ANTIGUA AND BARBUDA

TECHNOLOGY NEEDS ASSESSMENT REPORT

September 2020

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FOREWORD

To be completed by the Department of the Environment

EXECUTIVE SUMMARY

Antigua and Barbuda was selected along with four (4) other Caribbean countries, forming a group of twenty-three (23) developing nations from across the world, to participate in Phase III of the Technology Needs Assessment (TNA) project. The project originated within the *Strategic Programme on Technology Transfer* approved by the Global Environment Facility (GEF) in 2005. The global aim of the TNA is to assist developing country nations – parties to the United Nations Framework Convention on Climate Change (UNFCCC) – to analyse technology priorities for climate change adaptation and mitigation, determine a portfolio of Environmentally Sound Technologies (ESTs), along with context-specific programs/projects that would facilitate transfer of and access to selected ESTs, and progress towards implementation of Article 4.5 of the UNFCCC. The TNA project is implemented by United Nations Environment (UNEP) and executed through the UDP – a long standing partnership between UNEP and the Technical University of Denmark (DTU) – based in Copenhagen, Denmark. The project is fully supported by the Government of Antigua and Barbuda, through the Department of the Environment (DOE), within the Ministry of Health, Wellness and the Environment.

Antigua and Barbuda's first national communication on climate change in 2001, successfully outlined the national inventory of greenhouse gases (GHGs), climate change vulnerability and adaptation profile and target sectors for GHG mitigation. The second national communication that followed in 2009 used regional climate change projections to detail impacts on climate-dependent and climate-sensitive economic sectors for which adaptation and mitigation programs needed to be developed (GoAB 2001, 2009). Building on these and the overall national development agenda, Antigua and Barbuda communicated the Intended Nationally Determined Contributions (INDCs) to the UNFCCC in 2015. This document highlighted *buildings, water, energy, transportation,* and to a lesser extent, *waste* as the nation's priority sectors for climate change adaptation and mitigation. However, since the country previously addressed the energy sector with a renewable energy readiness assessment and identified energy targets – buildings, water and transport sectors were chosen for the TNA project.

The initial step was aimed at prioritising adaptation and mitigation technologies for Antigua and Barbuda. This report details the outcome of a participatory process where relevant stakeholders identified and assessed climate-smart technologies that would aid in achieving targets outlined in the INDCs, increasing overall resilience to the negative impacts of climate change and supporting the national development agenda.

The DOE is the TNA Coordinating Agency with responsibility for project activities, and the Coordinator acts as the core of the national TNA team, maintaining and managing communication between the TNA Steering Committee, the Technical Advisory Committee (TAC), national consultants and sectoral working groups. To facilitate a fully participatory process, stakeholder consultations, which encouraged candid feedback from all participants, were organized at strategic points in the prioritization process to garner input from a representative group from across the local society. Also essential to the TNA process is ensuring that gender considerations were maintained throughout all TNA activities. To this end, gender equity was incorporated by considering how climate change impacts affected women and female-led households, ensuring gender balance in stakeholder selection, and identifying technology options that would benefit both males and females equally.

Climate TechWiki technology platform database was utilized to identify technologies that would prove beneficial in Antigua and Barbuda's fight against climate change. This resource served as a starting point in producing a long list of probable technologies. The list was then scrutinized to highlight the options that were directly related to Antigua and Barbuda's Intended Nationally Determined Contributions (INDCs), thus generating the initial pre-screening list presented to sectoral working groups.

The Hadley Centre for Climate Prediction and Research PRECIS Model (2017) places Antigua and Barbuda at risk for increased mean annual temperatures between 2.4˚C and 4.5˚C by 2080; highly variable precipitation patterns, leading to reduced annual rainfall up to -18% and increased intense downpours; a 1m sea level rise coupled with storm surges, resulting in irreparable coastal erosion; and increased intensity and frequency of hurricanes and tropical storms. Collectively, these pose significant risks for the water sector and dependent sectors such as tourism, agriculture, health and education. Seven (7) water technologies were shortlisted after a screening workshop and approval by the TAC. The technologies then went through the Multi-Criteria Analysis (MCA) for prioritization:

I. Rainwater Harvesting
II. Stormwater Reclamation and Reuse *for controlled groundwater recharge and watershed rehabilitation*
III. Wastewater Reuse for Irrigation
IV. Climate-proofing Assets *(Resilient infrastructure)*
V. Solar Pumping Systems
VI. Atmospheric Water Generators
VII. Water Savers

In reference to adaptation in the building sector, the INDCs specified that by 2030, all buildings must be prepared to withstand extreme climatic events (GoAB 2015a). Therefore, the Environmentally Sound Technologies (ESTs) chosen sought to directly address this policy and target. Simultaneously, it was important that the selection of the building sector technologies would directly contribute to the goals set out in Antigua and Barbuda's INDCs. The five (5) building technologies listed were shortlisted and went through the MCA:

I. Passive House Designs / Site Selection
II. Best Roof Pitch Angle
III. Impact / Energy Efficient Windows & Doors
IV. Construction of Energy Efficient Building Infrastructure
V. LED Lighting (*formerly referred to as High Efficiency Lighting System*)

The transport sector focused primarily on mitigation efforts. The INDCs emphasised the establishment of efficiency standards for vehicles by 2020, in an attempt to reduce CO_2 emissions. Therefore, the chosen technologies aimed to meet this goal both directly and indirectly based on the level of projects adopted for technology implementation. Similar to the building sector, a shortlist of five (5) ESTs were identified for the transport sector for prioritization using the MCA:

I. Improvement of Road Infrastructure
II. Battery Electric Vehicles
III. Solar Renewable Charging Station
IV. Integrated Public Transport
V. Efficiency in Transport Sector

Technology factsheets were prepared for each of the abovementioned technologies and shared with sectoral working groups to help facilitate discussions during the Multi-Criteria Analysis (MCA) used to prioritize the technology options for the next step of the TNA process.

In March 2019, the UDP provided Consultants with a simplified MCA Excel tool and trained them in its use. This tool was then utilized during technology prioritization. A list of criteria was prepared on a sectoral basis, and stakeholders were allowed to choose 8 to 10 relevant, independent, and fully operational selections to be applied in the MCA. Shortlisted technology options were scored based on the criteria using an adapted Likert scale to apply a quantitative value to the range of qualitative criteria. The criteria were then weighted out a total of 100, based on their levels of importance. Finally, scores and weights were used to generate an overall ranking. These results were put through a sensitivity analysis to determine the robustness of the process and validity of the prioritization results.

Following the participatory MCA process for each of the sectors, the final lists of technologies that will be carried forward into the *Barrier Analysis* step are:

Water Sector:

1. Solar Pumping Systems
2. Rainwater Harvesting
3. Water Savers
4. Climate-proofing Assets
5. Stormwater Reclamation and Reuse

Building Sector:

1. Passive House Designs / Site Selection
2. Best Roof Pitch Angle
3. Impact / Energy Efficient Windows & Doors
4. Construction of Energy Efficient Building Infrastructure
5. LED Lighting

Transport Sector:

1. Improvement of Road Infrastructure
2. Battery Electric Vehicles
3. Solar Renewable Charging Station
4. Integrated Public Transport
5. Efficiency in Transport Sector

TABLE OF CONTENTS

LIST OF ACRONYMS

ACI:	American Concrete Institute
APUA:	Antigua Public Utilities Authority
BTU:	British Thermal Units
CARICOM:	Caribbean Community
CCCCC:	Caribbean Community Climate Change Centre
CDEMA:	Caribbean Disaster Emergency Management Agency
CIMH:	Caribbean Institute of Meteorology and Hydrology
CUBiC:	Caribbean Uniform Building Code
DCA:	Development Control Authority
DOE:	Department of the Environment
DTU:	Technical University of Denmark
EPMA:	Environmental Protection and Management Act
EST:	Environmentally Sound Technology
EV:	Electric Vehicles
GEF:	Global Environment Facility
GHG:	Green House Gas
GoAB:	Government of Antigua and Barbuda
HEV:	Hybrid Electric Vehicles
INDC:	Intended Nationally Determined Contributions
IWRM:	Integrated Water Resources Management
MCA:	Multi-Criteria Analysis
MEA:	Multilateral Environmental Agreements
NAP:	National Action Plan
NASAP:	National Adaptation Strategy and Action Plan
NDC:	Nationally Determined Contributions
RWH:	Rainwater Harvesting
SCCF:	Special Climate Change Fund
SIDS:	Small Island Developing States
SIRF:	Sustainable Island Resource Framework
SWG:	Sectoral Working Group
TAC:	Technical Advisory Committee
TAP:	Technology Action Plan
TNA:	Technology Needs Assessment
UDP:	UNEP-DTU Partnership
UNEP:	United Nations Environment Programme
UNFCCC:	United Nations Framework Convention on Climate Change
WIOC:	West Indies Oil Company

LIST OF BOXES

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1. OVERVIEW OF THE GLOBAL TNA PROJECT

1.1.1. Objectives

The Technology Needs Assessment (TNA) project was designed to support country Parties in carrying out evaluations to determine the potential for technology transfer within the framework of the United Nations Framework Convention on Climate Change (UNFCCC). The 2015 Paris Agreement references the employment of appropriate climate technologies by developing countries in order to reduce emissions and stabilize concentrations of atmospheric greenhouse gases (GHGs) and implement programs that would aid in building resilience through enhanced adaptive capacity. Thus, the global TNA project was developed as an integral pathway to support emerging economies – which are parties to the UNFCCC – in analysing and prioritizing technologies, and ultimately developing and implementing Technology Action Plans (TAPs).

At the foundation of the TNA project is the need to understand country-specific climate change scenarios, identify the technology needs for effective responsive actions, and use this knowledge to make investments in technologies that would assist in mitigating against and adapting to projected climate change impacts (UDP 2019a). The TNA process provides in-depth analysis that allows the emergent information to be utilized when setting priorities in accordance with national sustainable development plans.

The global TNA process is supported financially by a USD$20M grant from the Global Environment Facility (GEF) and is slated to cover over seventy (70) countries in a fifteen (15) year period from 2005-2020. The UN Environment Programme (UNEP) bears responsibility for implementation and provides overall strategic coordination, while execution is done through the UDP – a long-standing partnership between UNEP and the Technical University of Denmark (DTU) – based in Copenhagen, Denmark.

Project activities are organized around three (3) main components:

- i.) support for the development and strengthening of TNAs;
- ii.) development of tools and provision of methodological information to support the TNA and TAP processes; and
- iii.) establishment of a cooperation mechanism that aids preparation and refinement of TNA and TAP implementation and dissemination (Haselip et al. 2019).

Antigua and Barbuda is currently among twenty-three (23) countries globally, and six (6) within the Caribbean region – including Haiti which is grouped with the francophone African countries for regional support due to language – participating in this third phase of the TNA process. The project has full Government (GoAB) support through the Department of the Environment (DOE), within the Ministry of Health, Wellness and the Environment.

1.1.2. Purpose

Through the TNA project, developing country Parties to the UNFCCC will identify and analyse priority technology needs which can form the basis for a portfolio of environmentally sound technologies (ESTs) programs and projects. These programs and projects will facilitate the transfer of and access to the ESTs and know-how in the implementation of Article 4.5 of the UNFCCC. TNAs are central to the work of Parties, and present an opportunity to track an evolving need for new equipment, techniques, practical knowledge, and skills which are necessary to mitigate GHG emissions and/or reduce the vulnerability of sectors and livelihoods to the adverse impacts of climate change (UDP 2019b).

The main objectives of the TNA project are to:

1. Utilize country-driven participatory processes to identify and prioritize technologies that can contribute to the mitigation and adaptation goals of the participant countries, while meeting national sustainable development goals and priorities;
2. Identify barriers hindering the acquisition, deployment, and diffusion of prioritized technologies; and
3. Develop Technology Action Plans (TAP) specifying activities and enabling frameworks to overcome the barriers and facilitate the transfer, adoption, and diffusion of selected technologies in the participant countries.

1.1.3 Expected Outcomes

The threefold outcomes of the TNA project ultimately pave the way for the transfer, diffusion, and adoption of ESTs that provide adaptation and mitigation benefits to each individual country. This initial step has resulted in the production of the TNA Report which utilized a country-driven participatory process to prioritize sector-specific adaptation and mitigation technologies. These technologies align with Antigua and Barbuda's Intended Nationally Determined Contributions (INDCs), promote effective national adaptation planning, and contribute to the sustainable development agenda.

The second step in the TNA process will identify barriers to technology acquisition, deployment, and diffusion, as well as design a framework/s that promotes specific activities to overcome these barriers. The final step produces a national action plan with practical steps to aid in systematic and fiscally responsible implementation of the chosen ESTs.

1.2. SITUATION ANALYSIS AND VULNERABILITY ASSESSMENT OF ANTIGUA AND BARBUDA

1.2.1. Overview

The twin-island state of Antigua and Barbuda, with an estimated population of 95,000, is located in the Eastern Caribbean region. Antigua has an area of approximately 289km^2 with a deeply indented shoreline forming natural harbours and beaches *(Figure 1a.)*; while Barbuda is approximately 161km^2 with a single western harbour *(see Figure 1b.)*. Its geography makes the twin-island state vulnerable to a series of climate change impacts; this potential for devastating effects has necessitated the inclusion of climate change risk management in country-specific (and regional) planning and processes. In recent decades, this concern has been shared across Caribbean Small Island Developing States (SIDS) that experience similar climate risks and vulnerabilities (USAID 2013a, 2018a).

Within Antigua and Barbuda, population centres and critical infrastructure are often located in coastal areas, making them susceptible to impacts from tropical storms and sea-level rise. Similarly, surface and ground water resources are compromised by changing precipitation patterns and sea-level rise. While warmer, more acidic oceans threaten coastal ecosystems impacting coral reefs and mangroves, increased frequency and intensity of hurricanes pose significant threats to human life and national economic and ecological stability (USAID 2018b, 2018a). The regional climate projections with sector-specific impacts to 2050 for the Eastern Caribbean are summarized in the graphic below *(see Figure 2)*.

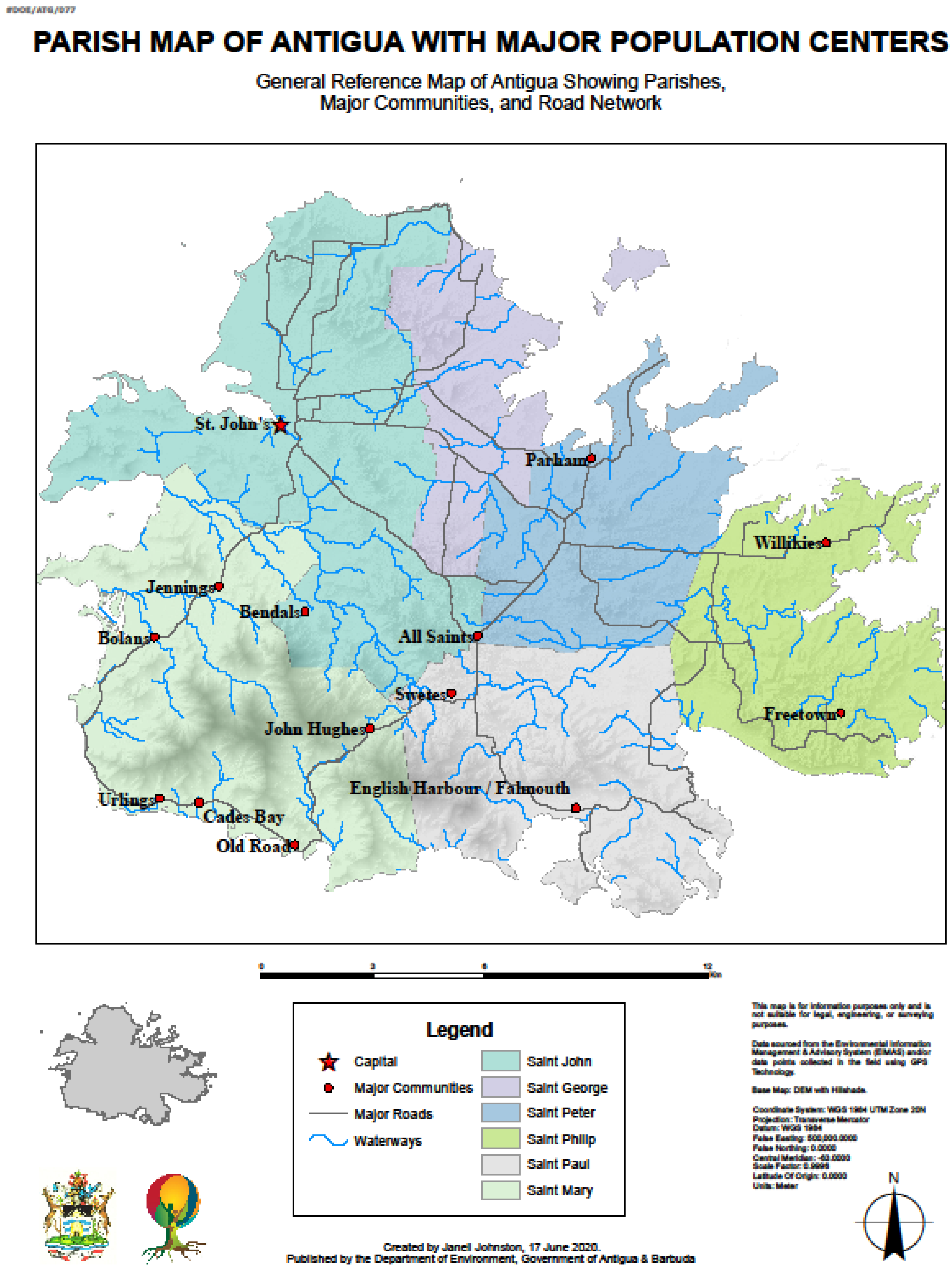


Figure 1a: Map of Antigua

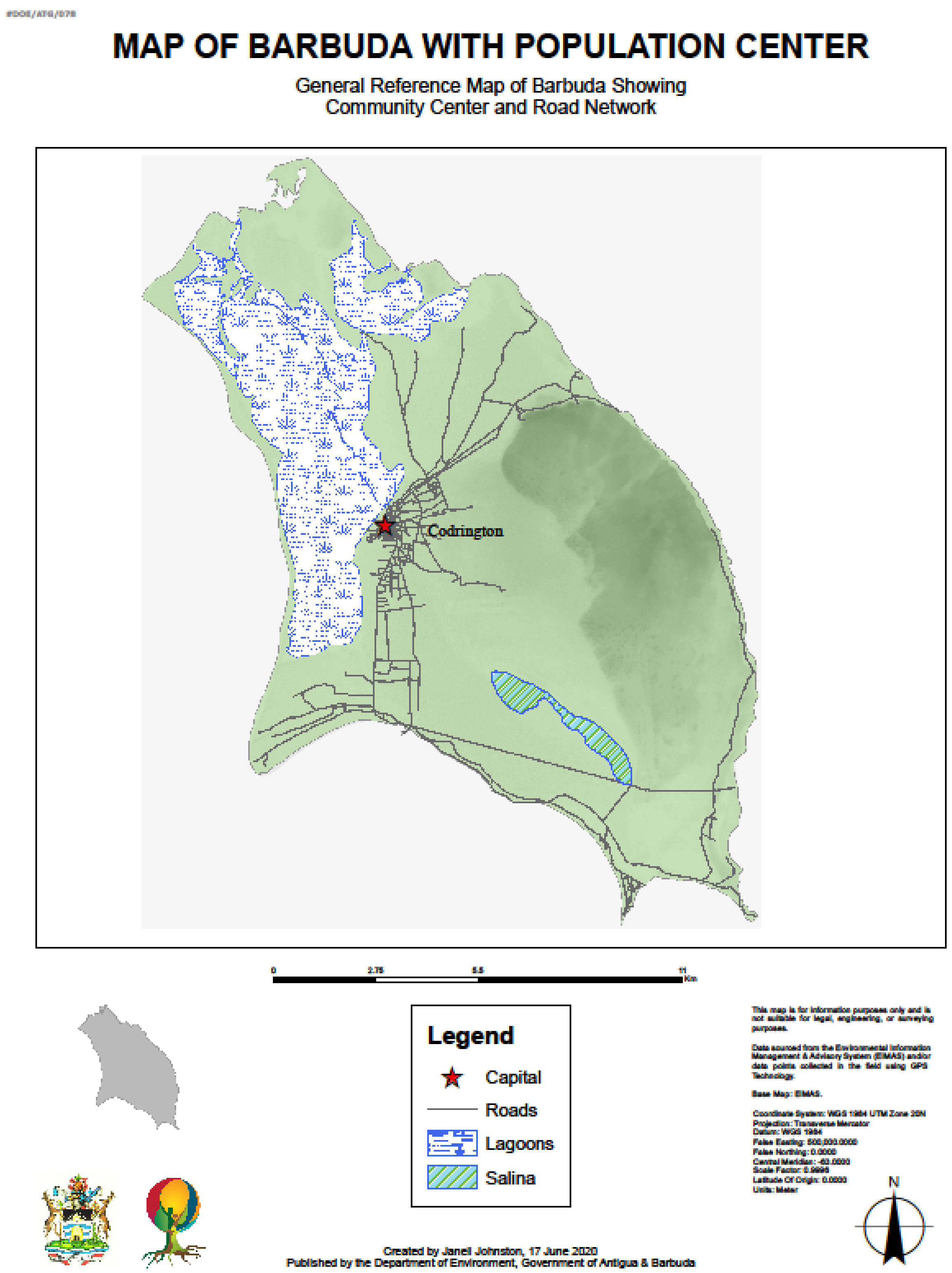


Figure 1b: Map of Barbuda

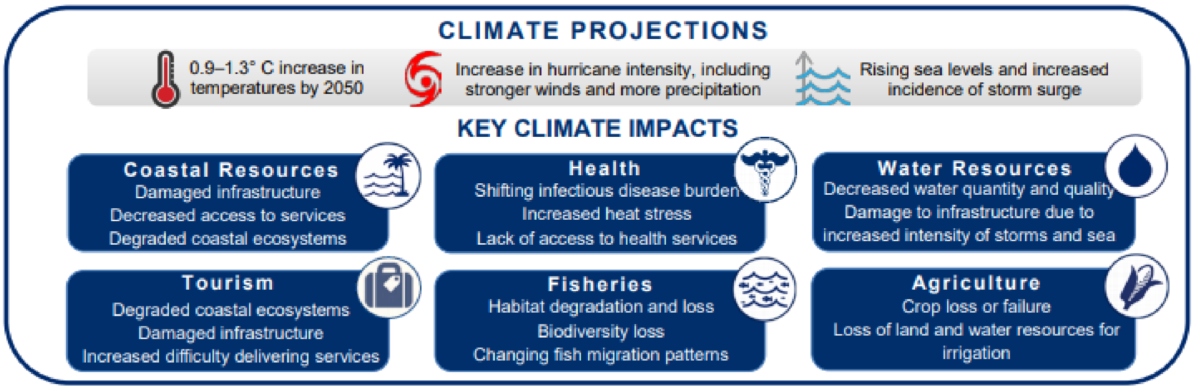


Figure 2: Climate Projections for Antigua and the Eastern Caribbean
Source: USAID Climate Links – Antigua and Barbuda (USAID 2018b)

1.2.2. Socio-Cultural Impacts

Climate change impacts facing Antigua and Barbuda have substantial influence on social, cultural, and traditional systems. Viewing the State's vulnerabilities through these lenses allows critical climate change issues to be connected to the daily lives of all residents, specifically giving voice to the socially vulnerable such as the poor, women, children, persons living with disabilities and other marginalized groups. Dulal et al. (2009) investigated the social equity considerations that should be included in national and regional climate change adaptation strategies, and highlighted *housing, transportation,* and *livelihoods* as key areas for policy action in Antigua and Barbuda.

Long term climate change planning and policies must benefit all societal groups. However, there is an acknowledgement that in severe crises, socially vulnerable groups are often the first and hardest hit, and the last to recover. Hence, adaptation programs must acknowledge them as key beneficiaries and ensure that activities promote increased access to services, relief materials, and natural resources. In Antigua and Barbuda, key linkages have been established between sustainable livelihoods and resilience to climate change; thus, for both ethical and practical reasons, adaptation interventions must not accentuate and/or perpetuate social, gender, economic, or cultural inequities (Dulal et al. 2009; USAID 2013a).

1.2.3. Environmental Impacts

Antigua has three main ecological zones: the north-eastern limestone formation, central plains, and volcanic region, with Boggy Peak as the highest elevation at 403m. By contrast, Barbuda is coralline and flat with the maximum elevation a mere 42m above sea level (FAO 2015; USAID 2018a). Population centres are dotted across Antigua at various elevations, both coastal and inland; while Codrington, Barbuda's single town on the West coast, houses the entire population.

Observed and projected climate change impacts affect both land and marine ecosystems. While disruptions in precipitation patterns reduce both quantity and quality of freshwater, increased high intensity precipitation promotes flooding, soil erosion, and sediment runoff into coastal waters, affecting Antigua and Barbuda's coral reefs and seabeds. This excessive sedimentation, coupled with the progressive lowering of ocean pH level from CO_2 uptake, severely impacts reef health making them more susceptible to invasive species. In addition, it affects marine food webs with knock-on effects on commercial fish stocks and food security for many islanders.

Flooding and loss of soil cover decrease the availability of and accessibility to freshwater as a result of contamination and infrastructure damage. In Antigua and Barbuda, the frequency and intensity of tropical cyclones have posed severe threats to the Utility's (APUA) efficiency and functionality – as observed in the aftermath of Hurricane Irma in 2017 on the island of Barbuda. Further, sea level rise and storm surges cause saline intrusion into the water table in coastal, low-lying areas, limiting access to these naturally occurring water resources (USAID 2013b, 2018b). Therefore, national level programs that support coastal zone and freshwater resources management, along with biodiversity conservation and management, are critical in combating adverse environmental impacts of climate change.

1.2.4. Economic Impacts

Antigua and Barbuda's local economy is driven by tourism and its associated services with infrastructure, amenities, beaches, and natural ecosystems all contributing to the unique Antiguan and Barbudan product. Consequently, predicted changes in the climate would significantly affect the rate of economic growth. Climate variability and change threaten these vital features, from the physical structures of coastal properties, to the energy, transportation, and water infrastructures that are critical for a thriving tourism industry.

Also affecting the country's tourism industry is increased annual temperatures which raise operational costs of hotels and resorts, negatively impacting the competitiveness of the tourism product. Increasingly intense tropical storms and hurricanes have caused severe damage to tourism, physical infrastructure, and have placed human lives at risk (GDFRR 2018). Additionally, changes in temperature and precipitation patterns threaten agricultural production, food security, and promote various types and patterns of human diseases. In 2017, Hurricane Irma damaged or destroyed 95% of properties in Barbuda, with conservative estimates for rebuilding placed the cost at ~USD$220M – highlighting the detrimental impacts of climate change on local economies (John 2017; USAID 2018b, 2018a).

1.3. NATIONAL POLICIES ON CLIMATE CHANGE AND DEVELOPMENT

The GoAB, through its Ministries and statutory agencies, has developed, and continues to improve, national policies that address the State's sustainable development agenda and responses to the changing global climate. The DOE, as the overarching government agency with responsibility for environmental management, has been assigned the premier role to *co-ordinate the development and implementation of government's sustainable development, climate change, environment and natural resources management policies and activities* (GoAB 2019).

The **Environmental Protection and Management Act 2019** (EPMA) is the guiding policy that allows the Department of Environment to develop plans and policies aimed towards preservation and conservation of the natural environment. It also provides the regulatory framework by which Antigua and Barbuda endeavours to meet the obligations of regional and international Multilateral Environmental Agreements (MEAs). Moreover, the EPMA gives the DOE responsibility for preparing a *National Environmental Policy Framework* which would recognize national ecological, economic, social, and cultural realities when assessing climate change risks and vulnerabilities that would ultimately impact long term sustainable development (DOE 2019a; GoAB 2019).

Natural resources management is addressed under the EPMA, and the declaration speaks to responsible usage of surface and groundwater resources, mangroves, and waterways for the purpose of maintaining their public usefulness for current and future generations. In this era of devastating climate change impacts, the GoAB has a greater vested interest in preventing, where possible, or mitigating against the effects of climate-induced erosion, sediment deposition, pollution, and flooding which affects natural water resources (GoAB 2019).

Also critical to adaptation interventions developed for the water sector, is the **Integrated Water Resources Management (IWRM)** policy. IWRM highlights the interdependence of all water users, and stresses the need for collective co-management in on-land practices that affect water resources; promotes collaborative, multi-sectoral decision-making that addresses climatic and anthropogenic risks; develops programs that reduce pollutant discharge; and rehabilitates watersheds and provides long-term watershed protection (GoAB 2011b). The IWRM roadmap demonstrates an equitable management approach that would potentially strengthen the sector by effectively assessing, mapping, and monitoring the declining water resources under climate change to ensure usage is maximized (GoAB 2001; GCF 2017; HRW 2019).

National Adaptation Strategy and Action Plan (NASAP) and **National Action Plan Combatting Desertification, Degradation and Drought 2015 – 2020 (NAP)** collectively support national high-level programs that address climate change mitigation and formalize ground-level guidance for adaptation interventions. Acknowledging that all communities across Antigua and Barbuda are not equally susceptible to, or affected by, the same level of climate change risks and impacts, a context-specific approach is necessary to build resilience. The NAP promotes community-level forecasting and monitoring that enables residents to fully participate in data collection and decision making (GoAB 2015a; DOE 2019b).

Another significant national adaptation instrument adopted by the GoAB is the **Building Climate Resilience Through Innovative Financing Mechanism for Climate Change Adaptation – the Special Climate Change Fund (SCCF).** The Project identifies vulnerable communities and sectors that are threatened by the impacts of increased frequency and intensity of extreme weather events; and proposes solutions to promote the implementation of cost-effective adaptation measures across Antigua and Barbuda. This is achieved by:

- Developing innovative financing mechanisms for funding adaptation interventions;
- Demonstrating adaptation interventions focused on ecosystems to reduce vulnerability of local communities;
- Building institutional and technical capacity to identify, implement, maintain, and upscale adaptation interventions; and
- Strengthening the national and regional knowledge base for climate change adaptation.

The objective of the SCCF project is to establish the adaptation window of the Sustainable Island Resource Framework (SIRF) Fund and demonstrate the funding of resilience in *building* and *waterways* management (DOE 2017b).

In 2015, the GoAB communicated its **Intended Nationally Determined Contributions (INDCs)** to the UNFCCC. Outlined in this document are specific adaptation and mitigations targets to 2030 *(see Box 1)*. Conditional adaptation targets address water, building, and energy sectors; while the mitigation targets focus on multi-sectoral efforts to reduce GHG emissions and sequester atmospheric carbon. Finally, the unconditional targets emphasize the State's pathway towards long-term sustainable development with specific focus on improving the quality of life for citizens and residents. Achievement of INDC targets necessitates international support for capacity building, technology transfer, and financing. Estimated costs for implementation are USD$200M and USD$220M over a 10-year period for adaptation and mitigation respectively (GoAB 2015).

Conditional Adaptation Targets

1. By 2025, increase seawater desalination capacity by 50% above 2015 levels.
2. By 2030, all buildings are improved and prepared for extreme climate events, including drought, flooding and hurricanes.
3. By 2030, 100% of electricity demand in the water sector[1] and other essential services (including health, food storage and emergency services) will be met through off-grid renewable sources.
4. By 2030, all waterways are protected to reduce the risks of flooding and health impacts.
5. By 2030, an affordable insurance scheme is available for farmers, fishers, and residential and business owners to cope with losses resulting from climate variability.

Conditional Mitigation Targets

1. By 2020, establish efficiency standards for the importation of all vehicles and appliances.
2. By 2020, finalize the technical studies with the intention to construct and operationalize a waste to energy (WTE) plant by 2025.[2]
3. By 2030, achieve an energy matrix with 50 MW of electricity from renewable sources both on and off-grid in the public and private sectors.[3]
4. By 2030, all remaining wetlands and watershed areas with carbon sequestration potential are protected as carbon sinks.

Unconditional Targets

1. Enhance the established enabling legal, policy and institutional environment for a low carbon emission development pathway to achieve poverty reduction and sustainable development.
2. By 2020, update the Building Code to meet projected impacts of climate change.

Box 1: Antigua and Barbuda INDC Targets to 2030
Source: (GoAB 2015) [123]

Current conditions and future climate projections for Antigua and Barbuda have led decision makers to adopt a precautionary approach and implement measures that increase the resilience of local economies, businesses, and communities to climate-related impacts. In their totality, the national policies discussed provide guiding principles for the GoAB's efforts in continuous development and improvement of national climate change and development planning. National efforts are supported through regional institutional arrangements with entities such as the Caribbean Community (CARICOM) and Caribbean Community Climate Change Centre (CCCCC) which coordinate regional response to climate change adaptation and mitigation; the Caribbean Meteorology and Hydrology (CIMH) which

[1] The water sector includes water generation (seawater desalination), distribution and usage, to ensure water delivery when grid electricity may be interrupted. Based on an informal assessment, water distribution and usage are equal to approximately 15% of GHG emissions in the electricity sector.

[2] This waste to energy target is not considered part of the 50 MW renewable energy target.

[3] This target includes distributive renewable energy capacity to be used as backup energy by the commercial sector and some residences. The assumption is that the commercial sector has full backup capacity of approx. 20 MW to continue business when electricity via the grid may be interrupted. Backup electricity generation is currently fossil fuel based.

provides capacity building, training and research; and the Caribbean Disaster Emergency Management Agency (CDEMA) which coordinates disaster responses throughout the region.

1.4. SECTOR JUSTIFICATION AND TECHNOLOGY SELECTION

1.4.1. TNA Sector Selection

According to GCF (2017) Country Program, Antigua and Barbuda's priority adaptation and mitigation sectors are *i.) buildings – including hotels, houses and commercial businesses, ii.) water – including wetlands, waterways, and coastal ecosystems, iii.) energy and iv.) transportation.* Building and water focus on increasing the adaptive capacity of Antiguans and Barbudans at all levels of the socio-economic spectrum, while energy and transportation are key sectors for the reduction of emissions. The unique challenge for providing mitigation interventions include market structure, and access to affordable financing and low emission technologies (GoAB 2015c; GCF 2017).

Water, building, and transport were selected by the TNA National Coordination Agency – the DOE – as focal sectors for technology transfer as they support the overall pathway outlined in the INDCs. Although energy was also considered as a potential sector, it was ultimately excluded because Antigua and Barbuda has already completed a renewable energy readiness assessment, and additional targeted studies have already resulted in identified energy targets.

Collectively, the three TNA sectors present an opportunity to develop adaptation and mitigation interventions that will be achieved through sector-specific technology transfer.

1.5. METHODOLOGY AND RESULTS OF TECHNOLOGY SELECTION PROCESS

1.5.1. Technology Prioritization Process

The technology prioritization followed the UDP guidelines recommended for the global TNA project. Figure 3 provided an overview of the process followed by Consultants and Sectoral Working Groups (SWGs) through a series of consultative workshops. Technology long lists for adaptation and mitigation were initially prepared by Consultants and screened by SWGs workshops to determine the short lists for each of the three sectors. During these workshops, stakeholders were given the opportunity to identify additional technologies for inclusion, and through open discussions, a final list was derived and presented to the TAC.

Figure 3: TNA Technology Prioritization Process
Details of Technologies discussed in Chapters 3, 4 & 5

Consultants were guided by the general criteria described in the TNA Handbook and SWGs were encouraged to make final selections based on the technology's *i.)* ***Technical potential:*** *ability to address adaptation needs or meet mitigation targets while considering existing local capacity and resources; ii.)* ***Climate Resilience potential:*** *aptitude to increase adaptive capacity and strengthen nationwide ability to withstand climate change impacts; and iii.)* ***Development Priority:*** *well-defined synergies with national development and climate change strategies* (Haselip et al. 2019). To effectively utilize this guidance during the technology selection, Consultants and the TNA Coordinator repeatedly directed stakeholders back to programs, policies, and targets outlined by the GoAB.

The TNA Coordinator and TAC were engaged for approval of technology short lists, after which detailed factsheets were prepared for dissemination to SWGs and discussion during the Multi-Criteria Analysis (MCA).

1.5.2. Multi-Criteria Analysis (MCA)

Multi-Criteria Analysis (MCA) is a structured decision-making approach utilized to determine a ranking of preferences among a list of options. While the overall process is quantitative – involving the assignment of scores and weights – the criteria utilized is most often a wide range of qualitative impact categories. Costs and benefits are weighed using social, environmental, and economic indicators, thus, acknowledging that both monetary and non-monetary objectives may influence decisions. Therefore, MCA provides useful techniques for comparing and ranking a list of activities or outcomes (UNFCCC 2005).

MCA is advantageous in climate technology prioritization since it:

- Is transparent and explicit;
- Gives decision-makers freedom to choose and/or change criteria by consensus;
- Allows scores and weights to be cross-referenced to actual values or detailed scientific information; and
- Provides an audit trail to re-evaluate process robustness and transparency (LSE 2009).

The MCA process was conducted with sectoral working groups and results were generated by using the UDP's MCA Excel tool. Chapters 3, 4, and 5 detail how the MCA was applied for each of the three target sectors.

2. INSTITUTIONAL ARRANGEMENT FOR TNA AND STAKEHOLDER INVOLVEMENT

2.1. INSTITUTIONAL ARRANGEMENT

The institutional arrangement for the TNA project in Antigua and Barbuda adhered to the general structure recommended by the UDP Step-by-Step TNA guidebook. *Figure 4* illustrates the structure and interactions between groups at the local and global levels.

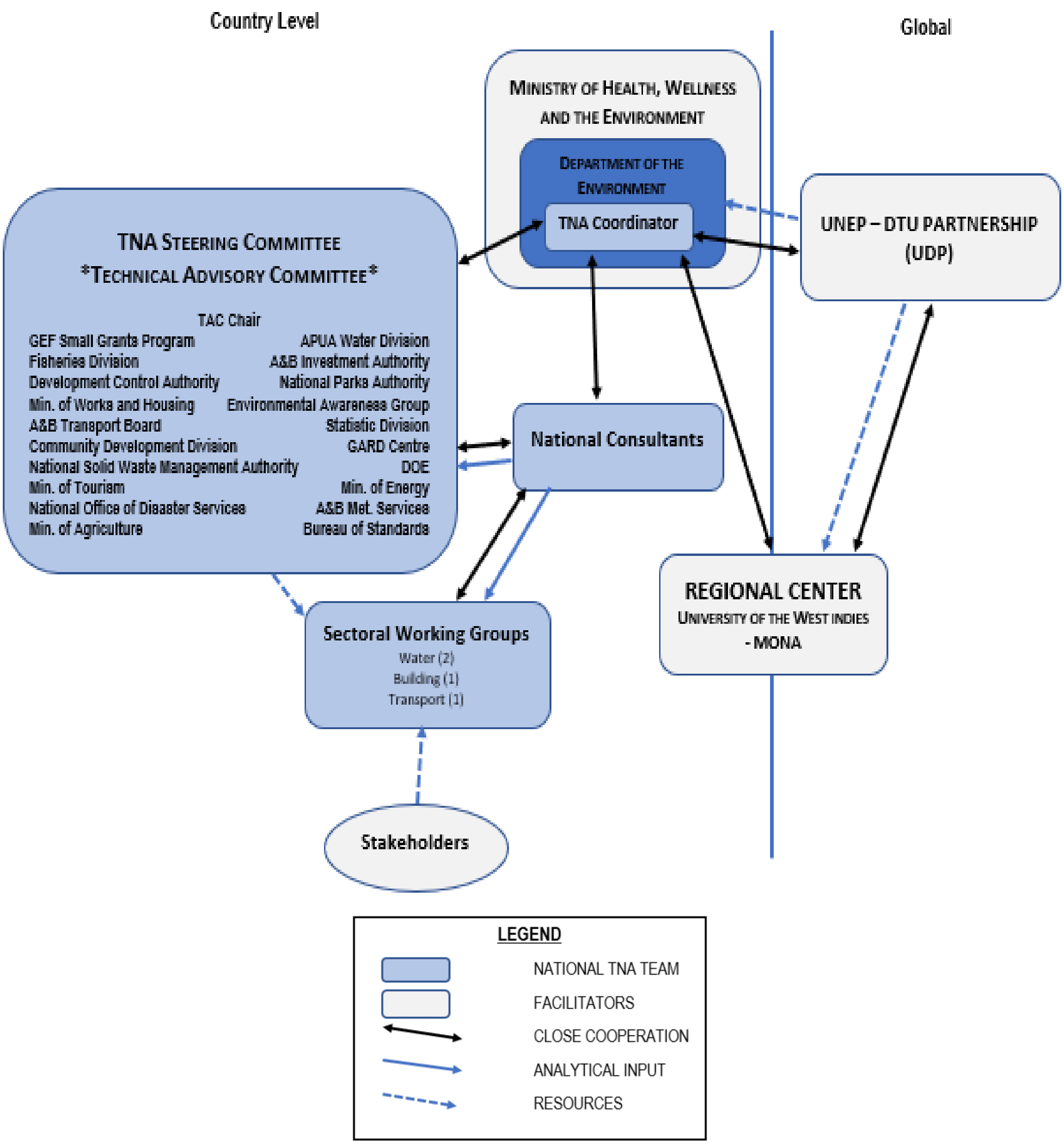


Figure 4: Institutional Arrangement for TNA Process in Antigua and Barbuda

2.2. NATIONAL TNA TEAM

2.2.1. TNA Project Coordinating Agency and Steering Committee

The Department of the Environment (DoE), within the Ministry of Health, Wellness and the Environment, acts in the capacity of Coordinating Agency for the TNA project. Further, the Technical Advisory Committee (TAC) of the DOE assumes the role of the project steering committee which is a core group of decision-makers. The steering committee includes representatives of relevant ministries responsible for implementing policies, along with technocrats familiar with national development objectives, sector policies, climate change science, potential climate change impacts for the country, and adaptation needs. In this role, the TAC provides leadership to the project in association with the TNA Coordinator.

According to TNA guidance notes, specific responsibilities of the TAC include:

- Deciding on the constitution of sectoral working groups;
- Approving technologies for mitigation and adaptation based on the recommendations of the Consultant and SWGs; and
- Reviewing and approving all project reports.

The TAC is comprised of approximately thirty (30) representatives from key national private and public sector and statutory government institutions, along with an additional ten (10) members of the DOE's technical staff. The list of organizations represented on the TAC can be found in *Appendix A*. This Committee is chaired by a DOE Senior Environment Officer.

TAC meetings are scheduled for the 3rd Wednesday of each month, and presentations by project Consultants were added to the agenda when necessary. During this step, the TAC heard presentations and had discussions regarding the TNA project on two (2) separate occasions. Initially, the TNA Coordinator briefed the TAC on the status of the project and garnered its input for recommendations for the formation of the SWGs. Consultants were then invited to present the technology long list and outcomes of the screening workshops that resulted in the short list.

2.2.2. TNA Coordinator

The TNA Coordinator was selected by the DOE and is a current member of its Project Management Unit. The Coordinator assumes full responsibility for the day-to-day TNA project activities. This role reports directly to the TAC and serves as the linkage between consultants and stakeholders in-country, as well as the regional and global team externally. The Coordinator, in their capacity, provides vision and leadership for the overall effort, facilitates the tasks of communication with the TAC, consultants, and SWGs, and maintains the project schedule to effectively meet deliverables. All formal communications and information sharing products, along with the project report, were vetted by the TNA Coordinator prior to dissemination.

2.2.3. Expert Consultants

The recruitment process for Expert Consultants was conducted through a collaborative process between the UDP and a local Project Coordinating Agency. The TNA Coordinator was responsible for overseeing the vetting of applications and interviewing potential consultants; however, finalization of all contractual arrangements was done by the UDP. Throughout the TNA process, the consultants worked closely with the TNA Coordinator to ensure that the overall TNA process remained cohesive and shared goals were achieved.

The consultants are tasked with facilitating the overall sector-specific TNA process, which includes engaging key stakeholders to:

- Review all relevant technologies for each sector, assess and prioritize selection, and present findings in a *TNA* Report;
- Determine existing barriers to diffusion of the selected technologies, design an enabling framework(s) to facilitate successful deployment, and present outcomes in a *Barrier Analysis and Enabling Framework* Report.
- Design a *Technology Action Plan (TAP)*, develop project ideas for TAP implementation along with policy and advocacy briefs; and
- Formulate a *Concept Note* which aims to target funding for a selected technology.

Further, consultants prepare all TNA related documents required to disseminate information and/or facilitate stakeholder meetings and workshops. Consultants must also be readily available to present written or verbal updates to the national, regional, and global TNA bodies.

2.2.4. Sectoral Working Groups

There was a total of four (4) sectoral working groups: two in the water sector (including stakeholders with interests in *potable* and *non-potable* water uses), and one each for the building and transport sectors. Stakeholders include representatives from the private and public sectors, Non-Governmental Organizations (NGO), Community-Based Organizations (CBOs), and users from high-demand and high-emission industries. Members of the four SWGs are not mutually exclusive, and consultants sought opportunities to merge project activities. To this end, all water sector consultations were held jointly in this initial TNA step.

The agreed procedure had all formal communications coming from the Coordinating Agency – from the desk of the TNA Coordinator – following which consultants were free to follow up with stakeholders via email, telephone calls, or in-person meetings. Working group sessions were organized on an as-needed basis, and brought stakeholders together to achieve very specific tasks, such as pre-screening the technology long list and executing the multicriteria analysis.

2.3. STAKEHOLDER ENGAGEMENT

2.3.1. Stakeholder Selection for Overall TNA Process

Stakeholders are essential to each stage of the TNA process to promote multi-level participation and to engage individuals vital to the implementation of prioritized technologies. Stakeholder groups were chosen based on the overall TNA process to ensure that the collective group was representative of the skillset, expertise, and input needed for each of the TNA steps, as well as to maintain continuity throughout the entire process.

Blobel et al. (2006) recommend the following five steps for active, inclusive stakeholder dialogue that will be sustained throughout the course of the technology needs assessment. These steps are:

i.) Identify stakeholder groups and individual stakeholders;
ii.) Define the project goals and objectives;
iii.) Clarify stakeholder roles;
iv.) Establish an ongoing process for stakeholder engagement; and
v.) Involve stakeholders in each stage of the process

Using the abovementioned steps as guidance, sectoral working groups included representatives from government agencies and institutions, potentially vulnerable sectors, private sector industries, non-governmental organizations, import and sale businesses, and technology users. Goals, objectives, and the working arrangements of the participatory process were discussed with the sectoral stakeholder groups prior to finalization of the SWGs, then reinforced with stakeholder representatives during the consultative workshops.

For the purpose of inclusivity, it was important to include senior level, technically competent, and expert representatives, alongside community-level participants who would bring lay experience and knowledge to the TNA process. Stakeholder groups will be re-engaged at the beginning of Step 2, and some may be asked to designate different stakeholder representatives for the upcoming project activities.

2.3.2. Stakeholder Consultation Process

A total of six (6) stakeholder consultations were completed during the TNA Step 1. Each priority sector had two workshops: the first to screen the technology long list and derive a short list, and the second for the MCA process. In addition, stakeholders received digital communications with information sharing products including the TNA Introduction Flyer and Technology Factsheets. Samples of the flyers and the attendance lists for the consultations are included in Appendices C & D.

The primary mode of communication was via emails initiated by the TNA Coordinator. One-on-one meetings, follow-up phone calls and/or emails were also used to garner commitments and feedback from stakeholders. All meetings were facilitated by the consultant, supported by the TNA Coordinator, and attended by select members of the DOE's technical staff. All stakeholders were provided with detailed information about the TNA Project. Candid feedback was also encouraged in all workshops and participant stakeholders provided invaluable input through spirited discussions.

2.4. GENDER CONSIDERATIONS

In keeping with the TNA Step-by-Step guide, gender considerations were maintained throughout all TNA activities. At a high level, gender representation in the Institutional Structure of the TNA process demonstrates balance throughout the TNA team *(see Table 1).* Further, gender equity was mainstreamed in three distinct processes to ensure balanced representation and that both men and women were equally involved in the TNA process and stood to benefit from the overall outcomes.

Firstly, the impacts of climate change on women and female-led households were considered during the vulnerability assessments across all three priority sectors. In some instances, gendered vulnerabilities were included in the challenges faced by socially vulnerable groups, and collective consideration was given to the impacts of climate change on the broader social grouping. Secondly, gender balance was encouraged during the stakeholder selection and the make-up of SWGs. Where possible, the TNA Coordinator and consultants ensured that both male and female perspectives were represented in the TNA activities. The breakdown of male-to-female stakeholders in each of the six workshops is shown in *Table 2* and both genders equally participated in activities and discussions. Thirdly, gender equity was considered when identifying and prioritizing technologies for transfer. It was acknowledged that given the different levels of vulnerability, specific care must be taken to ensure that both males and females equally benefit from adaptation interventions in terms of increased adaptive capacity.

Table 1: Gender Representation in the National TNA Team

	MALE	FEMALE
TAC CHAIR	**X**	
TNA Coordinator		**X**
National Consultants	**X**	**X**

Table 2: Male-to-Female Breakdown of Attendance at TNA Consultative Workshops

	MALE	FEMALE
June 13, 2019 (Building & Transport)	9	3
June 18, 2019 (Water)	5	3
July 23, 2019 (Water)	6	2
July 24, 2019 (Transport)	6	5
July 25, 2019 (Building)	6	3

3. TECHNOLOGY PRIORITIZATION FOR WATER SECTOR

3.1. KEY CLIMATE VULNERABILITIES

Climate variability continues to significantly impact Antigua and Barbuda's water sector. Research to date has attributed the nation's vulnerability to changing climate trends, with future models projecting that land and sea temperatures, precipitation, sea level rise, and hurricanes will be key aspects of its climate narrative. The Hadley Centre for Climate Prediction and Research PRECIS Model (2017) corroborated the projections of the Regional Climate Model (2012) which places Antigua and Barbuda at risk for:

- Increased mean annual temperatures between 2.4˚C and 4.5˚C by 2080;
- Highly variable precipitation patterns, leading to reduced annual rainfall up to -18% and increased intense downpours;
- A 1m sea level rise coupled with storm surges resulting in irreparable coastal erosion; and
- Increased intensity and frequency of hurricanes and tropical storms (Caribsave 2012; GCF 2017)

Tourism, agriculture, health, and education are highly dependent on water resources; thus, a reliable water supply is critical for their sustainability. Limited freshwater resources have already contributed to widescale water-stress, and climate-induced impacts will only continue to exacerbate the effects on an already vulnerable water sector. As tourism and its associated services account for ~70% of national GDP, an unreliable water supply engenders the commitment of the GoAB and APUA to ensure that hotels and resorts are adequately serviced by the water network even in the severest of drought conditions (GoAB 2015a; GCF 2017).

Agriculture, another major water consumer, is experiencing a rebirth since the nation's transition away from farming in the 1980s. Traditionally, farmers located near ponds, dams, and naturally occurring waterways, have been allowed to extract unmetered volumes of water for irrigation. However, during drought conditions when these water sources diminish, farmers would then, in most instances, access the Utility's potable water network or abandon cultivation if it becomes unsustainable (FAO 2015; DOE 2018). While Antigua and Barbuda is ranked among the 'high income non-OECD' countries, the FAO (2014b) has reported highlights that natural disasters and changing climatic conditions have a significant effect on national food security. This was observed in the aftermath of Hurricane Omar in 2013 and during the prolonged periods of drought from 2011 to 2015. In consequence, strengthening the national agriculture sector is a vital step towards achieving Sustainable Development Goal 2 'zero-hunger' in the twin island state.

Health and education are two essential services severely affected by water shortages. While the country's hospitals, clinics, and schools cannot be closed due to an undersupply of water, their quality of service, hours of operation, and number of nationals served daily are severely impacted. Further, with the absence of on-site water storage, shortened school days often result in inconvenient consequences where households are forced to accommodate children being out of school for unscheduled periods (O'Garro & Speek-Warnery 2009; UNICEF 2017). These concerns are heightened in low-income, single parent, and female-led families, where decisions are often made around water collection and use. Hence, productivity, education, and other vital activities tend to be limited until the *water problem* is solved (UNICEF 2017).

3.2. DECISION CONTEXT

Technologies identified for the water sector were chosen through examination of the current and future climate threats, natural landscape, socio-cultural context, and national adaptive capacity. Models and scenarios for the Eastern Caribbean region support the effects felt on the ground and were therefore given credence even in the absence of rigorous local studies (Caribsave 2012; Simpson et al. 2012). The National Adaptation Strategy and Action Plan (NASAP) to address climate change in the Water Sector, Integrated Water Resources Management (IWRM) Policy, and Environmental Protection and Management Act (2019), fully acknowledges the negative climate impacts and highlights the need to address adaptation measures for critical sectors. Further, they demand swift and sustainable action to lessen impacts on infrastructure, roads, coastal structures, natural ecosystems and biodiversity.

Under the UNFCCC, Antigua and Barbuda had submitted its *Intended Nationally Determined Contributions (INDCs)* which were established on the country's 'pillar of transformational change', defined as:

> *"changes to the current systems of governance and economic management to allow Antigua and Barbuda to adapt to the impacts of climate change such that the economy and the people can withstand a Category 5 hurricane, one meter of sea level rise, and a drought lasting over three years, while the core economy is still functioning at a capacity similar to that as if climate change were not occurring."* (GoAB 2015a)

The INDCs specify adaptation targets that address increasing potable water capacity – primarily through seawater desalination and improving watershed/waterway health to mitigate against flooding and adverse human health impacts. These overarching goals have prompted the TNA to examine options that enhance watershed health, improve water resources management, and increase infrastructure operational life.

At present, the Antigua Public Utilities Authority (APUA), as per the Public Utilities Act (1973), is exclusively responsible for the management of Antigua and Barbuda's freshwater resources. However, in a collaborative effort with the Ministries of Agriculture, Health and the Environment, as well as the Ministry of Works, the responsibilities for waterway maintenance, drainage, and flood mitigation are shared alongside APUA. Additionally, APUA's mandate is supported by the Antigua and Barbuda Meteorological Services and National Office for Disaster Services (NODS), allowing for cross-sectoral planning and dissemination of information relating to climatic patterns and pending extreme events.

The TNA process sought to acknowledge the full gamut of public and private resources that would influence technology transfer and encouraged input from all relevant personnel.

3.3. TECHNOLOGIES CURRENTLY UTILIZED

3.3.1. Seawater Reverse Osmosis Desalination

The nation's first desalination plant, capable of providing up to 50% of national demand at that time, was installed in response to the extreme drought conditions experienced in the mid-1980s. However, with increasing population and growth in commercial enterprises, the Water Utility procured additional seawater desalination facilities at Camp Blizzard, Ffryes Bay, Shell Beach, Pigeon Point Beach, and Barbuda. Currently, desalination covers up to 70% of the potable water supply during reliably wet years, with that percentage increasing to 100% during extreme droughts (GCF 2017). The desalination process is energy intensive, with large desalination pumps being run exclusively by power generated from fossil fuels. Unfortunately, this fossil fuel-powered process makes production extremely costly to the Water Utility and contributes heavily to the country's GHG emissions. Current water tariffs do not reflect these costs; instead, the loss is absorbed by APUA's other business units, which has made the process financially unsustainable in the past decades (HRW 2019).

Operation and maintenance issues at the Barbuda desalination plants have often resulted in an unreliable and intermittent water supply for the sister isle as well. Barbuda presents a unique case as residents have traditionally constructed private wells even while being serviced by APUA's desalination supplies. However, a lack of house-by-house metering indicated that it was uncustomary for Barbudans to remit payments for piped potable water despite maintaining an expectation of a continuous supply (HRW 2019).

As a result of the inconsistency, several major hotels and resort developments have procured private desalination plants and have installed oversized storage cisterns to lessen their dependence on APUA's network. Full proposals detailing plant capacity, intake and outfall locations, and potential environmental impacts must be reviewed by the designated government entities before purchase is approved. While owning and operating desalination plants is a costly endeavour, this investment aids hotels in insulating themselves from the water scarcity issues experienced by the general population. Since the sea functions as an abundant, replenishing source of water, the desalination process has been regarded as a climate resilient response to drought despite its contributions to GHG emissions.

Notwithstanding their importance, during extreme weather events, desalination facilities are still susceptible to flooding from storm surges, physical damage to plant enclosures by hurricane force winds, and damage to membranes due to poor seawater quality. Additionally, the increasing volumes of sargassum seaweed have become a maintenance challenge for the Utility, necessitating routine underwater cleaning of intake structures (GCF 2017; Editor 2018; HRW 2019).

3.3.2. Rainwater Harvesting

In the 1980s, the GoAB implemented several measures to meet national water demand. Along with installing seawater desalination capacity (discussed in Sec 3.3.1.), all residential and commercial properties were legally required to collect and store rainwater. This was included in the previous Building Code and is now legislated by the Antigua and Barbuda Physical Planning Act (2003) which governs the Development Control Authority (DCA). In addition, community cisterns were refurbished, existing properties were retrofitted with plastic storage tanks, and the practice of constructing in-ground cisterns within the foundation of newly constructed buildings was adopted (Damhaug & Fernandez 1998).

Succeeding decades have seen rainwater harvesting (RWH) at the household level become an important source of safe potable water, with many residents opting to consume their stored supply. Aquastats from the FAO (2015) country profile estimate the average household storage capacity at 5,000 gallons upwards to 20,000 gallons in commercial buildings. However, the degree to which RWH systems are properly maintained in hygienic conditions and whether the water is treated before use, cannot be confirmed. Moreover, in drier months, it is not uncommon for property owners to collect water from the Utility's network in their cisterns or refill the cisterns with water provided by bulk water distributors.

While RWH is generally accepted by the population as a necessity, reinforced concrete cisterns can increase construction costs up to 35%. This precludes many low-income households from fully complying with Development Control Authority (DCA) regulations during their build. Further, low-cost rentals and moveable plywood homes typically do not include rainwater catchments. Therefore, there is a need to improve how RWH is deployed, and a need for opportunities to explore its potential in the agriculture sector (FAO 2014a).

3.4. TECHNOLOGY TRANSFER OPTIONS

3.4.1. Atmospheric Water Generators (AWGs) – Adaptation Technology

Atmospheric Water Generators (water makers) produce potable water by extracting vapour from humid, ambient air – either by condensation or exposing the air to hydroscopic substances (drying agents) called desiccants. In modern water makers, vapour from the air is drawn into the external/roof-mounted unit and adsorbed into a specialized desiccant. Water is then desorbed and condensed into droplets. The liquid is piped into a tank where it can receive up to three levels of treatment before the purified drinking water is dispensed at a tap or cooler *(see Figure 5)*. Some water makers are solar powered and can even be fitted with network-connected water quality monitoring systems (Watergen 2018; ZeroMassWater 2018).[4,5]

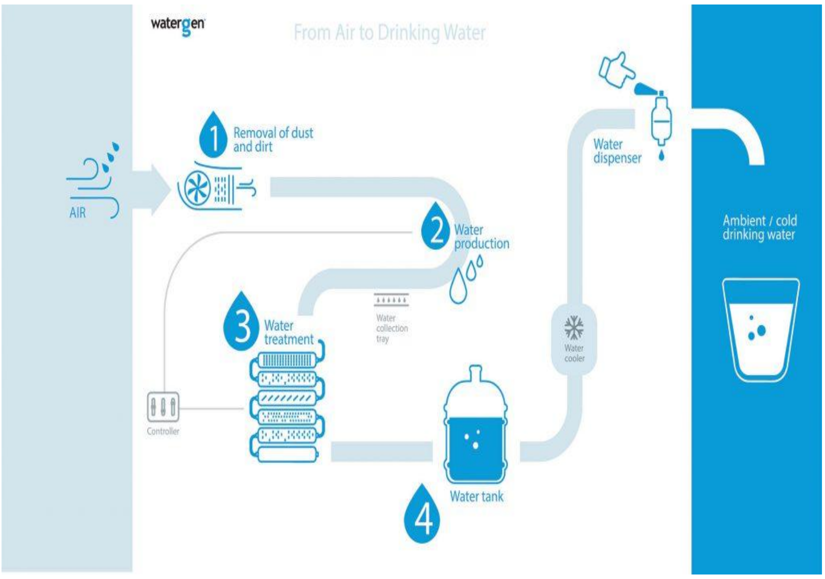


Figure 5: AWG - Process Diagram
Source: Watergen (2018)

Individual AWG units can be ground, roof, or trailer mounted, allowing for a range of applications. *Ground* units can be installed on acreage to produce 'water farms' from which drinking water is piped into storage or the Utility's network. On the other hand, *roof* units on private or public buildings can provide drinking water dispensed at a cooler throughout the day or stored for use by highly sensitive laboratory equipment. Alternately, *AWG trailers* can be mobilized during or after extreme climate events to provide a safe supply of drinking water until normalcy is restored. In Antigua and Barbuda, these applications are cross-sectoral with direct benefits for schools and health facilities, while also providing an alternative to delivering bottled water in disaster relief scenarios. Roof and ground units

4 SOURCE Perfect water for every person, every place. Zero Mass Water, www.zeromasswater.com

5 Genius Technology Energy efficient heat transfer and dehumidifying technologies. Watergen USA, https://www.watergenusa.com/technology-2/technology/

are mounted with similar specifications as PV Solar panels, bolted at angles to resist up to Cat. 4 hurricane force winds.

3.4.2. Brackish Water Desalination – Adaptation Technology

Brackish water results from the mixing of fresh and saline (sea) water in surface estuaries or underground aquifers. With brackish water, the salinity is higher than that of freshwater but lower than seawater, typically ranging from 0.5 – 30ppt NaCl. Modern brackish water desalination technologies are designed to provide a lower energy option to the seawater desalination process which produces freshwater from sources with 0.5 to 15ppt NaCl (Evoqua 2017).

Unlike seawater which yields 35% - 45% recovery of freshwater, brackish water can yield up to 90%, consequently producing proportionally less brine for disposal. This is considered a significant advantage of brackish water desalination; however, unique challenges may be presented depending on the composition of individual brackish water sources. As a result, these challenges may demand the design of extensive pre-treatment to prevent fouling and scaling of RO membranes by precipitates (Singh 2005). Brackish water desalination is especially viable in Barbuda and can also be explored along the northeast corridor of Antigua where the water table is relatively high, and where there is a lower concern of destroying aquifer integrity.

3.4.3. Climate-proofing Assets – Adaptation Technology

Climate-proofing can improve the reliability of the Utility's service and increase asset life by addressing the extent to which climate change threatens infrastructure. For critical water sector assets, it involves assessing *exposure* and *vulnerability*, developing risk management plans, and systematically de-risking (building resilience in) the Utility (ADB 2016). Resilient infrastructure can significantly reduce the disruptions to the Utility's service that are caused by climate-related risk factors; however, the issues may not be fully eliminated.

According to Taylor et al. (2018) and the Hadley's PRECIS Model, adverse climate change effects include frequent and intense hurricanes, unpredictable flooding rains, increased temperatures, and sea level rise. This translates to growing operational and maintenance cost for APUA, with coastal desalination facilities being highly susceptible to storm damage. Comprehensive de-risking must address every stage of the desalination and water provision process; this means managing physical assets such desalination facilities, pump stations, pipelines and all other components of the operation.

Climate-smart asset management for the Utility will include (HRW 2019):

- Protecting desalination facilities from storm surges and hurricane force winds, with attention given to all related infrastructure, intake and outfalls, reverse osmosis plants, building, electricals etc.;
- Relocating pipelines to accommodate storm surges, flooding and/or erosion; and
- Moving pumps and/or pumping stations to higher elevations.

3.4.4. Controlled Groundwater Recharge – Adaptation Technology

Controlled groundwater recharge *(Managed Aquifer Recharge)* utilizes principles of the hydrologic process to channel *surface* water into groundwater stores through deep percolation which utilizes ponds, recharge trenches, and/or injection wells *(see Figure 6)*. Water can be moved into the water table through seepage, or deeper into the saturated zone through artificial processes. Runoff is typically utilized for recharge, which simultaneously mitigates against flooding and erosion (Pavelic et al. 2010).

Groundwater recharge would be useful in improving the productivity of the southern well fields, allowing APUA to pump larger volumes annually. The Utility is interested in increasing groundwater abstraction to 1,400m^3/daily, and considers MAR as a viable option to increase groundwater capacity (HRW 2019).

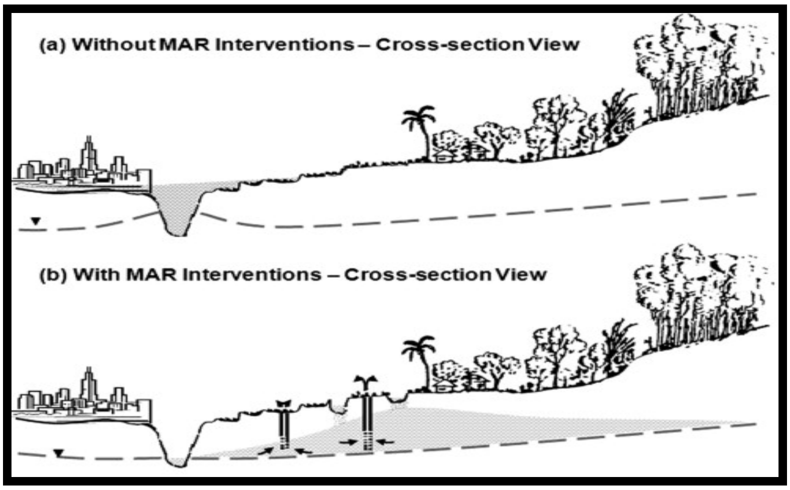


Figure 6: MAR
Source: Pavelic et al. (2010) [6]

3.4.5. Digital Warning Systems – Adaptation Technology

Through a *mobile application* patterned after early warning systems developed for natural disasters, the Antigua and Barbuda Meteorological Services, APUA, and other relevant government agencies

[6] Pavelic, Paul et. Al. 2010. "balancing-out floods and droughts: opportunities to utilize floodwater harvesting and groundwater storage for agricultural development in Thailand". Journal of hydrology. Vol 470-471, November 12, 2012. P 55-64.

would be able to feed water-related information into a central data hub where alerts, warnings, faults, and so forth can be shared with the public via the application. This software would allow two-way communication between Utility and user with real-time data sharing employed to enhance efficiency and consumer experience. The application's design and user interface would be tailored to engage all users with essential water information and tips conveniently at their disposal.

3.4.6. Rainwater Harvesting (RWH) – Adaptation Technology

Rainwater harvesting is the diversion, capture, storage, and treatment of precipitation for potable and non-potable use. While systems vary in size and complexity, all include catchment surfaces, transport, storage, treatment, and distribution systems *(see Figure 7).* Dependable rainfall patterns are essential to the technology's success, along with smart, conservative water users.

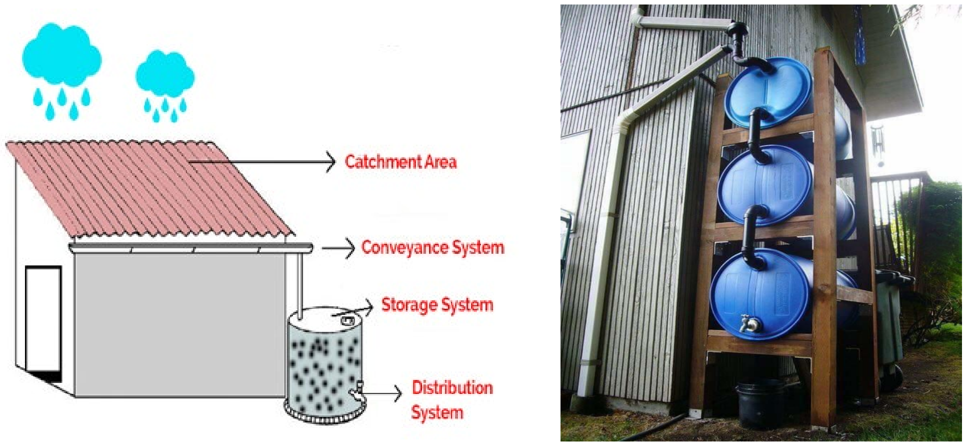


Figure 7: Rainwater Harvesting with Unconventional Storage
Source: Akruthi Enviro Solutions – Rainwater Harvesting for House (Akruthi 2016)

Traditionally, there are four classifications of RWH: *occasional*, where a day's water supply is stored in small containers; *intermittent*, which occurs during rainy periods where rainwater meets most water demands; *partial*, where rainwater is used throughout the year but the harvest is not enough for all domestic demands; and *full*, when all water needs are met by the rainwater harvest since there is no alternative water source. Systems across Antigua and Barbuda are typically designed to meet the needs of *occasional* to *partial* users.

While RWH is widely utilized and supported by Building Code and the Physical Planning Act (2003), further adoption of this process will be encouraged through the availability of cost-effective storage options. These storage alternatives will rival reinforced concrete underground cisterns that are valued between USD$12.5K - USD$18K for 10,000 US gallon capacity. Additionally, current applications can be improved with the inclusion of adequate treatment in residential systems, and viable options can be designed for the agricultural sector.

3.4.7. Solar Pumping Systems – Adaptation Technology

Solar pumping systems substitute grid-connected and diesel-powered water pumps for specialized equipment that utilizes power generated by solar photovoltaic (PV) panels. These systems vary in size and complexity, with *some* or *all* power requirements met by solar generation. Alternately, they can work in tandem with back-up generators and/or grid power *(see Figure 8)*. Whereas some systems would utilize batteries and Direct Current (DC) power, in other systems, power is converted to Alternating Current (AC) for the use of standard equipment. Further, simple stand-alone systems only allow for pumping during sunlight periods (WorldBank 2018).[7]

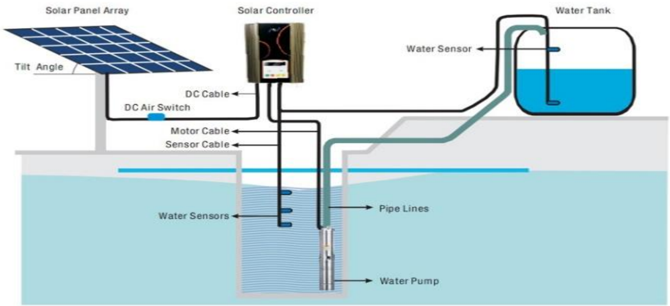


Figure 8: Solar Pumping Schematic
Source: Lorentz P2S Solar Water Pump (Dr.Solar 2018)[8]

In the past decade, solar has become a viable alternative to power a wide range of filtration systems. Manufacturers have developed several options which utilize solar energy to treat stream and well water up to 15,000 ppm TDS, to produce purified water for consumption and agriculture irrigation. Off-the-shelf systems employ membrane filtration technologies ranging from ultrafiltration (UF), to nanofiltration (NF), to reverse osmosis (RO); or a combination depending on the water quality required by the end user (Applied Membranes 2019). Off-grid, in-field units that operate 100% on solar are typically designed for up to 8 hours of operation, and are marketed both containerized and trailer mounted. In addition, to the DC high pressure pumps built into the filtration process, the units can also be fitted with DC distribution pumps to transport the treated water to a holding tank or it's end use.

Solar PV panels have become increasingly more affordable, and water pumping technology has improved significantly to where it allows for the transport of higher volumes of water over greater vertical distances. Since Antiguans and Barbudans have been previously exposed to solar water heating and grid-tied solar systems, water treatment system that use solar pumping technologies could be introduced as a variation of these accepted solar applications. Solar pumping systems can be designed for residential, commercial and municipal use and are suitable for potable and non-potable water which will allow for increased flexibility across water sector operations.

[7] World Bank. 2018. "Solar Pumping: The Basics." World Bank, Washington, DC.

[8] Dr. Solar: Engineering the Solar Revolution. "Solar Water Pumping System for Your Home".

3.4.8. Stormwater Reclamation and Reuse – Adaptation Technology

Stormwater reclamation involves the collection, accumulation, treatment, and storage of precipitation for reuse. This process differs from rainwater harvesting as runoff is collected from *storm* drains, waterways, and roadways instead of rooftops. Micro-catchments can be used to divert or slow runoff so that it can be stored before entering receiving waters. Alternately, stormwater can be collected directly from natural watercourses, although the required level of treatment would depend on pollutant loads and the intended use of the water.

After extreme rainfall and seasonal weather events, local watersheds are inundated with flash flood waters that quickly drain into the marine environment. Harvesting this water for non-potable uses such as groundwater recharge or replenishing natural wetlands, could provide social, environmental, and economic benefits – combating flooding and soil erosion, as well as lessening nutrient loads discharged to marine waters (Pavelic et al. 2010).

3.4.9. Underground Storage of Surface Water – Adaptation Technology

Also referred to as *Aquifer Storage and Recovery (ASR)*, underground storage of surface water allows for the capturing of precipitation during the rainy season, subsequently channelling it underground into a *closed* aquifer system to be recovered during drier periods. Raw or partially treated surface water is also injected underground at predefined percolation depths, and a 'mixing zone' between *introduced* and *native* groundwater is maintained to ensure that water quality variations are effectively managed (FEMA 2015). Developed as technology for drought and flood mitigation, storing surface water underground in a confined aquifer has gained popularity in areas where hydrogeology is substantially understood.

As a subsurface storage technique, ASR has more resilience than traditional storage methods like reservoirs or dams, as water is protected from evaporation and runoff pollutants. ASR also mitigates against dam failure, overflow, and downstream flooding. Moreover, strategically placed ASR systems can be used as a barrier to protect freshwater supplies in coastal areas where underground stores are threatened by saltwater intrusion resulting from sea level rise (FEMA 2015; Pathak et al. 2018). The Utility can then recover the stored water from the aquifer using wells when freshwater is needed.

3.4.10. Wastewater Reuse for Irrigation – Adaptation Technology

Domestic wastewater produced by residential and small commercial buildings includes water from sinks, showers, toilets, washing machines and restaurants. Treating and reusing this water for agriculture irrigation has been an increasingly useful approach to preventing the over-exploitation of limited freshwater resources. This technology allows up to 75% of initial wastewater to be saved for an additional purpose; provides nutrients that supplement chemical fertilizer usage; increases soil fertility; and provides safe disposal for wastewater. However, effective diffusion will depend on the collection, treatment, and delivery systems to farmers (Malki et al. 2017).[9]

Several wastewater treatment technologies can be considered; however, principle factors guiding selection are budgetary constraints and the level of treatment necessary to avoid microbial contamination of irrigated crops, with minimum tertiary treatment required to remove pathogens (Fernanda Jaramillo & Restrepo 2017).[10] Notably, the demonstration membrane bioreactor (MBR) plant in McKinnons can be utilized to promote wastewater reuse to farmers in the area, and serve as the pilot scheme for technology transfer.

3.4.11. Water Savers – Adaptation Technology

Modern water saving technologies use water efficient appliances, fixtures, and devices to augment water conservation efforts. In addition, they have a variety of commercial and residential applications within buildings, landscaping, pools, and factories. These technologies range from installation of low-flow faucets, shower heads, toilets and household appliances, to retrofitting older plumbing with aerators, high efficiency check valves, and flow restrictors and regulators *(Figure 9)*. Water savers can help to reduce water usage by up to 70%[11]; however, they are most effective when combined with improved practices by conscientious consumers. According to HomeWaterWorks (2018), the highest in-home water usage includes the kitchen (15.7%), bathroom (18.6%), laundry (21.7%) and unaddressed leaks (13.7%). Consequently, it is assumed that property owners will focus on these high usage areas due to the successes of water saving technologies.[12] Water efficient fixtures and appliances are locally available at several hardware stores in Antigua and Barbuda, most of which can be identified by the *water saving* green tag.

Figure 9: Water Efficient Fixtures

Source: Akruthi Enviro Solutions – How to Save Water at Home (Akruthi 2018)

[9] Malki, M. et. al. 2017. "Wastewater treatment and reuse for irrigation as alternative resource for water safeguarding in Souss-Massa region, Morocco". European Water. Vol. 59: P. 365-371.

[10] Fernanda Jaramillo, Maria and Restrepo, Inés. 2017. "Wastewater Reuse in Agriculture: A Review about Its Limitations and Benefits". Sustainability. Vol 9. P. 1753-1753.

[11] Akruthi Enviro Solutions Pvt. Ltd., http://neoakruthi.com/blog/how-to-save-water-at-home.html

[12] Home Water Works, *A Project for the Alliance for Water Efficiency,* https://www.home-water-works.org/indoor-use

3.4.12. Wave Powered Desalination – Adaptation Technology

Wave-powered desalination describes a self-sustaining system where the energy from waves is used to *power* a desalination system that produces freshwater from seawater. This technology has been utilized in applications ranging from *on-shore* systems that utilize ocean waves and a variety of seawater pumps to send pressurized water to on-shore desal facilities, to *at-sea* systems where the entire desalination process is done on the buoy and freshwater is pumped back to shore *(Figure 10)*.

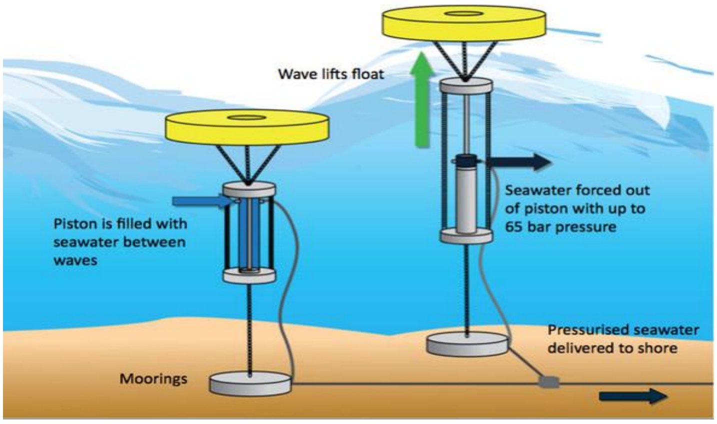


Figure 10: Wave Powered Desalination with On-Shore Facility
Source: SigmaHellas (2018)[13]

3.5. CRITERIA AND PROCESS FOR TECHNOLOGY PRIORITIZATION

3.5.1. Criteria, Weighting and Scoring

The Multi-Criteria Analysis process detailed in Section 1.5.2. was employed during the one-day Technology Prioritization Workshop held in the Conference Room of the Department of the Environment. During this workshop, stakeholders were introduced to or given recollection of the MCA process, and were presented with the UDP MCA tool.

Criteria Identification:

The SWG convened on July 23rd, 2019 for a one-day MCA workshop with the goal of finalizing the list of technologies that will progress to Step 2 of the TNA process. A list of sixteen (16) criteria was generated by the TNA Consultant and presented to the SWG for review. Stakeholders engaged in a process of *Selection and Validation* to produce a concise criteria list for the MCA. The objectives of this initial session were to:

- Review and discuss the factsheets of the seven (7) short-listed technologies *(See Table 3)* which were selected during the first SWG workshop [14] and validated by the TAC[15];

[13] SigmaHellas 2018, *Wave Powered Desalination*, Sigma Hellas, Athens, GR.
[14] Technology Screening Workshop, June 18, 2019, DOE Conference Room, 2pm to 4:30pm
[15] Technical Advisory Committee Meeting, June 19, 2019, DOE Conference Room, 9am

- Review the criteria long list and make amendments;
- Select six (6) to eight (8) independent criteria for use in the MCA;
- Arrange selected criteria into categories/sub-categories; and
- Create a criteria tree

Table 3: Technology Short List

RANKING	WATER SECTOR CLIMATE TECHNOLOGIES
1	RAINWATER HARVESTING
2	STORMWATER RECLAMATION AND REUSE *for Controlled Groundwater Recharge and Watershed Rehabilitation*
3	WASTEWATER REUSE FOR IRRIGATION
4	CLIMATE-PROOFING ASSETS (Resilient Infrastructure)
5	SOLAR PUMPING SYSTEMS
6	ATMOSPHERIC WATER GENERATORS
7	WATER SAVERS

Each criterion and corresponding *Measure* were thoroughly discussed, giving stakeholders the opportunity to accept or reject based on applicability to all seven technologies. The following list in *Table 4* was taken through two iterations and downsized from **seventeen** to **ten**, and finally, to **eight.**

Table 4: List of Evaluation Criteria

CHECK (X)	CRITERIA	UNIT OF MEASURE
X	**1. Capital Investment (CapEx)**	USD$
X	**2. Operation and Maintenance Cost**	USD$
X	**3. Potential for widescale adoption/replication (Scalability)**	H, M, L*
X	**4. Socio-cultural acceptance of technology**	H, MH, M, ML, L
X	**5. Ease of implementation**	VE, E, D, VD
	6. Capacity to increase water conservation (efficient water use)	H, M, L
	7. Positive Environmental Impact (reduce flooding, erosion…)	H, MH, M, ML, L
X	**8. Capacity to increase available volumes of water**	H, M, L*
	9. Reduction of water wastage	H, M, L
	10. ~~Need for additional infrastructure~~ *(counted as CapEx/reflected in Cr. #1)*	~~Y, N~~
	11. Availability of technical expertise	Y, N, M
	12. Economic benefits (business potential, local job creation)	H, M, L
X	**13. Positively impact socially vulnerable groups**	H, MH, M, ML, L
X	**14. Rapid recovery after significant climate event**	H, M, L*
	15. Political will	H, M, L
	16. Institutional/Organizational Structures in place	Y, N, M
	17. Need for relevant/additional legislation	Y, N, M

H: High; **MH:** Medium High; **M:** Medium; **ML:** Medium Low, **L:** Low ||
Y: Yes; **N:** No; **M:** Maybe/Possibly || **VE:** Very Easy; **E:** Easy; **D:** Difficult; **VD:** Very Difficult

Of the ten (10) highlighted criteria, the eight (8) marked by **X** were validated as *complete, free of redundancy,* and *fully operational*. Additionally, in follow-up discussions, it was agreed that all qualitative criteria would be evaluated on a 5-point scale during the *Scoring* process.

Stakeholders also completed a two-step criteria categorization, where *Costs* and *Benefits* were identified as broader categories. *Benefits* was further divided into *Social, Institutional,* and *Economic* sub-categories. Discussions were then centred around how technology diffusion would be influenced by the local context, and considerations of national climate change adaptation goals and overall development priorities were highlighted. *Figure 11* shows the Criteria Tree constructed at the end of the session.

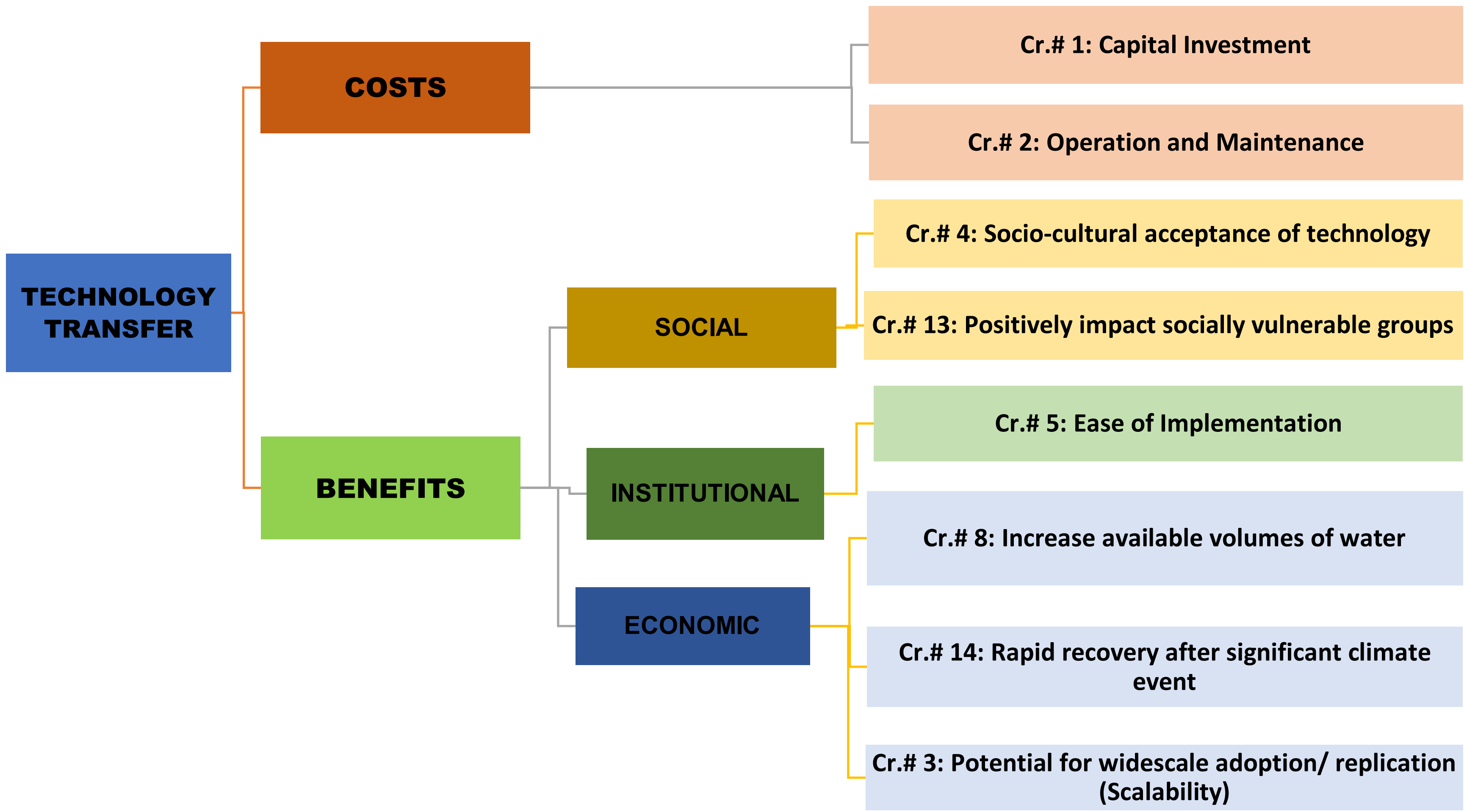


Figure 11: MCA Criteria Tree

Scoring:

The second session involved a two-step evaluation of the technologies based on the selected criteria. The process undertook a primarily qualitative approach, with an adapted 5-point Likert scale being used to evaluate technology options. First, stakeholders completed a *Performance Matrix*, which was then converted into a *Scoring Matrix*. Technologies were grouped based on scale, with four (4) small-scale representing residential/commercial applications and three (3) large-scale for municipal applications. *Table 5* highlights the Performance Matrix generated after robust discussions.

During spirited debates, stakeholders used value judgements to arrive at amicable decisions. In cases where a single point on the scale could not accurately measure performance, **(+)** or **(-)** were assigned to indicate that the score needed to be adjusted up or down when the matrix was converted.

Table 5: Performance Matrix

TECHNOLOGY OPTIONS		CRITERIA SCALE OF EVALUATION							
		CR.# 1	CR # 2	CR.# 4	CR.# 13	CR. # 5	CR.# 8	CR.# 14	CR. # 3
SMALL	RAINWATER HARVESTING	$7,200	$200	H	H	E++/D--	H	M+	M+
	SOLAR PUMPING SYSTEMS	$5,000	$500	H	H	E	M	M+	H
	ATMOSPHERIC WATER GENERATORS	$197,500+	$800+	L	L	E/D	M	M	M
	WATER SAVERS	$2,000	$0.00	MH	L	E	M	L	M+
LARGE	STORMWATER RECLAMATION AND REUSE	$5M	$500K	H	ML	D	M	L+	M
	WASTEWATER REUSE FOR IRRIGATION	$10M	$65K	L	M	D	M+	L	H
	CLIMATE-PROOFING ASSETS	$5M+	**	H	ML	D-	L	H	L+

H: High; **MH:** Medium High; **M:** Medium; **ML:** Medium Low, **L:** Low ||
Y: Yes; **N:** No; **M:** Maybe/Possibly || **VE:** Very Easy; **E:** Easy; **D:** Difficult; **VD:** Very Difficult

Using predetermined scores, the *Scoring Matrix* in *Table 6* was generated and stakeholders were given the chance to review scores and raise concerns before proceeding.

Table 6: Scoring Matrix

TECHNOLOGY OPTIONS		CRITERIA SCALE OF EVALUATION							
		CR.# 1	CR # 2	CR.# 4	CR.# 13	CR. # 5	CR.# 8	CR.# 14	CR. # 3
SMALL	RAINWATER HARVESTING	25	75	100	100	50	100	75	75
	SOLAR PUMPING SYSTEMS	75	25	100	100	80	5	75	100
	ATMOSPHERIC WATER GENERATORS	25	75	0	0	50	50	50	50
	WATER SAVERS	100	100	75	0	80	50	0	75
LARGE	STORMWATER RECLAMATION AND REUSE	50	0	100	25	40	50	25	50
	WASTEWATER REUSE FOR IRRIGATION	0	25	0	50	40	75	0	100
	CLIMATE-PROOFING ASSETS	50	75	100	25	30	0	100	25

High: 100; **M**edium **H**igh: 75; **M**edium: 50; **M**edium **L**ow: 25; **L**ow: 0 || **Y**es: 100; **N**o: 0; **M**aybe: 50 ||
Very **E**asy: 100; **E**asy: 80; **D**ifficult: 40; **V**ery **D**ifficult: 0

Weighting:

The Criteria Tree was utilized as a step-by-step guide throughout the weighting process. Each category and sub-category were progressively assigned weights indicative of their level of importance. This was done until all criteria were weighted as a percentage such that all weights equalled 100%. *Figure 12* documents in-session activities as weights were being assigned, while *Table 7* shows the Weighted Scoring Matrix that was generated and used to populate the UDP MCA Tool.

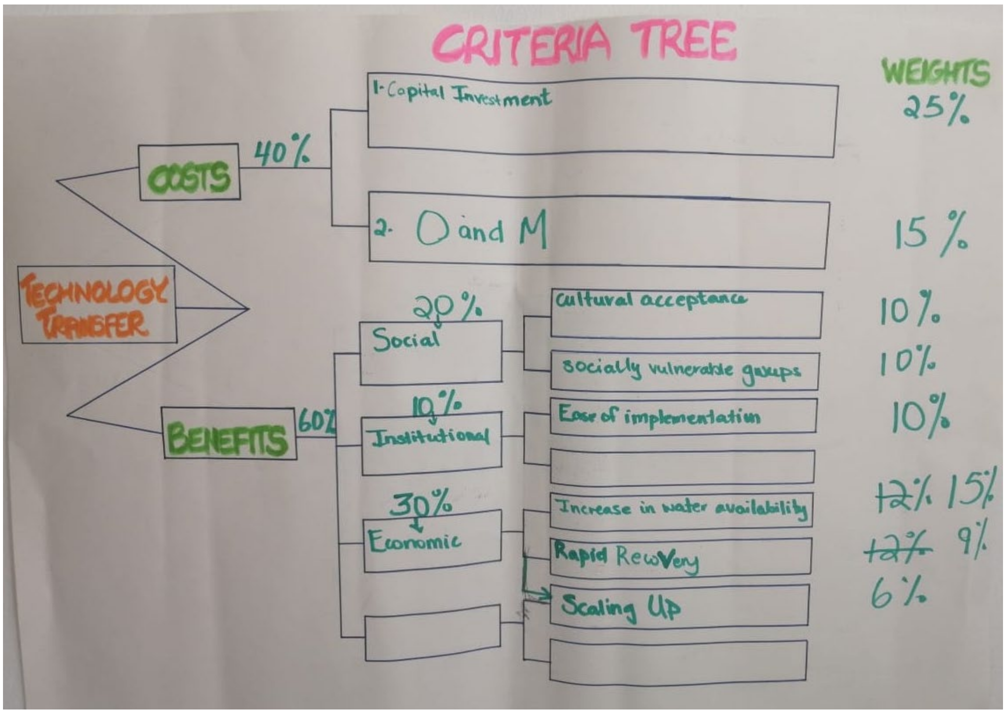


Figure 12: Workshop Criteria Weighting Session Activities

Table 7: Weighted Scoring Matrix

TECHNOLOGY OPTIONS		CRITERIA SCALE OF EVALUATION							
		CR.# 1	CR # 2	CR.# 4	CR.# 13	CR. # 5	CR.# 8	CR.# 14	CR. # 3
SMALL	RAINWATER HARVESTING	25	75	100	100	50	100	75	75
	SOLAR PUMPING SYSTEMS	75	25	100	100	80	5	75	100
	ATMOSPHERIC WATER GENERATORS	25	75	0	0	50	50	50	50
	WATER SAVERS	100	100	75	0	80	50	0	75
LARGE	STORMWATER RECLAMATION AND REUSE	50	0	100	25	40	50	25	50
	WASTEWATER REUSE FOR IRRIGATION	0	25	0	50	40	75	0	100
	CLIMATE-PROOFING ASSETS	50	75	100	25	30	0	100	25
	CRITERION WEIGHTS	**25**	**15**	**10**	**10**	**10**	**15**	**9**	**6**

3.6. TECHNOLOGY PRIORITIZATION RESULTS

The TNA process began with a long list of the twelve (12) technology options for the water sector (*see Table 8*). Consideration was given to current climatic impacts, national development and adaptation priorities, and contextual applicability. Technologies also considered potable and non-potable uses, and encompassed applications at the residential, commercial, and municipal scales.

Consultations with SWGs resulted in a *short list* of the top five (5) technologies. However, following further discussions during the Consultant's presentation to the TAC *(TNA Committee)*, Option 2 was amended to encompass controlled groundwater recharge (Option 9) and to include *watershed rehabilitation*. In addition, Options 6 and 7 were also chosen to be included in the MCA, resulting in the shortlist of seven (7) technologies outlined above in *Table 3*. Detailed technology factsheets in *Appendix E* were prepared for these seven (7) technologies.

Table 8: Long List of Technology Options

RANKING	TECHNOLOGY OPTIONS
1	Rainwater Harvesting
2	Stormwater Reclamation and Reuse
3	Wastewater Reuse for Irrigation
4	Climate-proofing Assets (Resilient Infrastructure)
5	Solar Pumping Systems
6	Atmospheric Water Generators
7	Water Savers
8	Brackish Water Desalination
9	Controlled Groundwater Recharge

RANKING	TECHNOLOGY OPTIONS
10	Digital Warning Systems
11	Wave Powered Desalination
12	Underground Storage of Surface Water

SWGs reconvened for an MCA workshop facilitated by the TNA Consultant, with the support of the TNA Coordinator, where the final ranking in *Table 9* was obtained after generating two iterations and the utilization of the UDP MCA tool. A sensitivity analysis was conducted where the following adjustments were made, and the final scores revised:

- Criteria 1 – "Capital Investment" score was adjusted down from **25** to **0** for Atmospheric Water Generators to account for the higher upfront cost of all residential/commercial scale options.
- Criteria 8 – "Capacity to increase volume of water available" was adjusted down from **15%** to **12%** and Criteria 14 – "Rapid recovery after significant climate event" was adjusted up from **9%** to **12%** to account for stakeholders' discussions of the relevance of these two criteria relative to each other *(see Figure 12)*.

However, since the ranking essentially remained unchanged, the initial results in *Iteration 1* were accepted by consensus. The top five (5) technologies were chosen to be considered for the *Barrier Analysis and Enabling Framework (BAEF)* step of the TNA process.

Table 9: Water Sector Technology Prioritization Results

RANKING	TECHNOLOGY OPTIONS	ITERATION 1	ITERATION 2	BAEF
1	Solar Pumping Systems	70.8	71.5	Y
2	Rainwater Harvesting	68.8	68.0	Y
3	Water Savers	67.5	66.0	Y
4	Climate-proofing Assets	49.8	52.8	Y
5	Stormwater Reclamation and Reuse	41.8	41.0	Y
6	Atmospheric Water Generators	37.5	31.3	N
7	Wastewater Reuse for Irrigation	30.0	27.8	N

Y: Yes | N: No

Following completion of Step 1, when the TNA Report was reviewed by the Department of Environment, a decision was made to reconsider Atmospheric Water Generators as a viable technology for the local water sector. AWGs present a unique opportunity to build resilience in the health and education sectors, given their usefulness during periods of extended droughts; and in addition, mobile units can be quickly routed to severely affected communities following extreme weather events. While this technology achieved a 6th place ranking in the MCA, oversight from the TNA Coordinating Agency determined that it should also be included in Step 2. Hence, a total of six (6) adaptation technologies are proposed for deployment Antigua and Barbuda's water sector.

4. TECHNOLOGY PRIORITIZATION FOR BUILDING SECTOR

4.1. CLIMATE CHANGE VULNERABILITIES

As previously discussed in *Section 3.1,* climate variability and change puts Antigua and Barbuda at significant risk for increased land and sea temperatures, reduced annual rainfall, sea level rise accompanied by increased storm surges, and extreme weather events. The country's building sector is especially vulnerable to the impacts of the increased frequency and strength of tropical weather systems. Hurricanes and tropical storms continue to cause irreparable damage to the physical structures of homes and businesses.

The nation's tourism, health, and education sectors are particularly vulnerable. In the past decade, tropical weather systems have resulted in damage to, or the destruction of, hotels and resorts, clinics, Barbuda's Hanna Thomas Hospital, and several schools. This has the knock-on effect of disrupting the livelihoods of residents and costing the government valuable revenue.

The process to determine the most viable technologies to be considered required the consultant to produce an initial long list which was further streamlined based on ranking and further selection by the SWG. During the first session on June 13th 2019, the long list was discussed by the SWG *(see Section 4.5, Table 11: Long List of Technology Options)*. This discussion included the merits and benefits towards the sector based on a country-driven concept technology which complements Mitigation/Adaptation. The group participated in prioritizing the technologies in terms of ranking by consensus, giving the highest to lowest rank to technologies presented. There were some technologies which the group felt were of similar content; therefore, it was agreed that they should be merged as one. These technologies are: *Passive House Designs and Site Selection* and *Impact and Energy Efficient Windows and Doors*. The final ranking was unanimously accepted at the end of the workshop. Based on the top five technologies, the consultant further prepared Factsheets to support the technologies and their relevance to the country.

As previously outlined, Antigua and Barbuda's INDC states that by 2030, all buildings are to be improved and prepared for extreme climate events, including drought, flooding, and hurricanes, which is the cumulative objective of the technologies prioritized for this sector (GoAB 2015c).

Additionally, the Antigua and Barbuda Second National Communication on Climate Change has outlined its adaptation strategies to engage in a "variety of mechanisms to reduce loss and damage from disasters made worse by climate change; these include disaster risk management, insurance and other compensatory schemes, building and development codes enforcement, and water storage, supply (ground water and desalination) and efficiency in usage, including irrigation technology and public education" (GoAB 2009)

Therefore, Antigua and Barbuda, as a member of the international climate change negotiations process, has joined forces with other nation states that support, inter alia, the following:

- Providing SIDS with new, predictable, direct access to grant financing and technology transfer to assist fast-tracking their adaptation efforts (GoAB 2009)

Outlined by The Antigua and Barbuda Third National Communication, the following statement on adaptation reads GoAB (2015b):

"Determining the degree to which a country or community is vulnerable to climate related events and the extent of their capacity to adapt and/or cope is important in order to ensure that investments in adaptation measures achieve desired outcomes. The results of a Vulnerability Assessment should be used to guide the decision-making process in prioritizing appropriate steps that ought to be taken to adapt to climate change. If the country/community is already highly vulnerable and does not have the financial, technical or human resource capacity to implement and sustain adaptation practices, it is less likely to adapt to the impacts of climate change." p. 68.

Women are agents of change and should be the driving force in the use of energy-efficient appliances derived from renewable power sources. Women are the main frontline users of these appliances, and therefore, should be trained in their use. They are also the best promoters of these appliances which are more user friendly (SADC 2016). The use of energy efficient appliances that are powered by non-fossil fuel power sources contributes to a more efficient building. Such examples are appliances which are powered by energy sources derived from solar and wind which provide zero CO_2 emissions. Wind and solar energy can be coupled with battery storage devices which can retain the power supply. This stored power is most beneficial when there are periods of heavy cloud cover and/or inadequate wind yields. It is encouraging to note that Antigua and Barbuda sits in a climatic zone where there is a large supply of wind and solar energy. Perhaps it is most useful to mention that off-the-grid sustainable power sources, to include naturally available solar and wind systems coupled with back up storage batteries, are other forms of supporting technologies to power these appliances.

Orientation of the buildings' architectural design plans within the landform contouring and positioning, are integral parts of building design. In order to maximize the positive natural attributes that bring comfort to the occupants, it is important that all elements work harmoniously to meet that goal. As it is most common that houses are fixed entities, all elements of wind, day light, rain, shade and so forth must be considered when positioning the house on the landform.

As one of the focal points of the TNA process, the analyzation of the *building sector* targets three (3) main objectives:

- To identify and prioritize mitigation/adaptation for selected sectors or sub-sectors;
- To identify, analyse, and address the barriers that hinder the development and diffusion of the prioritized technologies, and to create an Enabling Framework to overcome those barriers;
- To develop a Technology Action Plan with recommended measures based on the outputs obtained from the abovementioned deliverables.

The expected outcome for each priority technology is a purposeful, country-specific implementation plan that will positively impact climate change through adaptation/mitigation. In addition, it is important that the technology be of practical use that benefits the country's subsequent climate change objectives.

4.2. DECISION CONTEXT

The technologies selected are expected to primarily address adaptation and aid the country's resilience against climate change as it increasingly continues to affect Antigua and Barbuda considerably. In September of 1995, Category 4 hurricane 'Luis' became the most destructive hurricane to hit Antigua and Barbuda at that time. Ten days following hurricane Luis, hurricane Marilyn - a Category 1 - made landfall. The total cost attributed to the devastation of the island was estimated at US$128 million, which at the time which was 30.4% of the country's GDP (Gore-Francis 2014).

Today, buildings are especially vulnerable due to Category 5 hurricanes which can reach in excess of 157mph (NOAA 2019). It is important to note that prior to 2017, there were no formations of Category 5 tropical cyclones within the geographic zone of the Lesser Antilles. However, in September of 2017, hurricanes Irma and Maria — mere weeks apart — demonstrated that the region is experiencing increased levels of frequent and intensified hurricanes. Not only does this highlight the increased threat to infrastructure but signifies the need for updated Building Codes to meet the now foreseeable risks. Moreover, keen attention must now be placed on compliance to Building Codes such as the Caribbean Uniform Building Code (CUBiC), American Concrete Institute (ACI 318) and British Standards (BS8110).

4.3. EXISTING TECHNOLOGIES IN THE BUILDING SECTOR

The UNEP (2017) Concept Note, "Resilience to hurricanes, floods and droughts in the building sector in Antigua and Barbuda" outlines how investments are being pursued to facilitate the paradigm shift from existing low-quality infrastructure, towards the adoption of climate-resilient building approaches. Technical assistance was provided by CTCN to identify interventions that would enable buildings to withstand Category 5 hurricanes, extreme flooding, and extended drought, to ensure that the economy and critical services can continue to function (CTCN 2017).

The funding proposal to the GCF incorporated the proposed interventions to facilitate this paradigm shift. Although this Concept Note concentrated specifically on climate-resilient technologies, emphasis was placed on long-term public infrastructure and climate-proofing interventions such as disaster services, healthcare, fire services, and the police force (CTCN, 2017 p.3).

Antigua and Barbuda currently has Unconditional NDC Targets:

- Enhance the established enabling legal, policy and institutional environment for a low carbon emission development pathway to achieve poverty reduction and sustainable development.
- By 2020, update the Building Code to meet projected impacts of climate change.

Achievement of the conditional adaptation targets presented to NDC is contingent upon Antigua and Barbuda receiving international support for capacity building, technology transfer, and financial resources through the Green Climate Fund (GCF), the Global Environment Facility (GEF), the Adaptation Fund, and other multilateral agencies and bilateral agreements. The cost of implementing the adaptation targets is estimated at $20M USD per year for the next ten years.

Physical infrastructure in Antigua and Barbuda must be modified to address the elevated threats of water scarcity, increased precipitation, and intensified storms and hurricanes. By 2030, all buildings shall be improved and prepared to withstand extreme climate events. Antigua and Barbuda also recognizes the co-benefits of adaptation and mitigation in the area of low carbon development as an efficient and cost-effective strategy for sustainable development (GoAB 2015a).

4.4. TECHNOLOGY TRANSFER OPTIONS

4.4.1. Passive House Design – Crosscutting Technology

By utilizing the natural environment along with appropriate house orientation, the following climate change adaptation objectives are achieved:

- Maximized rainwater harvesting from the roof.
- Access of natural sunlight into the home without increasing indoor temperatures.
- Appropriate positioning of doors and windows to encourage natural air flow throughout the home. This also allows the free flow of windward and leeward winds, reducing the atmospheric pressure within the structure.
- Structural reinforcement of the windward walls of the structure to resist forces of 138 PSF—a contrast to the leeward side of 87 PSF (*Interim Guidelines for Build Occupant's Protection*

from Tornadoes and Extreme Winds; Technical Guidelines for Architects and Engineers TR – 83A/ Defence Civil Preparedness Agency/ September 1975).

- Selectively positioned trees surrounding the structure that lower indoor temperatures and reduce the energy-consumption of the home.
- Reduction or elimination of flooding through appropriate landscaping that enables runoff.

The abovementioned elements are considered crucial to the design of the structure. Moreover, they provide co-benefits as they reduce the need to acquire energy-consuming technologies such as air-conditioning units *(see Figure 13)*.

The addition of a solar air conditioning unit can assist in creating a passive house design. Solar air condition systems work 100% off grid using a combination of solar power and battery. Heating and cooling consume most energy for buildings therefore this solution seeks to reduce the burden by integrating solar panels to supply its energy needs.

These panels would allow the system to work independently from other connections in the building. They operate fully on DC power so there is no need for the purchasing on an inverter. The advantage of this is there is less wastage when the power must convert from DC to AC, then to DC again for the compressor. This would assist with the reduction in consumption of energy from the grid for heating and cooling in households and commercial building. The system can be designed according to how much backup power you would like based on operational hours of the air condition.

Figure 13: Passive House Design
Source: Treehugger.com[16]

[16] https://www.treehugger.com/sustainable-product-design/passive-house-design-from-canada-wins-competition-for-new-orleans.html

4.4.2. Best Roof Pitch Angle – Adaptation Technology

Hurricanes are the most significant annual risk to infrastructure for the Caribbean region. The increased heavy rains and high winds are usually too powerful for the average roof to withstand, resulting in devasting roof damage or loss. Traditionally, construction methodology focused on steep roof pitches which are more resistant to high wind gusts. There are a number of these buildings remaining which have become historic homes that continue to withstand the test of time. Unfortunately, the construction of pitched roofs has declined significantly across the region as individuals progress towards modern roof designs with reduced pitches. As a result, modern roofs are more susceptible to hurricane damage as those designs do not aid in reducing wind load. However, steep roof pitches are steep enough to resist uplift but shallow enough to resist overturning. Coupled with an aperture in the roof design, pitched roofs greatly reduce atmospheric pressure within and around the structure. *(see Figures 14 - 17)*.

Figure 14: Roofs with steeper pitch angle noticeably intact (Abaco, The Bahamas)
Source: CNBC[17]

Figure 15: Roof with steeper pitch angle noticeably intact (Abaco, The Bahamas)
Source: The Sun (UK)[18]

[17] https://www.cnbc.com/2019/09/06/dorians-death-toll-expected-to-soar-in-bahamas-there-must-be-hundreds.html
[18] https://www.thesun.co.uk/news/9890242/hurricane-dorian-bahamas-nuclear-bomb-70000-megastorm/

Figure 16: Courtesy of TNA - Barbuda Field Trip, February 19, 2020

Figure 17: Courtesy of TNA - Barbuda Field Trip, February 19, 2020

In 2019, hurricane Dorian had a maximum wind speed of 185 mph according to the National Oceanic and Atlantic Administration (2019), with several media outlets reporting wind gusts to have exceeded 220 mph (TampaBayTimes 2019). As wind speeds begin to surpass 157mph — the upper threshold of a Category 5 hurricane — it is apparent that "*A high percentage of framed homes will be destroyed, with total roof failure and wall collapse*" (NOAA 2019). Consequently, efforts must be made to recognize the significance of implementing pitched roofs within building designs to reduce the risk of roof damage or loss. Adoption of this technology is particularly fundamental when constructing a timber-framed roof structure and would complement other wind-resistant elements within the roof design.

4.4.3. LED Lighting – Mitigation Technology

Compared to standard incandescent bulbs, light-emitting diodes (LEDs) are estimated to be 90% more efficient and can last up to 25 times longer. Moreover, *"LEDs present enormous potential to outstrip many conventional lighting technologies in terms of colour quality, versatility, lifetime, and energy efficiency."* (Nanaki & Koroneos 2017).

Below, *Table 10* compares a 60 watt (W) traditional incandescent with CFLs and LEDs *(see Figure 18)* that provide similar lighting levels.

Table 10: Comparison of 60W Incandescent and Energy Efficient Light Bulbs

Comparisons between Traditional Incandescent, Halogen Incandescent, CFLs, and LEDs						
	60W Traditional Incandescent	43W Energy-Saving Incandescent	15W CFL		12W LED	
			60W Traditional equivalent	43W Halogen equivalent	60W Traditional equivalent	43W Halogen equivalent
Energy $ Saved (%)	–	~25%	~75%	~65%	~75%-80%	~72%
Annual Energy Cost*	$4.80	$3.50	$1.20		$1.00	
Bulb Life	1000 hours	1000 to 3000 hours	10,000 hours		25,000 hours	

*Based on 2 hrs/day of usage, an electricity rate of 11 cents per kilowatt-hour, shown in U.S. dollars.

Figure 18: High Efficiency Lighting Options
Source: Rutgers University – Green Manual[19]

4.4.4. Efficiency in Building Infrastructure Construction – Mitigation Technology

Increased utilization of energy-efficient building materials would contribute significantly to lowering energy consumption. For example, by simply selecting paints with specific chemical compounds that

[19] http://greenmanual.rutgers.edu/nr-high-efficiency-lighting-systems-and-networked-lighting-controls-nlcs/

can decelerate heat transfer through walls, consistent air conditioning use can be greatly reduced. There are also several natural environmental elements with which architects can incorporate within their building designs to create energy-efficient structures. When positioning buildings, a natural balance of air flow and shade can be achieved if the locality of the structure allows for adequate shade from surrounding trees, which in turn, reduces or eliminates the reliance on fans and air conditioning units.

One of the infrastructural efficient technologies in buildings is Phase Change materials. Phase Change Material (PCM) Cooling - is a material that uses the principle of latent heat of fusion to maintain the desired temperature of an object. PCM cooling for buildings works in the following way: during the night, outdoor air temperature is used to change the PCM from liquid to solid. During the day, as the inside air temperature starts to increase, a fan is used to circulate the air across to the PCM which reduces its temperature before the air re-enters the room. When the PCM absorbs the heat energy from the warm air, it starts melting. Based on system design, the PCM would absorb enough heat energy to completely melt and become a liquid by evening. The cycle of freezing and melting will continue the next day to provide cooling. PCM systems are designed as either a passive or an active system. The passive design uses air to transition the PCM between states while active systems use a liquid solution in a heat exchanger to make the PCM move between states. Electrical input is minimal for a PCM cooling system as only a fan or a pump is needed for the system to operate.

PCM Cooling is considered a climate adaptation technology because it is designed to make buildings resilient against the impacts of increasing global temperatures. Greenhouse gases emissions are considerably reduced with the use of a PCM cooling system as its energy requirements are much less than a traditional compressor-based air conditioning system in buildings.

4.4.5. Impact Resistant Doors and Windows – Adaptation Technology

Doors and windows are an integral part of roof survival during destructive gale force winds. If the doors and windows of a structure are destroyed during a hurricane, there is a greater probability of roof loss due to the creation of a wind tunnel effect within the structure that causes roof uplift. Through the installation of impact-resistant windows and doors, the extent of damages to the structure by wind and wind-borne debris is significantly reduced. It may be observed that the survival of a structure is reliant on the durability and design of its roof, doors, and windows; therefore, it is essential that these technologies are taken into consideration when designing and constructing buildings, particularly in hurricane-prone zones such as Antigua and Barbuda.

4.5. CRITERIA AND PROCESS OF TECHNOLOGY PRIORITIZATION

Table 11 details the full technology list presented at the SWG workshop on Thursday June 13, 2019. Only the top five listed technologies were prioritized.

Table 11: Long List of Technology Options

Item	Technology
1	Impact Doors and Windows
2	Best Pitch Roof Angle
3	Passive House
4	High Efficiency Lighting Systems (Merged with LED Task Lighting #10)
5	Efficiency in Building Infrastructure or Building Energy Management systems BEMS
6	Conservation and Energy Efficiency
7	Building Thermal Installations
8	Fibre and Fly Ash Reinforcements
9	Construction Energy Efficiency Infrastructure
10	LED Task Lighting

The technologies were prioritized across ten criteria and assessed individually during the MCA process. Importantly, it was observed that Criteria 1, *"Background notes and short description of the technology"*, lacked relevance to the process and was removed with agreement by stakeholders and the TNA Coordinator. The overlapping of some building sector technologies into both adaptation and mitigation was acknowledged throughout the workshop, which allowed for Criteria 2 to reflect their potential contributions to both areas. On the other hand, technologies that did not overlap were assessed based on their contribution to adaptation or mitigation, where applicable. The phrasing of Criteria 9 was debated due to the use of the terms *"disadvantage"* and *"barriers";* It was then determined that the term *"barriers"* would be removed as they would be subsequently addressed in the Barrier Analysis Enabling Framework (BAEF) Report.

The following are the main factors that were considered when defining criteria for selection and the prioritization of technologies:

- Contribution to the development priorities of the country
- Contribution to climate change adaptation with overlapping mitigation benefits such as GHG emissions reduction
- Market potential of the technology
- Access to/availability of technology in the sector
- Potential to improve functionality of the technology through technological advancements
- Meets Antigua and Barbuda's unconditional target to update the Building Code by 2020 to meet the projected impacts of climate change
- Resilience of the country's building sector to hurricanes, floods, and droughts in accordance with the UNEP (2017) Concept Note

The technology factsheets were prepared by the consultant and submitted to the TNA coordinator. The factsheets were then dispersed amongst all members of the SWG for familiarization one week prior to the Multi-Criteria Analysis (MCA). The MCA was conducted with one SWG for the *Building sector*, which was held on July 25th, 2019 from approximately 9:00am-4:00pm. Copies of the MCA procedural methods for the prioritization process were also disseminated to the SWG.

A long list of ten criteria was developed by the TNA consultant and shared amongst the SWG. The selected criteria were based on the objectives and goals of the specific sector and reflected the variations across technologies. During the commencement of the workshop, the technical expert provided an outline of the MCA process, explaining how the scores and weights would be applied. An outline of the MCA Sensitivity Analysis was also provided to aid stakeholders in reaching a consensus if any disputes in the ranking of a technology were to arise.

In addition, the technical expert explained the use of the forms and how varying scores would be assigned based on technology's impact on the country's needs. The scores were to be allotted from *'most likely'* to have a positive impact to *'least likely'* based on the stakeholder's assessment. Where individual stakeholders assigned a score, it was agreed that all scores would contribute to the average score calculation even if the scores were deemed outliers. The scores were then tabulated, and an average was produced.

Subsequently, a weight based on the criteria was produced, from 1 – 10, through the same method the score was achieved. Both scores and weights were presented in the MCA tables.

Following completion of Step 1, a subsequent review of the TNA Report by the Department of Environment, it was determined that home biodigesters, portable solar generators and rooftop wind turbines should have been considered as a viable technologies for the building sector. Unfortunately, these technologies were added after stakeholder consultations and therefore were not given the opportunity to be prioritised. Going forward however, they would be considered as some of the technologies that can be tested and implemented in Antigua and Barbuda.

Home Biodigester System- Mitigation Technology

This plug and play biodigester system would aid in producing alternative fuel in biogas for cooking. This gas would replace liquid petroleum gas (LPG) that is used currently as the fuel for cooking. Therefore, once implemented in household, it would diminish the dependence on fossil fuel as a source of energy for cooking and further to this reduce the carbon emissions from households. The food waste entering the system is anaerobically digested by microbacteria to form biogas. The biogas is a mixture of several different gases, however the filter in the system purifies the gas to ensure a high concentration of methane. This refined gas is what is used for cooking. Hence, this system would assist with waste management in the household since the waste produced would not enter landfills to emit harmful gases into the atmosphere. For the system to optimal, it requires the input of manure which is easily accessible on the island. Once the waste has been degraded the by-product of the system is a slurry which can be utilised as fertiliser for crops. This means the households can use this fertiliser to grow crops at home. The system has a life expectancy of 15 years, which would amass huge saving to the household.

Portable Solar Generator- Mitigation Technology

A portable solar generator is a compact off grid system that has an inverter, a battery and a charge controller built into a single device. These systems are designed to be charge from multiple sources such as a solar module, a car's 12V cigarette port or a standard 120v socket. The solar modules are usually sold separately from the generator.

There are a myriad of solar generators available to be purchased as companies provide a different combination of the following characteristics: battery technology used, battery capacity, recharging time, and inverter capacity. The size of the inverter controls the number of devices that can be operated simultaneously while the capacity of the battery determines how long the system can supply electricity to meet its load.

Antigua and Barbuda has a large backup diesel generator sector to respond to the frequent blackouts. Diesel generators allow individuals to have power when the electric grid is down during and after a natural disaster. The operation however, diesel generator has a continuous operational and maintenance cost. Therefore, by introducing portable solar generators into the market, persons will be able to benefit from a low maintenance, no fuel required, no toxic gas emission, no noise and a system that can operate not just in an emergency system but every day at no additional expense.

Small Scale Wind Turbines- Mitigation Technology

A small-scale wind turbine is known as a microgenerator of electricity as opposed to a large commercial wind turbine. Wind energy is a clean and indigenous source of renewable energy. There are certain areas in Antigua and Barbuda that experience sufficient wind regimes which could harness this natural resource and resultantly increase their resilience to climate change. Therefore, small scale wind turbines would be beneficial to home users and businesses to lower their grid energy consumption and ultimately reducing their energy build. Since wind energy is a clean form of energy production, this reduces the carbon emissions from households.

4.6. TECHNOLOGY PRIORITIZATION RESULTS

Table 13 provides a summary of five (5) technologies prioritized for the Building Sector.

Table 12: Summary of Prioritization Results

Passive House Designs / Site Selection Through a crosscutting Co-Benefit of Mitigation / Adaptation	
Prioritization Category # 1	
Description	Passive house designs have adopted the Passive House Planning Package (PHPP), which is an energy modelling programme that projects energy usage in the building design by taking into account almost every aspect related to energy consumption, including the site's weather data, orientation, type of construction, materials used, window designs and locations, ventilation system, appliances, lighting and other electrical equipment used in the building. When designing for climate change, designers will need to consider changes that will have a positive outcome. Houses will need to be designed to: Respond appropriately to a changing climate with higher temperatures, different wind and rainfall patterns and potentially increased incidence of hazards such as flooding and storms
Benefits	• Considering the factors which would benefit due to incorporating passive design factors, one would attribute the benefits within the design structure by considering through adaptation winds, temperature, rainfall, rising sea levels, fire risk and changes to building regulatory planning rules. By adopting these categories within the design, benefits that would be attributed are: • Increasing structural design to deal with increased wind load • Designing buildings to make more use of natural ventilation • Designing the roof, roof drainage, and storm water run-off to cope with higher and more intense rainfall • Potential flood risk in low-lying areas • Limiting building in flood-prone areas or coastal regions that are likely to experience increased erosion in the future • Designing buildings with more shading in response to increased solar radiation • The resulting lower energy demand from passive houses helps reduce electricity peak load and create further savings by avoiding additional investment to increase the capacity of the local power infrastructure and power plants. • Passive houses are a priority measure in terms of the country's social development because they allow future saving of significant amounts of energy thus reducing emissions of greenhouse gases in the atmosphere and saving of financial resources. • Construction of energy efficient infrastructure in design brings optimization for daylight and thermal comfort. Passive house design and technologies offer building occupants better thermal comfort, indoor environment, indoor air quality and visual connection to outdoors. These benefits lead to a healthier and higher quality of life. • Passive house design and technologies do not rely on active systems and high-tech equipment to deliver environmental benefits. • Passive house design and techniques can also be considered one of the cost-effective cross cutting options providing resilience to climate change.
Best Roof Pitch Angle	
Prioritization Category # 2	
Description	Roofs are the major vulnerabilities in the Caribbean susceptible to hurricanes gale force winds due to the ever-increasing impact of climate change. This technology is a regeneration of an old technology through adaptation with has its steeper roof pitches and open apertures. Its successes are prevalent and a standout across the Caribbean during times of catastrophic disasters.

Benefits	• Less capital cost for reconstruction of roofs when they have met the basic criteria in design of >30º in pitch angle in tandem with all the other elements of shorter eves, aperture venting and adequate brace strappings. • Less vulnerability in hurricane force wind conditions. Less reliance on safe houses as shelter, such as churches which have already adopted this design from old technology applications where they were more prevalent past design architectures.
Impact Windows & Doors	
Prioritization Category # 3	
Description	These are high impact window and doors that can be hurricane, blast and burglar resistant to enhance safety and security. Having catered for these factors, the climate change would have less impact through adaptation across the building sector. According to the US Department of Energy (DOE), super high efficiency windows and doors would offer up to seven times the insulating value (U-factor) of double glazing and help create "zero energy" homes. The high-performance window and door glass products of insulated double-paned or triple-paned glass and low- E coatings have cut U-factor ratings. With the addition of highly insulated frames and warm edge technology you can select a product that is efficient because of the design improvements. These co-benefits serve a double purpose of adaptation and mitigation within the products of impact doors and windows.
Benefits	• Hurricane resistant windows and doors can increase the overall cost of construction, but they offer great protection. The investment may well pay off due to the damage they reduce through adaptation to climate change. • Will survive winds up to 200mph without blowing out once the frames are of good quality and rating • Available in sizes tailored for your convenience. • The co-benefits through climate change mitigation would be sufficient where the application also gives; on the financial side co-benefits that are also recognised by the insurer which could reduce homeowners' insurance premiums.
Construction of Energy Efficient Building Infrastructure	
Prioritization Category # 4	
Description	Energy use is the largest operating expense in office buildings and accounts for nearly 20% of the country's annual greenhouse gas emissions. According to the International Energy Agency (IEA), buildings could potentially account for 41% of global energy savings by 2035 if energy-efficient construction practices are followed. To help reduce energy consumption, builders need to consider energy efficiency in the planning and construction stages by using advanced designs and construction techniques that reduce heating, cooling, ventilation and lighting energy consumption, upgrading buildings and replacing equipment with energy-saving devices and managing energy.
Benefits	• Increases building resale value as a financial co-benefit • As a financial co-benefit energy, efficient buildings typically have longer lifecycles, lower maintenance fees, and cost less to operate. • As a crosscutting co-benefit, it reduces energy consumption and achieves sustainable energy structure for our society. • Improving your home or building's energy efficiency will reduce costs as a financial co-benefit. For example, the average homeowner can reduce up to approximately 30 percent of their energy bill. • Improves indoor comfort - A model energy efficiency building controls the flow of air, heat and moisture.

	● Healthy, fresh, clean air.
LED Lighting System	
Prioritization Category # 5	
Description	LEDs, Light Emitting Diode systems, are one of the most important climate change mitigation measures for the building sector. They produce approximately 90% more efficiently than incandescent light bulbs. Thermal management is the single most important factor in the successful performance of an LED over its lifetime. It uses the heat sink to absorb the heat produced by the LED and dissipate it into its surrounding environment. Generally, it is reported that lighting consumes about 21% (Levine et al., 2007) of the household energy and 17.5% (Levine et al., 2007) of the global electricity. Reverting to a more energy efficient alternative will contribute to a reduction by 18% of the demand for electricity worldwide (UNEP, 2009). Incorporating natural daylight, user-control and dual lighting circuit systems in designs are all part of the contributory factors towards reducing energy consumption. Efficient lighting technologies include energy efficient lamps, ballasts and light fixtures.
Benefits	● LED lamps consume one-fifth (or less) of the energy incandescent lamps. They are also more energy efficient than incandescent and compact fluorescents (CFL's) ● Large-scale implementation of the product can reduce the cost at the consumer level. ● Manufacturing for lighting component production can help create jobs, upgrade skills of the local workforce and provide cost effective energy efficient lighting fixtures to the local end-users. ● Contributes to security of energy supply as they make a significant contribution to reduction in electricity demand. ● Enhance health and living conditions for building occupants. ● The use of LED helps reduce eyestrain and fatigue, increases productivity in workplaces and provides better quality of life. Using a renewable power source which is sustainable, energy efficient Lamps such as LED would provide zero GHG emissions. Additionally, since that they require less power in operations, the requirements for expensive renewable capacity is less.

5. TECHNOLOGY PRIORITIZATION FOR TRANSPORT SECTOR

5.1. DECISION CONTEXT

The objective of the country's transportation sector is to *"Enhance the established enabling legal, policy, and institutional environment for a low carbon emission development pathway"* (GoAB 2015d). Supported by the Antigua and Barbuda Energy Transition Initiative Paper, the country's renewable energy goals are intended to have a *"25% reduction in greenhouse gas emissions below 1990 value by 2020."* (NREL 2015). As a result, the analysis undertaken during the TNA process was designed to identify technologies that would facilitate the achievement of this objective. To reduce or eliminate the country's reliance on fossil fuels and lower its GHG emissions, the technologies that are expected to achieve that objective will require practical implementation. Consequently, the selected technologies would have the common goal of reducing CO_2 emissions irrespective of their mediums.

The following was outlined within the Antigua and Barbuda SIDS 2014 Preparatory Progress Report (July 2013):

> *"A preliminary report compiled by the Ministry of Transport highlighted that Antigua has approximately 443 miles (713 kilometres) of primary main roads and 120 miles (193 kilometres) of secondary roads. However, road infrastructure in Barbuda accounts for 7miles (11km) of paved major roads while 34 secondary roads and other routes are mainly made of dirt, gravel, or crushed corals. The network in Antigua provides for good coverage throughout the island except within the southwest and southeast regions that are comprised mainly of steep mountain slopes and large resort estate limiting public access"* (Gore-Francis 2014) p.33.

Since the publication of the aforementioned report, Antigua and Barbuda has undergone major road development.

5.2. EXISTING TECHNOLOGIES IN THE TRANSPORT SECTOR

5.2.1. Overview

Achievement of the conditional mitigation targets presented in the INDCs are contingent upon Antigua and Barbuda receiving international support for capacity building, technology transfer, and financial resources through the Green Climate Fund (GCF), the Global Environment Facility (GEF), the Adaptation Fund, and other multilateral agencies and bilateral agreements. From 2015 through to 2025, the cost of implementing the mitigation targets is estimated at $220M USD (GoAB 2015d).

Antigua and Barbuda has implemented several adaptation and mitigation measures in an effort to reduce the impacts of climate change, and has joined forces with other nation states that support, inter alia, the enactment of the following climate change negotiations standards for mitigation (Antigua and Barbuda's Second National Communication on Climate Change, 2009):

- Long term stabilisation of GHG below 350ppm CO_2 equivalent levels
- GHG emissions peak by 2015 then decline
- Reduction of GHG emissions by more than 85% below 1990 levels by 2050
- Annex I parties to UNFCCC reduce collective GHG emissions by 45% below 1990 levels by 2050, and
- Direct access to grant financing and technology transfer for small island developing states to assist with fast-tracking mitigation efforts

Antigua and Barbuda has continuously undergone efforts to mitigate greenhouse gas emissions despite its negligible contribution. Antigua and Barbuda is categorised a non-Annex I party to the UNFCCC; according to article 3.2 and 4.8 of the UNFCCC, the country is characterized as being particularly vulnerable to the impacts of climate change and deserving of support of the international community to address climate change impacts (GoAB 2015b).

Along with 141 other developing countries (non-Annex 1 parties), Antigua and Barbuda has expressed its intention to be listed as agreeing to the accord since the issuance of the COP during its 15th session. The country has accepted voluntary emissions targets with the aim of significantly changing the increasing rate of global emissions. This voluntary declaration is referred to as the Nationally Appropriate Mitigation Actions (NAMAs). Antigua and Barbuda made this commitment as part of the Copenhagen Accord (GoAB 2015b).

Within this context, 'transport sector' refers to road transportation, which is a major GHG emitting sector. This sector utilizes petroleum fossil fuels which generate significant amounts of carbon dioxide (CO_2) and other greenhouse gases (N_2O, CH_4, CO, NO_X, NMVOC and SO_2). Data provided by the West Indies Oil Company (WIOC) reported that motorised transportation consumed approximately 54% of all fuel imports (GoAB 2012). It is important to note that there are substantial environmental concerns associated with emissions and the disposal of fuel; as such, relevant standards are expected to be developed, implemented, and continuously monitored.

Since Antigua and Barbuda does not engage in the manufacturing of vehicles, the country is a major importer of motorised transportation and recognizes the need to promote clean fuel and efficient fuel consumption. As such, the National Energy Policy focuses on how vehicles are utilized, improving the quality and attractiveness of public transportation, and utilizing fiscal incentives to promote the use of energy efficient transportation. The Government of Antigua and Barbuda Transport Board's National Energy Policy has outlined the existing technologies detailed below.

5.2.2. Ground Transportation

The following statement was outlined in the Antigua and Barbuda National Energy Policy in relation to Ground Transportation:

> *"The Government will take a lead in the application of efficient vehicles and cleaner fuels within its fleet. Capitalizing on the country's small size and relatively flat terrain, the Government shall explore the feasibility of introducing electric vehicles into its fleet.*
>
> *In addition to the changes in its own consumption patterns, the Ministry of Transport in conjunction with other government institutions – recognizing that transportation is simply a means to access people and services – will develop and/or promote:*
>
> - *New legislation for emissions;*
> - *Regular checks of tire pressure levels to minimize tire rolling resistance;*
> - *Reduce the demand for travel while protecting social and economic needs for access;*
> - *Improve access by identifying and removing the obstacles to more sustainable choices such as carpooling, walking and cycling" (*GoAB *2011a, p.24)*

The policy also refers to the establishment of an energy-efficient city transportation system and a modernized public transportation system.

5.2.3. Efficiency and Emission Standards

Antigua and Barbuda has outlined its mitigation actions at the 20th conference of Parties to the UNFCCC. Due to the country's size and consumption levels, fossil fuel imports are relatively small when compared to global market demands. However, national GHG emissions can still be lessened through the adoption of battery electric vehicles (BEVs) and other GHG mitigation technologies. Through government regulation and fiscal policies, those technologies can be diffused nationwide. Additionally, the introduction of a legal framework that provides for mandatory vehicle inspections, emission standards, and tax relief on imported of fuel-efficient vehicles, is also necessary for this transition.

5.2.4. Electric Bus Program

One of Antigua and Barbuda's main initiatives in the transportation sector is the Electric Bus Program. The *"Antigua and Barbuda Sustainable Low- Emissions Island Mobility Project"* will target the public transportation system by aiding the private sector in transitioning to an electric bus system. This project is due for submission in June 2020.

Description

The *Electric School Bus* project will be one of the first public sector electric vehicle initiatives in the region. With implementation and plans for upscaling, this initiative will be the first step towards creating a green transportation system and reversing the current trend of importing new and used GHG emitting vehicles.

Objectives

Specific objectives of this project are to:

- Pilot an electric vehicle in the public sector as a means of collecting data to assist with transitioning Antigua and Barbuda to clean technology and sharing the results within the Caribbean region.
- Build the capacity of the Transport Authority to manage and maintain clean technology vehicles.
- Develop local capacity through training in operations and maintenance of electric vehicle systems and hands-on educational opportunities for young individuals and the private sector.
- Scope for a carbon tax and/or verified GHG emission reduction credits as a sustainable financing approach.

Components

- Component 1: Feasibility Assessments (Technical and Financial) - This component focuses on the collection and analysis of data to determine whether transitioning to electric vehicles is a viable option for Antigua and Barbuda from technical and financial perspectives.
- Component 2: Project Structuring and Implementation - Component 2 will purchase the electric school bus and install charging stations.
- Component 3: Knowledge Management and Upscaling - A comprehensive view towards the development of education and training programs is the emphasis of this component. This will include bus drivers and mechanics at the Transport Board within the first instance. This component will further look at the communication strategy and the means by which the project can be replicated across the Caribbean region.

5.3. TECHNOLOGY TRANSFER OPTIONS

5.3.1. Battery Electric Vehicles (BEV) – Mitigation Technology

Hybrid Electric Vehicles (HEVs) provide a mid-way option to the standard electric vehicle (EV). HEVs cost considerably less than EVs, while still providing emission-reducing qualities. HEVs utilize their electric motors at low speeds and switch to their internal combustion engine (ICE) at higher speeds. In Antigua and Barbuda, electric vehicles (EVs) have begun to gather greater interest and momentum, thanks in part to the efforts of the DOE. The consistent advocacy for this green technology is in keeping with the Government's agenda to eliminate fossil fuel dependency. In 2000, CO_2 emissions in the energy sector highlighted that the transportation sector accounted for 49.1% of the country's GHG emissions *(see Table 14)*; this figure can be drastically reduced through the introduction of BEVs across the transportation sector. A corresponding factsheet for BEVs is presented in the appendices below.

Table 13: Summary of Antigua and Barbuda's CO_2 Emissions in 2000
Source: GoAB (2009)

Summary of Antigua and Barbuda CO2 Emissions in 2000

	Sectoral Approach	
Sector	Gg (CO2)	%
Total Energy	371	
Energy Industries	177	47.7%
Manufacturing Industries & Construction	0.00	
Transport (Road)	182	49.1%
Commercial/ Institutional	5.52	1.49%
Residential Sector	7.36	1.98%
Agriculture, Forestry; Fishing (Mobile)	0.00	
Total	371	100.0%

5.3.2. Solar Charging Station – Mitigation Technology

Solar is one of two renewable energy sources which is 100% sustainable and is consistently available due to our climatic conditions. The self-contained solar charging station contains a battery storage facility which provides a 24hr supply of electricity, enabling use at night and during heavy cloud cover. It is important to note that the charging stations are also sustainable as they do not produce any CO_2 emissions *(see Figure 19).* Moreover, these facilities are mounted on wheel trailers to facilitate easy movement. The listed manufacturer cost of approximately US$121,413.00 would determine the likelihood of high market demand, which is also dependant on the benefit-cost ratio of the technology.

Figure 19: Solar Powered Charging Station
Source: Ohm Home Now[20]

5.3.3. Improvements of Road Infrastructure – Crosscutting Technology

With regard to adaptation and mitigation, road infrastructure improvements would overlap into both areas, providing co-benefits. The following are the contributions of improved road infrastructure to both climate change mitigation and adaptation:

20 https://www.ohmhomenow.com/companies-pursue-combined-solar-ev-charging-stations/

- Improved road infrastructure, coupled with adequately sized drainage facilities, would contribute to the reduction of flooded road surfaces and adjacent properties during heavy rainfall.
- Designing elevated roadways creates the appropriate environment for stormwater runoff. With accompanying drainage and outfall systems, this design will prevent the deterioration of road infrastructure.
- Adopting *Antigua and Barbuda Blueprint for Road Infrastructure*: Hydrological flood return periods of 1 in 20-years return periods would be one of the fundamental design parameters recommended by the *Blueprint for Road Infrastructure*. Therefore, it is important that rainfall data from agencies such as the Meteorology and Hydrometer office at VCB International Airport, APUA Hydrological Unit, and the Ministry of Agriculture is used to provide deeper analysis when preparing for road infrastructure improvements.
- Tire wear would decrease, reducing the rate of tire disposals at landfills.
- According to Jiao and Bienvenu (2015, p.202), *"results show less fuel is consumed on rigid pavement opposed to flexible pavement by 2.25% at 93 km/h and 2.22% at 112 km/h. Fuel differences are found statistically significant at 95% Confidence Level (C.L.). Fuel savings on rigid pavement exhibits good…"*. Although these speeds are in excess of the average speed limits in Antigua and Barbuda, the truth remains that surface texture and road conditions can contribute positively or negatively to fuel consumption.
- Burying of Electrical and Telecommunications Lines. Communication and electricity Lines are currently installed overhead. Electrical and telecommunication lines were once secured to utility poles that ran adjacent to the roadway. Burying the lines allows for less susceptibility to outages during high winds and storms. Improves post storm safety where persons are no longer at risk of electrocution from felled lines.
- Changing PVC water pipes to High Density Polyethylene (HDPE) pipes. Water pipes are buried alongside the roads using PVC pipes. The PVC pipes are installed using "ghut sand" to allow for the cushioning of the pipes. HDPE pipes are able to withstand higher pressures due to compression and contraction and has the best joint pressure resistance. These pipes are more heat resistant. They are also able to dampen and absorb shock waves, thus minimizing surges that may affect the water pipeline system.
- Installations of Gabions. Installation of gabions are not a norm in Antigua, thus there are none currently in place. Gabions are sustainable, whereas concrete structures can have a high carbon footprint. They assist with reducing soil erosion and allows for good drainage due to its water permeability. Gabions offer an easy-to-use method for decreasing water velocity and protecting slopes from erosion.
- Installation of Culverts. Culverts are in place for a maximum 1:20 year rain event. Since construction, the 1:20 year event happens even more frequently. These culverts are less than

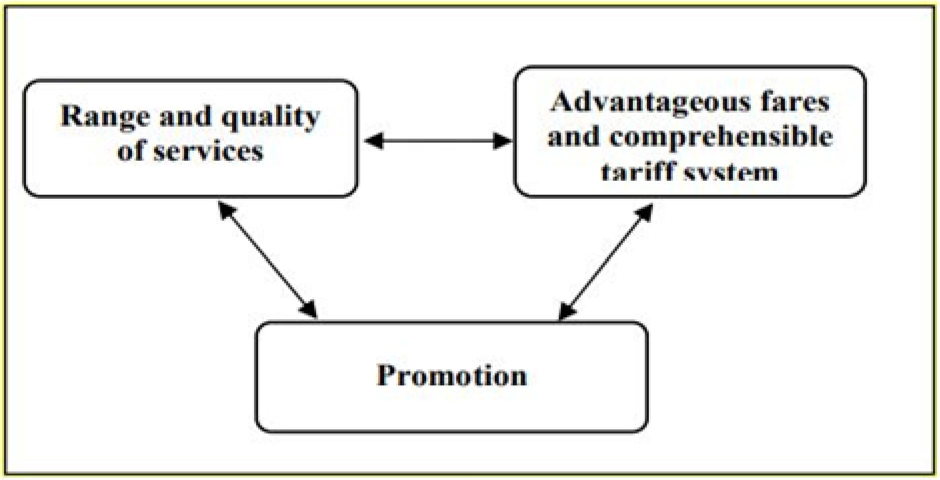
15 years old but need to be replaced earlier than intended. Existing culverts consist of an extensive network of concrete, HDPE and galvanized culverts. Culverts can withhold any tensile and compressive stress. They promote the easy distribution of water under the roadway, thus preventing the road and nearby areas from becoming flooded. Construction of these culverts are economical and require very little, if any, structural maintenance.

- Installation of Rip Rap. Shot rock, Rock Armor or Rubble used to protect embankment. Riprap offers an easy-to-use method for decreasing water velocity and protecting slopes from erosion. They are simple to install and maintain.
- Applying Double Bituminous Surface to Road. Single layer being currently used. Sand can be used within to strengthen the mixture— only if financing for sand is available at the time. During the rainy season, a paved road will have better resistance to flooding, will drain the water from the surface more easily and will reduce the risk of potholes and water stagnation on the road surface. A paved surface will also reduce the risk of water penetrating and submerging the road construction layers and thereby reduce the bearing capacity of the road. In the dry season, a paved surface will reduce the risk of dust on and around the road.
- Increase in the foundation and height of the Roads. An Asphalt and Base thickness test concluded the existing road currently has a 3.45 Inch Asphalt Layer and a 3.3-inch Base. Increasing the Base thickness helps to reduce road deformation due to vehicle overpass and rainfall, thus reducing the rate of maintenance required of the road. Increasing the base thickness also helps to improve road drainage after rainfall.

Under the Road Rehabilitation Project, extensive road improvements are currently being undertaken in Antigua and Barbuda. In addressing road infrastructure, complementary surface and sub-surface drainage systems are vital to effective and efficient functioning after heavy rains. Potholes can also impede functionality, as stormwater can pool and settle within the roadway causing eventual erosion. Attention must also be placed on the off-road trails and alleyways used by motorists to avoid traffic congestion on the main highways.

5.3.4. Integrated Public Transportation – Mitigation Technology

The city of St.John's is densely populated, congested, and undergoing urban development; while Codrington, the capital of Barbuda, is smaller by comparison with lower population density. It was highlighted by members of the SWG that the availability of parking has become a significant barrier when accessing services within and around St.John's. Integrated public transportation and parking on the outskirts of the city can be a solution to this issue. This solution contributes to climate change mitigation by reducing the quantity of vehicles on the roadways and tailpipe emissions through centralized public transportation. For successful implementation, there would need to be a shift in social norms with regard to the operation of the public transportation system. The introduction of new regulations, fares, schedule times, and points of collection are some of the areas that must be considered during the planning phase *(see Figure 20)*.



The key factors of ITS success and their interconnection

Figure 20: The key factors of Integrated Transport Systems (ITS) Success and their Interconnection
Source: Semantic Scholar[21]

5.3.5. Efficiency in the Transport Sector – Crosscutting Technology

Antigua and Barbuda's 2015 NDC has set *"Conditional Mitigation Targets by 2020, to establish efficiency standards for the importation of all vehicles….".* The implementation of this policy is a notable start towards reducing the country's GHG emissions as older vehicles are the greatest emitters on GHGs. According to the First National Communications to the UNFCCC, the total CO_2 emissions for 1990 and 1994 were 288.3Gg and 334.40Gg, respectively. Of this, Gas/Diesel Oil (27.6% in 1994) was used for electricity and road vehicular transport. It is expected that emissions levels have declined since then (GoAB 2001).

The Antigua and Barbuda Second and Third National Communications on climate change showed a significant increase in CO_2 emissions from 1990 to 2006. Improvements within the transport sector towards climate change mitigation would have a positive impact on decreasing the rate of all emissions shown below in *Table 16*.

[21] https://www.semanticscholar.org/paper/KEY-SUCCESS-FACTORS-OF-INTEGRATED-TRANSPORT-SYSTEMS-Poliakov%C3%A1/fb54a2c7e474caacbb83f8b80597fc2801ab8c07

Table 14: National Emission Reporting Source Categories in Gigagrams (Gg)
Source: (GoAB 2015b)

Year	1990[22]	1994[23]	2000[24]	2006[25]
Carbon Dioxide (CO_2)	288.22	334.13	383	945.544
Methane (CH_4)	4.67		6.6	0.639
Nitrous Oxide (N_2O)	0.0051		0.159	0.079
Nitrogen Oxides (NOx)			2.3	
Carbon Monoxide (CO)			11.9	
Non-methane volatile organic compounds (NMVOC)	0.65		2.7	0.035
Sulphur Dioxide (SO_2)	2.83	3.25	2.8	
Hydrofluorocarbons (HFC)			0.0037	114.034

The most recent GHG inventory of Antigua and Barbuda closely evaluated emissions from 2006

Efficiency standards for imported vehicles is a necessary tool for successfully reducing GHG emissions in Antigua and Barbuda. However, the affordability of used vehicles is a significant barrier to the implementation of this tool. Fiscal incentives issued by the Government could be a solution to that barrier, as it would prompt consumers to invest in energy-efficient vehicles. Moreover, policies can be implemented to regulate the age of the fossil fuel vehicles being imported.

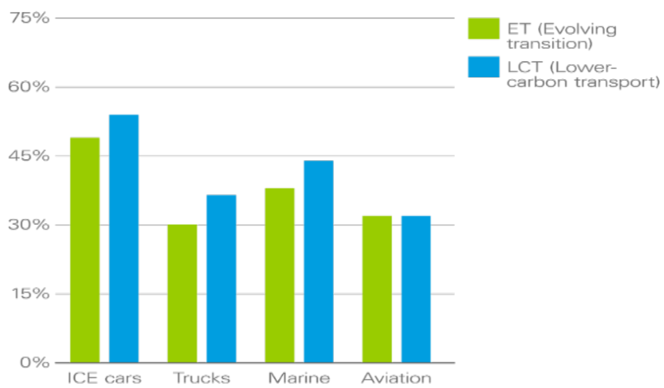


Figure 21: Efficiency Improvements 2017-2040 (%)
Source: BP[22]

22 https://www.bp.com/en/global/corporate/energy-economics/energy-outlook/demand-by-sector/transport.html

Table 17 details the full technology list presented at the SWG workshop on Thursday June 13, 2019. Only the top five listed technologies were prioritized.

Table 15: Transport Sector Technology Long List

Item	Technology
1	Improvement of Road Infrastructure
2	Hybrid Electric Vehicle (Replaced with Battery Electric Vehicle: TAC Decision)
3	Solar Renewable Charging Station
4	Integrated Public Transport
5	Efficiency in the Transport Sector
6	Road Training Program
7	Erosion Control
8	Using Alternate Fuel (LPG)
9	Oil inhibitors / Additives

Table 16: List of Evaluation Criteria

CHECK	ITEM	CRITERIA	AVERAGE UNIT OF MEASURE FOR TRANSPORT	Stakeholders Ave. Scores Across the Technologies
✔	2	How does this technology contribute to mitigation	MH++, H++, M, VE, E	64, 74,86,87,54
✔	3	How does it diffuse across the subsector	M ++, MH +++, E	44,54,62,65,67
✔	4	Cost of Operating the Technology in USD$	M +++, ML ++, E, D	45,44,34,54,22
✔	5	Contribution to social development priorities	MH +++, H, E, VE	65,75,75,77,83
✔	6	Contribution to the country economic development and benefits	M, MH, H +++	58,75,86,87,89
✔	7	Social Benefits	, MH +++, H ++	72,80,86,78,84
✔	8	Environmental Benefits	MH +++, H ++	73,79,93,85,76
✔	9	Disadvantages of the technology	ML +++, M ++	38,45,38,41,38
✔	10	Upscaling	MH ++, H +++, E, VE	69,69,84,85,83
✔	11	Coherence with the national development policies and priorities	MH +++++	71,63,77,78,70

H: High, MH: Moderately High, M: Moderate | Y: Yes; N: No; VE: Very Easy; E: Easy; D: Difficult; VD: Very Difficult,
N.B: Criteria #1 was removed during the stakeholder group workshop and hence the numbering continued as 2 – 11

Scores	Attainment Description
81 - 100	H: High
61 -80	MH: Medium High
41 -60	M: Medium
21- 40	ML: Medium Low
1 - 20	L: Low
0	VL: Very Low

+: Frequency of occurrence

5.4. CRITERIA AND PROCESS OF TECHNOLOGY PRIORITIZATION

The following are the main factors that were considered when defining criteria for selection and the prioritization of technologies for mitigation:

- Contribution to the development priorities of the country
- Market potential of the technology
- Easy diffusion of the technology
- Economic cost associated with the technology

- The technology's impact on the enhancement of the environment
- Social benefits
- Mitigation factors as it relates to climate change
- Potential to improve functionality of the technology through technological advancements
- Meeting Antigua and Barbuda's conditional mitigation targets for transportation by 2020

The technology factsheets were prepared by the consultant and submitted to the TNA coordinator. The factsheets were then dispersed amongst all members of the SWG for familiarization one week prior to the Multi-Criteria Analysis (MCA). The MCA was conducted with one SWG for the *transportation sector*, which was held on July 24th, 2019 from approximately 9:00am-4:00pm. Copies of the MCA procedural methods for the prioritization process were also disseminated to the SWG.

A long list of ten criteria was developed by the TNA consultant and shared amongst the SWG. The selected criteria were based on the objectives and goals of the specific sector and reflected the variations across technologies. During the commencement of the workshop, the technical expert provided an outline of the MCA process, explaining how the scores and weights would be applied. An outline of the MCA Sensitivity Analysis was also provided to aid stakeholders in reaching a consensus if any disputes in the ranking of a technology were to arise.

In addition, the technical expert explained the use of the forms and how varying scores would be assigned based on technology's impact on the country's needs. The scores were to be allotted from *'most likely'* to have a positive impact to *'least likely'* based on the stakeholder's assessment. Where individual stakeholders assigned a score, it was agreed that all scores would contribute to the average score calculation even if the scores were deemed outliers. The scores were then tabulated, and an average was produced.

Subsequently, a weight based on the criteria was produced, from 1 – 10, through the same method the score was achieved. Both scores and weights were presented in the MCA tables.

<u>Technology Criteria</u>

The technologies are prioritized across a range of ten criteria. The priority of the technology for each criterion is assessed and deduced individually during the MCA process.

Changes made to the criteria during a previous workshop *(refer to Section 4.5)* were presented to the SWG and accepted.

5.5. TECHNOLOGY PRIORITIZATION RESULTS

Scoring Matrix and Results

Transportation Sector Workshop - Wednesday 24th, July 2019

Table 17: Scoring Matrix of Category Technologies

Scoring Matrix

	Costs			Benefits										Other			
				Economic			Social			Environmental			Climate related	Institutional/Implementation		Political	
	Cost to set up and operate the technology per beneficiary /year				Country economic development and economic benefit		Background notes & short description of the technology	Country social development priorities	Social Benefit	mitigation How does this technology contributes to	Environmental Benefits		Upscaling	How does this technology would be diffused access the sub sector	Disadvantages or Barriers	Coherence with national development policies and priority	
Criteria	4				6		1	5	7	2	8		10	3	9	11	
Efficiency in Transport Sector	45				43			65	71	64	73		69	44	38	71	
Integrated Public Transport	44				66			75	80	74	71		69	54	45	63	
Alternate Fuels & Biofuels	34				86			75	85	86	93		84	62	38	77	
Hybrid Electric Vehicles (HEV)	54				87			77	78	87	85		85	65	41	78	
Improvement of Road Infrastructure	22				89			83	84	54	76		83	67	38	70	
Scoring scale	0=very high cost --> 100=very low cost				0= Very low --> 100= Very high		0= Very low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high	0=Very Difficult -->100=Very Easy	0=Very Difficult -->100=Very Easy	0=Very Difficult -->100=Very Easy	0= Very low --> 100= Very high	
Criterion weight	15				13		0	8	8	18	12	0	5	8	7	6	100
Criterion weight, sensitivity	15				13		0	8	8	18	12	0	5	8	7	6	100

Decision Matrix: Weighted Scores																	
	Costs			Benefits										Other			
				Economic			Social			Environmental			Climate related	Institutional/Implementation		Political	
	Cost to set up and operate the technology per beneficiary /year	0	0	0	Country economic development and economic benefit	0	Background notes & short description of the technology	Country social development priorities	Social Benefit	mitigation How does this technology contributes to	Environmental Benefits	0	Upscaling	How does this technology would be diffused access the sub sector	Disadvantages or Barriers	Coherence with national development policies and priority	Total Benefit
Efficiency in Transport Sector	675	0	0	0	559	0	0	520	568	1152	876	0	345	352	266	426	5739
Integrated Public	660	0	0	0	858	0	0	600	640	1332	852	0	345	432	315	378	6412
Alternate Fuels &	510	0	0	0	1118	0	0	600	680	1548	1116	0	420	496	266	462	7216
Hybrid Electric Vehicles (HEV)	810	0	0	0	1131	0	0	616	624	1566	1020	0	425	520	287	468	7467
Improvement of Road Infrastructure	330	0	0	0	1157	0	0	664	672	972	912	0	415	536	266	420	6344
Criterion weight	15	0	0	0	13	0	0	8	8	18	12	0	5	8	7	6	100

Step 1: Add your criteria: D7 - M7
Step 2: Add your options: A7 - A16
Step 3: Add criteria weights: B18 - M18
Step 4: Rate how well the options contribute to each criterion: B7 - M16
Step 5: View weighted results and total benefit results in second table, 'Weighted Scores': B24 - M33
Note: You may need more or less rows for technology options or columns for criteria. Just add/delete them within the framework provided.

Table 18: Results of Technology 1 – Efficiency in Transport Sector

TECH 1 - EFFICIENCY IN TRANSPORT SECTOR										
CRITERIA	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	**AVE**
	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	**SCORE**
2	60	60	50	60	60	60	75	80	75	**64**
3	50	50	30	20	40	60	30	60	57	**44**
4	70	30	75	50	40	20	25	50		**45**
5	40	50	70	80	70	80	50	80		**65**
6	40	20	70	30	60	70	80	95		**58**
7	60	60	70	80	81	81	80	60		**72**
8	60	95	80	20	80	85	81	80		**73**
9	40	40	20	50	40	50	50	15	40	**38**
10	60	80	70	60	61	65	70	85		**69**
11	80	80	40	50	80	80	70	90		**71**

Table 19: Results of Technology 2 – Integrated Public Transport

TECH 2 - INTEGRATED PUBLIC TRANSPORT											
CRITERIA	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	SH10	**AVE**
	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	**SCORE**
2	68	75	90	70	65	75	75	85	60	81	**74**
3	60	80	40	60	60	41	20	80	50	50	**54**
4	50	60	35	35	60	30	50	40	35	40	**44**
5	80	65	90	70	75	60	90	75	70	70	**75**
6	85	50	85	85	75	60	90	75	60	80	**75**
7	85	70	90	90	80	80	90	80	65	70	**80**
8	80	80	95	80	90	65	75	80	65	81	**79**
9	50	40	30	35	60	50	30	50	70	30	**45**
10	61	40	85	60	85	50	80	65	80	80	**69**
11	65	75	90	60	80	80	5	30	70	75	**63**

Table 20: Results of Technology 3 – Alternate Fuels & Biofuels

TECH 3 - ALTERNATE FUELS & BIOFUELS										
CRITERIA	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	**AVE**
	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	**SCORE**
2	81	90	95	76	75	75	100	95	90	**86**
3	50	70	50	75	80	50	60	75	50	**62**
4	20	55	20	10	50	30	40	50	35	**34**
5	80	85	80	75	85	60	100	80	30	**75**
6	85	85	95	85	90	70	100	80	85	**86**
7	85	90	95	90	85	70	100	90	65	**86**
8	85	100	95	85	95	95	100	95	90	**93**
9	65	40	20	30	60	40	30	40	20	**38**
10	75	90	95	85	85	70	100	70	90	**84**
11	70	90	90	95	80	80	40	60	90	**77**

Table 21: Results of Technology 4 – Efficiency in Transport Sector

TECH 4 - HYBRID ELECTRIC VEHICLES (HEV)											
CRITERIA	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	SH10	**AVE**
	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	**SCORE**
2	81	100	95	79	81	90	100	85	80	80	**87**
3	61	50	75	85	60	50	70	80	65	55	**65**
4	50	50	50	55	40	50	50	70	60	60	**54**
5	85	70	80	99	70	70	100	85	75	40	**77**
6	80	75	96	90	90	90	100	85	75	85	**87**
7	75	75	90	85	80	60	100	80	70	60	**78**
8	60	80	90	80	85	95	100	95	85	80	**85**
9	80	30	30	20	50	40	20	50	40	50	**41**
10	80	90	95	89	80	70	100	80	80	90	**85**
11	75	60	90	75	85	80	70	75	80	90	**78**

Table 22: Results of Technology 5 – Improvement of Road Infrastructure

TECH 5 - IMPROVEMENT OF ROAD INFRASTRUCTURE										
CRITERIA	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	**AVE**
	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	**SCORE**
2	50	30	50	60	60	65	60	50	60	**54**
3	81	70	60	50	80	95	40	40	90	**67**
4	35	30	10	20	15	20	5	30	30	**22**
5	100	70	90	80	85	100	70	60	95	**83**
6	90	70	90	90	95	100	95	85	90	**89**
7	85	70	90	95	95	100	80	40	100	**84**
8	70	80	60	80	85	90	95	40	85	**76**
9	50	55	30	40	45	35	10	30	50	**38**
10	90	85	90	80	85	70	75	90	80	**83**
11	100	80	70	80	80	80	5	50	85	**70**

Table 23: Weighting of the Criteria

WEIGHTING OF THE CRITERIA											
CRITERIA	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	SH10	**AVE**
	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	SCORE	**SCORE**
2	10	25	20	22	21	15	20	10	10	25	**18**
3	10	10	10	5	15	5	10	10	4	5	**8**
4	20	10	15	5	20	10	15	20	10	20	**15**
5	5	10	10	10	5	10	5	10	10	5	**8**
6	15	15	10	10	5	20	10	15	16	10	**13**
7	5	5	10	10	5	5	10	10	15	5	**8**
8	10	5	10	22	10	20	10	10	13	5	**12**
9	10	5	5	5	10	5	5	5	6	10	**7**
10	5	10	5	10	5	3	5	5	1	10	**5**
11	10	5	5	1	4	7	10	5	15	5	**6**
										Total	**100**

Scores	Attainment Description
81 - 100	H: High
61 -80	MH: Medium High
41 -60	M: Medium
21- 40	ML: Medium Low
1 - 20	L: Low
0	VL: Very Low

Table 25 provides a summary of five (5) technologies prioritized for the Transport Sector.

Table 24: Summary of Prioritization Results

Improvement of Road Infrastructure	
Prioritization Category # 1	
Description	Road infrastructure consists of fixed assets including surface road, storm water drainage, pedestrian paths and vehicle pull-off stops. The improvement of these carriageways allows smoother flow of vehicles, etc. along these carriageways reduces travel time, improves safety for both traffic and pedestrian use, improves efficiency and generates employment in sectors as aggregate influences the aggregate demand for goods and services which ultimately leads to increase in growth in the economy and development.
Benefits	• Policy decisions at the Political level influences the Public Works Department's decisions on upgrading existing road infrastructure and providing both surface and subsurface storm water drainage which leads to job creation, thus, positively affecting poverty outcomes and stimulating economic growth. This provides a co-benefit factor in adaptation through climate change • Road infrastructure development fights against poverty by providing access to employment, social, health and education services. • Roads also open up more areas and stimulate economic and social development. • A direct positive result of road infrastructure development is the Improvement of fuel efficiency, reduction of wear and tear and also the reduction tailpipe emission of CO_2 due to an efficient road surface. Hence, this climate change through mitigation is a beneficial factor which contributes also in a co-benefit economic relationship. • There would be a general reduction in noise, dust, vibrations and waste along the carriageways. • The improvement of road infrastructure would contribute to increased resilience in the road sector and socioeconomic development of Antigua and Barbuda.
Hybrid Electric Vehicles	
Prioritization Category # 2A	
Description	The hybrid electric vehicle (HEV) is a type of hybrid vehicle that combines a conventional internal combustion engine (ICE) system with an electric propulsion system (hybrid vehicle drivetrain). The HEV provides an illustration of one of the fundamental laws of energy, where potential energy is converted into kinetic energy to provide electricity. Electric vehicles are the most efficient vehicles.
Benefits	• Hybrid electric vehicles offer a proven technology that can replace the use of fossil fuel generated motor vehicle use through direct replacement. • Vehicles employed in urban areas like small passenger cars, local delivery trucks and city busses benefit from hybridization. Lowest tailpipe emission of CO_2 depending on the traffic dynamics i.e. 23 -43% reduction in emissions. They have the advantage of higher fuel efficiency and reduced CO_2 emissions without additional infrastructure requirements (Canes, n.d.).

Battery Electric Vehicles BEV	
Prioritization Category # 2B	
Description	A battery electric vehicle (BEV) is an electric vehicle that utilises chemical energy that is stored in rechargeable battery packs. Battery electric vehicles are the least complicated of the technologies that are under consideration for road transport, with considerably fewer component parts than a conventional ICEV – no ignition system and no gearbox, for example (Science Direct, n.d.).
Benefits	● Battery electric vehicle (BEV) offer the potential to reduce the CO_2 emissions of the traffic sector and the dependence on fossil fuel oil. The reasons for this are the higher efficiency of electric power trains and the possibility of using renewably generated electricity for transportation (Science Direct, n.d.). ● Once made readily available to the wide spectrum of the public sector underscoring the cost, all the existing transport benefits alluded for the electric vehicle imports can further benefit the consumer. ● The island's gentle rolling topography supports the use of the BEV Island wide. Where there are significant challenges for battery power of steep grades, it would be well supported in Antigua and Barbuda. ● The low cost of electric transport as indicated by AECOM estimated the lifecycle cost of electric cars to be up to US$2 per 100km less than equivalent petroleum vehicles, with the cost saving predicted to exceed US$10 per 100km in 2040 (Saltar et al, 2011). ● Zero tailpipe emissions. ● BEVs are a pathway to achieving a sustainable transportation industry by reducing emissions of greenhouse gases while increasing energy security ● The use of renewable energy power supply charging station sources is complemented by the availability of a varying range of manufactured infrastructures which supports the BEV industry which takes advantage of all year availability of a steady source of sunshine and wind energy. Having this condition met and achieved would justify zero emissions on BEVs
Solar Powered Renewable Charging Station	
Prioritization Category # 3	
Description	Non-oil energy sources account for more than 50 percent of the increase of energy used in transport. The provision of Solar renewable charging stations is a technology which is fully autonomous, mobile, and 100 percent solar charged EV station. The European Photovoltaic Industry Association states that solar power could provide energy for more than one billion people by 2020 and 26 percent of global energy needs by 2040.
Benefits	● Less reliance on the importation of fossil fuel-based products retains the island's foreign reserves, which could be used to invest in more efficient energy technologies, reducing GHG emissions to zero because of its rechargeable power source. Having renewable solar charging stations dotted throughout the island, directly reduces the use of fossil fuel dependency once an active influx of EVs are in use across the transport sector. ● Lower CO_2 and air pollutants from the road transport sector

Integrated Public Transport	
Prioritization Category # 4	
Description	This technology is the organizational process through which the planning and other systems are associated regardless of transportation mode, providers and institutions with the aim to increase economic and social benefits. T*he process of integration includes* many *partial steps* and each of these *steps* can *contribute differently to the success of integrated transport system (ITS)*.
Benefits	● Establishing a fixed route service encourages commerce activities along the route. ● The outcome of the IPT is to give the regular public transport users increase level of service, attract some of the users to hold special access permits and contribute to an efficient coat efficient public transport. ● Public transit is an effective means for reducing GHG emissions without requiring a large capital investment once used by the public at large. ● Once used by people who see the benefit of commuting on Public transportation, the number of cars will be reduced, thus improving air quality and alleviating traffic congestion, noise and the amount of tailpipe emissions associated with those vehicles. Through these mitigation measures, incremental positives are achieved to offset climate change. ● One of our focuses is the importance of using the IPT system to take care of the early and disabled. Single transit vehicles can use more fuel than a private vehicle and the average amount of energy used per passenger is far less than a single-occupancy vehicle. Using public transportation can help individuals lower their personal carbon footprint and reduce their transportation-related emissions.
Efficiency in Transport Sector	
Prioritization Category # 5	
Description	The IEA states that through GHG reduction methods there are four policies which can improve the efficiency within the transport sector, which are improving tire energy efficiency, fuel economy standards for light vehicles, fuel economy standards for heavy duty vehicles and eco-driving.
Benefits	● Healthier transport strategies can lead to health equity gains by providing vulnerable groups, such as low-wage earners, women and the elderly with greater access to social and economic opportunities, services, food markets, education and social and recreational outlets for the broader public. ● Enhancing public transport can bring social inclusion benefits by providing new or additional services to areas not previously well-served, as well as improving accessibility levels for less able travellers. Free and concessionary fares can also help address affordability issues for some groups in society. ● Safe, equitable and energy-efficient urban transport can help achieve multiple health and sustainability goals. ● Eco-driving can contribute to better safety, reduce noise and stress. There are eco-driving programmers, which are integral for road safety programs like the popular radio show “Drive Time” in the island of Montserrat. Improvements in levels of emissions and air quality from moving to newer, higher quality public transport vehicles. Policies that improve the energy efficiency of urban transport systems could help save as much as USD 70 trillion in spending on vehicles, fuel and transportation infrastructure between now and 2050, according to a new report from the International Energy Agency.

6. SUMMARY AND CONCLUSIONS

6.1. PROCESS OVERVIEW

6.1.1. Summary

Upon initiating the TNA process, a long list of technologies was established, which was solely selected in the interest of the island's technology transfer determinations for climate change through adoption. SWG sessions were held to facilitate the prioritization process, which included the initial screening workshop and an intensive MCA workshop. TAC endorsement was sought at every stage of the process and the final lists of chosen technologies are representative of a shared country vision to meet adaptation and mitigation targets.

6.1.2. Chosen Technologies

<u>Water Sector:</u>

The initial TNA step for Antigua and Barbuda's water sector involved a two-step technology selection and prioritization process. An initial literature review was used to generate the long list of twelve (12) probable technologies, and these were presented to SWGs for pre-screening. Stakeholders used disseminated information and value judgements garnered from their understanding of the local context to generate a short list which was reviewed by the TNA Coordinator and TAC before being taken through a multi-criteria analysis. During the MCA, detailed factsheets and spirited discussions assisted in final technology prioritization.

UDP's resources were used to guide this prioritization process and all final decisions were achieved through the input and consensus of the sectoral working groups and the TAC. This successful participatory process resulted in five (5) climate technologies being chosen for their potential to build resilience and aid in achieving national development and adaptation goals. All technologies on this final list are suitable for potable applications, and three (3) could be specifically adapted for non-potable *(see Table 26).*

Table 25: Final Technology List – Water Sector

TECHNOLOGY OPTIONS	POTABLE	NON-POTABLE
Solar Pumping Systems	X	X
Rainwater Harvesting	X	X
Water Savers	X	
Climate-proofing Assets	X	
Stormwater Reclamation and Reuse	X	X

Building Sector:

A similar process was followed for the building sector and the results in *Table 27* represent the list of technologies chosen from the initial list of ten (10) to progress to Step 2.

Table 26: Final Technology List - Building Sector

Item	Technology
1	Impact Doors and Windows
2	Best Pitch Roof Angle
3	Passive House
4	High Efficiency Lighting Systems (Merge with LED Task Lighting #10 now as LED Lighting)
5	Construction Energy Efficiency Infrastructure

Transport Sector:

The transport sector discussions began with a list of nine (9) technologies of which the five (5) listed in *Table 28* have been chosen for Step 2.

Table 27: Final Technology List - Transportation Sector

Item	Technology
1	Improvement of Road Infrastructure
2	Hybrid Electric Vehicle (Replaced with Battery Electric Vehicle: TAC Decision)
3	Solar Renewable Charging Station
4	Integrated Public Transport
5	Efficiency in the Transport Sector

N.B: Refer to tables 18 -24 for scores and analysis

6.1.3. Preview of TNA Stages 2 and 3

The prioritized technologies have been reviewed by Technical Advisory Committee (TAC) and have been approved to move forward into Stage 2 of the TNA process. The *Barrier Analysis and Enabling Framework* procedure will analyse local market conditions for each technology, and identify existing environmental, financial, social, technological, and policy barriers likely to affect diffusion in the Antiguan and Barbudan context. Outcomes will ultimately lead to the preparation of a Technology Action Plan (TAP) and the development of a concept note to target funding for technology transfer.

6.2. CONCLUSIONS AND RECOMMENDATIONS

On completion of a successful Stage 1, it can be concluded that the preceding stages will be enhanced through maintaining a higher level of stakeholder participation. Recommendations for the BAEF stage include:

- Encouraging increased private sector stakeholder involvement in SWGs workshops;
- Promoting private sector ownership of technology diffusion, thus paving the way for introducing new technologies into the Antiguan and Barbudan market;

- Engaging community influencers to support knowledge transfer, informing the populace of key activities in the TNA process; and
- Keeping decision makers informed, involved, and committed to the TNA process by continuously highlighting longer term benefits to the state.

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APPENDIX A: ORGANIZATIONS REPRESENTED ON THE TECHNICAL ADVISORY COMMITTEE

ORGANISATION
Community Development Division
GEF Small Grants Programme MEPA Trust
Development Control Authority (DCA)
Fisheries Division
GARD Centre
National Solid Waste Management Authority
Antigua Barbuda Investment Authority
Antigua and Barbuda Transport Board
Ministry of Tourism
National Parks Authority
MET Office
Statistics Division
Ministry of Energy
Ministry of Works and Housing
Environmental Awareness Group
Fauna-Flora International
National Office of Disaster Services
Bureau of Standards
Ministry of Agriculture
Ministry of Health, Wellness and the Environment
APUA, Water Division
Department of the Environment

APPENDIX B: TNA INFORMATION PRODUCTS

Water Sector: Flyer

UNEP DTU PARTNERSHIP

TNA TECHNOLOGY NEEDS ASSESSMENT

Antigua and Barbuda's NDCs have specified *adaptation* targets in the WATER sector, and *mitigation* targets in the TRANSPORTATION and BUILDING sectors.

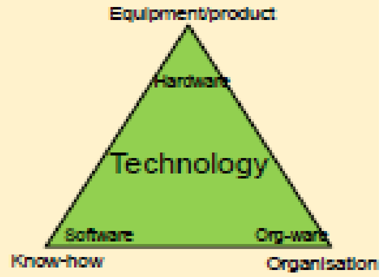
THREE STEP TNA PROCESS:

- **TECHNOLOGY ASSESSMENT**
  Identify and prioritize mitigation and adaptation technologies for the selected target sectors.
- **BARRIED ANALYSIS AND ENABLING FRAMEWORK**
  Identify, analyse and address potential barriers that will hinder the deployment and diffusion, and develop enabling frameworkls to overcome these barriers for the prioritized technologies.
- **TECHNOLOGY ACTION PLAN**
  Draw up a Technology Action Plan with suggested actions presented with the form of practical project ideas.

A **Technology Needs Assessment** is a set of country-driven, participatory activities leading to the identification of ***climate technologies*** in order to *reduce greenhouse gas emissions (mitigation)*, or *reduce vulnerability to climate change (adaptation)*. The TNA is designed to be integrated with similar ongoing processes that support and promote national sustainable development, such as the *National Determined Contributions (NDCs).*

The UNFCCC Intergovernmental Panel on Climate Change defines a ***climate technology as a piece of equipment, technique, practical knowledge or skill utilized for performing a particular (adaptation or mitigation) activity.***

The three distinguishable components of each ***climate technology*** are shown in pyramid and further explained for the adaptation technology ***drip irrigation***:



- **HARDWARE** – tangible component such as equipment and/or products, such as *perforated hoses or pipes, pumps, water source , storage tanks etc.*
- **SOFTWARE** – processes associated with the use of the hardware ... *the knowledge and training necessary for installation, operation and maintenance*
- **ORGWARE** – institutional framework or organization involved in the adoption and diffusion of the technology ... *commercial farm or community farming cooperative or irrigation scheme user groups*

Overall **TNA PROJECT OUTCOMES** vary based on a country's sustainable development progress. In Antigua and Barbuda:

- **Actions** outlined in the Technology Action Plan will contribute to the development of the *National Adaptation Plan* and *Nationally Appropriate Mitigation Action.*
- **Project ideas** will be used to draw up tangible proposals as a step towards implementing investment-ready projects that target national or international funding agencies.
- **Sectoral policy briefs** will be developed and national dissemination supported to educate the public and engagement potential donors.

Identifying and engaging stakeholders is a fundamental aspect of the TNA process which was designed to be collaborative and participatory. Relevant parties with an interest in or who will be affected by the process or its outcomes have been identified as ***stakeholders***. The consultation process is also ***gender-sensitive*** in its process and content, and will consider the perspectives of women and men to ensure that both have an opportunity to make contributions.

Building and Transport Sectors: Flyer

UNEP DTU PARTNERSHIP

TNA TECHNOLOGY NEEDS ASSESSMENT

Antigua and Barbuda's NDCs have specified *adaptation* targets in the **WATER** sector, and *mitigation* targets in the **TRANSPORTATION** and **BUILDING** sectors.

THREE STEP TNA PROCESS:

- **TECHNOLOGY ASSESSMENT**
  Identify and prioritize mitigation and adaptation technologies for the selected target sectors.
- **BARRIED ANALYSIS AND ENABLING FRAMEWORK**
  Identify, analyse and address potential barriers that will hinder the deployment and diffusion, and develop enabling framework/s to overcome these barriers for the prioritized technologies.
- **TECHNOLOGYACTION PLAN**
  Draw up a Technology Action Plan with suggested actions presented with the form of practical project ideas.

A **Technology Needs Assessment** is a set of country-driven, participatory activities leading to the identification of ***climate technologies*** in order to *reduce greenhouse gas emissions (mitigation)*, or *reduce vulnerability to climate change (adaptation)*. The TNA is designed to be integrated with similar ongoing processes that support and promote national sustainable development, such as the *National Determined Contributions (NDCs)*.

The UNFCCC Intergovernmental Panel on Climate Change defines a ***climate technology*** as ***a piece of equipment, technique, practical knowledge or skill utilized for performing a particular (adaptation or mitigation) activity.***

The three distinguishable components of each ***climate technology*** are shown in pyramid and further explained for the mitigation technology ***electric vehicles***:

- **HARDWARE** – tangible component such as equipment and/or products, such as *electric vehicles, charging stations, batteries etc.*
- **SOFTWARE** – processes associated with the use of the hardware ... *the knowledge and training necessary for optimal operation and maintenance for electric motors*
- **ORGWARE** – institutional framework or organization involved in the adoption and diffusion of the technology ... *EV dealerships, potential consumer base, specialized automotive mechanics*

Overall **TNA PROJECT OUTCOMES** vary based on a country's sustainable development progress. In Antigua and Barbuda:

- **Actions** outlined in the Technology Action Plan will contribute to the development of national plans and meeting our environmental targets
- **Project ideas** will be used to draw up tangible proposals as a step towards implementing investment-ready projects that target national or international funding agencies.
- **Sectoral policy briefs** will be developed and national dissemination supported to educate the public and engagement potential donors.

Identifying and engaging stakeholders is a fundamental aspect of the TNA process which was designed to be collaborative and participatory. Relevant parties with an interest in or who will be affected by the process or its outcomes have been identified as ***stakeholders***. The consultation process is also ***gender-sensitive*** in its process and content, and will consider the perspectives of women and men to ensure that both have an opportunity to make contributions.

DEPARTMENT of ENVIRONMENT Antigua and Barbuda

APPENDIX C: TNA WORKSHOP ATTENDANCE

Water Sector: June 18, 2019

	NAME	DESIGNATION	ORGANIZATION
1.	Camaria Holder	TNA Consultant	
2.	Jamila Gregory	TNA Coordinator/ Project Development Associate	Dept. of the Environment
3.	Amira McDonald	Project Assistant	Dept. of the Environment
4.	William Keith Thomas	TNA Consultant	KTEC
5.	Mackisha Calvert	Accounts Dept	Island Coolers
6.	McClure Simon	Engineer	APUA – Water Division
7.	Keanna Payne	Community Member	Barnes Hill Community Dev. Org.
8.	Martin Cave	Executive Director	Antigua/Barbuda Chamber of Commerce
9.	Tajah Edwards	Srn. Public Health Inspector	Central Board of Health
10.	Rashauna Adams-Matthew	Environment Social Safeguard Officer	Dept. of the Environment
11.	Ato Lewis	Senior Environment Officer	Dept. of the Environment
12.	D'Kaboo Brann	Community Outreach	Dept. of the Environment
13.	Robyn Browne	Project Assistant	Dept. of the Environment

Water Sector: July 23, 2019

	NAME	DESIGNATION	ORGANIZATION
1.	Camaria Holder	TNA Consultant	
2.	Jamila Gregory	TNA Coordinator/ Project Development Associate	Dept. of the Environment
3.	Amira McDonald	Project Assistant	Dept. of the Environment
4.	William Keith Thomas	TNA Consultant	KTEC
5.	Jael Lewis	Community Member	Barnes Hill Community Dev. Org.
6.	Sharon Dalso	Community Development Officer	Community Development Div.
7.	Hastin Barnes	Engineer	APUA – Water Division
8.	Martin Cave	Executive Director	Antigua/Barbuda Chamber of Commerce
9.	Ogden Burton	Park Manager	Codrington Barbuda/ DOE
10.	Ato Lewis	Senior Environment Officer	Dept. of the Environment
11.	Kelly Hedges		Dept. of the Environment
12.	Arry Simon		Dept. of the Environment

13.	Ameera Ramdin	Technical Data Consultant	Dept. of the Environment
14.	Daryl George		Dept. of the Environment

Building and Transport Sectors: June 13, 2019

	NAME	DESIGNATION	ORGANIZATION
1.	Jamila Gregory	TNA Coordinator/ Project Development Associate	Dept. of the Environment
2.	Amira McDonald	Project Assistant	Dept. of the Environment
3.	William Keith Thomas	TNA Consultant	KTEC
4.	Jovita White	Secretary	KTEC
5.	Shayon Cordington	Engineer	Ministry of Works
6.	Ogden Burton	Park Manager	Codrington Barbuda/ DOE
7.	Eli Fuller	Operations Manager	Adventure Antigua
8.	Laurent Gilkes	President	Antigua/Barbuda Contractors Association
9.	Alex Piggot	President	Antigua/Barbuda Institute of Architects
10.	Trevor Gonsalves	Engineer	Antigua/Barbuda Engineers Association
11.	Arif Jonas		Antigua/Barbuda Transport Board
12.	Mali Barnes	Energy Officer	Ministry of Energy
13.	Itajah Simmons	Energy Officer	Ministry of Energy
14.	Sherrod James	Deputy Director	National Office of Disaster Services
15.	Cashel Stewart	Technical Officer	Dept. of the Environment
16.	Joan Sampson	Project Coordinator	Dept. of the Environment
17.	D'Kaboo Brann	Community Outreach	Dept. of the Environment
18.	Shema Roberts	Environment Officer	Dept. of the Environment
19.	Ameera Ramdin	Technical Data Consultant	Dept. of the Environment
20.	Bryan Payne	Project Technical Officer	Dept. of the Environment
21.	Martin Barriteau	Project Coordinator	Dept. of the Environment
22	Robyn Browne	Project Assistant	Dept. of the Environment

Building Sector: July 25, 2019

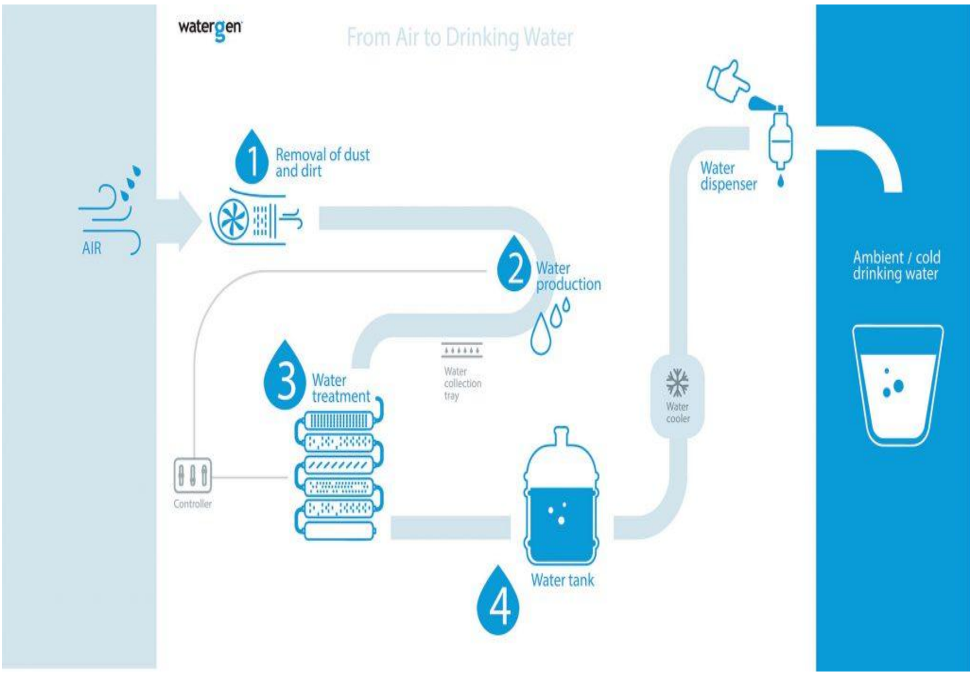
	NAME	DESIGNATION	ORGANIZATION
1.	Jamila Gregory	TNA Coordinator/ Project Development Associate	Dept. of the Environment
2.	Amira McDonald	Project Assistant	Dept. of the Environment
3.	William Keith Thomas	TNA Consultant	KTEC
4.	Camaria Holder	TNA Consultant	
5.	Sharon Dalso	Community Development Officer	Community Development Div.
6.	Ogden Burton	Park Manager	Codrington Barbuda/ DOE
7.	Lennox Doran	Representation	CHAPA/BAU Panel
8.	Martin Barriteau	Project Coordinator	Dept. of the Environment
9.	Joan Sampson	Project Coordinator	Dept. of the Environment
10.	Ato Lewis	Senior Environment Officer	Dept. of the Environment
11.	Adien Greenoway		Dept. of the Environment
12.	Arry Simon		Dept. of the Environment
13.	Kelly Hedges		Dept. of the Environment

Transport Sector: July 24, 2019

	NAME	DESIGNATION	ORGANIZATION
1.	Jamila Gregory	TNA Coordinator/ Project Development Associate	Dept. of the Environment
2.	Amira McDonald	Project Assistant	Dept. of the Environment
3.	William Keith Thomas	TNA Consultant	KTEC
4.	Camaria Holder	TNA Consultant	
5.	Sharon Dalso	Community Development Officer	Community Development Div.
6.	Ogden Burton	Park Manager	Codrington Barbuda/ DOE
7.	Vashti Casimir	Representative	Ministry of Tourism
8.	Stanley Barreto	Representative	Mega Power Antigua
9.	Ian Joseph	Representative	United Taxi Association
10.	Melisa Jno Baptiste	Representative	United Taxi Association
11.	Mali Barnes	Energy Officer	Ministry of Energy
12.	Jaquasha Tegaue	Representative	Development Control Authority
13.	Arif Jonas		Antigua/Barbuda Transport Board
14.	Bryan Payne	Project Technical Officer	Dept. of the Environment
13.	Kelly Hedges		Dept. of the Environment

APPENDIX D: WATER SECTOR FACTSHEETS

TECHNOLOGY FACTSHEET

TECHNOLOGY NAME:	**ATMOSPHERIC WATER GENERATORS "AWGS/WATER MAKERS"**
SECTOR:	**WATER SECTOR**
SUB-SECTOR:	☒ Potable; ☐ Non-potable
SCALE:	Residential and Commercial
TIMELINE FOR OBSERVED IMPACT:	☒ Short-term; ☒ Medium-term; ☐ Longer-term
TECHNOLOGY CHARACTERISTICS	
INTRODUCTION:	**Atmospheric Water Generators** produce potable water by extracting vapor from humid, ambient air – either by condensation or exposing the air to desiccants. In modern water makers vapour from the air is drawn into the external/roof-mounted unit and adsorbed into a specialized desiccant. Water is then desorbed and condensed into droplets. The liquid is piped into a tank where it receives up to three levels of treatment before the purified drinking water is dispensed at a tap or cooler. Some water makers are solar powered and can even be fitted with network-connected water quality monitoring systems.[23,24]  Source: Watergen USA

[23] SOURCE Perfect water for every person, every place. Zero Mass Water, www.zeromasswater.com

[24] Genius Technology Energy efficient heat transfer and dehumidifying technologies. Watergen USA, https://www.watergenusa.com/technology-2/technology/

Three (3) types of water makers and their applications in the local context are:

TYPE	SPECIFICATIONS	APPLICATIONS
Home and Office Appliance *(Hot and Cold)*	▪ Water Generation: 2.5 – 7gpd ▪ Storage Capacity: 5 – 15 gallons ▪ Dimensions: 1.7’x1.3’x4.3’ ▪ Power: 120V OR 4’x8’ solar panel ▪ Weight: 155lbs	▪ Homes ▪ Schools/Offices ▪ Clinics
Medium Scale (Emergency Response/Trailer)	▪ Water Generation: ~225gpd ▪ Storage Capacity: 50 gallons ▪ Dimensions: 4.5’x4.5’x5.8’ ▪ Power Consumption: 5.6kW/H ▪ Weight: 1,700lbs **Mobile Add-ons:** customized heavy-duty trailer | 18KVA diesel generator | 130g fuel tank | 375gal reservoir | emergency lighting	▪ Clinics ▪ Schools ▪ Hurricane Shelters ▪ Relief Tents
Large Scale *(per module)*	▪ Water Generation: ~1,300gpd ▪ Storage Capacity: N/A ▪ Dimensions: 10’x10’x7’ ▪ Power Consumption: 60kW/H (3Ph power required) ▪ Weight: 6,000lbs **Add-ons:** Standby generator | storage tanks | Shelter/shed	▪ Remote areas (Codrington) ▪ Hospitals

STATUS IN-COUNTRY:

There are no *known* atmospheric water generators installed in country.

ACCEPTABILITY:

Water makers will have to be introduced. It is presumed that they will be well received as an option to lessen dependency on bottled water and provide safe drinking water following disasters.

INSTITUTIONAL/ ORGANIZATIONAL REQUIREMENTS:

AWGs can be implemented on an individual/institutional basis without direct backing of a national entity. However, longer term success will require support from local organizations with the technical know-how for installation, operation maintenance. Systems retained by national entities – NODS, APUA, Barbuda Council – for deployment after a climate emergency, will require budgetary allocations by the state government for their operation and maintenance.

COSTS

CAPITAL COSTS:

Water makers are increasing in popularity, with reputable brands marketed internationally. The table below gives estimated pricing per unit:

DEVICE	COST (USD$)	*COST (XCD$)
Home and Office Appliances	$2,185	$9,795.15
Medium Scale (Emergency Response/Trailer)	$37,500 $145,000	$152,825.65 $590,925.75
Large Scale	$197,500	$804,881.65

*Estimated retail price per unit in Antigua and Barbuda

OPERATION AND MAINTENANCE:

Water Generation Efficiency ranges from USD$0.08 to USD$0.15/US gallon OR XCD$0.35 to XCD$0.68/ US gallon | 750Wh/g – 1.325kWh/g. The amortization period for the medium to large-scale systems is approximately 15 years. Larger units require minimum maintenance, with twice yearly filter and UV lamps changes costing approximately USD$375 OR XCD$1,685.

ADDITIONAL/ MISC.:	Large-scale systems are not fitted with storage tanks. Water is either piped into the existing infrastructure or separate storage will have to be installed.

IMPACTS AND BENEFITS	
DIRECT:	▪ Affordable, renewable source of clean, fresh drinking water. ▪ Water quality meets WHO standards for drinking water and is approved for use in medical facilities. ▪ Eliminates the need to refill, store and replace 5-gallon water bottles. ▪ Mobile water trailers designed for emergencies/extreme weather events, produce and dispense water in areas without grid electricity, thus supporting quicker on-streaming of essential services following disasters. ▪ Units are modular and scalable, can be used to create *water farms* in drought prone areas.
INDIRECT:	▪ Not vulnerable to negative environmental influences, positively impacts the environment by reducing reliance of plastic water bottles *(reducing plastic waste)*. ▪ Decreases government expenditure for bottled water in public buildings, clinics and hospitals. ▪ Provides new business/job opportunities.
LOCAL CONTEXT	
OPPORTUNITIES:	Atmospheric water generators installed in schools and national health facilities will further support achievement of SDG6, thus creating opportunities for increased functionality of these institutions – especially during drought periods. Although AWGs are promoted primarily for disaster relief and sustainable development applications, the Utility can explore their use as an alternative for water production. *Water farms,* supported by solar PV grid-tied systems to offset energy requirements, can produce potable water for a fraction of the price of desalination.
BARRIERS:	Concerns about performance and reliability, along with support for repair and maintenance of this technology might prohibit adoption. AWGs may also present a threat to bottled water companies and the livelihoods they provide for nationals.
MARKET POTENTIAL:	Atmospheric water generators will provide new business opportunities for both suppliers and service technicians.

TECHNOLOGY FACTSHEET

TECHNOLOGY NAME:	**CLIMATE-PROOFING ASSETS "RESILIENT INFRASTRUCTURE"**
SECTOR:	**WATER SECTOR**
SUB-SECTOR:	☒ Potable; ☐ Non-potable
SCALE:	Municipal
TIMELINE FOR OBSERVED IMPACT:	☐ Short-term; ☒ Medium-term; ☒ Longer-term
TECHNOLOGY CHARACTERISTICS	
INTRODUCTION:	**Climate-resilient infrastructure** reduces but may not fully eliminate disruptions to the Utility's service, cause by climate-related risk factors. This will potentially improve reliability of service and increase asset life, by addressing the extent to which climate change translates into risks to infrastructure. **Climate proofing** critical water sector assets involves assessing *exposure* and *vulnerability*, developing risk management plans and systematically de-risking (building resilience in) the Utility. Adverse effects of climate change predicted for the Caribbean region includes frequent and intense hurricanes, unpredictable but extreme rainfall *(flooding rains)*, increased temperature and sea level rise, which translates into growing operational and maintenance cost for APUA. Surface and ground water stores have become increasing unreliable, while coastal desalination facilities are susceptible to storm damage. Comprehensive de-risking must address every stage of the supply process, therefore, managing physical assets *(addressed here)* – desalination facilities, pump stations, pipelines etc. – will be a *part* of a more global, dynamic process. Climate-smart asset management will include: ▪ Protecting desalination facilities from storm surges and hurricane force winds, this will address **all** related infrastructure such as, intake lines, outfalls, RO plant, building, electricals etc. ▪ Relocating pipelines to accommodate storm surges, flooding and/or erosion. ▪ Moving pumps and/or pumping stations to higher elevations.
STATUS IN-COUNTRY:	The Utility and the Government are highly aware of the need to address resilience in the water sector. Outside of APUA's regular business development planning, there are ongoing projects to comprehensively address de-risking, this includes a concept note – *Sustainable Integrated Water Resources Management to Build Resilience to Climate Change in the Water Sector of Antigua and Barbuda* – submitted to the Green Climate Fund.

ACCEPTABILITY:	The public is appreciative of forward planning that will enhance APUA's operational capabilities and improve service. Efforts to lessen disruptions following climate events and resume network coverage always garner public support.
INSTITUTIONAL/ ORGANIZATIONAL REQUIREMENTS:	APUA, along with the Ministries of – Works, Finance, Environment and Lands, and with the support of private sector engineering firms and regional/international climate financing entities, **must** all collaborate for successful implementation. Since there are ongoing projects, there would need to be transparency to ensure that project activities are not duplicated. Further, gaps in capacity would need to be identified and addressed to ensure continuity and longer-term sustainability.
COSTS	
CAPITAL COSTS:	Following vulnerability assessments and the development of a risk management plan *(financed separately)*, upgrades to physical assets is estimated at a *minimum* investment of USD$5M over the course of a decade.
OPERATION AND MAINTENANCE:	Operation and maintenance costs are not accounted for separately and would be included in the Utility's regular operational expenditure.
ADDITIONAL/MISC.:	N/A
IMPACTS AND BENEFITS	
DIRECT:	▪ Lessens service disruptions by improving functionality and reliability. ▪ Allows for quicker on-streaming of network service following disasters. ▪ Improves operation of the *single* production facility on Barbuda. ▪ Increases asset life ensuring a greater return on capital investment. ▪ Lessens operation and maintenance costs.
INDIRECT:	▪ Improved service might pave the way for a phased *water tariff increase* ▪ Promotes financial self-sufficiency of the Water Business Unit.
LOCAL CONTEXT	
OPPORTUNITIES:	There is potential to develop and document context specific climate-smart codes for water sector assets. Thus, ensuring that new facilities are built to a higher standard, which would lessen O&M costs in the longer-term. It also allows for proactive management.
BARRIERS:	Major infrastructure works would include service disruptions, rationing and prolonged civil works. While the public would welcome the long-term benefits, the associated interruptions would not be appreciated. The sitting government would likely receive a political backlash for the inconvenience faced by the populace.
MARKET POTENTIAL:	N/A

TECHNOLOGY FACTSHEET

TECHNOLOGY NAME:	**RAINWATER HARVESTING**
SECTOR:	**WATER SECTOR**
SUB-SECTOR:	☒ Potable; ☒ Non-potable
SCALE:	Residential and Commercial
TIMELINE FOR OBSERVED IMPACT:	☒ Short-term; ☒ Medium-term; ☐ Longer-term

TECHNOLOGY CHARACTERISTICS

INTRODUCTION:

Rainwater harvesting is the diversion, capture, storage and treatment of precipitation for potable and non-potable use. It provides an alternate water source that supplements the Utility’s supply system. Systems may vary in size and complexity, but all include *catchment surface, transport, storage, treatment and distribution.* Dependable rainfall patterns are a key asset to the technology’s success, along with smart, conservative water users.
Rainwater systems can be classified in four types:

- **Occasional** – a day’s supply of water is stored in small containers. Suitable when the rainfall pattern is uniform *(very few days without rain)* or Utility’s supply is reliable.
- **Intermittent** – harvesting occurs during rainy periods and rainwater meets most water demands. Supply is supplemented by Utility or trucked water in the dry season
- **Partial** – Rainwater is used throughout the year but the ‘harvest’ is not enough for all domestic demands.
- **Full** – All water needs are met by the rainwater harvest. There is no alternative water source. Water use is well managed and there is adequate storage to bridge dry periods.

Local systems are designed to meet the needs of *occasional* to *partial* users. Further adoption will be encouraged by the availability of cost-effective storage options, suitable for the local context *(see table)*.

TYPE	SPECIFICATIONS	APPLICATIONS
Rainwater Pillow[25,26] 	▪ Above ground ▪ Materials: PVC, Polyethylene (PE), Thermoplastic polyurethane (TPU) ▪ Size: => 10,000 gallons ▪ Completely collapsible, mobile, minimal installation **suitable for beneath plywood homes*	▪ Non-potable ▪ Potable **ideal for renters*
IBC Totes	▪ Above ground ▪ Materials: PVC ▪ Size: 275 & 330 gallons, stackable	▪ Non-potable ▪ Potable

25 Tanks for Less. Water Tanks and Rain Harvesting Equipment. “Fol-da-Tank”. https://www.tanksforless.com/c/366/fol-da-tank

26 Chongqing Mola Technology Co.,Ltd. The Best Solution for Water Storage. Fuel Storage. “Drinking Water.” http://molatank.quality.chinacsw.com/c1423314-drinking-water-tank

		▪ Installed on concrete block (no masonry work needed), mobile ***Purchased used from bulk suppliers*	**food grade tanks ideal for renters*
	Galvanized Sheet Metal Tanks[27] 	▪ Above ground ▪ Materials: Prefabricated galvanized sheet metal ▪ Size: => 3,000 gallons ▪ 30-deg roof pitch catchment ▪ Hand bolted on-site	▪ Potable (Large scale applications) ▪ Non-potable
	Plastered Tire Cisterns[28,29] 	▪ Sub-surface ▪ Materials: Used tires, earth. Backfill, wire mesh/rebar, plywood concrete (plaster) ▪ Size: *Any* ▪ Labour intensive	▪ Potable
	This list is not a fully exhausted. It is mainly indicative of alternative options.		
STATUS IN-COUNTRY:	Rainwater harvesting is widely practiced. Development Control Authority (DCA) guidelines dictate that all newly constructed buildings must include rainwater capture and storage for the architectural plans to be approved. However, there is often no follow up to ensure that construction complies with the approved plans. Further, owing the cost of sub-surface reinforced concrete cisterns *(=>USD$12.5K)* and limited land space for above ground storage, many homeowners are inhibited from installing adequately sized storage tanks. The practice is therefore disproportionate, favouring those with more disposable income. There is no stipulation for rainwater harvesting in the agriculture sector. Farmers are limited the absence of on-site buildings that provide roof catchments.		
ACCEPTABILITY:	Rainwater harvesting is widely acceptable; however, economic inequity affects the level to which lower income families and renters' benefit.		
INSTITUTIONAL/ ORGANIZATIONAL REQUIREMENTS:	DCA is the entity responsible for ensuring that rainwater harvesting is practiced. Dispatching inspection officers during the construction phase would promote higher % compliance. To overcome income inequality, cheaper, innovative storage should be marketed, and the government may need to subsidize solutions for the most vulnerable social groups. Similarly, the Min. of Agriculture could find ways to incentivize farmers to adopt the technology on farms.		

27 Tanks for Less. Water Tanks and Rain Harvesting Equipment. "30 Deg Roof Rainwater Tank". https://www.tanksforless.com/p/13703/contain-cgsr-model-902s-3453-gallon-30-degree-roof-water-storage-tank-contain-902S

28 Pushard, Doug. 2014. "Comparing Rainwater Storage Options". Harvest H2O. http://www.harvesth2o.com/rainwaterstorage.shtml

29 Long Way Home. 2004. "Cisterns". https://www.lwhome.org/designsconstruction

<table>
<tr><td colspan="2">COSTS</td></tr>
<tr><td>CAPITAL COSTS:</td><td>The table below gives estimated costs for the storage options discussed.
<table>
<tr><th>DEVICE</th><th>COST (USD$ | XCD$)</th><th>EST. COST / BENEFIT</th></tr>
<tr><td>Rainwater Pillow (5,000gal)</td><td>$3,500 | $15, 690</td><td>H+</td></tr>
<tr><td>IBC Totes (330gal)</td><td>$250 | $1,125</td><td>M++</td></tr>
<tr><td>Galvanized Sheet Metal Tank (5,000gal)</td><td>$7,200 | $32,276</td><td>M</td></tr>
<tr><td>Plastered Tire Cisterns (>5,000gal)</td><td>$6,700 | $30,035</td><td>H</td></tr>
</table>
*H – High | M – Medium | L – Low | (+) – Above Average</td></tr>
<tr><td>OPERATION AND MAINTENANCE:</td><td>Operation costs are limited to energy required for distribution pump, which could easily be included in the monthly power consumption of property or offset with by pairing with renewables. Maintenance costs are minimal. Systems should be periodically flushed with disinfecting solution. Routine integrity checks are necessary for leak prevention.</td></tr>
<tr><td>ADDITIONAL/MISC.:</td><td>Treatment and distribution would be at additional cost. Routinely cleaning rooftops, gutters and storage, along with simple chlorination and cartridge filtration (or ultraviolet sterilization) would ensure the water is safe for human consumption.</td></tr>
<tr><td colspan="2">IMPACTS AND BENEFITS</td></tr>
<tr><td>DIRECT:</td><td>▪ Enhances availability and access to water for potable and non-potable uses.
▪ Prevents lifestyle disruptions during dry periods and outages in Utility supply.
▪ Promotes self-sufficiency, is simple and relatively easy to maintain.
▪ Provides safe water for human consumption after adequate treatment
▪ Provides opportunities to create niche market jobs for design and installation of lower cost rainwater storage.</td></tr>
<tr><td>INDIRECT:</td><td>▪ Raises the level of awareness and promotes water conservation practices.
▪ Reduces public health risks for households dependent on rainwater storage for drinking water supply</td></tr>
<tr><td colspan="2">LOCAL CONTEXT</td></tr>
<tr><td>OPPORTUNITIES:</td><td>Although rainwater harvesting is effective as a single technology, there are opportunities to pair it with other climate-smart water technologies to increase adaptation impacts. It can be coupled with solar water pumping for distribution and water savers to improve water conservation. Users can be educated of cost-effective treatment options that would allow rainwater to be consumed.</td></tr>
<tr><td>BARRIERS:</td><td>Unconventional above ground storage systems may not be deemed aesthetically pleasing to property owners. This might lessen potential adoption of cheaper alternatives. Adoption will be lower during periods of prolonged drought, as the systems might be seen as unnecessary investments without reliable rainfall.</td></tr>
<tr><td>MARKET POTENTIAL:</td><td>There is potential to introduce low cost storage options to the Antiguan market. Private sector companies can provide full-service design, supply, installation and maintenance of a diverse range of built and modular options.</td></tr>
</table>

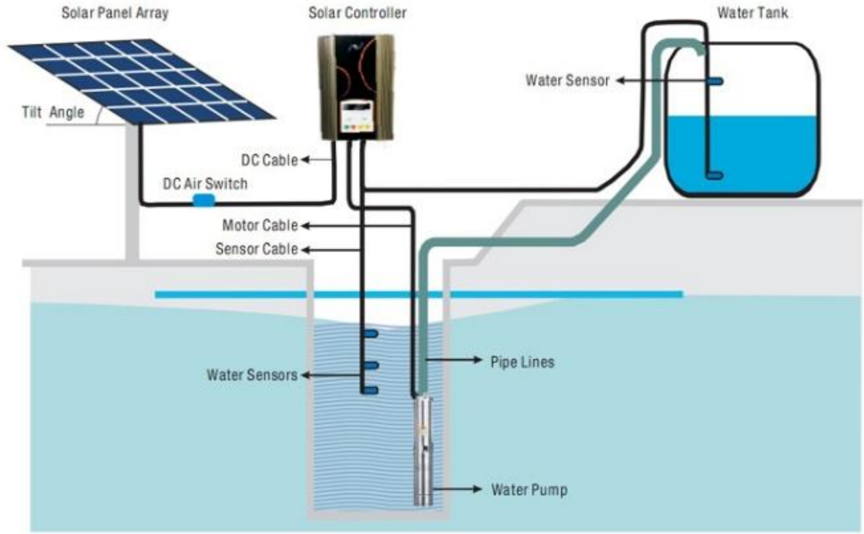
TECHNOLOGY FACTSHEET

TECHNOLOGY NAME:	**SOLAR PUMPING SYSTEMS "SOLAR"**
SECTOR:	**WATER SECTOR**
SUB-SECTOR:	☒ Potable; ☒ Non-potable
SCALE:	Residential, Commercial, Municipal
TIMELINE FOR OBSERVED IMPACT:	☒ Short-term; ☒ Medium-term; ☒ Longer-term

TECHNOLOGY CHARACTERISTICS

INTRODUCTION:

Solar pumping systems substitute grid electric and diesel run water pumps, for specialized equipment run on power generated by solar photovoltaic (PV) panels. Systems can vary in size and complexity, with *some* or *all* power requirements met by solar generation, or alternately they can work in tandem with back-up generator and/or grid power. Some utilize batteries and a full array of DC electronics, while in others power is inverted to AC for standard equipment. Further, simple stand-alone systems only allow for pumping during sunlight periods.[30]



Source: Dr. Solar (Lorentz P2S Solar Water Pump)[31]

In the past decade, solar PV panels have become more affordable. Pumping technology has also improved significantly, allowing lift of higher volumes of water over greater vertical distances. Key applications for the local context would include:

TYPE	DESCRIPTION	APPLICATIONS
Potable	▪ Retrofit existing water distribution systems with **solar** to replace or supplement grid power.	▪ Homes ▪ Schools ▪ Clinics, Hospitals
Potable	▪ Design systems for water distribution from community reservoirs to homes/standpipes;	▪ Community-scale water supply

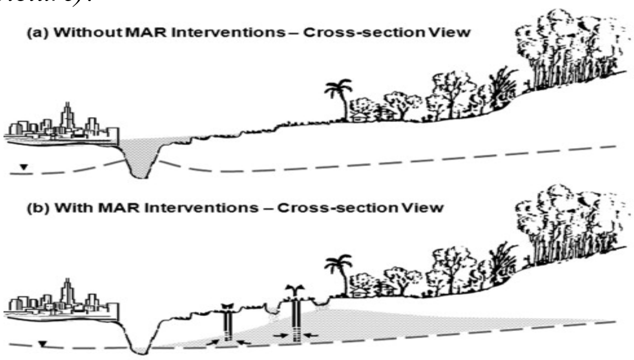
30 World Bank. 2018. "Solar Pumping: The Basics." World Bank, Washington, DC.

31 Dr. Solar: Engineering the Solar Revolution. "Solar Water Pumping System for Your Home".

<table>
<tr><td></td><td><table><tr><td></td><td>OR to lift water up to elevated storage tanks.</td><td></td></tr><tr><td>Non-potable</td><td>▪ Design systems to extract and distribute raw surface or ground water for use on farm.</td><td>▪ Livestock watering
▪ Agriculture irrigation</td></tr></table></td></tr>
<tr><td>STATUS IN-COUNTRY:</td><td>A variety of solar PV applications are readily available in country. Solar water heating systems have been utilized since the 1990s. While, specialized solar water pumping systems are less prominent; property owners have installed grid-tied solar arrays to offset power consumption.</td></tr>
<tr><td>ACCEPTABILITY:</td><td>Solar PV as an alternate power source is widely accepted. Thus, mainstreaming solar pumping, as an alternative to standard grid-electric systems, will provide a feasible option for daily use and rapid recovery following extreme climate events.</td></tr>
<tr><td>INSTITUTIONAL/ ORGANIZATIONAL REQUIREMENTS:</td><td>Solar pumping systems can be implemented on an individual/institutional basis without direct backing of a national entity, or as government (subsidized) projects to build nationwide resilience. National climate change adaptation targets include ensuring that 100% of power demand in the water sector is offset by renewables, therefore adoption of solar pumping systems will receive support from government and the Utility. In the case of non-potable water for agriculture, NGOs, farm owners or farming cooperatives will have to retain responsibility for installation, operation and maintenance. These systems will need technical support from private sector suppliers.</td></tr>
<tr><td colspan="2">COSTS</td></tr>
<tr><td>CAPITAL COSTS:</td><td>Major system components include PV modules, pump and motor, electronic components, and interconnected cables. Electronics may include an inverter, power conditioner or pump controller, controls, and water sensors. The estimated cost of an off-grid pumping system, 380-1200W, pumping up to 25gpm, is approximately USD$3,500 - $5,000 | XCD$15,690 - $22,415.</td></tr>
<tr><td>OPERATION AND MAINTENANCE:</td><td>Operation costs will vary based on complexity and demand on the system. Maintenance costs will cover cleaning solar panels and routine repairs of faulty components. O&M for simple, off-grid systems is ~10% of installation cost.</td></tr>
<tr><td>ADDITIONAL/MISC.:</td><td>Systems with back-up generators or grid power will have additional costs.</td></tr>
<tr><td colspan="2">IMPACTS AND BENEFITS</td></tr>
<tr><td>DIRECT:</td><td>▪ Allows quick on-streaming of water distribution from storage (cisterns/tanks) after a climate event – prior to restoration of grid-power.
▪ Reduces dependence on grid-power for daily water distribution.
▪ Supports farming operations with efficient, cost-effective, low maintenance standalone systems.</td></tr>
<tr><td>INDIRECT:</td><td>▪ No adverse environmental impact.
▪ Provides business/job opportunities for suppliers and service technicians.
▪ Aids in the achievement of NDC targets.</td></tr>
</table>

LOCAL CONTEXT	
OPPORTUNITIES:	Solar pumping systems installed in residential to municipal scale applications will improve the lives of Antiguans/Barbudans and promote quicker on-streaming of water distribution after disasters. Increased deployment will result in competition and lower costs. It will also create demand for trained service specialists, providing opportunities to upskill plumbing and electrical technicians.
BARRIERS:	Cost will be a major barrier to the adoption at all scales. Concerns around systems' robustness and ability to withstand storm force winds will also have to be overcome. Government funding, incentives and grants will be necessary to overcome the initial capital expense.
MARKET POTENTIAL:	This technology will provide new business opportunities for both suppliers and service technicians. There are also opportunities for local firms to perfect, package and export solutions to neighbouring Caribbean islands.

TECHNOLOGY FACTSHEET

TECHNOLOGY NAME:	**STORMWATER RECLAMATION AND REUSE "FLOOD HARVESTING"**
SECTOR:	**WATER SECTOR**
SUB-SECTOR:	☐ Potable; ☒ Non-potable
SCALE:	Municipal
TIMELINE FOR OBSERVED IMPACT:	☐ Short-term; ☒ Medium-term; ☒ Longer-term
TECHNOLOGY CHARACTERISTICS	
INTRODUCTION:	Stormwater reclamation involves the *collection, accumulation, treatment* and *storage* of precipitation for reuse. It differs from rainwater harvesting because runoff is collected from *storm drains, waterways and roadways* instead of rooftops. Micro-catchments can be used to divert or slow runoff so that it can be stored before it enters receiving waters. Alternately, stormwater can be collected directly from natural watercourses. Level of treatment depends on pollutants and intended use. Stormwater is a source for *controlled groundwater recharge (Managed Aquifer Recharge)* and to *replenish wetlands,* thus mitigating against flooding and erosion. Groundwater recharge channels surface water into underground stores through deep percolation, utilizing recharge trenches and/or injection wells *(see picture)*.  Source: Journal of Hydrology [32] Natural wetlands are essential parts of watersheds that provide ecosystem services like mitigating flooding, reducing erosion, recharging aquifers and providing wildlife habitats. Watering wetlands helps to restore their natural functionality and reverses the damage from adverse environmental and anthropogenic changes.[33] While stormwater harvesting can be practiced across Antigua, for these intended purposes, activities will be limited to south-west.
STATUS IN-COUNTRY:	Precipitation is primarily collected in a network of roadside storm drains which eventually discharge into the marine waters. Runoff also collects in inland catchments – the Body Ponds, Big Creek etc. – from which water can be extracted for agriculture irrigation. However, there is no practice of *treatment* before reuse.

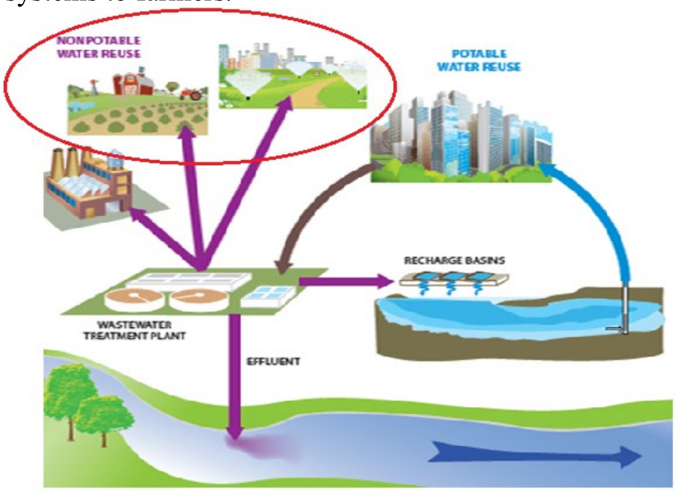
32 PAVELIC, PAUL ET. AL. 2010. "BALANCING-OUT FLOODS AND DROUGHTS: OPPORTUNITIES TO UTILIZE FLOODWATER HARVESTING AND GROUNDWATER STORAGE FOR AGRICULTURAL DEVELOPMENT IN THAILAND". JOURNAL OF HYDROLOGY. VOL 470-471, NOVEMBER 12, 2012. P 55-64.

33 Moseley, Will. 2015. "Wetlands provide ecological and economic benefits". Noble Research Institute. May 2015.

ACCEPTABILITY:	Reusing stormwater to recharge groundwater and replenish wetlands should be widely accepted. The public is appreciative of efforts to capture and utilize excessive runoff following heavy precipitation. Support is anticipated since the end use will have positive environmental impacts and improve nation's water stores.
INSTITUTIONAL/ ORGANIZATIONAL REQUIREMENTS:	National entities – APUA, Ministry of Works, Dept. of the Environment, etc. – would need to collaboratively revisit existing stormwater management plans to include *storage, treatment and reuse*. Capital investment will be needed for infrastructure to collect and store runoff, and divert treated water to *recharge trenches, injection wells and wetlands.* APUA would maintain responsibility for facilities and infrastructure, and facilitate groundwater recharge; however, the DoE along with community NGOs will be better suited to champion wetlands restoration activities. The technology aligns with the National Strategy and Action Plan (NASAP), the Integrated Water Resources Management (IWRM) Policy and Environmental Protection and Management Bill, 20190.
COSTS	
CAPITAL COSTS:	The capital expenditure for the civil works to construct a surface water reservoir *(or series of small reservoirs)* with primary treatment, along with piping and pumping infrastructure to collect and convey water will be in excess of USD$5M.
OPERATION AND MAINTENANCE:	Operation and maintenance costs will be limited to routine checks of infrastructure, cleaning waterways and pump maintenance. These can be included in APUA, Min. of Works, Min. of Agriculture operation schedules. Precipitation patterns will determine how much resources are needed. Due to this uncertainty annual O&M costs are not easily estimated.
ADDITIONAL/MISC.:	Selected groundwater recharge methods will add to the capital expenditure. Constructing discharge trenches and/or injection wells will be determined in the design phase. Siting of the reservoir(s) and the types of fixed assets will determine if security would be an added cost.
IMPACTS AND BENEFITS	
DIRECT:	▪ Augments groundwater capacity and increases Utility's extraction volumes. ▪ Moderates saline intrusion in shallow aquifers. ▪ Mitigates flooding and soil erosion after heavy downpour or severe climate event. ▪ Reduces discharge load to marine waters. ▪ Protects wetlands ecosystems and improves their ability to provide ecological and environmental benefits. ▪ Creates jobs for skilled/unskilled workers during phased implementation.
INDIRECT:	▪ Promotes the diversification and conservation of water resources which facilitates implementation of the national IWRM Policy. ▪ Provides additional irrigation supplies to farmers. ▪ Protects aquatic ecosystems by reducing the quantity of nutrients discharged.
LOCAL CONTEXT	

OPPORTUNITIES:	Stormwater reclamation and reuse will provide opportunities for climate change adaptation and sustainable economic and environmental development, with significant benefits in the wet years, or periods with predictable rainfall patterns. Groundwater recharge creates more opportunities for the Utility to incorporate the southern wellfields into their supply system, thus lessening production costs.
BARRIERS:	Decreased precipitation and irregular rainfall patterns, due to climate change, is now more prominent. Hence, the capital investment necessary for adoption would have to be justified, and return on investment demonstrated for public buy-in.
MARKET POTENTIAL:	There might be limited potential to charge farmers a *raw water tariff* if they extract irrigation supply from the surface water reservoir or micro-catchments. Reliability would be necessary to convince framers to invest in infrastructure to bring water onto their farmlands.

TECHNOLOGY FACTSHEET

TECHNOLOGY NAME:	**WASTEWATER REUSE FOR IRRIGATION**
SECTOR:	**WATER SECTOR**
SUB-SECTOR:	☐ Potable; ☒ Non-potable
SCALE:	Commercial
TIMELINE FOR OBSERVED IMPACT:	☐ Short-term; ☒ Medium-term; ☒ Longer-term
TECHNOLOGY CHARACTERISTICS	
INTRODUCTION:	**Domestic wastewater** generated by residential and light commercial buildings includes water from sinks, showers, toilets, washing machines and restaurants. **Treating and reusing** this water for agriculture irrigation has been an increasingly useful approach to prevent overexploitation of limited freshwater resources. This technology allows up to 75% of first-use water to be saved for an additional purpose; provides nutrients that supplement chemical fertilizer usage; increases soil fertility and provides safe disposal for wastewater. Effective diffusion will depend on collection, treatment and delivery systems to farmers.[34]  Source: National Academies Press – Understanding Water Reuse There are several wastewater treatment technologies that can be explored. A principle factor guiding choice would be budgetary constraints and the level of treatment necessary to avoid microbial contamination of irrigated crops. A minimum of tertiary treatment is required to remove pathogens.[35] The demonstration membrane bioreactor (MBR) plant in McKinnons can be utilized to promote wastewater reuse with farmers in the area.
STATUS IN-COUNTRY:	There is municipal scale wastewater collection and treatment facilities in country. However, housing developments, commercial buildings and all major hotels have been treating, and in some cases reusing effluent for landscape irrigation. In addition, the DoE has developed a concept note to expand the McKinnons MBR demo plant to 100K gpd and pilot an irrigation scheme with farmers in the area.

[34] Malki, M. et. al. 2017. "Wastewater treatment and reuse for irrigation as alternative resource for water safeguarding in Souss-Massa region, Morocco". European Water. Vol. 59: P. 365-371.

[35] Fernanda Jaramillo, Maria and Restrepo, Inés. 2017. "Wastewater Reuse in Agriculture: A Review about Its Limitations and Benefits". Sustainability. Vol 9. P. 1753-1753.

ACCEPTABILITY:	The public still considers wastewater reuse in the agriculture sector as *taboo*, even though for years many establishments have watered their landscapes with effluent. Culturally, treated effluent is still considered *sewage,* and therefore unhealthy. While, some farmers are willing to use effluent for drip irrigation, they will not spray it on leafy crops.
INSTITUTIONAL/ ORGANIZATIONAL REQUIREMENTS:	For widescale diffusion, wastewater treatment facilities will need to be constructed through public sector investment or development grants. Operation and maintenance would either be outsourced or undertaken by the Utility. Government policies to minimize health risks and influence adoption by the agriculture sector will be paramount, and regulations will have to be context specific, respect traditions, realistic and achievable. The technology aligns with the National Strategy and Action Plan (NASAP) and the Integrated Water Resources Management (IWRM) Policy.
COSTS	
CAPITAL COSTS:	The capital expenditure for expanding the McKinnons plant and installing the collection and distribution infrastructure is estimated at a minimum of USD$10M.
OPERATION AND MAINTENANCE:	Operation costs will include technical and supervisory management of the facility, energy, chemicals and routine testing of treated effluent; while maintenance costs would incorporate repair and replacement of mechanical parts. Estimates for annual operation *(less energy requirements)* is USD$50K and routine water testing is USD$15k. Operation and maintenance costs can be offset by income generated from sewer connection fees and sale of treated effluent.
ADDITIONAL/MISC.:	Cultural sensitization and education campaigns will be necessary to *ease* diffusion of wastewater reuse into local practice. Cost of training for Ministry of Agriculture extension officers and farmers will also add to the cost of widescale adoption.
IMPACTS AND BENEFITS	
DIRECT:	▪ Reduces the water deficit which results from increased droughts, thus decreasing crop failures and loss of income. ▪ Promotes positive environmental impacts by reducing discharge load to receiving coastal and marine waters. ▪ Reduces farmer dependence on the Utility's network for irrigation supply and the lessens the use of potable water for non-potable purposes. ▪ Creates of jobs for skilled technicians needed systems' operation and maintenance.
INDIRECT:	▪ Promotes the diversification and conservation of water resources which facilitates implementation of the national IWRM Policy. ▪ Provides a reliable irrigation supply and potential to upscale farms and improve economic livelihoods within farming communities. ▪ Increased local agriculture production will lessen dependence on imported food products and strengthen national food security. ▪ Creates secondary opportunities to utilize surplus treated effluent for groundwater recharge or wetlands restoration.

LOCAL CONTEXT	
OPPORTUNITIES:	Wastewater reuse is directly aligned with the NASAP and IWRM Policy which provide foundational guidelines for utilizing treated effluent for non-potable purposes. Thus, it increases opportunities for sustainable economic and environmental development, by lessening sectoral competition for potable water.
BARRIERS:	Conventional wastewater treatment facilities and associated collection and distribution infrastructure are expensive to install and operate. The initial capital expenditure will be the first major hurdle. Presently there is no irrigation transmission network to pipe treated effluent to farms, and since agricultural lands are located across the island, achieving widescale coverage will be a challenge. In addition, there are the obvious socio-cultural challenges related to reusing wastewater, and there will also be lingering concerns about efficient operation of treatment facilities and consistency of effluent quality.
MARKET POTENTIAL:	Mobilizing treatment facility construction and irrigation transmission network installation, along with longer term operational support, will create potential investment opportunities for private sector entities.

TECHNOLOGY FACTSHEET

TECHNOLOGY NAME:	**WATER SAVING DEVICES "WATER SAVERS"**
SECTOR:	**WATER SECTOR**
SUB-SECTOR:	☒ Potable; ☐ Non-potable
SCALE:	Residential, Commercial
TIMELINE FOR OBSERVED IMPACT:	☒ Short-term; ☒ Medium-term; ☒ Longer-term

TECHNOLOGY CHARACTERISTICS

INTRODUCTION:

Modern **water saving technologies** use water efficient appliances, fixtures and devices to augment water conservation efforts. Water savers have a variety of commercial and residential applications within buildings, landscaping, pools and factories. They range from installation of low-flow faucets, shower heads, toilets and household appliances, to retrofitting older plumbing with aerators, high efficiency check valves and flow restrictors/regulators. Water savers are most effective when combined with improved practice by conscientious consumers and can help to reduce water usage up to 70%.[36]

According to *Home Water Works,* the highest in-home water usage include kitchen (15.7%), bathroom (18.6%), laundry (21.7%) and leaks (13.7%, not addressed). Success of this technology assumes that the property owners will focus on these high usage areas. Estimated savings for an average 4-person household are: [37]

DEVICE	ESTIMATED CONSUMPTION	WATER SAVING DEVICES	ANNUAL % SAVINGS
Aerators 	▪ Faucet: 2.2gpm ▪ Household: 9,800g/yr	▪ Faucet: <1.5gpm ▪ Household: ~6,500g/yr	~30%
Shower Heads	▪ 1990s: >5gpm ▪ 2000s: 2.5gpm	▪ Low-flow: <1.8gpm	~30%
Toilets	▪ 1990s: 3.6gpf ▪ Household: 26,000g/yr	▪ Dual flush: 1.1gpf ▪ High Efficiency: 1.3gpf ▪ Ultra-low-flush: 1.6gpf ▪ Household: ~11,000g/yr	~55%
Washing Machines	▪ Standard: 40-45g/load ▪ Household: 12,000g/yr *Water Factor: 10	▪ High efficiency: 12-25g/load ▪ Household: ~4,500g/yr *Water Factor: 8	~60%

STATUS IN-COUNTRY:

A wide range of water savers are available for purchase locally. Homeowners and property developers can also import preferred options. Buildings constructed in the last decade will more likely have been fitted

[36] Akruthi Enviro Solutions Pvt. Ltd., http://neoakruthi.com/blog/how-to-save-water-at-home.html

[37] Home Water Works, *A Project for the Alliance for Water Efficiency,* https://www.home-water-works.org/indoor-use

<table>
<tr><td></td><td>with water saving devices, while older construction and lower cost dwellings of low-income households may not be.</td></tr>
<tr><td>ACCEPTABILITY:</td><td>The level of acceptability is proportional to awareness and education about the benefits of water saving devices. While property owners may not opt to change out older, less efficient devices which are still operational, most would consider high efficiency options during routine maintenance or renovations.</td></tr>
<tr><td>INSTITUTIONAL/ ORGANIZATIONAL REQUIREMENTS:</td><td>Water savers can be implemented on an individual/household basis and does not need the support of a national institution to be successful. The expertise for choice, implementation and maintenance will come from knowledgeable suppliers, plumbing technicians and savvy property owners. In keeping with Antigua/Barbuda’s climate change mitigation targets to 2030, the State can further support this technology with the establishment efficiency standards restricting the importation of low-efficiency devices and appliances. Developers who meet predefined conservation, usage and, wastage targets can also be incentivized.</td></tr>
<tr><td colspan="2">COSTS</td></tr>
<tr><td>CAPITAL COSTS:</td><td>Property owners will determine individual levels of investment based on budgetary constraints. This table highlights affordable options at local hardware stores. Small scale installation can easily be done without employing a technician who would typically cost USD$30/hr.
<table>
<tr><th>DEVICE</th><th>COST (USD$ | XCD$)</th></tr>
<tr><td>Aerators</td><td>$7 | $32</td></tr>
<tr><td>Low- flow Shower Heads</td><td>$18 | $80</td></tr>
<tr><td>Hight Efficiency Toilets</td><td>$365 | $1,485</td></tr>
<tr><td>Washing Machines</td><td>$925 | $4,145</td></tr>
</table></td></tr>
<tr><td>OPERATION AND MAINTENANCE:</td><td>O&M costs over time is negligible and will be accounted for in routine maintenance expenditure.</td></tr>
<tr><td>ADDITIONAL/MISC.:</td><td>Negligible</td></tr>
<tr><td colspan="2">IMPACTS AND BENEFITS</td></tr>
<tr><td>DIRECT:</td><td>▪ Reduces demand on Utility’s supply.
▪ Lessens water consumption and lowers monthly bill.
▪ Promotes more efficient water usage and reduces wastage.</td></tr>
<tr><td>INDIRECT:</td><td>▪ Surplus can be utilized by Utility to increase nationwide network coverage.
▪ Utility’s production costs may be reduced.
▪ In-home water storage will last longer during drought or Utility outages.
▪ Public will become more conscientious and educated water users, and the raised level of awareness may lead to the adoption of additional conservation methods.</td></tr>
</table>

LOCAL CONTEXT	
OPPORTUNITIES:	Promoting water saving will encourage property owners/developers to become creative about water usage. This can potentially encourage the integration of other technologies such as *harvesting*, *recycling* and *reuse*, and may result in a cultural shift towards zero-wastage. Additionally, bringing this awareness to schools and other social settings, and tying it to on-going environmental awareness efforts would create opportunities to raise a generation of water conservation champions.
BARRIERS:	The cost associated with retrofitting older properties may be a significant barrier that deters owners from considering water savers. Since the current water tariff is heavily subsidized, lower volume consumers and those with unreliable network coverage, may not be motivated to spend on water savers if they only receive a negligible return on investment. Concerns relating to functionality of high efficiency devices, the inconvenience of adopting a new behaviour and the perception of the attitudes of other users might also be prohibitive.[38] E.g. a single parent in Yorks, may not be willing to replace a 15-yr old washing machine if she only receives water for 15 hours each week and perceives that homes in Paradise View have an uninterrupted supply and occupants can take 20-minute showers.
MARKET POTENTIAL:	Water savers are not new to the local market. However, suppliers will find that affordable, high performing, warrantied options have greater market potential.

[38] Addo, IB, Thoms, MC & Parsons, M 2018, 'Barriers and Drivers of Household Water-Conservation Behavior: A Profiling Approach', *Water*, vol. 10, no. 12, p. 1794

APPENDIX E: BUILDING SECTOR FACTSHEETS

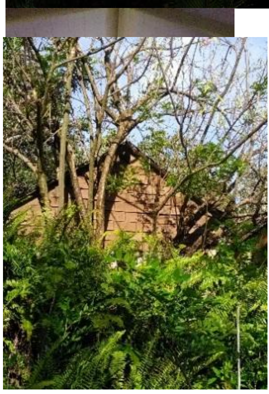
Technology Fact Sheets

Building Sector Technology Fact Sheet	
Sector	Building
Adaptation/ Mitigation Needs	Crosscutting – Adaptation & Mitigation
Technology Name	Passive Homes
How this technology contributes to Adaptation / Mitigation as a co-benefit factor	1. Good orientation: to respond positively to landform, sun path and seasonal prevailing wind directions. 2. Spatial organization: to locate less habitable areas, e.g., storeroom and bathroom, on the western side of the building to act as additional thermal buffer; and to expose living room with glazing/window toward the south for sunlight accessibility. 3. Self-shading design: where windows or glazing areas are exposed to hot afternoon sun, they should be shaded by other components of the buildings, such as balconies above, planter boxes, roof overhang, or sun-shading devices. 4. Compact form: to reduce building envelope area and thus heat loss.
Background/ notes, short description of the technology option source.	Passive houses designs have adopted the Passive House Planning Package (PHPP), which is an energy modelling programme that projects energy usage in the building design by taking into account almost every aspect related to energy consumption, including the site's weather data, orientation, type of construction, materials used, window designs and locations, ventilation system, appliances, lighting and other electrical equipment used in the building.
Implementation assumptions - How the technology will be implemented and diffused across the subsector	Through the planning authority, these can be in effect a fundamental requirement to provide enough details by the engineer or architect when filing the application for construction.
Cost	They are equal to or at a ceiling of 20% above the regular house construction.
Country Social Development Priorities	Passive houses are a priority measure, because as a co-benefit to climate change through mitigation, they allow future saving of significant amounts of energy thus reducing emissions of greenhouse gases in the atmosphere and saving of financial resources.
Country Economic development economic benefits	● The resulting lower energy demand from passive houses helps reduce electricity peak load and create further savings by avoiding additional investment to increase the capacity of the local power infrastructure and power plants.

	• Passive houses are a priority measure in terms of the country social development because they allow future saving of significant amounts of energy thus reducing emissions of greenhouse gases in the atmosphere and saving of financial resources.
Social Benefits	Construction of energy efficient infrastructure in design brings optimization for daylight and thermal comfort. Passive house design and technologies offer building occupants better thermal comfort, indoor environment, indoor air quality and visual connection to outdoors. These benefits lead to a healthier and higher quality of life.
Environmental Benefits	• The technologies bring benefits to environmental development, including energy saving for artificial lighting and ventilation and air conditioning. • Passive house design and technologies do not rely on active systems and high-tech equipment to deliver environmental benefits. • Passive house design and techniques can also be considered one of the cost-effective mitigation options hence adapting to climate changes.
Other Considerations and Priorities (such as market potentials)	The promotion of passive house implementation also helps upgrade the skills of local construction work forces and improve building and living standards for the local residents. This results in better job prospects, healthier communities and greener economies. However, it is argued that an incremental investment cost can be balanced by avoiding costs of investing in sophisticated heating, ventilation and air conditioning systems and their high operating costs. Instead of investing in air-conditioning systems, passive houses invest in better building envelopes, which also improves the building.
Capital Cost (per facility)	A passive house is considered to be cost effective when the combined capitalized costs over a period of 30 years does not exceed those of an average new home all-inclusive of operation and maintenance costs (Passive House Institute, 2010). However, in some studies it is assessed that one should accommodate for at least 20% higher in cost than the standard home construction.
O&M Cost (per facility)	Less than that of the standard built house if constructed to be truly passive in design
Disadvantages / Barriers	The implementation of energy efficient designs often relies on the use of new technologies and techniques, which can introduce difficulties and problems because of their innovation. This can create technical barriers and risks, but there are also a number of social, cultural, and economic non-technical barriers.
Up Scaling Potential	Positive

References

- Passive House Design: http://www.climatetechwiki.org/technology/passive-house-design
- Technology Fast Sheet: https://tech-action.unepdtu.org/wp-content/uploads/sites/2/2013/12/ref26x96-35.pdf

Building Sector Technology Fact Sheet	
Sector	Building
Adaptation/ Mitigation Needs	Adaptation
Technology Name	Increased Roof Pitch Angles with Apertures
How this technology contributes to Mitigation	*The pitch angle of the roof is indirectly proportional to the resistance against wind forces. Simply put, the steeper the pitch, the less the atmospheric pressure chance forces on it, when it is associated with an aperture for venting. An increased pitch roof of 8/12 to 9/12 is steep enough to resist uplift, but shallow enough to resist overturning.* Flat and low-slope roofs normally fail in high winds due to a force known as “uplift.” In other words, the wind sucks the roof up off the building. A really steep roof, on the other hand, is so tall that the horizontal force of the wind simply turns the roof (and the building, if it’s well-attached) over on its side. **Hip & Gable Roofs > 18.3 < 36° with Apertures:**     
Background/ notes, short description of the technology option source.	This is the most favourable shape for a roof from the point of view of resisting wind forces. Although the theoretical maximum pressures (and suction forces) are not very different from those for gable roofs, the practical performance of hipped roofs in hurricanes is demonstrably superior to that of gable roofs. The reasons are: ● Lightly lower maximum values of pressures and suction forces; ● More even distribution of pressures and suction forces over the roof surface;

	● More favourable structural form leading to better (and less onerous) distribution of the loads from the roof to the walls. The way to reduce or eliminate atmospheric pressure change forces is to install a venting system at high point in your steep angled hip or gable roof. This design factor coupled with a relative steep pitch contributes to a substantial resilience against high winds. This also serves the laws of thermodynamics whereby hot air rises and vents through apertures helping to reduce the pressure. *Pressure and temperature are directly related, i.e. as pressure increases temperature increase as well. (Gay-Lussac's Law).* Architect Julian Bruney, of Independent Drafting, Estate Development & Surveying (I.D.E.A.S.), stated that this had everything to do with the pitch of the roofs. Bruney notes: “Just look at churches. They have steeper pitches – almost 45 degrees or more – and churches were built to shelter people in times of stormy weather” Bruney further explains that a steep roof is expensive to build. “People choose to go cheap.” he says. “Easier to build, less lumber and easier walkability when working on the roof.” As an architect, Bruney says to people who goes the cheap route when building a roof: “See you in October!”
Implementation assumptions - How the technology will be implemented and diffused across the subsector	● Enforce building codes – see to it that they are implemented. ● Not only approve drawings, but also check the actual building to see that the approved pitch is implemented on the actual constructed roofs. ● Not just upgrade the building codes but put inspectors out there to control and enforce these as well.
Cost	Roof at =< 18.3^{o} @ EC$39/sf (plan area) Roof at >18.3^{o} to 36^{o} @ EC$45/sf (plan area) An increase of up to 14% over the same pan area
Country Social Development Priorities	Less vulnerability to hurricane active force - having a better secured roof which can withstand hurricane gale force winds due to its pitch reduces the impact of mobilizing people to shelters.
Country Economic development economic benefits	Less capital cost for reconstruction of roofs when they have met the basic criteria in design of >30^{o} in pitch angle in tandem with all the other elements of shorter eves, aperture venting and adequate brace strappings.
Social Benefits	● Less vulnerability in hurricane force winds conditions. ● Less reliance on safe houses as shelter, such as churches which have already adopted this design from old technology applications where they were more prevalent past design architectures.
Environmental Benefits	● Reduction in catastrophic roof damages as frequent roof repairs or rebuilding is done every hurricane season when winds are in excess of 120 mph upwards to 200mph. ● Debris reduction in roofing materials where a high percentage are non-decomposable at the landfill or the addition burning of wood debris adding to carbon dissipation.
Capital Cost (per facility)	Approximately 20% - 40% increase over the standard Hip and or Gable roof at a 25% grade.

O&M Cost (per facility)	The steeper the roof, the quicker rainwater would flow off, avoiding cause for leakage. Roofs with steeper pitch angles are less likely to have rotten spots which are common when the angles or percent grades are very low such as < 20%.
Disadvantages / Barriers	• A steeper roof pitch creates a working risk safety concern during construction • Increased construction costs due to a small increase in materials quantity and directly an increase in labour cost.
Up Scaling Potential	Great potential for upscaling due to the B/C > 1

References

- Cool Roofs: http://www.climatetechwiki.org/technology/cool-roofs
- Detailing for Hurricanes: https://www.oas.org/pgdm/document/mhbdc/b3_text.pdf
- Hurricane Design: http://www.studiosky.co/blog/2014/hurricane-design.html
- The Reason Why Certain Roofs Survived Hurricane Irma: http://today.sx/environment/reason-certain-roofs-survived-hurricane-irma/

Building Sector Technology Fact Sheet	
Sector	Building
Adaptation/ Mitigation Needs	Crosscutting - Adaptation & Mitigation
Technology Name	Impact Resistant Windows & Doors
How this technology contributes to Adaptation / Mitigation as a co-benefit factor	This type of technology provides a co-benefit where the impact windows and doors adapt to extreme high windy conditions through cause by climate change but are also efficient through mitigation. According to the US Department of Energy (DOE), super high efficiency windows and doors would offer up to seven times the insulating value (U-factor) of double glazing and help create “zero energy” homes. There are high performance window and doors that can be hurricane, blast and burglar resistant to enhance safety and security. The high-performance window and door glass products of insulated double-paned or triple-paned glass and low- E coatings have cut U-factor ratings. With the addition of highly insulated frames and warm edge technology you can select a product that is both resilient to disastrous climatic situations and also efficient because of the design improvements.
Background/ notes, short description of the technology option source from Climate Technique Summaries etc.	Hurricane resistant or storm proof windows and doors are constructed with impact-resistance glass treated with a lower or multiple layer of polyvinyl butral (PVB) or ethylene –vinyl acetate (EVE). Manufacturing and technology advancement have allowed for the enhancement of these products over the past decade. One such product is the impact-resistance glass, which has helped protect homes from severe weather, burglary and noise penetration. These help to keep the home safe and are also very energy efficient, which generally helps in lowering the electricity bill in an air-conditioning environment. A Low- E glass within a door or window frame of efficient standard is a thin–film coating or metal or metallic oxide that allows light to pass through but blocks the UV rays reducing heat transfer. This reduces the energy loss between 30 – 50%. These E-glass are now the norm. An energy efficient impact resistant glass must have a rating of maximum U-factor of 0.75 or less and solar heat gain coefficient (SHGC) of 0.30 or less. In order to provide the impact resistance additional lamination is done. Even though tempered, heated or chemically strengthened glass is stronger than annealed glass, it is still breakable. Providing the thick and multiple lamination in glass products proves resistance in ● Hurricane ● Burglary ● Ballistic – or bullet Engineers and the University of Missouri and the University of Sydney Australia are currently working to provide a thinner and lighter blast-

	resistant glass that can be used in home use since thicker glass is what is required for ballistic and blast resistance. It is noted that to meet the requirements of hurricane resistant glass, it must withstand a nine-pound, two-by-four plank shot out of an air cannon at a speed of 50 feet per second, resist ball bearings at 80 feet per second impact and pass design pressure test. The US DOE requires that a product to be label hurricane resistance must be able to withstand the minimum of 144PSF.
Implementation assumptions - How the technology will be implemented and diffused across the subsector	Demanding code use for impact resistant energy efficient products throughout would enable more use of the product and less reliance of boarding up windows and doors in high wind situation. Recently, our hurricanes have approached category 5, thus, design requirements should implement the pressure ratings. This is to be the focus when the in-feature door or window is shut. Hence there are two safety glazing categories - Category I and II. Category I is recommended for most hazardous conditions and can be selected based on the category ratings.
Cost	A genuine hurricane resistant glass product is on the order of US$40 – 55 per square foot. A hurricane resistance standard door 60x80 inches cost about US$1900 while a sliding window 72x80inches is about US$1950.
Country Social Development Priorities	Merchants are geared to stock doors and windows which are easily sold due to price. Hence, hurricane resistant doors and windows are seldom stocked unless special order as a preferential item. the social attribute is to have enough standard doors and windows in stock to keep the supply in line with demands.
Country Economic development economic benefits	Hurricane resistant windows and doors can increase the overall cost of construction, but they offer great protection. The investment may well pay off due to the damage they reduce.
Social Benefits	No glass is entirely break proof, but hurricane resistant, storm-proof window and doors have great advantages such as: ● Will survive winds up to 200mph without blowing out once the frames are of good quality and rating ● No flying glass ● Available in sizes tailored for your convenience ● Good insulation for sound and heat transfer ● Blocks 99% of transmitted UV light ● May reduce homeowner's insurance
Environmental Benefits	● Reduction in catastrophic roof damages as frequent roof repairs or rebuilding is done every hurricane season when winds are in excess of 120 mph upwards to 200mph. ● Debris reduction in roofing materials where a high percentage is non-decomposable at the landfill or the addition burning of wood debris adding to carbon dissipation.
Other Considerations and Priorities (such as market potentials)	Studies have shown that total home destruction is caused when there is a sudden change in atmospheric pressure chance forces when entering the home which blows off the roof (with the absence of a venting aperture at a high elevation in roof ceiling or wall). Keeping the windows and doors intact preventing these sudden pressure chances can save homes from

	devastating collapse. Therefore, adequate hurricane resistant and energy efficient systems can limit this occurrence.
Capital Cost (per facility)	It was estimated that in 1992 it cost Florida an approximate US$25M
O&M Cost (per facility)	An estimation of at least 15 to 20 years at replacement value
Disadvantages / Barriers	● Generally higher cost than regular or standard window and doors. ● Availability of the commodity at the local hardware ● Special order takes a considerable amount of time, subsequent to delays in completion of your home construction at the finishing level
Daily Supply Capacity (per facility)	
Up Scaling Potential	

References

- Detailing for Hurricanes: https://www.oas.org/pgdm/document/mhbdc/b3_text.pdf
- Hurricane Design: http://www.studiosky.co/blog/2014/hurricane-design.html
- The reason why certain roofs survived hurricane Irma: http://today.sx/environment/reason-certain-roofs-survived-hurricane-irma/

Building Sector Technology Fact Sheet	
Sector	Building
Adaptation/ Mitigation Needs	Crosscutting - Adaptation & Mitigation
Technology Name	Construction of Building Infrastructure to lessen the effect of Climate Change
How this technology contributes to Adaptation / Mitigation as a co-benefit factor	Energy use is the largest operating expense in office buildings and accounts for nearly 20% of the country's annual greenhouse gas emission. According to the International Energy Agency (IEA), buildings could potentially account for 41% of global energy savings by 2035 if energy-efficient construction practices are followed. To help reduce the effect of climate change on building construction, builders need to consider the effect that climate change has on the planning and construction stages by: ● Setting strong mandatory minimum standards: Creation of strong minimum standards for buildings, equipment and appliances, and establishment of a forward trajectory for future standards. ● Creating targeted incentives and programs: Support higher performance in the short-to-medium term through incentives and programs including the use of government market power and a range of possible financial incentives for building owners and tenants. ● Using advanced designs and construction techniques that reduce heating, cooling, ventilation and lighting energy consumption. Buildings and Construction sector is also responsible for significant non-CO_2 GHG emissions such as halocarbons, CFCs, and HCFCs (covered under the Montreal Protocol), and hydrofluorocarbons (HFCs), due to their applications for cooling, refrigeration, and in the case of halocarbons, insulation materials. ● Managing energy consumption with active and ongoing methods
Background/ notes, short description of the technology options.	Providing buildings which lessen the effect of climate change for construction applies to every part of the process, from the equipment used to the appliances installed in a new building. With respect to strengthening existing buildings, however, autonomous adaptation will be limited if owners are not familiar with weaknesses in the bearing elements of their buildings. Adaptation will only occur in new constructions if standards are enhanced.
Implementation assumptions - How the technology will be implemented and diffused across the subsector.	Contractors should also consider the following factors when building homes to adapt to climate change, which will also have some co-benefits to mitigation: ● Removing barriers to finance, design and construction ● Landscaping: Landscape designers can plant trees to shade a home from the sun and help keep it cool during the summer. ● Cool roofs: Cool roofs keep homes cooler during the summer by reflecting more light and absorbing less heat. ● Incorporating energy efficiency, renewable energy and sustainable green design features into buildings.

	● Advanced House framing: This is a technique which builders can use to reduce lumber use and waste and improve energy efficiency by replacing lumber with insulation material. ● Solar power: Homes can be designed to use solar power for electricity and water heating. ● Architects and engineers who incorporate energy design concepts and methods into their design projects can play a significant role in reducing energy consumption and achieving sustainable energy structure for our society.
Cost	Improvements in buildings often have low or no marginal cost or provide a return on investment in the form of energy cost savings.
Country Social Development Priorities	Buildings last 40 years or more and construction creates more jobs than other sectoral investments. Investments in the building sector are less risky and create better returns when directed toward energy-efficient buildings.
Country Economic development economic benefits	● Increases building resale value ● Adaptation for resilient and efficient building structures would typically have longer lifecycles, lower maintenance fees, and cost less to operate. ● Improvements in the resilience of the building construction and its efficiency are particularly important for the lowest income urban residents, who pay a larger portion of their income on energy and are least able to afford higher energy prices or cope with unexpected fluctuations in energy costs.
Social Benefits	● Policy makers, architects and engineers would need to incorporate the policies indicating how could be defuse across the Building. Sector. Through energy design concepts and methods their design of projects can play a significant role in reducing the vulnerability of climate change and achieving a sustainable resilient structure for our society. ● Improving your home or building's where weaknesses in the structure can be enhanced, such as roof bracing, column and beam supports which can be improved, strengthened and effectively save you money in times of natural disasters ● Improves indoor comfort - A model energy efficiency building controls the flow of air, heat and moisture. Insulation, ENERGY STAR® certified windows and air sealing work to keep the air inside the building warm and dry. Mechanical ventilation systems (fans, heat recovery ventilators and air exchangers on heating systems) circulate the internal air as well as expel unwanted moisture and other pollutants. Controlling the air flow throughout the building, minimizes the occurrences of differential temperatures across all rooms.
Environmental Benefits	Energy efficient buildings use less energy and cost less to operate and produce fewer greenhouse gasses, which is good for you and the environment. ● Breathe healthy, fresh, clean air - Controlling the airflow with mechanical ventilation helps confirm that the air in the building is being refreshed with outside air as often as required by building

	codes. For example, the air in a home should be completely replaced with fresh air every three hours. Fresh air takes less energy to heat than the inside air that slowly becomes contaminated with moisture and odours. An energy efficient and well-ventilated home is a healthy home. ● Reduce fossil fuel use and greenhouse gas emissions - Through energy ● Promoting eco-friendly designs: In the design phase of a project, it is important to consider options and opportunities to make eco-friendly choice. Design teams must also consider the durability of a building or structure, as well as its long-term waste production and energy consumption needs. ● Storms will constitute a safety risk in those parts of existing buildings that do not meet the building code's safety requirements. In the longer term, more and longer-lasting heat waves could have health-related consequences, especially for the elderly and weak, in nursing homes, for example. ● Enabling that there is a co benefit through mitigation, the average home built 20 years ago has the potential to lower their energy bills by 30% and to reduce the amount of greenhouse gasses the house produces by 4.5 tons per year. Lowering the total amount of greenhouse gasses in the atmosphere is an important step to reducing the impacts of climate change, both locally and globally.
Capital Cost (per facility)	
O&M Cost (per facility)	Marginal or zero
Disadvantages / Barriers	● High upfront costs of converting to energy-efficient methods ● Lack of access to financing ● Hidden Costs and risks due to potential incompatibilities, performance risks, transaction costs ● Market failures in the limitations of the typical building design process Fragmented market structure ● Behavioural and organizational barriers in Tradition, behaviour and lifestyle, ● Political and structural with insufficient enforcement of standards lack of detailed guidelines, tools and experts ● Lack of technological expertise to design, construct and maintain buildings and equipment ● Poor incentives to invest in educational programmes within the building resiliency energy efficiency programs ● Difficulty in coordinating construction industry stakeholders' problems with gathering reliable information ● Buildings face major risks of damage from the projected impacts of climate change, having already experienced a big increase in extreme weather damage in recent decade
Up Scaling Potential	Positive

References

- 17 Must Haves When Building an Energy Efficient Home: https://www.bautexsystems.com/blog/energy-efficient-home-design
- Energy Efficiency in Construction: http://see-net.net/uploads/seenet/document_translations/doc/000/000/046/energy_efficiency_in_the_construction.pdf?1322851276
- Energy Efficiency for Construction: https://www.shipleyenergy.com/energy-101-guides/guide/2018/09/19/energy-efficiency-for-construction

Building Sector Technology Fact Sheet	
Sector	Building
Adaptation/ Mitigation Needs	Crosscutting – Adaptation & Mitigation
Technology Name	LED Lighting
How this technology contributes to Adaptation / Mitigation as a co-benefit factor	LED are one of the most important climate change mitigation measures for the building sector but also have a co benefit adaptation contribution. Generally, it is reported that lighting consumes about 21% (Levine et al., 2007) of the household energy and 17.5% (Levine et al., 2007) of the global electricity. Reverting to a more energy efficient alternative will contribute to a reduction by 18% of the demand for electricity worldwide (UNEP, 2009). Due to longevity in the life of more efficient lights, a reduced amount of disposed light bulb fixtures to the landfill helps reduce materials which are not biodegradable as waste, which reduces the risk of affecting climate change.
Background/ notes, short description of the technology option source.	LEDs typically have low energy consumption, a small size, longer lifetime and faster switching than incandescence lamps and because of that, they have a wide palette of applicability.
Implementation assumptions - How the technology will be implemented and diffused across the subsector	LED systems can be implemented from two approaches which are the top down or the bottom-up approach. In a bottom-up approach, individual building/house owners can make a decision to adapt and use LED lighting fixtures with a onetime small investment cost, which will be paid back through savings from energy bills. The decision to adopt the bottom up approach can be facilitated by top-down policies, such as: 1. Reducing/removing import tariffs on LED and associated components 2. Initiating LED use programs to educate the public on the technology on its benefits versus conventional lighting systems. 3. Supporting local manufacturers to produce LED components and systems, to further bring down the cost 4. Introducing LED is beneficial to providing safe disposal of CFLs at the end of their life due to the mercury used in the lamps. One measure is to establish a CFL recycling plant, which can handle mercury and other environmental safety issues.
Cost	LED, which is an energy efficient lighting system, has been adapted widely due to several business cases throughout showing energy savings and returns on investments. It was projected that the global market potential for energy efficient lighting was expected to increase from US$13.5 billion to US$32.2 billion from 2010 to 2015, representing an annual growth rate of 19%. It was also projected that the growth will be strongest in commercial lighting from 2010 to 2012, followed by residential lighting from 2012 to 2015 (Pike Research, 2010).
Country Social Development Priorities	LED technologies are among the technologies that are most feasible to implement at a large scale as a result of their smaller investment cost, easy

	and straightforward installation and the fact that they are a necessity for daily life.
Country Economic development economic benefits	● LED technologies are more energy efficient than thermal radiator lamps. For example, compact fluorescent lamp (CFL) converts 25% of the energy to visible light, whereas an incandescent lamp converts only 5% of the energy consumed into visible light, leaving 95% to be emitted as heat (UNEP, 2009). ● In terms of economic development, large-scale implementation of the product can reduce the cost at the consumer level. ● Manufacturing for lighting component production can help create jobs and upgrade skills of the local workforce and provide cost effective LED fixtures to the local end-users. ● It also contributes to security of energy supply as they make a significant contribution to the reduction in electricity demand.
Social Benefits	● LED technologies enhance health and living conditions for building occupants especially as it relates to the eyes. ● The use of high frequency electronic ballasts helps reduce eyestrain and fatigue, increase productivity in workplaces and provide better quality of life. ● LED lamps consume one-fifth (or less) of the energy incandescent lamps required for the same illumination capacity and they are approximately 1,000 times more energy efficient than kerosene lamps (Mills, 2005). In terms of lifespan, compared to incandescent lamps, CFLs last eight times longer with a lifespan of up to 8,000 operating hours (Hausladen et al., 2005).
Environmental Benefits	Implementing LED technologies brings many benefits to environmental protection, and, energy resource conservation. Energy efficient lamps such as LED can substantially reduce GHG emissions from lighting buildings. (Hausladen et al., 2005). It was reported that this may reduce the GHG emissions over a 30-year period.
Capital Cost (per facility)	Cost of one bulb approximately USD2 -3 / bulb Cost of GHG reduction 0.087 USD per kg CO_2
O&M Cost (per facility)	None
Disadvantages / Barriers	● Lack of information about lighting; scepticism about new technologies among building managers, architects, designers and end-users; the higher purchase cost of LED sources; ● The current state of technology development customer ignorance about pay-back periods; ● Quality issues with LED (aesthetic, colour temperature, slow time delay to full output); ● Customer mistrust of LED due to early failures; ● Increase in the use of low-voltage halogen lamps and double-ended high voltage lamps separation of capital expenditure and operating expenditure, with developers and property owners most interested in lower initial capital costs, which often means less efficient lighting systems being installed such as LED. ● Tenants or purchasers are then forced to pay the higher costs of operation.

Up Scaling Potential	Small scale

References

- Efficient Lighting Systems: http://www.climatetechwiki.org/technology/efficient-lighting-systems
- Technology Factsheet - Passive Solar Energy (Hot Water) And Solar Photovoltaic (Electricity): https://tech-action.unepdtu.org/wp-content/uploads/sites/2/2013/12/ref23x13-35.pdf
- What are the Barriers to Efficient Electric Lighting within a Domestic Environment?: https://www.researchgate.net/publication/257835694_What_are_the_Barriers_to_Efficient_Electric_Lighting_within_a_Domestic_Environment

TECHNOLOGY NAME:	**BIODIGESTER**
SECTOR:	**BUILDING SECTOR**
ADAPTATION/MITIGATION NEEDS	Mitigation
SCALE:	Residential
TIMELINE FOR OBSERVED IMPACT:	☐ Short-term; ☒ Medium-term; ☒ Longer-term
TECHNOLOGY CHARACTERISTICS	
INTRODUCTION:	This technology is a plug and play[39] biodigester system that would assist with household waste management while producing biogas for cooking. This gas would replace liquid petroleum gas (LPG) that is used currently as the fuel for cooking and hence reduce the cost incurred by households. Food waste from the home is place in the system and mixed with manure. Microbacteria then breaks down the food waste via a process of anaerobic digestion to produce biogas. Biogas main component is methane. The biogas produced is filter by the system and sent to the stove to be used for cooking. This filtration process is to ensure the biogas has a high level of methane while removing the other unwanted gases that are produced in lesser concentration. The system has the capacity to produce biogas for two (2) hours of cooking. 
STATUS IN-COUNTRY:	None in Antigua and Barbuda currently.
ACCEPTABILITY:	This technology would assist with waste management in the household while produce gas that can be used for cooking or heating and cooling
INSTITUTIONAL/ ORGANIZATIONAL REQUIREMENTS:	The Department of Environment (DOE) is responsible for ensuring that the home biodigester systems are procured and tested in Antigua and Barbuda to determine their feasibility. This would serve under the Green climate fund (GCF) projects for building resilience for climate change.
COSTS	
CAPITAL COSTS:	System cost USD$720.00 and comes with a biogas stove, 1300L flexible digester tank, 700L gas tank, a gas filter, inlet sink, indoor gas tube and 7M pipe for system to kitchen stove. The lifetime of the system is 15 years.
OPERATION AND MAINTENANCE:	For this system to run optimally, there must be a daily input of 6L of kitchen waste, 45L of slurry (15L of manure and 30L of water). The biogas filter should be changed every 4 months.
IMPACTS AND BENEFITS	
DIRECT:	• Assist with waste management of households. • Produced cleaner gas for cooking in households.
INDIRECT:	• Produces fertilisers than can be used for household farming. • Reduce dependence on LPG for cooking in households and hence less carbon emissions.
LOCAL CONTEXT	
OPPORTUNITIES:	This system would help with reduction in cost of cooking in households. For lesser income families, this is a great opportunity of producing a natural source of energy to facilitate their cooking requirements. Added to that the generation of fertiliser as

[39] Plug and play means no assembly or installation is required.

	a by-product of the system directly would assist with production of their own crops for food production.
BARRIERS:	Public knowledge on the operations of the system and its requirements for optimal production.
MARKET POTENTIAL:	This technology will provide new business opportunities for suppliers. There is the option of selling the biodigester system as it, or capturing, storing, and selling the biogas produced.

SECTOR	Building
ADAPTATION/ MITIGATION NEEDS	Crosscutting – Adaptation & Mitigation
TECHNOLOGY NAME	Portable Solar generators
TECHNOLOGY CHARACTERISTICS	
INTRODUCTION	A portable solar generator a compact off grid system that have an inverter, a battery and a charge controller built into a single device. These systems are designed to be charge from multiple sources such a solar module, from your car 12V cigarette port or a standard 120v socket. The solar modules are usually sold separately from the generator. There are various types of solar generators that varies in battery technology and capacity, recharging time, and inverter sizing. The size of the inverter controls the number of devices that can be operated simultaneously while the capacity of the battery determines how long the system can supply electricity to meet its load. Antigua and Barbuda as a large diesel generator back up sector to respond to the frequent blackouts. Diesel generators allow individuals to have power when the electric grid is down during and after a natural disaster. The operational however  Source Jackery 2020[1]
STATUS IN COUNTRY	There presently several solar systems on the island that are being used for both residential and commercial systems. The status of the portable solar system is unknown
ACCEPTABILITY	A solar system is a mainstream technology which is already being used in the Antigua. Thus, portable solar system acceptability should not be a problem. Also due to its flexibility, it could be used by persons that work in remote location with no direct access to the electric grid.
INSTITUTIONAL/ ORGANIZATIONAL REQUIREMENTS:	can be installed in any building and will not need any special permit to be installed. t these systems are high compared to the traditional diesel generators, therefore, to increase of the system special import regulation may be necessary.
COST	
CAPITAL COST	Portal solar generators are increasing in popularity, with reputable brands marketed internationally. The table below gives estimated pricing per unit:

Size	Device	Cost (USD)	Cost (XCD)
Small	167Wh Generator with a 60W solar panel	310	837

	Large | 2kWh generator with a 300W solar panel | 2400 | 6,480
OPERATION AND MAINTENANCE:	No special skill is required to operate the system. However, to extend its life span there are best practices that can be followed. Manufacturers instructions should be followed. Maintenance is low for this system. The solar panels surface should be cleaned when if it becomes dirty, the solar generator should be maintained according to manufacturer's instructions.
IMPACT AND BENEFITS	
DIRECT	• If used to replace a diesel generator, this will reduce GHG emissions provided solar power is used to supply the energy. • Eliminates the need to buy diesel oil to generator electricity. • Units are modular and scalable, can be used to provide electrical to remote location
INDIRECT	• Reduction of vulnerability to climate change- After natural disasters such as hurricane persons some communities are without electricity as power grids are destroyed. This system will ensure persons able to have electricity during these events to power essential devices. • Provides new business/job opportunities
LOCAL CONTEXT	
OPPORTUNITIES:	• Antiguans experience frequent blackouts due to grid instabilities. Furthermore, with the cost of oil increasing, it is becoming more expansive to operate diesel generators during power outages. Therefore, solar generators can be used to solve this problem by providing a free fuel method of providing electricity. • Vendors that rely on diesel generators could benefit from this technology. • Construction workers that use diesel generators for their power tools can this system.
BARRIERS	• A major barrier will be a high transportation cost due to its weight. • Capital cost of the system is high.
MARKET POTENTIAL	Opportunities for investment is high due to the projected increase in global temperature resulting from climate change. The high operational cost of current air conditioning system as already set the stage for persons to seek alternative solutions

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https://www.amazon.com/stores/Jackery+Inc/page/DAEA79E9-5DC3-4634-BFBE-0178220D8A5E?ref_=ast_bln

TECHNOLOGY NAME:	**SMALL SCALE WIND TURBINE**
SECTOR:	**BUILDING SECTOR**
ADAPTATION/MITIGATION NEEDS	Mitigation
SCALE:	Residential
TIMELINE FOR OBSERVED IMPACT:	☐ Short-term; ☒ Medium-term; ☒ Longer-term
TECHNOLOGY CHARACTERISTICS	
INTRODUCTION:	**Small Scale Wind Turbine is** known as a microgenerator of electricity as opposed to a large commercial wind turbine. Wind energy is a clean and indigenous source of renewable energy. It has less generating capacity than large commercial turbines found on wind farms, but their reduction in price and their versatility allow wind energy to wider disrupted around the country. There are certain areas in Antigua and Barbuda that experience decent wind regimes that could harness this natural resource and resultantly increase their resilience to climate change. Therefore, small scale wind turbines would be beneficial to home users and businesses to lower electricity bills. Small scale wind turbines are those turbines that have their rotor diameter ranging from 3m to 10 m and a power capacity of 1 to 20 kW. (Tummala Abhishiktha et AL, 2016).  24 v vertical axis wind turbines. Source [40] The most common type of turbine is the horizontal axis wind turbine (HAWT). The simplified model generates wind energy and has a wind vane behind the blade, but more complex has sensors and a motor that would direct the blades towards the wind. Due to advanced technology, there is a smaller HAWT. Vertical axis turbine (VAWT) is a fundamentally different turbine design that can capture the wind from all directions. These turbines are convenient and easy to handle.

40 https://www.aliexpress.com/item/4001080117772.html?spm=a2g0o.productlist.0.0.612961124E8ylm&algo_pvid=04cc053b-88db-4960-9921-2883ad0745d1&algo_expid=04cc053b-88db-4960-9921-2883ad0745d1-4&btsid=0b0a555161003996707768 79ee059&ws_ab_test=searchweb0_0,searchweb201602_,searchweb201603
_

STATUS IN-COUNTRY:	There are a few Large-scale wind turbine, wind hybrid (wind and solar Energy) interactive power systems, and few small-scale turbines currently available in Antigua and Barbuda[41].
ACCEPTABILITY:	Small scale wind turbine is mainstream technology already being used in Antigua and Barbuda.
INSTITUTIONAL/ ORGANIZATIONAL REQUIREMENTS:	The Department of Environment (DOE) is responsible for ensuring that the small-scale wind turbine is practiced. Entities like the Green climate fund (GCF) or government-subsidized projects to build nationwide resilience.
COSTS	
CAPITAL COSTS:	Major system components include a battery, grid tried inverter, mppt charge controller, wind turbine only. Electronics may include a battery sensor. The estimated cost of a grid-tied wind turbine system, 1, 2, 3 kW and 10kW system is approximately **USD$5,00 – 17,000| XCD $13,000- $60,000**. The system can eventually pay back itself through reduced electric bills.
OPERATION AND MAINTENANCE:	The lifetime of the turbine is dependent on the manufacturer which is usually 10 years. The manufacturer of the wind system or dealer can assist the customer in installing a small wind turbine. The small-scale wind turbine installation can be a do-it-yourself project, but a credible installer may provide additional services such as permitting, a licensed electrician is also needed. Tower and turbine manufacturers should provide their maintenance plan. Some turbines need periodic lubrication, oil changes, or replacement of wear and tear surfaces such as blades.[42]
IMPACTS AND BENEFITS	
DIRECT:	▪ Wind system for homes and business can reduce energy consumption which will significantly lower utility bills by making homes more energy efficient
INDIRECT:	▪ Provides new business/job opportunities for suppliers and service technicians and electricians. ▪ Climate change impact is lesson during a hurricane with households that only depend on PV systems. .

41 https://environment.gov.ag/news/article/31

42 https://windexchange.energy.gov/small-wind-guidebook

APPENDIX F: TRANSPORT SECTOR FACTSHEETS

Technology Fact Sheets

Transport Sector Technology Fact Sheet	
Sector	Transport
Adaptation/ Mitigation Needs	Crosscutting – Mitigation & Adaptation
Technology Name	Improvement of Road Infrastructure
How this technology contributes to Mitigation/ Adaptation co - benefit	● Provides adequate road improvement infrastructure ● Provides more efficient disposition of your vehicle
Background/ notes, short description of the technology options.	Road infrastructure consists of installing fixed assets including surface road, storm water drainage, pedestrian paths and vehicle pull-off stops. Operation of vehicles along these carriageways reduces travel time, improves safety for both traffic and pedestrian use, improves efficiency and generates employment in sectors as aggregate influences the aggregate demand for goods and services which ultimately leads to increase in growth in the economy and development.
Implementation assumptions - How the technology will be implemented and diffused across the subsector.	The improvement of road infrastructure would contribute to increased resilience in the road sector and socioeconomic development of Antigua and Barbuda.
Cost	£13,900,000 (CDB Budgeted Value)
Country Social Development Priorities	● Roads make crucial contribution to economic development and growth and bring important social benefits. ● In addition, providing access to employment, social, health and education services makes a road network crucial in fighting against poverty. Roads open up more areas and stimulate economic and social development. For those reasons, road infrastructure is the most important of all public assets.
Country Economic development economic benefits	● The greatest benefits are experienced when road infrastructure improvements are made in rural areas. This shows that Government planning should priorities investment in road infrastructure in low income areas where the plight of the poor is directly addressed, mainly in the form of providing market and service access, lowering transport cost and facilitating economic growth. ● The Political will and the Public Works Department should focus on upgrading existing road infrastructure and providing both surface and subsurface storm water drainage. This further leads to job creation, thus, positively affecting poverty and stimulating economic growth.

Social Benefits	• Road infrastructure development fights against poverty by providing access to employment, social, health and education services. • Roads also open up more areas and stimulate economic and social development.
Environmental Benefits	• Improvement of fuel efficiency, reduction of wear and tear and also the reduction tailpipe emission of CO_2 due to an efficient road surface. • Additionally, there would be a general reduction in noise, dust, vibrations and waste along the carriageways.
Other Considerations and Priorities (such as market potentials)	When the private sector is consulted and involved when new road infrastructure is planned, private sector investment tends to follow public road infrastructure investment. This will allow both the government and private sector to maximize the benefit derived from the investments.
Capital Cost (per facility)	Pending
O&M Cost (per facility)	Pending
Disadvantages / Barriers	• Climate change can contribute to an acceleration in the degradation of roadway when there is an absence of adequate storm water drainage facilities of surface and sub-surface application. • Additionally, there [43]may be rising sea levels and more frequent storms associated with heavy flooding. • Persistent roaming of live stocks on roads creates a safety hazard and degradation to condition of unpaved road surfaces.
Up Scaling Potential	Large Government input

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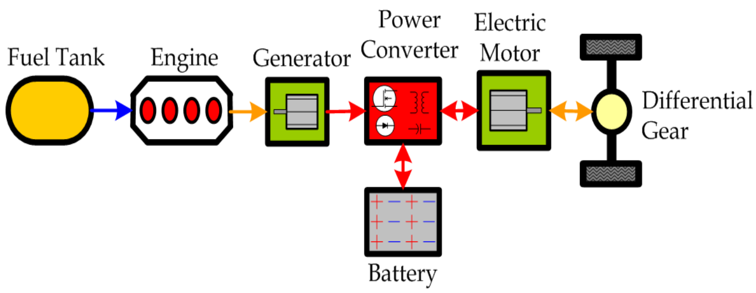
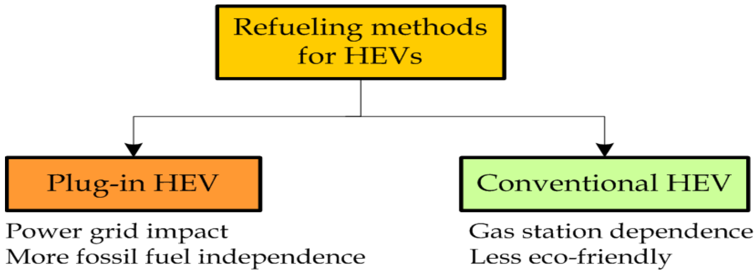
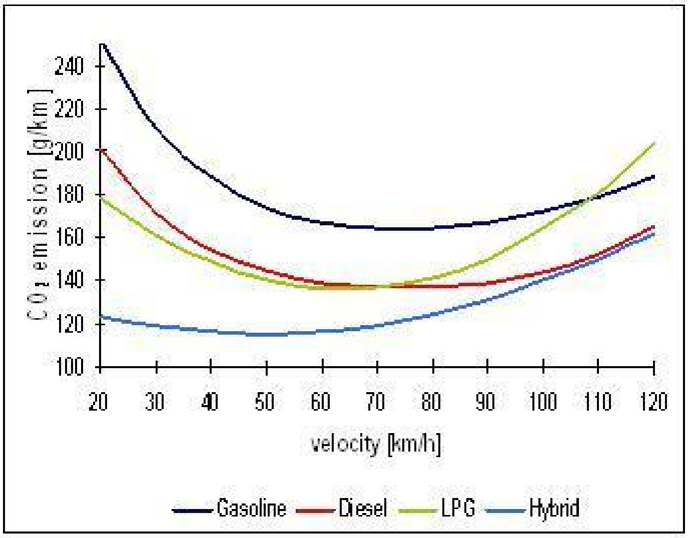
- Climate-resilient public road infrastructure key to development in Guyana: https://www.caribank.org/newsroom/news-and-events/climate-resilient-public-road-infrastructure-key-development-guyana
- Road Infrastructure Rehabilitation: https://www.caribank.org/our-work/projects-map/road-infrastructure-rehabilitation
- What is Road Infrastructure: https://www.igi-global.com/dictionary/convergence-and-equality-of-road-infrastructure/55615

43

Transport Sector Technology Fact Sheet	
Sector	Transport
Adaptation/ Mitigation Needs	Mitigation
Technology Name	Hybrid Electric Vehicles (HEV)
How this technology contributes to Mitigation	Vehicles employed in urban areas like small passenger cars, local delivery trucks and city buses benefit from hybridization and show substantially lower CO_2 emissions, ranging from 23 to 43% depending on the traffic dynamics.
Background/ notes, short description of the technology option.	There are two technical pathways in the reduction of GHG emissions today, which are: ● The deployment of low carbon alternative fuels such as biofuels, LPG, CNG and LNG ● The improvement of the energy efficiency of the vehicles through downsizing of the engine and various levels of hybridization and electrification. Electric vehicles are the most efficient vehicles. However, there are some constraints which its manufacturing has led to: 1. High purchase cost 2. Frequent recharging 3. Short driving ranges   An alternative, but complementary solution is the hybrid electric vehicle (HEV), which combines both internal combustion and technologies full electric vehicle motor. An HEV is a type of hybrid vehicle that combines a conventional internal combustion engine (ICE) system with an electric propulsion system (hybrid vehicle drivetrain). The HEV provides one of the fundamental laws of energy, where potential energy is converted into kinetic energy to

	provide electricity through regenerative braking. This energy is converted back, to charge the battery. During the breaking process, the energy dissipated by the break disc is converted to kinetic energy, which is connected to the electric motor. This is then converted into electricity, which is stored to power the vehicle through its electric technologies on board. There are several versions of HEV available in production, such as: ● Micro Hybridization: Electric motor is not used to power the vehicle, but through breaking it powers the generator which in turn powers the battery on board. ● Mild Hybridization: Electric motors are used to propel the vehicle, but this cannot be used solely. They have to rely on regenerative breaking ● Full Hybridization: Full electricity can be used at low speed and incorporates the internal combustion at high speeds or when the electricity on board is low to propel the vehicle. ● Series Hybridization: These are full electric vehicles. The difference between this and the HEV is that internal combustion engine is used as a generator to power the vehicle. 
Implementation assumptions - How the technology will be implemented and diffused across the subsector.	HEVs are mostly used in urban areas where there is quite a lot of breaking, stop and go. They have low tailpipe CO_2 emissions at low speed, hence the use in urban areas or where the minimum speed is between 40 – 60 km/hr. Antigua and Barbuda has initiated an Electric School Bus Pilot program. This can be a pathway to that full electric technology where the cost barrier may be a challenge - an intermediary step towards EV.
Cost	A normal passenger HEV car can cost USD$3000 - $6000, whereas for buses the cost may be 30% higher than a non-hybrid bus.
Country Social Development Priorities	HEVs only have low tailpipe CO_2 at low speeds and hence it matches the speed limits of the tendency for speed regulated by traffic departments especially suited for Antigua and Barbuda. Studies which compared the HEV with the regular vehicle showed that regular buses have 23-43% lower CO_2 emissions and 18-39% lower NOx emissions in comparison to similar new non-hybrid diesel articulated

	buses. Since our traffic department regularized speed limits are < 40km/hr, the HEV type of vehicle would be most suited.
Country Economic development economic benefits	The hybrid car was a way to give the electric car more action time while still keeping its environmental approach. Hybrid electric vehicles offer a proven technology that can reduce fossil fuel use and accompanying emissions. A hybrid vehicle is cheaper to own as it runs on either no or very little oil-based products compared to a standard vehicle.
Social Benefits	Vehicles employed in urban areas like small passenger cars, local delivery trucks and city busses benefit from hybridization.
Environmental Benefits	Lowest tailpipe emission of CO_2 depending on the traffic dynamics i.e. 23 - 43% reduction in emissions. They have the advantage of higher fuel efficiency and reduced CO_2 emissions without additional infrastructure requirements. When calculating the energy return on investment of the various technologies based on the current energy generation mix, hybrid vehicles show the greatest environmental benefits, although this would change if electricity was made with high amounts of renewables.
O&M Cost (per facility)	The costs of maintenance of full hybrid cars are expected to be equal to non-hybrid vehicles. It is expected, however, that the overall costs over the lifetime of a vehicle are lower for a hybrid vehicle due to better fuel efficiency. For buses, on the other hand, the O&M costs are about 15% lower than the normal diesel-operated buses.
Disadvantages / Barriers	Hybrid vehicles are still more expensive than traditional vehicles using an internal combustion engine.
Up Scaling Potential	A large advantage of hybrid vehicles compared to other options for reducing GHG emissions in transport is the fact that no additional infrastructure investments are required.

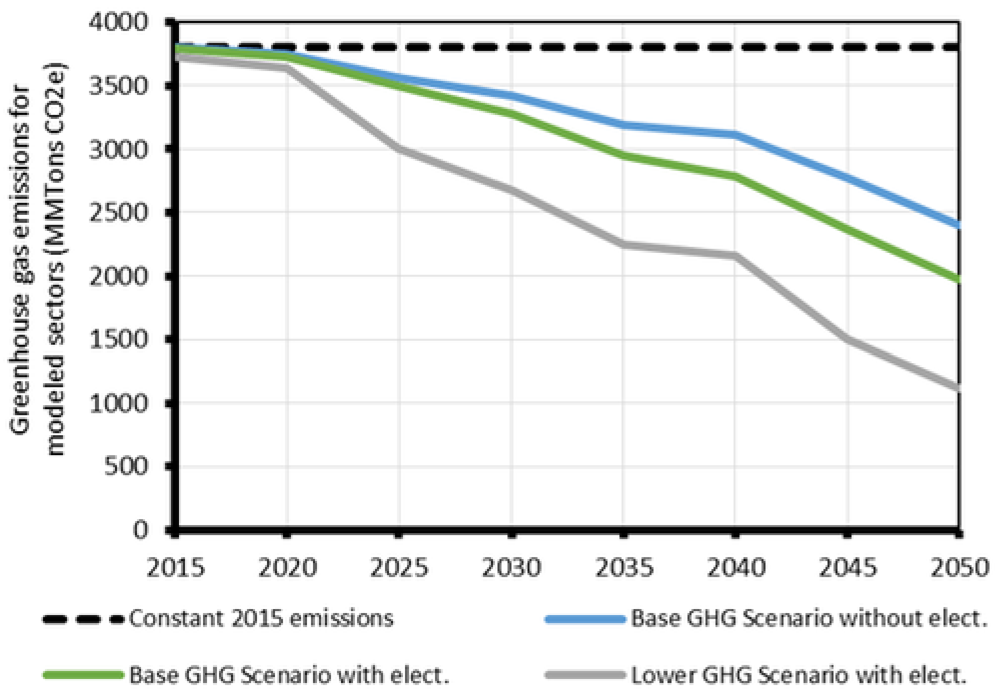
References

- Electric Bus Pilot Project: https://environment.gov.ag/projects-reports#/Electric-Bus-Pilot-Project
- Hybrid Electric Vehicles: http://www.climatetechwiki.org/technology/hev

<table>
<tr><th colspan="2">Transport Sector Technology Fact Sheet</th></tr>
<tr><td>Sector</td><td>Transport</td></tr>
<tr><td>Adaptation/ Mitigation Needs</td><td>Mitigation</td></tr>
<tr><td>Technology Name</td><td>Battery Electric Vehicles (BEVs)</td></tr>
<tr><td>How this technology contributes to Mitigation</td><td>Vehicles employed in urban areas like small passenger cars, local delivery trucks and city buses benefit from hybridization and show substantially lower CO_2 emissions, ranging from 23 to 43% depending on the traffic dynamics. It is established that a transition to electric vehicles (EVs) will immediately reduce toxic air pollution.

BEVs emit fewer greenhouse gases and air pollutants over their entire life cycle than petrol and diesel cars, according to a European Environment Agency (EEA) report, published 22 November 2018 (EEA, 2018).

It is important to consider that through climate-projection goals, the global environment is striving for an 80 per cent reduction in greenhouse gas (GHG) emissions from 1990 levels by 2050. About 60 per cent of carbon pollution from the transportation sector comes from passenger vehicles. It is claimed that If we electrify all of them with renewably generated, zero-carbon electricity by 2050, we will address a huge part of the climate challenge for transportation.

The figure below shows the combined emissions for the modelled electricity and transportation sector. When the transportation sector is electrified in the Base GHG Scenario, 2050 emissions are reduced by 48 per cent from 2015 levels. In the Lower GHG Scenario, total emissions are reduced by 70 per cent from 2015 levels (Tonachel, 2015).

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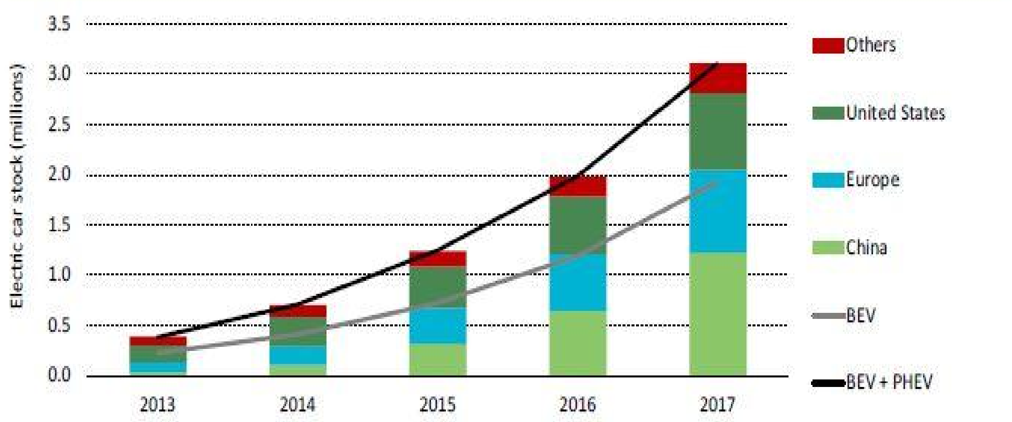
Background/ notes, short description of the technology option.	This technology presentation deals with cars, buses and trucks for both private and public transportation. The EV global sales have passed 1 million units in 2017. This represents a growth in new electric car sales of 54% compared with 2016, where electrification of other transport modes is also developing quickly, especially buses, which had sales of about 100,000 in 2017. The figure below shows the evolution of the global stock of EVs (IEA, 2018). **Figure ES 1 • Evolution of the global electric car stock, 2013-17**  Notes: The electric car stock shown is primarily estimated on the basis of cumulative sales since 2005. Where available, stock numbers from official national statistics have been used (provided that the data can be shown to be consistent with sales evolutions). EVs are also known as plug-in electric vehicles (PEVs) or BEVs. They are comprised of electric motors for propulsion, powered by electricity provided mainly off-board of the vehicle. Some energy is generated on-board by regenerative braking, which supports the on-board power source by charging the batteries. There are great benefits of BEVs: ● They can be recharged from a sustainable renewable energy source. ● They provide a low running cost based on energy consumption and maintenance. ● Zero tailpipe gas emissions during operations. One of the major barriers about the BEV is the cost of the on-board batteries. They are predominantly the major cost in producing the BEV, hence, improved battery technology is one of the hopeful directional trends that would ultimately bring down the cost of the vehicle. On a fully charged battery, a BEV could travel up to 200km (Robertson, n.d.).
Implementation assumptions - How the technology will be implemented and diffused across the subsector.	Antigua and Barbuda has initiated an Electric School Bus Pilot program. This can be a pathway to that full electric technology, where the cost barrier may be a challenge - an intermediary step towards EVs. Due to its dependency on external technology source, the constraints which the country faces would require significant intervention by the policy makers for meaningful changes. Such changes in transportation efficiencies would likely result in reductions in GHG emissions, which will be driven by technology and economic forces independent of policies and actions taken at the national level.

<table>
<tr><td>Cost</td><td>The table below provides appropriate investment and incentive levels for EVs. This will, in turn, promote market transformation and facilitate the electrification of the transportation sector (Malmgrem, 2016).

Table 4: Total Ownership Cost over Life of Vehicle
<table>
<tr><th></th><th>Nissan Leaf</th><th>Honda Civic</th></tr>
<tr><td>Vehicle Cost</td><td>$ 29,010</td><td>$18,640</td></tr>
<tr><td>Charging Station Cost (including installation)</td><td>$ 1,000</td><td>0</td></tr>
<tr><td>Federal Incentive (U.S.)</td><td>-$ 7,500</td><td>0</td></tr>
<tr><td>Energy Costs</td><td>$ 2,750</td><td>$ 6,880</td></tr>
<tr><td>Socialized Environmental Costs (CO2)</td><td>0</td><td>$ 866</td></tr>
<tr><td>Socialized Health Costs</td><td>0</td><td>$ 1686</td></tr>
<tr><td>Economic Development Benefit</td><td>-$ 965</td><td>0</td></tr>
<tr><td>National Security Costs</td><td>0</td><td>$ 3,268</td></tr>
<tr><td>Maintenance</td><td>$ 1080</td><td>$ 2,568</td></tr>
<tr><td>Total 10 Year Cost to Owner and Society</td><td>$25,375</td><td>$33,908</td></tr>
</table></td></tr>
<tr><td>Country Social Development Priorities</td><td>BEVs have no tailpipe gases and, therefore, do not contribute to GHG emissions. Antigua and Barbuda is expected to adopt the climate change negotiating standards by reducing GHG emissions by greater than 85% below 1990 levels by 2050. The increase in use of BEVs over conventional combustion vehicles is expected to contribute to the reduction in GHG emissions (Antigua and Barbuda's Second National Communication on Climate Change, 2009).</td></tr>
<tr><td>Country Economic development economic benefits</td><td>● Fuel Cost Savings and Job Growth: EVs reduce transportation fuel costs through more efficient vehicle technology, freeing up cash many owners would spend on other goods and services, which would create more jobs.
● Energy Resilience: With Antigua and Barbuda gearing to a non-reliance on fossil fuel base power source, a sustainable renewable source power would be most applicable.
● Use of Existing Infrastructure: Where there would be existing facilities, such as overhead electricity power supply generated from the national grid, it is strongly supported that the supply could be feeding from a renewable source in the near future.
● Energy Efficiency: The energy of the vehicle is store on-board through limited moving parts with high energy efficiency. Additionally, the fact that energy is also created through regenerative braking, the excess energy is stored on-board for other use when the vehicle is in use. Therefore, the BEV has about 3 times the efficiency of the normal combustion vehicle.
● Low Cost of Electricity: Use of a 100% sustainable renewable power source would provide limited or no use on the national grid. Supporting a renewable power source infrastructure can provide a well-defined BEV transportation system.</td></tr>
<tr><td>Social Benefits</td><td>EVs readily available across the broad spectrum of consumers of varying income groups, can be a very economical medium of mobility. Here, the cost of the electric fuel and the maintenance would be less. Using less energy for transport, there would be more readily available income for alternate needs.

There are great benefits of wellbeing and health attributes to the general public through the fact there is no pollution with the reduction of harmful exhaust emissions. This</td></tr>
</table>

<table>
<tr><td></td><td>provides better air quality. This will lead to fewer health problems and costs caused by air pollution. Additionally, there is minimal noise as EVs are quieter than petrol/diesel vehicles, which means less noise pollution.</td></tr>
<tr><td>Environmental Benefits</td><td>Less Pollution: EVs help to reduce harmful air pollution from exhaust emissions. An EV has zero exhaust emissions.
Renewable Energy: The use of sustainable renewable energy to recharge EVs can reduce GHG emissions even further.
Eco-friendly Materials: There is also a trend towards more eco-friendly production and materials for EVs. The Ford Focus electric vehicle is made up of recycled materials and the padding is made out of bio-based materials (Ergon Energy Network, 2019).</td></tr>
<tr><td>O&M Cost (per facility)</td><td>The BEV has far fewer moving parts than a conventional petrol/diesel car. There is little servicing required and no expensive exhaust systems, starter motors, fuel injection systems, radiators and other parts that are needed in a conventional petrol/diesel car. The table below shows the maintenance cost savings of owning and operating an EV (Malgrem, 2016).

Table 2: Maintenance Costs over First 100,000 miles
<table>
<tr><th>Service/Maintenance</th><th>Traditional Vehicle</th><th>Electric Vehicle</th></tr>
<tr><td>Tires</td><td>$700</td><td>$700</td></tr>
<tr><td>Oil Change (every 5,000 miles)</td><td>$600</td><td>0</td></tr>
<tr><td>Automatic Transmission Fluid</td><td>$ 60</td><td>0</td></tr>
<tr><td>Spark Plugs and Wires</td><td>$200</td><td>0</td></tr>
<tr><td>Muffler</td><td>$180</td><td>0</td></tr>
<tr><td>Brakes</td><td>$400</td><td>$200</td></tr>
<tr><td>Total</td><td>$2140</td><td>$900</td></tr>
</table></td></tr>
<tr><td>Barriers</td><td>Barriers facing the EV market are the incremental costs of the vehicles. Consequently, many of the benefits of electric vehicles are not well understood and are omitted from cost-benefit analyses. Batteries for use in EVs are still expensive and have relatively limited driving ranges. Most existing EVs need to be recharged after a maximum of 150km to 300 km. It takes about an hour of charging for a vehicle to travel about 25 miles (Robertson, n.d.).</td></tr>
<tr><td>Up Scaling Potential</td><td>It is forecasted that BEVs would be about 5-10% of the global market by 2020 and it would also have a rapid uptake.</td></tr>
</table>

References

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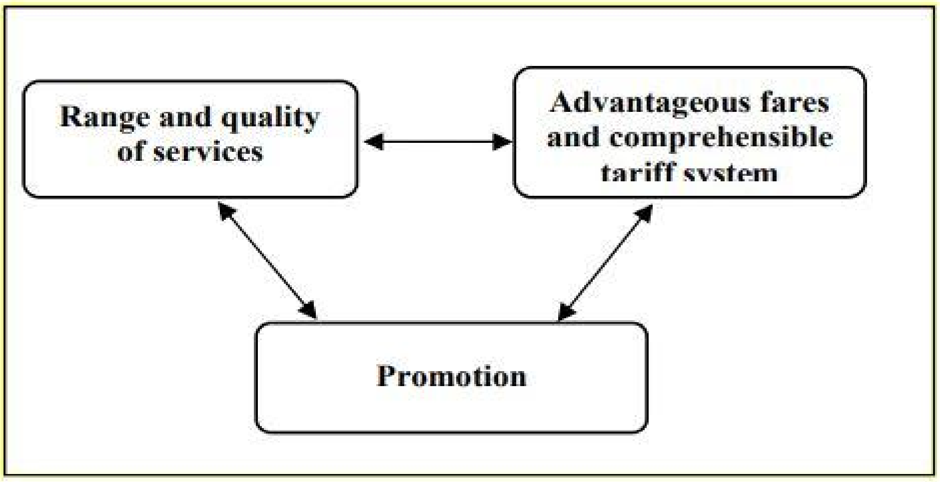
Transport Sector Technology Fact Sheet	
Sector	Transport
Adaptation/ Mitigation Needs	Mitigation
Technology Name	Renewable Solar Charging Station
How this technology contributes to Mitigation	The European Photovoltaic Industry Association states that solar power could provide energy for more than one billion people by 2020 and 26 percent of global energy needs by 2040. Solar power provides us with the possibility of a cleaner and more renewable future. The development and installation of solar powered charging stations will reduce the amount of greenhouse gases emitted into the atmosphere, future costs associated with climate change and health issues.
Background/ notes, short description of the technology option source	*Solar Power Charging Stations*: An Electric Vehicle Autonomous Renewable Charger (EV ARC) is fully autonomous, completely mobile and provides total renewable electricity for EVs in public areas. The charger is designed to fit within the dimensions of a single parking space (9'x18') and produces between 3,800 to 7,000 kWh of solar electricity annually i.e. 16 kWh per day. The system would have an amount of energy storage, which even allows EV owners to charge their vehicles at night. It is claimed that they can produce up to 100 electric miles per day, promising not an ounce of carbon emissions. As it is off the grid, the EV ARC requires no foundation, electrical upgrades, or building permits, making it very attractive for its forcible use. 
Implementation assumptions - How the technology will be implemented and diffused across the subsector	Renewable charging stations across the island at minimum range as specified can be integrated in parking lots and pull-offs designed along the road carriageway and isolated areas of uninterrupted activities of construction or heavy traffic.
Cost	Base Price @ USD$57,500.00 Additional upgrades excluding base price = USD$63,913.00

Country Social Development Priorities	Renewable solar charging stations for electric vehicles or hybrid electric vehicles are just one way in which the country can move towards a more resource-efficient economy and decarbonized transport system. Reducing the reliance on fossil fuel conventional vehicles with electric vehicles HEV powered by alternate fuels power source of solar which is in abundance as a source can help reduce emissions, due to the renewable source it uses to power the vehicle.
Country Economic development economic benefits	Less reliance on the importation of fossil fuel-based products retains the island's foreign reserves, which could be used to invest in more efficient energy technologies, reducing GHG emissions.
Social Benefits	● Lower CO_2 and air pollutants from the road transport sector ● An overall net benefit in terms of lower emission of CO_2 and sir pollutants nitrogen oxide (NO_x) and particular matters
Environmental Benefits	Solar Charging Station has zero CO_2 emissions Solar is one of two sources with zero emissions across the board.
Capital Cost (per facility)	As the country moves to electric vehicles the demand would govern the number of units required by the cost previously noted for the units.
O&M Cost (per facility)	Zero or minimal
Disadvantages / Barriers	High percentage of renewable energy of greener fuels are still fossil. Charging off the grid is still contributing to GHG emissions since the power source to the grid is mostly fossil fuel based. The oil industry heavy supplier promoting that increasing efficiency, rather than fuel switching, is the main factor causing transport carbon emissions to fall from current levels.
Up Scaling Potential	Positive

References

- Hybrid Electric Vehicles: http://www.climatetechwiki.org/technology/hev
- How to Charge your EV with Clean Energy: https://www.fleetcarma.com/charge-ev-clean-energy/
- Transport: https://www.bp.com/en/global/corporate/energy-economics/energy-outlook/demand-by-sector/transport.html

Transport Sector Technology Fact Sheet	
Sector	Transport
Adaptation/ Mitigation Needs	Mitigation
Technology Name	Integrated Public Transport through Centralized Bussing
How this technology contributes to Mitigation	The transport sector contributes to about a quarter of the global CO_2 emissions. Therefore, the implementation of low carbon policies is required to achieve the 2°C and 1.5°C targets, according to Environmental Research Letters, which intends to reduce emissions over the period 2005 – 2100. Study has shown that drastic decarbonization in the transport sector can be achieved by implementing transportation polices such as: ● Vehicle technology innovations in the electric car, public transport developments, and increasing in the car occupancy rate. ● Energy efficiency improvements.
Background/ notes, short description of the technology options.	This technology is the organizational process through which the planning and other systems are associated regardless of transportation mode, providers and institutions with the aim to increase economic and social benefits. The process of integration includes many partial steps and each of these steps can contribute differently to the success of integrated transport system (ITS). The key success factors are shown below:  *Figure 1.* The key factors of ITS success and their interconnection
Implementation assumptions - How the technology will be implemented and diffused across the subsector.	● Users of public transport: These individuals are the decision makers who create the demand and determine the success of the venture, through their behaviours. ● Providers of public passenger transport: These persons have to be willing to provide the interconnection of their system in terms of transport, economic, organizational and tariff. ● Authorities of transport such as the Transport Board: As the legislators, they are obligated to establish the framework of how the integrated public transport must be implemented.
Cost	If this becomes a Public Private Partnership (PPP) project, then an investment of this nature can bring the cost of such a facility to fruition. Based on the fact that

	the capital cost may be of a high magnitude, Government input would be necessary as part sharing since it will heal the less fortunate needs of the society.
Country Social Development Priorities	Alternate fuel use in charging stations for EV or HEV vehicles are just one way in which the country can move towards a more resource efficient economy and decarbonised transport system. Another way to do this is by reducing the reliance on fossil fuel conventional vehicles with electric vehicles HEV powered by alternate fuels power source of wind, solar and biofuels can help reduce emissions, due to the renewable source it uses to power the vehicle. (The social benefits of having an integrated public bussing transport system could be categorized in ● This transport system could increase mobility and access: A definitive transport system helps overcome distances which would be challenging for those with limited options and also helps them to reach access to social and economic destinations in measured time. ● Provides and ensures a more balanced transportation system: Less stressful alternatives for travellers deciding their option and mode of transport. ● Provides safety: Having set stop locational areas provides safe gathering of passengers at a centralized point, therefore, reducing ad hoc stops reducing in the risk of accidents. ● Spur the development of neighbourhoods along the pathway route: Enhancing physical features intersection upliftment lends to the beautification of the neighbourhood which promotes the community's positive attributes. ● Increases community cohesion: It can stimulate social interaction, increase civic participation, foster closeness among neighbourhoods and increase people's sense of safety.
Country Economic development economic benefits	● Through Organization-Economic Integration: The main aim is to manage and realize financial flows between the subjects. Hence, dividing the revenues from fares and subsidy flows could be used to cover the costs which are not covered by the revenues. ● Promoting the integrated system and the services which it provides is essential. ● Establishing a fixed route service encourages commerce activities along the route. ● The outcome of the IPT is to give the regular public transport users increase level of service, attract some of the users to hold special access permits and contribute to an efficient coat efficient public transport. ● Public transit is an effective means for reducing GHG emissions without requiring a large capital investment
Social Benefits	● By having IPT departing and arriving at a specific time provides public behavioural patterns which becomes unique to all interrelated mobility in the transport and pedestrian model of the transport system. ● One of our focuses is the importance of using the IPT system to take care of the early and disabled. ● By reducing the amount of emissions from transportation in dense urban areas, public transportation can help cities to reduce smog, to meet air quality standards, and to decrease the health risks of poor air quality to their residents.

Environmental Benefits	● Public transportation reduces the number of cars in street and thus helps improve air quality, alleviate traffic congestion, noise and the amount of tailpipe emissions associated with those vehicles. ● Single transit vehicles can use more fuel than a private vehicle and the average amount of energy used per passenger is far less than a single-occupancy vehicle. Using public transportation can help individuals lower their personal carbon footprint and reduce their transportation-related emissions.
Other Considerations and Priorities (such as market potentials)	● Today, most transportation services for these user groups are demand responsive services of a door-to-door type. The cost to social services could be significantly reduced if some portion of these persons can utilize the integrated service instead of using taxi service the entire way. ● In the event of bad weather, having excess luggage or having to walk for long distances to your next bus stop or destination. ● Safety at nights and to satisfy demand in low density areas where there is no public transport offered.
Disadvantages / Barriers	● Political: The political will to make radical changes that could have positive or negative consequences through the implementation process. 1. Politicians and legal structure: Financial limitations, transportation organization, prioritization of cars by politicians, short sightedness in politics 2. Infrastructure and special planning: Process of spatial planning, lack of infrastructure, prioritization of cars through infrastructure, connection to politics. ● Business: 1. Service: time, comfort, storage space and low frequency 2. Communications and marketing: knowledge, prioritization of cars 3. Ticketing: Number of persons in the area, number of operators, method of payment, collaboration with stakeholders 4. Cost: Fares and end users ● General Public: 1. Behaviour: Mindset and habits, incentives and behaviour 2. Customer and demand: People living in rural areas, working population, knowledge about customer needs, low demand for international transportation
Up Scaling Potential	Positive

References

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- Sea Region: https://www.diva-portal.org/smash/get/diva2:1217832/FULLTEXT01.pdf
- Environmental Research Letters: https://iopscience.iop.org/article/10.1088/1748-9326/aabb0d/pdf
- Evaluation of an Integrated Public Transport System: a Simulation Approach: http://webstaff.itn.liu.se/~carha/Parallell_v_LITRES_paper.pdf
- Key Success Factors of Integrated Transport Systems: http://www.tsi.lv/sites/default/files/editor/science/Publikacii/RelStat_13/session_3_ed_poliakova_ok.pdf
- Urban transport in Denmark – efficient and innovative: http://www.climateaction.org/climate-leader-papers/urban_transport_in_denmark_efficient_and_innovative

<table>
<tr><th colspan="2">Transport Sector Technology Fact Sheet</th></tr>
<tr><td>Sector</td><td>Transport</td></tr>
<tr><td>Adaptation/ Mitigation Needs</td><td>Mitigation</td></tr>
<tr><td>Technology Name</td><td>Efficiency in the Transport Sector through increased quality of road infrastructure & driving behavioural changes</td></tr>
<tr><td>How this technology contributes to Mitigation</td><td>The IEA states that there are four polices which can improve the sufficiency within the transport sector, which are:
● Improving tire energy efficiency
● Fuel economy standards light vehicles
● Fuel economy standards for heavy duty vehicles
● Eco-driving: Operating the vehicle in a manner that minimizes fuel consumption and emissions, such that the following are achieved:
1. Driving at efficient speeds
2. Optimization of gear changing
3. Reducing unnecessary weight in the vehicle when not items are not in use.
4. Avoiding vehicle idling
5. Avoiding rapid acceleration and deceleration
The European Union estimated that the average change in emission in a regular car is:
● from 2005 at 161gCO_2/km
● to 2015 at 130 g CO_2/km.
Additionally, another 10gCO_2/km is reduced due to complementary measures of tire efficiency, gear shifting indicators, air conditioners and more use of low-carbon biofuels.
Through eco-driving, improvements in driving techniques can significantly improve on-road fuel efficiency and CO_2 emissions.</td></tr>
<tr><td>Background/ notes, short description of the technology option.</td><td>The three major vehicle manufacturing regions of USA, Europe and Asia have recommended policies which ultimately reduce CO_2 emissions. Two of the main areas of concertation are related to tires and fuel efficiency. Such mandatory measures include the Tire Pressure Monitoring System (TPMS) on cars, multipurpose vehicle, buses and trucks.</td></tr>
<tr><td>Implementation assumptions - How the technology will be implemented and diffused across the subsector.</td><td>● Users of public transport: These individuals are the decision makers who create the demand and determine the success of the venture through their behaviours.
● Providers of public passenger transport: These persons have to be willing to provide the interconnection of their system in terms of transport, economic, organizational and tariff.
● Authorities or transport such as transport board: As the legislators their obligation is to establish the framework of how the integrated public transport must be implemented.</td></tr>
<tr><td>Cost</td><td>The relationship of cost would depend on the individual’s attitude towards the efficiency changes.
Applying these changes to pathways would inherently be cost beneficial over the period of time for the owner of that vehicle.</td></tr>
<tr><td>Country Social Development Priorities</td><td>Transport strategies that prioritize public transport, safe walking and cycling networks can support physical activities and reduce traffic injuries.</td></tr>
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Country Economic development economic benefits	Healthier transport strategies can lead to health equity gains by providing vulnerable groups, such as low-wage earners, women and the elderly with greater access to social and economic opportunities, services, food markets, education and social and recreational outlets for the broader public. These groups often lack access to private vehicles on an equal basis opportunity.
Social Benefits	● Enhancing public transport can bring social inclusion benefits by providing new or additional services to areas not previously well-served, as well as improving accessibility levels for less able travellers. Free and concessionary fares can also help address affordability issues for some groups in society. ● Safe, equitable and energy-efficient urban transport can help achieve multiple health and sustainability goals. ● Eco-driving can contribute to better safety, reduce noise and stress. There are eco-driving programmers, which are integral for road safety programs like the popular radio show “Drive Time” in the island of Montserrat.
Environmental Benefits	● Improvements in levels of emissions and air quality from moving to newer, higher quality public transport vehicles. ● The main gains are lower pollution for human health, although these can be unevenly distributed as concentrations of pollutants can vary even within a small urban area. It is possible, however, that the greatest benefits will be enjoyed by those suffering the worst air quality impacts, thus making the distribution of benefits a fair one.
Disadvantages / Barriers	● Having more involvement from the political directives and advocating public acceptability, would take some time for implementation of such a project ● Financial support for strategies, without inducing policy bias ● Split or duplicated responsibility between government and agencies ● Legislative and regulatory to support these requirements ● Trying to process consistency in planning over the long term ● Identifying objectives, specifying problems, selecting possible solutions, appraisal, implementation
Up Scaling Potential	High scale at the governmental level

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- Key Success Factors of Integrated Transport Systems: http://www.tsi.lv/sites/default/files/editor/science/Publikacii/RelStat_13/session_3_ed_poliakova_ok.pdf
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