is estimated to commence before the end of the first year of operation, generating revenues to offset operational cost. The GOB will be contributing in-kind to this climate change mitigation technology initiative through the provision of office and land resources, some heavy equipment, and technical personnel from the Forest and Agriculture Department, and the University of Belize School of Agriculture.
Status	A successful reforestation pilot project was carried out in the mid 80s- to the mid 90s in the Programme for Belize Forest Reserve in the Orange Walk District through GEF funding (Nature conservancy, 2010). The pilot project is projected to sequester and avoid emission of millions of tons of carbon dioxide through two primary approaches: i) Prevention of deforestation; ii) Sustainable forest management and regeneration. The Conservancy points out that the project is a model project demonstrating how saving forests is part of the solution to climate change. Reforestation initiatives in Belize are also being conducted mainly by private landowners on small plots of less than 100 ha. In 2002, an ambitious, reforestation project was started in the Mountain Pine Ridge Forest Reserve by Global Forest Nursery Development Inc. ─ Silviculture Belize Ltd., the Mountain Pine Ridge Forestry Company Ltd., and the Government of Belize, targeting initially some 4047 ha, and later an additional 24,282 ha (or 70, 000 acres total in 4-year period), and funded partially through private sector investments (62 %) and the Clean Development Mechanism (CDM) LULUCF facility (38 %). Unfortunately, this promising initiative faltered before the middle of the second year, as funding from stakeholders did not come through. Thereafter, all operations ceased and the project closed down.

Barriers	*– includes barriers to implementation and issues such as the need to adjust other policies to accommodate the mitigation option.* - Policy/Legal Framework: Lack of Coordination among agency. Project will address. - Outdate Forest legislation, does not have any provision to stimulate or encourage reforestation. Does not consider Climate Change. - There is a draft Forest Policy that considers both reforestation and climate change. Measure - get Cabinet to adopt the Strategy - *Finance:* High capital cost. Tourism market downturn - *Security:* Key to maintain security of the area. Now it is only for Caracol, need to be expanded to MPR and the Chiquibul National Park - *Institutional and Technical Capacity:* Weak institutional capacity among some stakeholder agencies - *Extreme weather events and bushfires*: Hurricane impacts and extreme drought resulting in uncontrolled bushfires in Mountain Pine Ridge Forest Reserve - Lack of comprehensive management plan for MPRFR
Acceptability to local stakeholders	*Not all mitigation technologies will be equally attractive to all stakeholders for political, economic, social, or, a cultural reason.* The proposed TNA project mitigation technology intervention, " *Improved Tropical Hardwood & Pine Caribe Species Nurseries and Reforestation (MPR & Chiquibul Forest Reserves)"* is highly favoured by local stakeholders including the Forest Department that is directly responsible for the management of the Mountain Pine Ridge Forest Reserve and the Chiquibul National Park.
Endorsement by experts	*– in some countries decision-makers will partly base their selection on consistency of proposed adaptation options with international best practices* Experts in the Forestry Sector (both public and private), policymakers and NGOs endorse this initiative as another step forward to rehabilitate the tropical forests in the MPR and Chiquibul.
Timeframe	*Specify timeframe for implementing the technology* The time horizon for the Nursery and reforestation of a portion of the degraded forest in the MPR and Chiquibul is for 5-years.
Institutional capacity	*How much additional capacity building and knowledge transfer is required for the mitigation option to be implemented* For a viable and sustainable nursery and reforestation programme, and marketing of the concept, "*plant your tree in Belize and halt global warming",* will require additional capacity and knowledge

	transfer for Forest Department and Tourism personnel, field workers and others. This can be in the form of workshop training and field demonstration. Experts in Silviculture Systems and Agro-Forestry and marketing will be invited or procured to facilitate training as needed.
Adequacy for current climate	*– are there negative consequences of the mitigation option in the current climate? Some mitigation may be targeted at the future climate but may have costs and consequences under the current climate* Very adequate after the failure of the Global Forest Nursery Development Inc. to complete its reforestation objectives and target back in 2002-2004. Also, the forest management of the area has much to be desired mainly because of the lack of public funds to carry out the work.
Size of beneficiaries group	*– adaptation technologies which provide small benefits to large numbers of people will often be favoured over those that provide larger benefits, but to fewer people* The size of the beneficiary group will include forest field workers and technicians, tour operators, traders in local tourism industry, and families in the buffer communities. For the country at large, it will enhance increase visitors to the area and provide much need foreign exchange into the national economy.

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10 Integrated Landscape Forest Management: A Management Alternative in the Vaca Forest Reserve

Sector: Land use, Land use Change and Agroforestry	
Sub-Sector/Technology Option: Agroforestry	
Technology: *Integrated Landscape Forest Management: A Management Alternative in the Vaca Forest Reserve*	
Introduction	Sequestering atmospheric carbon (C) and storing it in the terrestrial biosphere is one of the options, which has been proposed to compensate greenhouse gas (GHG) emissions. Agricultural lands and degraded forests are believed to be a major potential sink and could absorb large quantities of C if trees are reintroduced to these systems and judiciously managed together with crops and/or animals (Albretch and Kandji, 2003). Thus, the importance of agroforestry as a land-use system is receiving wider recognition not only in terms of agricultural sustainability but also in issues related to climate change. Carbon sequestration potential of tropical agroforestry systems produce a median sequestration value of 95 metric tonnes/ha/yr. (Albrecht & Serigne, 2003). Considering variables of location, soil type, rainfall and species it can be as high as 228 metric tons per hectare. Assuming a median of 95,000 kg divided by 1,250 trees per hectare one would get 76 kg (167 lbs) per tree. In a managed plantation trees are culled back to about 600 trees per hectare, which would result in 158 kg (348 lbs) per tree per year (Albrecht & Kandji, 2003). Managed plantation generally produces 20 to 30 times more wood than do natural forests, resulting in higher sequestration rates per hectare (Dombro, 2015). Soil Carbon sequestration is another realistic benefit in many agroforestry systems. The potential of agroforestry for CO_2 mitigation is well recognised. However, some shortcomings that need to be considered include the uncertainties related to future shifts in global climate, land-use and land cover, the poor performance of trees and crops on substandard soils and dry environments, pests and diseases such as nematodes. In the area of Silvicultural Systems, Dombro (2013) cited studies in Science Daily indicating that natural African tropical forests absorb about 600 kg (1,323 lbs) of carbon per hectare per year. If one takes 600 kg by 25 times more wood per hectare in a plantation setting, you get 15,000 kg (33,000 lbs) per hectare per year divided by 600 plantation trees per hectare, which results in 25 kg (55 lbs) of carbon sequestered per tree per year. One of the topical species recognized as an efficient nitrogen fixing tree (NFT) is *Acacia mangium* (Dombro, 2013). A Springer publication cited by Dombro (2013) showed that NFT's sequester more carbon in the soil than do other

types of tropical trees.

Another study from the Netherlands (Samalca, *et al.* 2007 in Dombro, 2013) confirms and shows that 50% plus of a tropical tree's woody biomass is carbon. That means that fast-growing tropical trees like those planted by the NGOs CO2 Tropical Trees and Amazonia Reforestation, which reach maturity in just 10 years' time, are excellent carbon storage vessels.

The proposed Agroforestry technology transfer under the TNA project, namely: *Integrated Landscape Forest Management: A Management Alternative in the Vaca Forest Reserve,* is targeting a group of 20 farmers operating in the de-reserved zone of the Vaca Forest Reserve (VFR) in the Cayo District of Belize. The agriculture frontier in the buffer zone of the Vaca Forest reserve has been putting stress on the Reserve in the form of logging, farming, cattle ranching, exploitation of non-timber forest products, wildlife poaching and looting (FCD, 2010). Additionally, widespread illegal logging, deforestation, and looting by illegals in the border region of the Reserve continue to exacerbate the degradation. The Defence Force of Belize and the FCD forest rangers operating in the Chiquibul National Park to the south are spread thin to contain the problem.

According to a legal review of the Belize Forest Act (FCD, 2010), the Act does not make provision of the co-management of forest reserves. Thus, the Forest Department does not have the lawful authority to enter into co-management agreements with NGOs (e.g. FCD) or communities. However, it calls for buffer community indolent/cooperation to ensure that there is proper use and management of the reserve.

Definitions:

Deforestation: A reduction of the capacity of a forest to provide goods and services (Expert meeting, FAO, 2002).

Afforestation: is the establishment of a forest or stand of trees in an area where there was no previous tree cover. *Reforestation*: is the reestablishment of forest cover, either naturally (by natural seeding, coppice, or root suckers) or artificially (by direct seeding or planting) (Ford-Robertson, 1971).

	Think of the rain forest canopy as a place that is busy absorbing carbon 365 days a year. Compare that with boreal trees that are only on the job 3 months of the year, and on average only sequester 1 kg or 2.2 lbs. of carbon per year. (Source: Albrecht & Kandji, 2003)
Technology characteristics	The proposed agroforestry technology endorsed by FCD and the Forest Department for the stewardship of the Vaca Forest Reserve by farmers operating in the area, is the re-introduction of the Forest Landscape Management approach as an alternative and innovative means of management and conservation of the reserve. The target group will be 20 farmers from three buffer communities and the coordinating agencies will comprise of the Friends for Conservation and Development and the Forest Department. Other public and private stakeholders will be invited to activate a Vaca Forest Reserve Working Group. The time horizon for the project is five (5) years. The general objective is to reduce emissions arising from land use and land-use change through a community forestry program incorporating sustainable livelihood strategies and diversifying local economic opportunities. Four main components are: 1) Activate the Landscape Management Strategy for the VFR. Special attention will be given to already impacted areas of the reserve by farmers. The Strategy recommends a set of mitigation, restoration and production activities at the farm and landscape level, that can benefit farmers, and help maintain the natural environment and restore degraded areas 2) Establish two reforestation nurseries for native and fast-growing timber species, and develop and implement a comprehensive reforestation programme and silviculture system. Technical expertise will be required to assist farmers. 3) Promote Integrated Farming Systems. This will be in line with the sound recommendations of the Technical Assessment Report of the Maya Mountain Massif that calls for the promotion of sustainable income generating activities such as apiculture, cacao and *xate* production among others. Activate the FCD Agro-ecology Practical Guide. 4) Develop a five-year Agro-business and Marketing plan with the participation of farmers and business stakeholders in the communities. Farmers will be encourage to implement the business marketing products. 5) Employment: 2 technical staff; 4 extension service staff. Total 6 personnel.
Costs, including	Travel and logistics, programmes, nurseries and small demonstration

	activities (soil management, drip irrigation and fertigation, seed collection and harvesting, etc.).
Cost to implement mitigation options	Capital cost**: US $40,000 per year. Total US $200,000 for the five-year project cycle.**
Cost of not modifying the project	The no action alternative (doing nothing; accepting the status quo) is further degradation/loss of biodiversity of the Vaca Forest Reserve, weak or insignificant forest management, increased impacts of climate change (threatened watershed, droughts and uncontrolled bushfires). Operational Cost: **US 15,000.00 per year. Total US $ 75,000.00**
Potential development impacts, benefits	Development impacts is the increase stress and wanton exploitation of the Reserve. Benefits if interventions in the proposed TNA technology transfer will ameliorate the pressure on the Reserve and increased livelihood of famers from the buffer communities.
Economic	*Costs, employment, investment, other* Stimulate the local economy in the buffer communities and uplift the livelihoods of famers and their families
Social	*Income, education, health, other* Improved self-employment for farmers, more income, increase livelihood security and improved water quality for downstream communities. Preservation of this patrimony for all Belizeans.
Environmental	*Local pollution, GHG emissions, other*
Status	*Status of technology in the country* The Central American Commission for Environment and Development (CCAD) Regional Environmental Plan 2010-2014, called for actions in the promotion of greenhouse gas emissions (GGE) reduction and taking advantage of opportunities in the carbon market. During the period of the Plan and to date, not much has been done in GGE reductions through carbon sequestration in Belize, and little if any, in ceasing opportunities in the carbon market, for one reason or the other. Some recent activities in reforestation are: A successful reforestation project was carried out in the mid 80s- and early 90s in the Programme for Belize Forest Reserve in the Orange Walk District through GEF funding (PFB, 2010). In 2002, an ambitious, reforestation project was started in the Mountain Pine Ridge Forest Reserve by Silviculture Belize Ltd - Global Forest Nursery Incorporated, the Mountain Pine Ridge Forestry Company Ltd. and the Government of Belize, targeting initially some 4047 ha and an additional 24,282 ha (or 70,000 acres in total in a 4-year period), funded partially through private sector (62 %) and the facility of the Clean Development Mechanism (CDM) LULUCF (38 %). Unfortunately, this promising initiative faltered by the middle of the second year, as funding/cooperation from private/public stakeholders did not come through as planned.

	Thereafter all operations ceased and the project closed down. Reforestation initiatives have been conducted mainly by private landowners on small plots of less than 100 hectares. In August 2010, through the leadership of Friends for Conservation (FCD) and with a small grant from the GEF-SGP (Belize) and the Tropical Agricultural Research and Training Centre (CATIE), ten farmers operating in the buffer zone of the Vaca Forest Reserve were organized, trained and provided with small grants to promote Landscape Management in the Vaca Forest Reserve through Community Development and Support. Farmers were trained and equipped with tools to reduce land degradation through Beekeeping, demonstration projects using sustainable land management approach such as agro-ecological methods, reforestation, farming plans and soil management. This initiative started off very well, but soon came to an end as the funds dried up by late 2012. FCD lost contact with farmers and famers got disinterested and returned to their customary, unstainable practices, and putting more pressures on the Vaca Reserve.
Barriers	*– includes barriers to implementation and issues such as the need to adjust other policies to accommodate the adaptation option* 1) Policy: Weak state and stakeholder ties with respect to the management of the VFR 2) Institutional: Lack of institutional capacity of leading NGOs to facilitate most of the proposed programs 3) Technical: Weak technical capacity of leading NGO. Some farmers have very limited education. Poor Climate Change knowledge, attitude and perception (KAP) among most farmers 4) Financial: Limited or no co-financing among main stakeholders. Capital cost may be too high. Difficulty with marketing of farm products. Sustainability of the Agro Forestry and Silviculture programmes after project phase out. 5) Social and cultural: Lack of interest among some farmers to participate. Cultural clash with some farmers with respect to forest and biodiversity conservation, and climate change mitigation measures. 6) Physical and Environmental: In accessibility to vehicular transport during rainy season. Seasonal bush fires. Impacts of hurricanes and flash floods.
Acceptability to local stakeholders	*Not all mitigation technologies will be equally attractive to all stakeholders for political, economic, social, or, a cultural reason* The local stakeholders are buffer communities farmers and their families. Some of these farmers were participants in an earlier Agro Forestry initiative coordinated by FCD and the Forest Department in

	2011-2013. Famers in the area have expressed a keen interest to participate in the proposed Agroforestry technology interventions to sequester carbon and improve their livelihood options through improved forest management.
Endorsement by experts	*– in some countries decision-makers will partly base their selection on consistency of proposed mitigation options with international best practices* Experts in the Forest and Lands Department, NGOs and private sector like the Belize Electric Company who operate the nearby Hydro Electric facility in the upper Macal River all endorse the Integrated Landscape Forest Management of the Vaca Forest Reserve.
Timeframe	*Specify timeframe for implementing the technology* The time horizon for the Agro Forestry and Integrated Forest Management of the VFR is projected for five (5) years.
Institutional capacity	*How much additional capacity building and knowledge transfer is required for the mitigation option to be implemented* Technical capacity in Silviculture and Agro-Forestry, and Marketing techniques will be required for new personnel from FCD and the Forest Department working in the Vaca Forest Reserve. This can be done at the start of the programme and repeated on a timely basis as new experts are invited to participate in the activities.
Adequacy for current climate	*– are there negative consequences of the adaptation option in the current climate? Some adaptations may be targeted at the* future *climate but may have costs and consequences under the current climate.* This proposed intervention under the TNA project initiative is highly need and timely.
Size of beneficiaries group	*– adaptation technologies which provide small benefits to large numbers of people will often be favoured over those that provide larger benefits, but to fewer people* The beneficiary group(s) will be the participating farmers, FCD/Forest Department and buffer communities of the Vaca Forest Reserve.

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Annex II: List of Stakeholders and small working group members

List of Stakeholders for Mitigation Technology Consultations

Name	Organisation	Approach	Topics
Shaw	Chairman, cooperative of bus operators	Small Working Group	Public transport sun-sector and proposed technology factsheets
Paul Schmidt	Transport Officer (Ret)	Interviews	CC Mitigation technology factsheets
Elena Torres	BELTRAIDE	Interview	Incentives for RE technologies through Belize Trade Investment Development Service (Solar PV, SWH, Wind etc.).
Ambrose Tillett	MESTPU	Interview	Discussed proposed Energy Sector technology factsheets
Edilberto Romero	Programme for Belize	Small Working Group	Integrated Forest Landscape Management Vaca F. R. and MPRFR
German Novelo	Forest Department		Integrated Forest Landscape Management Vaca F. R. and MPRFR; Micro Hydro
Paul Williams	Ministry of Transport	Small Working Group & Workshop	Review technology factsheets for Transport Sector
Claudia Elena	Development Finance Corporation	Small Working Group	Review prioritized technology and discuss barriers
Vallan Hyde	Department of Transport	Small Working Group	Review prioritized technology and discuss barriers
Santos Chicas	University of Belize	Small Working Group	Review prioritized technology and discuss barriers
Eli Mendez	ProSolar Engineering Ltd.	Small Working Group	Technology verification and barriers prioritization
Maria Petkan	ProSolar Engineering Ltd.	Small Working Group	Review prioritized technology and discuss barriers
Felipe Rivera	Customs and Excise Department	Small Working Group	Review prioritized technology and discuss barriers & custom regulations
Lloyd Orellano	Belize Bureau of Standards	Small Working Group	Review prioritized technology and discuss key barriers
Gian Hernandez	BELTRAIDE	Small Working Group	Verification and prioritisation of barriers
David Perera	Forest Department	Small Working Group	Review technology factsheets, prioritized technologies for MCA and discuss barriers
Jorge Nabet	Forest Department	Small Working Group	Review technology factsheets, prioritized technologies through MCA and discuss barriers
Ramón Frutos	Adaptation Consultant TNA	Small Working Group	Coordinate working group sessions; review technology factsheets, prioritized

Name	Organisation	Approach	Topics
			technologies through MCA and discuss barriers
Colin Mattis	TNA Assistant Coordinator	Coordinated Small Working Group meetings and Workshops	Mitigation technology factsheets. Review TNA documents
Aureliano Bautista	Tomza Gas Ltd.	Small Working Group	Review technology factsheets, prioritized technologies through MCA and discuss barriers
Jose Sanchez	Tomza Gas Ltd.	Small Working Group	Review technology factsheets, prioritized technologies through MCA and discuss barriers
Oscar Alonso	Belize Electric Company Limited (BECOL)	Small Working Group	Review technology factsheets, prioritized technologies through MCA and discuss barriers for Forest Landscape Management
Clifford Martinez	Agriculture Department	Small Working Group	Review technology factsheets, prioritized technologies through MCA process and discuss barriers and enabling framework for agroforestry
Oscar Ulloa	Forest Department	Interview	Timber species nurseries and reforestation
Ester Sanchez	Friends for Conservation and Development	Interview	Integrated Forest Landscape Management Vaca F. R.
Rashida Garcia	Forest Department	Phone interview	Mitigation factsheets; discuss potential barrier
Mateus Furtado	Belize Natural Energy Ltd.	Phone interview	Discussed factsheet for gasification and LPG retrofitting technologies.
George Hanson	Self employed (Former employee of Forest Department)	Phone interview	Fact check on Forest Legislation
Roberto Sho	Toledo Teacher's Credit Union Ltd.	Phone interview	Credit unions in Toledo
Mr. A. Pletts	LP Gas Supplies	Interview	Status of LPG retrofitting technology
Mark Miler	Plenty – Belize	Phone interview	Solar programme in Santa Teresa, Toledo
Martin Tobias Sengfelder	Gogreenbelize Limited; RE expert	Interview	Status and future for Renewal Energy technologies in Belize
Maria Guerrero	Mitigation Consultant	Coordinator	Small Working group sessions
Lucien Chung	Former Mitigation Consultant	Coordinator	Small Working groups for the Energy and Transport sector technologies