Jamaica

TECHNOLOGY NEEDS ASSESSMENT REPORT

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Jamaica
Technology Needs Assessment Report

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JAMAICA
TECHNOLOGY NEEDS ASSESSMENT

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Foreword

This **Technology Needs Assessment (TNA) Report** represents the first deliverable of a three-step process that seeks to identify and create *climate technology pathways for implementation of the Paris Agreement*. The process is country-driven and in that regard the consultants have held extensive stakeholder discussions with public private and civil society actors within the sectors selected by the Government of Jamaica for climate technology interventions.

The country's main socio-economic and environmental assets are already experiencing the adverse effects from more extreme climate-triggered events (rainfall, droughts and storms), sea-level rise, storm surges, and increased temperatures. Several constraints have been noted through varying studies, but implementation of solutions is often stymied by resources.

At the 2017 UN Climate Change Conference in Bonn, a special event on innovation underlined the importance of technological innovation for achieving the goals of the Paris Climate Change Agreement. It was noted that "climate technology represents one of the most potent and powerful ways to accelerate the transformation to low-emission, sustainable societies that are resilient to climate impacts". The session emphasised the "need to bring together green finance and technological innovation in technological solutions to fight global warming". It was also noted that "Technological innovation is a complex and multifaceted issue. But it is also one of the keys for solving the climate challenge" (UN, 2017).

The Government of Jamaica has endorsed the need to embrace technological innovation and has embarked on the three-step process which includes the barrier analysis for deployment and implementation of interventions and the Technology Action Plans, in addition to this Technology Action Plan.

This document is organised into four sections**:** **Part One** presents the setting and overview**; Part Two** presents the adaptation technologies; and the mitigation technologies are presented in **Part Three** and **Part Four** is the Summary and Conclusion.

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List of Acronyms and Abbreviations

ADRM	Agriculture Disaster Risk Management
BAEF	Barrier Analysis & Enabling Framework
BAU	Business-as-usual
BPO	Business Process Outsourcing
C–FISH	Caribbean Fish Sanctuary Partnership Initiative
CCADRR	Change Adaptation and Disaster Risk Reduction Project
CC	Climate Change
CCD	Climate Change Division
CFC	Chlorofluorocarbon
CH_4	Methane
CO_2	Carbon Dioxide
CO_{2e}	Carbon Dioxide
CSA	Climate Smart Agriculture
CSGM	Climate Studies Group Mona
CSP	Concentrated Solar Power
DC	District Cooling
DTU	Technical University of Denmark
EaaS	Energy as a Service
EMEP	Energy Management and Efficiency Programme
EREC	Eight Rivers Energy Company
EST	Environmentally Sound Technology
EU	European Union
EV	Electric Vehicles
FAO	Food and Agriculture Organization
GCCT	Gas Combined Cycle Turbine
GDP	Gross Domestic Product
GEF	Global Environment Facility
Gg	Giga tonnes
GHG	Greenhouse Gas
GMI	Global Methane Initiative
GoJ	Government of Jamaica
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
IDB	Inter-American Development Bank
IICA	Inter-American Institute for Cooperation on Agriculture
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Purchase
JA$	Jamaican Dollar
JICA	Japan International Cooperation Agency
JIS	Jamaica Information Service
JNCS	Jamaica National Cooling Strategy
JNEP	Jamaica's National Energy Policy
JPS	Jamaica Public Service
K-CEP	Kigali Cooling Efficiency Program
kW	Kilowatt
kWh	Kilowatt-hours
LRT	Light Rail Transit
MCA	Multi-Criteria Analysis
MEGJC	Ministry of Economic Growth and Job Creation
MeT Office	Meteorological Office of Jamaica
mbgl	Meters below ground level

MW	Megawatt
MSET	Ministry of Science, Energy and Technology
MSW	Municipal Solid Waste
Mt	Mega tonnes
NAMA	Nationally Appropriate Mitigation Action
NAP	National Adaptation Plan
NDA	National Designated Authority
NDC	Nationally Determined Contribution
NEPA	National Environment and Planning Agency
NGCC	Natural Gas Combined Cycle
NGGIP	National Greenhouse Gas Inventories Programme
NHC	National Hurricane Centre
NIC	National Irrigation Commission
NMVOC	Non-methane Volatile Organic Compounds
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxide
NRCA	National Resources Conservation Authority
NWC	National Water Commission
ODP	Ozone Depletion Potential
ODPEM	Office of Disaster Preparedness and Emergency Management
PAT	Pump-as-turbine
PIOJ	Planning Institute of Jamaica
PPCR	Pilot Program for Climate Resilience
PV	Photovoltaics
RADA	Rural Agricultural Development Authority
RDF	Residue-Derived Fuel
SDC	Social Development Commission
SDG	Sustainable Development Goal
SE4All	Suitable Energy for All
SLR	Sea Level Rise
SO_x	Sulphur Oxide
SWAC	Seawater Air Conditioning
TAP	Technology Action Plan
TNA	Technology Needs Assessment
TNC	Third National Communication
UDP	UNEP DTU Partnership
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
US$	United States Dollar
VCA	Vulnerability Capacity Assessment
WAD	Wave attenuation device
WBGMI	World Bank and Global Methane Initiative
WRA	Water Resources Authority

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Executive Summary

Background

This Technology Needs Assessment (TNA) Report 2020 represents the first deliverable (Multi-Criteria Analyses – MCA) of a three-step process that seeks to identify and create *climate technology*[1] *pathways for implementation of the Paris Agreemen*t. Steps 2 and 3, the Barrier Analysis & Enabling Framework (BAEF) and the Technology Action Plan, will follow in subsequent reports. The MCA process, though being undertaken simultaneously in Antigua and Barbuda, St Lucia, Suriname, Trinidad and Jamaica, is specifically country-driven and involves engaging multiple and diverse stakeholder discussions from public, private and civil society. **This MCA report is specific to Jamaica**.

The sectors in Jamaica selected for Adaptation and Mitigation using the MCA methodology were Agriculture, Coastal Resources, Water Resources, and Energy. The objective is to ultimately select Jamaica-specific and appropriate climate technologies which could be funded by the Global Environment Facility, UN Environment, to accelerate the transformation to low-emission, sustainable societies which are resilient to climate impacts. This would advance implementation of the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement in Jamaica which is a Party to the Agreement.

The national agency driving the country's climate change agenda is the Climate Change Division (CCD) of the Ministry of Economic Growth and Job Creation (MEGJC).

Climate model projections show that climate change could result in upward changes in ambient temperature, the frequency and intensity of extreme weather events, greater climate variability, vector-borne disease and rising sea levels. Jamaica therefore has a number of national strategies, policies and legislation, and is party to international agreements which facilitate adapting to the expected impacts of climate change and also mitigating its contributions to climate change. These include:

- Jamaica's National Development Plan – Vision 2030;
- The Climate Change Policy Framework for Jamaica;
- Nationally Appropriate Mitigation Actions (NAMA);
- National Determined Commitments (NDC);
- UN Framework Convention on Climate Change (UNFCCC);
- Strategic Programme for Climate Resilience;
- The Climate Change Policy Framework (prepared under the GoJ/EU/UNEP Climate Change Adaptation and Disaster Risk Reduction (CCADRR) Project);
- Third National Communication to the UNFCCC;
- Draft Jamaica National Climate Change Policy and Action Plan (JNCCPA, 2010);
- NEPA Climate Change Response Strategy 2010–2015;
- Jamaica National Energy Policy 2009–2030 (and National Renewable Energy Policy 2009–2030).

The agriculture sector and coastal resources were selected by the Climate Change Division of the Ministry of Economic Growth and Job Creation for this MCA process as they were previously assessed

[1] *Any hardware (equipment/material system), software (electronic programmes/IT) or organizational strategy [orgware] (process or way of doing things) which achieves the climate mitigation or adaptation goal.*

as being at the greatest risk, given their significant contribution to the country's GDP and to the labour force, and exposure to the impacts of natural elemental forces. Water and energy were selected due to their importance to Jamaica's economy as essential and ubiquitous inputs for all the island's important sectors and also in light of their significant contribution to emissions and the potential for reducing those emissions.

The selected sectors above are all contributors to Jamaica's greenhouse gas emissions as the table below demonstrates:

EMISSION SOURCES	EMISSIONS (CO_2e)	
	2006	**2014**
Energy	12 Mt	7.4 Mt
Industrial Processes	660 kt	950 kt
Land Use Change & Forestry	770 kt	780 kt
Agriculture	680 kt	620 kt
Waste	430 kt	420 kt
Gross Absolute Values	**14 Mt**	**10 Mt**

(*Source*: Climate Watch 2019).

If Jamaica receives conditional support for its NDC, considering mitigation actions across all sectors and in particular, the energy sector, the absolute emissions reduction targets for Jamaica would be as follows:

Year	Abatement Target
2025	1.344 Mt CO_2e
2030	1.449 Mt CO_2e

Source: Third National Communication of Jamaica to the United Nations Framework Convention on Climate Change 2018. Ministry of Economic Growth and Job Creation (MEGJC)

Methodology

To establish the basic framework for the development of the TNA Project in Jamaica, a TNA Coordinator (based at CCD), who also serves as the National Designated Authority (NDA) with respect to the UNFCCC Technology Mechanism in Jamaica, was selected. The CCD is further supported by a National Project Steering Committee, and provides the consulting team with overall vision, leadership support, communication and guidance. Finally, two independent national consultants were contracted to develop the recommendations for climate mitigation and adaptation, vulnerability assessment and adaptation planning, guided by the TNA methodology. To ensure the TNA methodology is followed, the consulting team were trained via a Capacity Building Workshop along with their Caribbean peers from the TNA Group of Caribbean countries. Training will be ongoing throughout the consultancy. Prioritisation of the climate technology options for future Global Environment Facility (GEF) support was then done through phased consultations with sector stakeholders.

Stakeholders were selected through a mapping process in the selected sectors, inclusive of public sector, private sector, academia and others. Gender balance was considered during the stakeholder mapping and the selection of the working groups for each sector. Selected stakeholders were very knowledgeable about their respective sectors and the relevant technologies. The selection process was also guided by the TNA Guidance for Gender-Responsiveness (2018) (UNDP DTU, 2018).

Interviews were conducted with stakeholders to identify known and available climate-related technologies and to validate an initial long list of such technologies developed by the national consultants. The working groups for each sector were also determined from the stakeholder mapping exercise. Sector working groups were initially engaged through a survey and interviews to determine the short list of technologies. They were provided with prepared technology fact sheets for the short-listed climate technologies, and engaged in workshops for the respective sectors.

The sector working groups ultimately selected the preferred climate technologies from the technology sheets, short listing as guided by the MCA methodology. In the respective sector stakeholders working groups, the stakeholders participated in the following activities;

- Discussed the technology fact sheets for all the short-listed technology options, including the capital and operational costs, benefits, current status of the use of the technologies, disadvantages of the technology options and how the technology could assist the sector in adapting to the effects of climate change. Some adjustments were made based on stakeholders' recommendations;
- Developed criteria based on cost, economic, social, environmental and climatic benefits. The approved criteria were then used for rating the technology options from the short list of technologies;
- Developed weights for each criterion, for each technology;
- Rated/scored each technology option based on the criteria and weighting using the MCA worksheet template provided.

Ultimately, the identification of climate technologies had general alignment with national development objectives, with a focus on sustainable development and the facilitation of transformative change using these climate technologies. For the MCA process, working group sessions were staged in October 2019.

Working Group Sessions held for the TNA Project

	Sector Working Group	**Stakeholder Session**
1	Energy Sector	Wednesday, 8 October 2019
2	Water Resources	Wednesday, 8 October 2019
3	Coastal Resources	Thursday, 9 October 2019
4	Agriculture Sector	Thursday, 9 October 2019

Concentrating the meeting dates over a two-day period assisted with time efficiencies for consultants and stakeholders, and the sessions were scheduled based on the availability of stakeholders.

Outcomes

The overall sector scores and top two (2) climate technologies for selection to the next stage (Barrier Analysis and Enabling Framework) are as follows:

MCA Scores for Adaptation Technology Options for the Agriculture Sector

Rank	Technology Options	Score
1	Sprinkler and Drip Irrigation	7785
2	Rainwater Harvesting Systems	6813

MCA Scores for Adaptation Technology Options for Coastal Resources

Rank	Technology Options	Score
1	Wetland Restoration	7550
2	Coral Reef Ecosystem Restoration	6100

MCA Scores for Water Resources Technology Options

Rank	Technology Options	Score
1	Rainwater Harvesting and Restoring of Barbeque Catchments	7506
2	Creation and Restoration of Minor Tank Networks	6956

MCA Acores for Mitigation Options for the Agriculture Sector

Rank	Technology Options	Score
1	Concentrating Solar-Powered Systems	6575
2	Aerobic Biological Treatment (composting)	6500

MCA Scores for Mitigation Technology Options for the Energy Sector

	Technology Options	Score
1	Refuse-Derived Fuel Production	5873
2	Biogas	6528

Part I – Overview and Contextual Setting

1 Introduction

This report represents the first deliverable in the Technology Needs Assessment (TNA) for Jamaica. It outlines the process followed to determine the prioritised technologies for adaptation and mitigation to climate change in four sectors viz. coastal resources, water resources, energy, and agriculture, and presents the draft selected technologies for each sector.

Document review including completed Technology Needs Assessment (TNA) Fact Sheets and reports from other territories, along with extensive stakeholder consultation, was used to develop the long list of technologies for each sector. A shorter list of technologies was then extracted based on survey feedback and consultation with the sector working groups. Working group sessions were conducted for each sector in which TNA Fact Sheets were discussed and multi-criteria analysis (MCA) conducted to prioritise the technologies for each sector.

The TNA process for Jamaica is informed by the Third National Communication (TNC), the Nationally Appropriate Mitigation Action (NAMA), the Renewable Energy NAMA, and the Nationally Determined Contributions (NDCs).

1. 1 - Overview of the Global TNA Project

The Global Technology Needs Assessment project is funded by the Global Environment Facility (GEF) and executed by the United Nations Environment Programme (UNEP) in collaboration with the UNEP DTU (Technical University of Denmark) Partnership (UDP) on energy, climate and sustainable development. The Global TNA is a strategic programme on technology transfer, designed to support countries to carry out Technology Needs Assessments within the framework of the United Nations Framework Convention on Climate Change (UNFCCC) and under the Paris Agreement. Its main aim is to avert the risks and impacts of climate change and to reduce national greenhouse gas (GHG) emissions.

1.1.1 - Objectives

The main objectives of the TNA project are:

1. To identify and prioritise through country-driven participatory processes, technologies that can contribute to adaptation and mitigation goals of the participant countries, while meeting their national sustainable development goals and priorities;
2. To identify barriers hindering the acquisition, deployment, and diffusion of prioritised technologies;
3. To develop Technology Action Plans (TAPs) specifying activities and enabling frameworks to overcome the barriers and facilitate the transfer adoption, and diffusion of selected technologies in the participant countries.

Further, the TNA process will develop concept notes for attracting funding to implement selected technologies as prioritised by the respective sector groups and the TNA Project Steering Committee.

1.1.2 - Purpose

The purpose of the TNA is to assist developing countries to identify and analyse priority technology needs, which can form the basis for a portfolio of environmentally sound technology (EST) projects and programmes to facilitate the transfer of, and access to the ESTs and know-how in the implementation of Article 4.5 of the UNFCCC Convention. Therefore, the TNAs are central to the tracking of 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.

1.1.2 - Expected Outcomes

The TNA process has helped participating countries to identify technological needs for sectors vulnerable to the impacts of climate change and for reducing emissions so as the attain the global and national targets for stemming global warming. Some of these outcomes included: -

I. Inputs into developing NDCs, National Adaptation Plans (NAPs) and NAMAs;
II. Use of the TNA methodology to assess other local needs;
III. Defining project proposals as a step towards investment-ready projects for national and international funding.

1.2 Jamaica – Situational Analysis

1.2.1 Development Priorities

Jamaica's National Development Plan – Vision 2030 (PIOJ, 2009) – articulated a strategic and transformative roadmap toward a vision of "*Jamaica, the place of choice to live, work, raise families, and do business".* The journey embodies moving the country from a middle-income developing country to developed country status by 2030. The Plan identifies four primary strategic goals, each with outcomes, and which are synergistic in that they are mutually supporting. Goals 3 and 4 are of import to the TNA project.

1.2.2 Status of Climate Projections and Vulnerability

The Climate Change Policy Framework for Jamaica (GoJ, 2015) provides a detailed description of climate projections for Jamaica. Climate model projections show increasing temperatures for the Caribbean region that could result in changes in the frequency and intensity of extreme weather events, greater climate variability and rising sea levels. Consequently, this will have negative impacts on critical sectors including the freshwater resources, coastal and marine resources, human settlements and infrastructure, terrestrial resources and biodiversity, agriculture, fisheries, tourism, human health and energy. Among others, the following specific changes are projected:

- The mean annual temperature for Jamaica is projected to increase between 0.7˚C to 1.8˚C by the 2050s and 1.1 ˚C and 3.2 ˚C by the 2090s, based on existing models;
- Projected rainfall changes range from –44% to +18% by the 2050s and –55% to +1 8% by the 2080s;
- The likelihood of more severe hurricanes will increase, although the overall frequency of hurricanes remains uncertain;
- Sea level is projected to rise between 0.18 m and 0.59 m by 2100 relative to 1980–1999 levels;
- Beaches, including coastal lands, will be eroded as a result of sea-level rise and changing processes that affect the coastline (*NAMA ,2019).*

1.2.3. Existing National Policies for Climate Change Mitigation and Adaptation

At the international level, Jamaica is party to the UN Framework Convention on Climate Change (UNFCCC), and since 1999, the country has been party to the Kyoto Protocol under which it has prepared and submitted three National Communications, including national GHG inventories. There is a strong policy and institutional environment to support climate change management and decision-making at the national level in Jamaica. To this end, several initiatives, policies and projects have been developed and implemented, guided by the Vision 2030 National Development Plan (2009), the overarching plan for the mainstreaming of climate change adaptation and mitigation into the country's national development processes.

One of the first institutional initiatives implemented to drive the country's climate change agenda was the establishment of the Climate Change Division (CCD) by the Ministry of Economic Growth and Job Creation (MEGJC), with the specific mandate to address climate change issues. The Government of Jamaica (GoJ) has also appointed a Climate Change Advisory Committee and established the Climate Change Focal Point Network to facilitate a multi-sectoral approach to climate change. Other significant legal, policy and regulatory mechanisms to develop, coordinate and implement a holistic programme for climate mitigation and adaptation include:

- The Strategic Programme for Climate Resilience;
- The Climate Change Policy Framework (prepared under the GoJ/EU/ UNEP Climate Change Adaptation and Disaster Risk Reduction (CCADRR) Project;
- The Third National Communication to the UNFCCC;
- The Draft Jamaica National Climate Change Policy and Action Plan;
- The National Environment and Planning Agency's (NEPA) Climate Change Response Strategy 2010–2015;
- The National Energy Policy 2009–2030;

- The National Renewable Energy Policy 2009–2030.

1.3 Sector Selection

The agriculture sector and coastal resources are among those sectors at greatest risk, given their significant contribution to the country's gross domestic product (GDP) and to the labour force. These two sectors were also highlighted as among the five most vulnerable to climate change in assessments conducted for Jamaica's Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC). Furthermore, the country's long-term sustainable development plan, Vision 2030 Jamaica – National Development Plan, articulates climate change adaptation as a priority for not only a healthy, natural environment, but also for achieving developed country status by 2030.

Jamaica is highly dependent on service industries especially tourism which accounts for some 70% of GDP. Most of the tourism industry is located along the coastline (GoJ, 2015). Agriculture accounts for 7% of GDP, however, the sector is important for providing food security for the country. Jamaica is also a small island developing state and as such, these key sectors are vulnerable to the impacts of climate change. This includes rising sea levels, droughts, coastal erosion, reduced rainfall and increasing temperatures. The 2015 Climate Change Policy Framework for Jamaica (GoJ, 2015) has identified 7 sectors which are highly vulnerable to climate change:

1. Coastal and Marine Resources
2. Tourism
3. Water Resources
4. Human Health
5. Human Settlements and Infrastructure
6. Energy
7. Agriculture.

1.3.1 Process and Results of Sector Selection

The sectors were selected by the Climate Change Division of the Ministry of Economic Growth and Job Creation. The assessment included the vulnerability of the sectors to climate change and would have taken into account the contributions to GDP from each sector. This evaluation led to the selection of the following four sectors:

1. Agriculture
2. Coastal Resources
3. Water
4. Energy.

1.4 Sector Overview

1.4.1 Agriculture

Agriculture in Jamaica is an established economic sector inclusive of the cultivation of crops and the operation of livestock, aquaculture farms and fisheries. In Jamaica, the agriculture sector has both large-scale monoculture commercial plantations (such as cocoa, citrus, coffee, banana, pimiento and sugarcane) which produce mainly for export, and small-scale mixed farms which produce for household subsistence, the domestic market (mainly legumes, vegetables, fruits, plantains, potatoes, yam and other tubers) and export. Farming occurs in the hilly terrain as well as on coastal plains depending on the specific requirements of the crop being grown (FAO, 2010). The variability in the types of farming and crop output has not only influenced location, but also vulnerability within the sector.

Changes in Jamaica's climate over the years have led to several extreme climate events which have, in turn, impacted the industry (Beckford, Barker, & Bailey, 2007). Particularly since the early 2000s, there have been notable increases in the frequency and severity of hurricanes and droughts which seem to interchange from one extreme to the other, causing significant losses to the sector. Between 2002 and 2008, the island experienced the passage of Hurricanes Charley and Ivan in 2004, followed in late 2004 to early 2005 by a seven-month drought period which was also accompanied by numerous bush fires. Hurricane Ivan accounted for 62% loss in total earnings from the sector (FAO, 2010), and JA$4,560 million worth of traditional export production (PIOJ, 2008). Subsequent impacts from Tropical Storm Wilma and Hurricanes Dennis and Emily resulted in further loss in profits and decline in GDP (Cambell, Barker, & McGregor, 2011). Tropical Storm Nicole in 2010 caused an estimated JA$576.5 million in damages to crops and livestock (PIOJ, 2010). Hurricane Sandy in 2012 and the effect of other passing systems add to the plethora of extreme climatic events impacting the sector.

Hurricanes, floods, landslides, storm surge inundations (fishing beaches overwashed with sand and debris or heavily eroded, changing the landscape), droughts, and bush fires have all caused significant damages to agricultural infrastructure, as well as losses in domestic and export crops, livestock production, fisheries and employment (Table1.1). Between 1994 and 2010, these events have incurred an estimated JA$14,390 million in agricultural losses (RADA, 2011). High value crops like bananas, coffee and sugarcane are more vulnerable to hurricane and drought risks. The extensive flooding associated with hurricanes and other rainfall and flood events, coupled with water scarcity associated with droughts, affects sugarcane growth. The citrus growing regions are susceptible to sustained winds, soil erosion, and flower and fruit dropping.

Table 1.1: Damages and losses caused by Hurricane Dean (2007) to Agriculture in Jamaica

INDUSTRY	DAMAGES (MILLION)	LOSSES
Coffee	JA$1,231	45% of total coffee crop
Sugarcane	JA$761	Reduced sugarcane production by 21%
Banana	US$15 (export market) US$25 (domestic market)	85% loss in standing crops 95% loss of maiden suckers
Dairy	–	25% loss in daily milk production due to lack of electricity and water supply

INDUSTRY	DAMAGES (MILLION)	LOSSES
Poultry	–	30–35% of small poultry farmers suffered damages
Fisheries	JA$9,806 JA$106 (aquaculture)	Substantial damage to south coast due to inundated beaches and loss of gear

Source: (PIOJ, 2007)

Some areas become more vulnerable than others because of their localised conditions. Across Jamaica, there are some areas more susceptible to greater damage despite being impacted by the same event. In some cases, unsustainable agricultural practices in naturally vulnerable areas, like along the steep hillside slopes, increase the risk of greater damage (IICA, 2017). These practices lead to soil erosion, flooding and degradation of watersheds.

The impact of prolonged drought periods on agriculture is also exacerbated in areas where there are poor irrigation systems, inefficient water management and inefficient use of runoff for storage and later use, due to reliance mainly on rainfall for irrigation. Consequently, reduced rainfall periods add more pressure since there are no alternative water sources. The eastern and southern sections of the island are some of the main areas impacted by the passage of hurricanes (PIOJ, 2010). These areas have experienced significant damage to crops and livestock over the years due to flooding and strong winds associated with hurricanes and tropical storms.

1.4.2 Coastal Resources

Coastal areas play a critical role in the social and economic life of Jamaica. An estimated 75% of economic assets including air and seaport facilities, urban centres, industries as well as tourism infrastructure are concentrated in coastal areas and are responsible for generating approximately 90% of the island's GDP (Met Office, 2010). The demand for coastal space in Jamaica has also intensified with the increase in population over the last 10–15 years, resulting in approximately 70% of the population residing along coastal plains (SDC, 2011). This has led to an increase in vulnerability to the more frequent and intensified natural hazards being experienced within the Caribbean as a result of climate change. In turn, this has impacted many coastal infrastructures and settlements, resulting in loss of lives, livelihoods, and damage amounting to billions of dollars.

Jamaica's coastal resources, like those of other small island states, are of major environmental, social and economic significance. These include both man-made and natural resources such as harbours, beaches, coral reefs, mangroves, and swamps, all of which play a unique part in the development of industries and establishment of livelihoods for locals.

Extreme weather events, influenced by climate change and which impact coastal resources, include hurricanes, tropical depressions, tropical storms, storm surges, and terrestrial flooding (Table 1.2). This leads to loss of high value land, increased inundation of coastal wetland and lowlands, deterioration of coastal road infrastructure, degradation of beaches, disruption of livelihoods, and loss of tourism infrastructure, coastal habitats and species. Gradual sea level rise (SLR) has already been attributed to warming temperatures which further exacerbate the impacts of weather events and raises concern for the low-lying, high population density coastal areas, thus placing industrial, commercial and tourism development at high risk (Mimura, et al., 2007). Among the ecosystems most vulnerable to sea level rise are beaches, wetlands, sea-grass beds and coral reefs.

Beach erosion patterns are expected to change due to the increased magnitude and speed of winds, tides and currents. Coral reefs are expected to be impacted significantly due to their sensitivity to temperature and acidity changes brought about by climate change.

Table 1.2: Impacts of Climate Change on Jamaican coastal areas

Change Factor	Potential Impact on the Coast
Sea Level Rise	• Flooding and inundation of low-lying areas and coastal communities • Dislocation of coastal communities • Land loss • Saltwater intrusion in coastal aquifers
Hurricane/Storm Surge	• Increased coastal erosion and damage to coastal infrastructure and buildings • Loss of tourism investments and subsequent negative impact on employment and the national economy • Increased likelihood of flooding • Increased risk to human life and risk of infectious disease • Damage to coastal resources such as coral reefs, seagrasses and mangroves
Temperature	• Coral bleaching from high sea surface temperatures
Rainfall	• Increased rainfall duration/intensity may result in higher incidence of flooding

Source: (Powell, 2010)

Damage and loss incurred by the climate-induced extreme events are further exacerbated by new infrastructure and building development within the coastal zone.

Hurricanes tend to be the most destructive climate change-related extreme weather events to impact the island's coastal resources. Jamaica and the wider Caribbean have experienced an increase in the frequency and intensity of hurricanes, tropical depressions and storms (IPCC, 2018). During the 2004–2007 period, Jamaica was impacted by six major hurricanes which caused damage and losses estimated at US$1.2 billion (Met Office, 2010). These events have contributed to decline in the health of coral reefs, loss of seagrass beds, severe beach erosion and loss of forested mangrove areas (PIOJ, 2010). In addition, the country experienced loss of lives and property, damage to infrastructure, periodic isolation of communities, and disruption to the school system and health services. To gain perspective on the change in hurricane frequency during this period compared to the years prior to 2004, the frequency of events was significantly less with Hurricane Charley impacting the island in 2004 and Hurricane Gilbert in 1988 (a 26-year gap).

Major flood rains which seem to be occurring more frequently due to often short duration high intensity events have also caused significant damage to coastal regions directly as well as indirectly, when land-based debris is brought down by stormwater runoff causing further damage to the marine ecosystems.

Storm-related events also incur economic losses as government revenues are impacted as a result of the decline in business activities and reduced sales (and taxes). In coastal regions, the declines arise from damage to the commercial and industrial properties and other infrastructure located along the coastline.

The tourism sector is most vulnerable to these events and has been severely affected by the more frequent and intense storm events. The impact on the industry has been threefold. Firstly, the coastal ecosystems on which the tourism and fishing industries depend would typically suffer extensive damage. For example, during Hurricane Ivan in 2004, beaches and coral reefs in southern and western Jamaica sustained damage due to the action of the storm surge that in some places reached three metres in height. Secondly, damage to the infrastructure and the consequent reduction in visitor arrivals inevitably lead to considerable economic loss. Flood rains in 2002, in addition to Hurricanes Ivan (2004), Dennis (2005), Emily (2005) and Dean (2007) resulted in direct losses to the sector of US$1.6 billion (PIOJ, 2010). Lastly, the livelihoods of many tourism workers are impacted due to disruption in their employment.

Storm surges often create storm/hurricane tides (>5m) which can lead to severe coastal flooding, especially when combined with normal high tide (NHC, 2007). Jamaica's ability to predict storm surge activity is limited by lack of data. Modelling the impacts of storm surges and sea level rise for Jamaica has been done by the Mona Geo-Informatics Institute to assist with better understanding these events and the areas where they are most detrimental (Mona GeoInfomatics, 2016). The model revealed that there will be "critical loss of land in several parts of the island, particularly the south coast". The predicted loss of land area is 101.9 km^2 if the sea level increases by a 0.18 m rise and 416.4 km^2 for a 10 m increase (PIOJ, 2013). The areas that are most likely to be affected by sea level rise are Palisadoes, Portmore, Old Harbour Bay, Rocky Point/Portland Cottage, Black River, Savanna-la-mar and Negril. These areas include some of the fastest growing centres (Old Harbour Bay and Portmore) and are the locations of many of the tourism and fishing economic activities. The Palisadoes which connects the Norman Manley International Airport (NMIA) and Port Royal to the mainland would be completely inundated with a 1 m rise in sea level. This spit acts as a means of protection for the harbour and therefore, if completely inundated, it would mean this protection barrier would also be lost.

1.4.3 Water Resources

Water resources are important to Jamaica's economy as it supports the island's important sectors including tourism, mining, food and beverage processing, agriculture and fisheries, and manufacturing. Jamaica's freshwater resources come from surface sources (rivers and streams), underground sources (wells and springs) and from harvesting rainwater. Groundwater supplies account for approximately 80% of Jamaica's water demands and represent 84% of the island's exploitable water (CSGM, 2010). With climate change, Jamaica has experienced increased temperatures and more frequent and longer drought periods. Major users of water are irrigated agriculture (33%), residential water users (21%), and the environment (39%). Manufacturing, hotels and mining use less than 7% of the annual available water (CSGM, 2010).

Rainfall is critical to Jamaica's water sector as it is the only source to feed surface and groundwater flows: rivers, wells, springs and aquifers. The surface water resources in Jamaica have seasonal variability in flow as they are linked directly to rainfall. Groundwater is also directly recharged by rainfall and indirectly from rivers and streams. If annual rainfall is significantly reduced and drought conditions become longer and more severe, then the water resources are affected as there is reduced potential for groundwater recharge, lower minimum streamflow, declining water levels and reduced replenishment of rivers, springs and aquifers (Witter, 2007). Therefore, less water is available for communities, farms, factories and other industries, thus compromising food security.

Climate change will bring an increase in the frequency of very intense rains, storms and hurricanes in the short to medium term. Very heavy rains will increase soil erosion on unprotected slopes triggering aggravated sediment loads in stormwater runoff which, in turn, requires diversion of water intakes or additional filtering and higher water treatment costs for potable and non-potable uses. In many cases, water intakes are closed during intense periods of rains to avoid sediment-loaded water entering the potable water catchment and distribution systems. Additionally, many of Jamaica's wells which are used for agriculture, public water supply and industry are located near the country's coasts. Sea level rise poses a threat to coastal aquifers as it increases the risk of saline intrusion into coastal aquifers, thereby compromising the quality of water. Salination of water supplies and soil will also lead to decline in soil fertility. In addition, the evident decrease in the quality of water needed for domestic and industrial/commercial use is further intensified by a number of combined factors: very low stream flows; lower water table levels; higher temperatures resulting in increased levels of bacterial, nutrient and metal contamination; and increased flooding which flushes urban and agricultural waste into water source systems.

1.4.4 Energy

In 2019, Jamaica diversified its fossil fuel base to 45% oil, 37% natural gas and 18% renewable energy. Currently, imported oil and natural gas are still the dominant fuels used for electricity production.

The current net installed capacity of generation plants is 930 megawatts (MW) from the Jamaica Public Service Company (JPS) and Independent Power Producers (IPPs), of which almost 33% of the net thermal capacity comprises oil-fired plants which are over 40 years old. There are, however, two exceptions: 120 MWs of generation from an existing natural gas combined cycle (NGCC) plant; and a new 190 MW NGCC plant commissioned at the end of 2019. Over 260 MWs of this installed generation capacity come from renewable energy IPPs, JPS and smaller net billing customers. JPS has also implemented its 24.5 MW capacity flywheel-battery hybrid storage facility to moderate the addition of intermittent renewable energy sources on the grid.

Electricity demand is projected to grow at an average rate of 3.8% per annum over a 20-year planning horizon (2010 to 2029). Over the next 20 years, approximately 1,400 MWs of new fossil fuel power plant capacity will have to be constructed in Jamaica, including distributed generation systems, to meet the projected demand for electricity, and approximately 800 MWs of this new capacity need to be constructed in the coming decade. Although Jamaica's National Energy Policy's (JNEP) renewable energy target is 20% by 2030 (50% recently advocated by the Government), this will have implications for total GHG emissions from new fossil plants and thus Jamaica's commitment to climate change mitigation.

The Jamaica's National Energy Policy (JNEP) 2009–2030 is supported by seven goals for the energy sector which incorporate energy conservation and efficiency; modern infrastructure; renewable energy sources; reduced greenhouse gas (GHG) emissions (Table 1.3 and Table 1.4); environmental stewardship; enabling governance, institutional, legal and regulatory framework; and state leadership. In addition, the policy framework for achieving these targets and developing an efficient and more environmentally benign sector is supported by five sub-policies, namely, the National Renewable Energy Policy, Energy Conservation and Efficiency Policy, Trading of Carbon Credits Policy, National Energy from Waste Policy, and Biofuels Policy.

Jamaica's National Developmental Plan to 2030, *Vision 2030*, also supports the objectives of JNEP and states that *"Jamaica will create a modern, efficient, diversified and environmentally sustainable energy sector providing affordable and accessible energy supplies with long-term energy security that contributes to international competitiveness throughout all the productive sectors of the Jamaican economy*.

These realities spurred Jamaica to accede to the UNFCCC in 1995 considering that though the country is not a significant contributor to global warming, it has a responsibility to contribute to the overall reduction of the contributing factors. Jamaica is therefore reducing its GHG emissions significantly through mitigation actions including the reduced use of fossil fuels, increased use of renewable energy options, and energy efficiency.

Jamaica also signed on to the Sustainable Energy for All (SE4ALL) initiative in 2012 to provide universal access to clean modern energy services, double the rate of improvement in energy efficiency, and double the share of renewable energy in the global energy mix. Worldwatch Institute's Sustainable *Energy Roadmap for Jamaica* outlines a clear pathway to meeting such goals and access opportunities for a clean, renewable and energy-efficient future.

Table 1.3: Jamaica's historical green house has emissions by sector (2006 and 2014)

EMISSION SOURCES	**EMISSIONS (CO_2e)**	
	2006	**2014**
Energy	12 Mt	7.4 Mt
Industrial Processes	660 kt	950 kt
Land Use Change & Forestry	770 kt	780 kt
Agriculture	680 kt	620 kt
Waste	430 kt	420 kt
Gross Absolute Values	**14 Mt**	**10 Mt**

Source: (Climate Watch, 2019)

Table 1.4: Summary of Greenhouse Gas Emissions (Gg CO_2 EQ) 2006–2012

	2006	2007	2008	2009	2010	2011	2012
CO2	11,205	9,857	10,658	7,918	7,285	7,870	7,387
CH4	818	835	841	857	847	831	852
N2O	3,870	4,985	6,874	6,662	6,643	4,426	6,594
HFC	87	92	95	95	93	92	89
LULUCF	-1,685	-1,638	-1,631	-1,622	-1,618	-1,616	-1,626
Total excluding LULUCF	15,918	15,770	18,468	15,532	14,868	13,220	14,922
Total including LULUCF	14,296	14,131	16,836	13,911	13,250	11,604	13,296

Source: Third National Communication of Jamaica to the United Nations Framework Convention on Climate Change, 2018. Ministry of Economic Growth and Job Creation (MEGJC)

Energy alone contributes over 70% of Jamaica's total emissions over multiple years. Jamaica's Nationally Determined Contribution (NDC) covers mitigation actions in the energy sector (IPCC source category 1) which will unconditionally mitigate the equivalent of 1.1 million metric tons of carbon dioxide per year by 2030 versus the business-as-usual (BAU) scenario. This is a reduction of 7.8% of emissions versus BAU, however, Jamaica will conditionally increase its ambition to a reduction of GHG emissions of 10% below the BAU scenario, subject to the provision of international support. The period for implementation is from 2005 to 2030 (with an interim target in 2025). Specific emissions of interest include CO_2, CH_4, N_2O, NOx, CO, non-methane volatile organic compounds (NMVOCs), and SO_2. The Kigali Amendment requires the phase-down of hydrofluorocarbons (HFCs) and Jamaica has undertaken the preparatory activities to ratify the Amendment.

The Third National Communication (TNC) of Jamaica to the United Nations Framework Convention (UNFCCC) on Climate Change (2018) includes, among various mitigation projects, energy security, and efficiency enhancement projects where energy efficiency and renewable energy potentials would be developed. Nationally Appropriate Mitigation Actions (NAMAs) and Nationally Determined Contributions (NDCs) would also involve the implementation of renewable, energy-efficient and low-carbon energy strategies in the near term. The unconditional Nationally Determined Contribution (NDC) for this combined policy scenario, including mitigation actions, consists of a mid-term emission reduction by 2025, as well as final additional emission reductions to be achieved by 2030 (Table 1.5). In the unconditional scenario, the NDC specifies emission reduction targets for the energy sector as outlined below:

Table 1.5: Absolute Emission Reduction Targets embodied by Jamaica's Unconditional NDC

Year	Abatement Target
2025	1.073 $MtCO_2e$
2030	1.124 $MtCO_2e$

Source: Third National Communication of Jamaica to the United Nations Framework Convention on Climate Change 2018. Ministry of Economic Growth and Job Creation (MEGJC)

A policy scenario satisfying Jamaica's conditional NDC goals was also assessed. These goals are moderately more aggressive, contingent on the accessibility of international finance mechanisms; hence, they are conditional. The projections are given in Table 1.6.

Table 1.6: Absolute Emission Reduction Targets embodied by Jamaica's Conditional NDC

Year	Abatement Target
2025	1.344 Mt CO_2e
2030	1.449 Mt CO_2e

Source: Third National Communication of Jamaica to the United Nations Framework Convention on Climate Change 2018. Ministry of Economic Growth and Job Creation (MEGJC)

Mitigation actions across all sectors and in particular the energy sector, will be a critical strategy for achieving these targets.

1.5 Key Sector Vulnerabilities

The impact of climate change on Jamaica's key sectors has been noted in many reviews and studies and essentially all sectors, land and livelihood have been considered vulnerable.

For the water sector, the following changes are predicted (GoJ, 2015):

- Changes in temporal and spatial distribution due to increased climate variability and occurrences of severe weather events in particular droughts and tropical cyclones;
- Saltwater intrusion: Contamination of ground water resources due to the intrusion of sea water into coastal aquifers as sea level rises;
- Greater levels of sedimentation in reservoirs and dams and sediment transport to coastal areas as soil erosion increases with the greater incidence of more intense rainfall and hurricane events;
- Changes in temperature are expected to result in adverse shifts in climatic conditions for agricultural cultivation;
- Increasing degradation and destruction of watersheds caused by the displacement of traditional activities/livelihoods such as farming;
- Shortage of water during periods of prolonged droughts;
- Damage to infrastructure (roads, bridges, electricity generation and transmission systems, seaports, airports, pipelines, dams) caused by extreme and slow onset events.

With respect to coastal resources and communities, the following is noteworthy:

- At-risk residents in coastal communities make up about 60% of Jamaica's population and while community nuances are different, they are generally vulnerable to storm surges, hurricanes and flooding;
- Male-dominated livelihoods like farming and fishing are very vulnerable to climate change;

- Some livelihood practices are unsustainable and exacerbate vulnerability. However, communities are willing to adapt if resources and training are provided;
- Under the smallest SLR scenario (0.5 m), 35 percent to 68 percent of the highly valued beach resources in several parishes would be damaged or lost;
- Ports are the most threatened of the coastal infrastructure, with 100 percent of port lands in Jamaica projected to be inundated with a 1 m SLR;
- Increasing sea temperatures have already exacerbated acidification and coral bleaching and those occurrences together with storm events have damaged coral reefs along several sections of the reef environment;
- Wetlands, including mangrove stands, seagrass beds and other marine resources in the nearshore, have been compromised or removed from several coastal areas by the burgeoning tourism plant expansions particularly on the north coast of Jamaica.

2 Institutional Arrangement – TNA and Stakeholder Involvement

The Climate Change Division (CCD) in the MEGJC is the driver of the climate change mitigation and adaptation agenda in Jamaica. The CCD was established to provide strategic support, to coordinate and manage the transformational change towards a climate resilient society in Jamaica. Summarised below are the CCD's core functions:

1. Coordinate the mainstreaming of climate change adaptation in strategic policy formulation, development planning and decision-making;
2. Promote the implementation of specific adaptation measures to address key vulnerabilities in Jamaica;
3. Promote actions to reduce GHG emissions through fossil fuel reduction, conservation, and by switching to renewable and cleaner energy;
4. Promote awareness of climate variability and climate change and corresponding behavioural changes.

2.1 National TNA Team

The structure of the TNA Project in Jamaica followed the structure recommended by the TNA Process (Figure 2.2). The TNA Coordinator, who also serves as the National Designated Authority (NDA) with respect to the UNFCCC Technology Mechanism in Jamaica, is supported by a National Project Steering Committee, and provides the consulting team with overall vision, leadership support, communication and guidance.

The national consultants for mitigation and adaptation are independent consultants with experience in climate change mitigation, vulnerability assessment and adaptation planning. They are responsible for the following tasks and outputs:

1. Identification of technology options and the prioritisation of technologies for the mandated sectors;

2. Conducting stakeholder mapping in keeping with the requirements of the TNA, including gender balance considerations;
3. Preparation of technology fact sheets for selected technology options;
4. Organisation of stakeholder meetings and consultations. At these meetings the consultants are expected to:
    a guide the stakeholder working groups through the technology fact sheets to gain feedback and
    b guide the group through the technology prioritisation process including the Multi-Criteria Analysis (MCA);
5. Analysis of the MCA results and completion of sensitivity analysis on the MCA;
6. Preparation of the deliverables for the TNA.

The consulting team attended the 1st Regional Capacity Building Workshop for the TNA Group of Caribbean Countries in Kingston, Jamaica from 20–22 March 2019. The team was trained in the conduct of the TNA and the MCA methodologies required by the TNA for prioritising technologies.

The sector working groups are national in scope and were selected from the private and public sectors, government agencies, research centres and institutes, technology-users such as farmers, regulators and utility agencies. The groups represented the sectors that were identified for the TNAs, and they contributed to the development of the technology fact sheets and the prioritisation of the technologies using the Multi-Criteria Analysis.

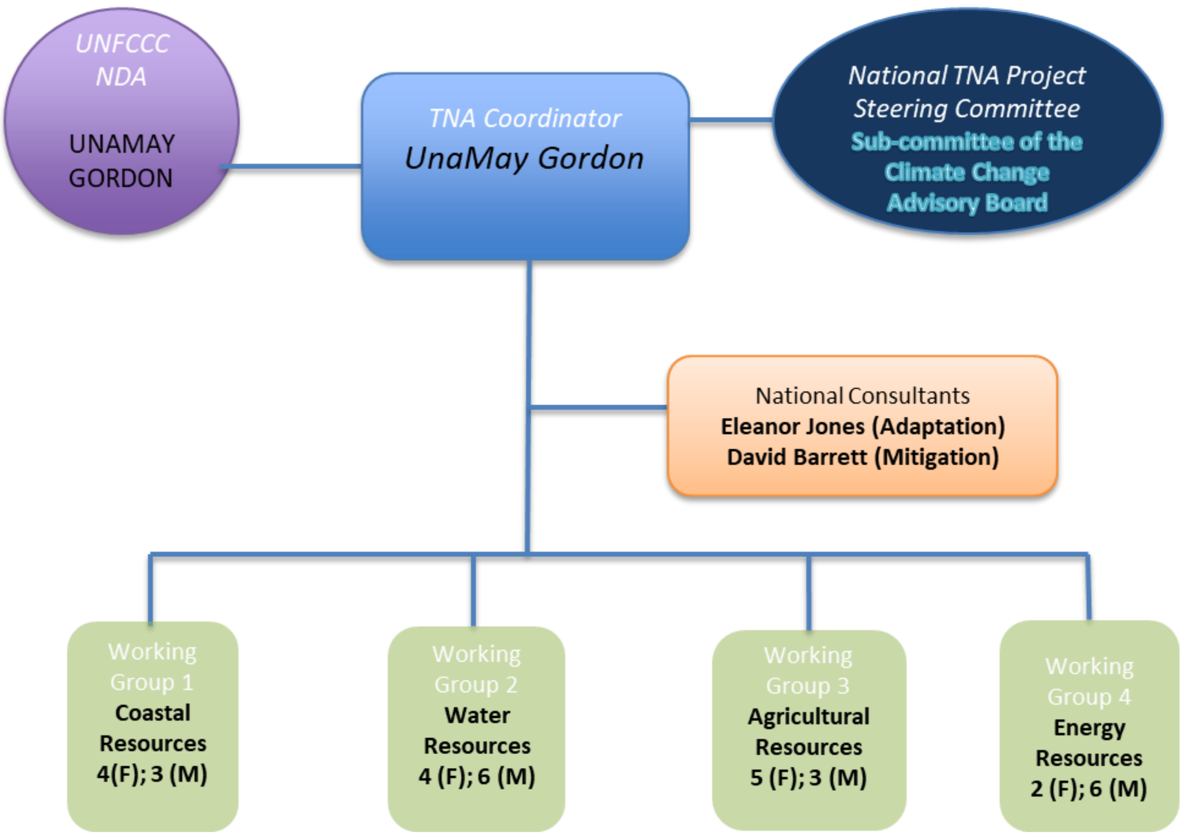

Figure 2.2: Structure of the Technology Needs Assessment Team for Jamaica

2.2 Stakeholder Engagement Process

Stakeholder mapping was first conducted to identify persons in the relevant sectors. This included persons in government and public agencies, private companies, consultants, researchers and research groups, academics and individual entrepreneurs. A list of stakeholders is presented in **Appendix I.**

Interviews were conducted with stakeholders to identify technologies and to validate the long list of technologies developed by the national consultants. The working groups for each sector were also determined from the stakeholder mapping exercise. The working group for each sector is named in **Appendix II.** Gender balance was considered during the stakeholder mapping and the selection of the working groups for each sector. This was guided by the TNA Guidance for Gender-Responsiveness (2018).

The sector working groups were initially engaged through a survey and interviews to determine the short list of technologies. Technology fact sheets for the short list of technologies were discussed at workshops for the respective sectors (Table 2.). The working groups were very knowledgeable about their respective sectors and the relevant technologies and provided feedback on what was proposed. They also suggested other possible scenarios given the current use of technologies in Jamaica. The identification of interventions essentially sought Alignment with national development objectives, Focus on sustainable development, and Facilitation of transformative change.

At the sector working group sessions, the criteria for the MCA were developed and confirmed along with weights for each criterion. Some groups completed the scoring for each technology at the session, while other groups were sent the MCA worksheet to complete scoring. These persons preferred or required additional time to complete the scoring.

Table 2.1: Working Group Sessions held for the TNA Project, Jamaica

	Sector Working Group	Stakeholder Session
1	Energy Sector	Wednesday, 8 October 2019
2	Water Resources	Wednesday, 8 October 2019
3	Coastal Resources	Thursday, 9 October 2019
4	Agriculture Sector	Thursday, 9 October 2019

2.3 Consideration of Gender Aspects in the TNA Process

The Technology Needs Assessment Report for Jamaica covers four sectors: agriculture, energy, water, and coastal resources. In assessing climate technologies related to these sectors, i.e., equipment, techniques, practical knowledge or skills, it is important not to overlook the gender perspective. Men and women are affected by climate change differently, particularly those persons who are heavily reliant on natural resources for their livelihood and/or have the least capacity to respond to natural hazards.

This section examines the gender mainstreaming[2] process associated with these sectors in the Jamaican context.

Jamaican statistics indicate that female-headed households were 46.4 percent of all households in 2010 and these households comprised a larger proportion of children and other family members (disabled, elderly, sick) (Statististical Institute of Jamaica, 2011). Further, the data showed that female-headed households consistently, throughout many decades, record a larger mean household size, surviving on a single income. This group of female-headed households is largely represented in the poorest quintile. This trend has several implications for how men and women utilise natural resources, and how they are affected by or may benefit from climate change technologies as defined in this report.

In 2018, the Global Gender Gap Index for Jamaica stood at 0.724, ranking 44 in the world (World Economic Forum, 2018). This index ranks countries according to their proximity to gender equality and it seeks to measure the relative gaps between women and men across four key areas: health, education, economy and politics. Of the four areas, Jamaica has the greatest gender gap of 83% under the political empowerment category and in terms of economic participation and opportunity, there is a 25% gender gap. It is important to note that the gender gaps, as determined by these indicators (health, education, economy and politics), have implications for what is evident in the four sectors (agriculture, energy, water, coastal resources) examined in this TNA. Preliminary gender perspectives associated with these four sectors have been presented in Sections 2.3.1 to 2.3.4 below.

2.3.1 Agriculture Sector

Approximately 51% of Jamaica's population is female. Both males and females are heavily involved in the agriculture sector in Jamaica as farmers and labourers for various crops and livestock. Based on the 2015 data available from the Rural Agricultural Development Authority (RADA), there were 154,324 registered farmers and of that number, 54,013 (35 percent) are women. However, not all farmers are registered. Anecdotal evidence suggests that this trend (35 percent) is similar with respect to unregistered farmers. Despite the heavy involvement of both sexes in agriculture, only two percent of land in Jamaica is owned by women. This does not reflect gender equality[3] which is goal # 5 of the global sustainable development goals (SDGs). Given that land is a key resource in farming, it is clear that there are significant issues impacting this gender disparity.

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[2] Gender mainstreaming is the process of assessing the implications for women and men respectively of any planned action, including legislation, policies or programmes, in all areas and at all levels. This is a strategy for making women's as well as men's concerns and experiences an integral dimension of the design, implementation, monitoring and evaluation of policies and programmes in all political, economic and social spheres so that women and men benefit equally, and inequalities are not perpetuated. The ultimate goal is to achieve gender equality (UNDP DTU, 2018).

[3] Gender Equality as defined by the UN refers to the equal rights, responsibilities and opportunities of women and men and girls and boys. Equality does not mean that women and men will become the same but that women's and men's rights, responsibilities and opportunities will not depend on whether they are born male or female. Gender equality implies that the interests, needs and priorities of both women and men are taken into consideration, recognizing the diversity of different groups of women and men. Gender equality is not a women's issue but should concern and fully engage men as well as women. Equality between women and men is seen both as a human rights issue and as a precondition for, and indicator of, sustainable people-centered development (United Nations, 2001).

Reports have indicated that the majority of female farmers work smallholdings for cash crop or subsistence production and are principally engaged in food production for domestic consumption (FAO, 2010)

Although, in Jamaica, there are no direct legislation, policy or regulations that hinder women from having a fair chance at land ownership and high agricultural yields, the data indicates that there are inherent biases favouring male farmers, which will need to be explored in the TNA process. FAO studies globally show that access to extension services is limited for women because of cultural attitudes, discrimination and a lack of recognition for their role in food production, and so women enjoy limited to no benefits from extension and training in new crop varieties and technologies as well as limited access to credit (Duncan-Price, 2016). The Food and Agriculture Organization (FAO) has reported that up to 30 percent yield gaps between men and women farmers occur because of these issues (ibid).

2.3.2 Coastal Resources

Much of Jamaica's development occurs within the coastal zone. Jamaica's coastal resources, like those of other small island states, are of major environmental, social and economic significance. These include both man-made and natural resources such as harbours, beaches, coral reefs, mangroves, and swamps, all of which play a unique part in the development of industries and establishment of livelihoods for locals. Gender perspectives will be explored as it relates to access to resources to gain a livelihood directly or indirectly from available coastal resources.

Additionally, extreme weather events, influenced by climate change, such as hurricanes, tropical depressions, tropical storms, storm surges, and terrestrial flooding impact coastal resources. The impacts of these extreme weather events will be examined from a gender perspective in the TNA process. It is known that men and women are impacted differently by natural hazards and the rate at which a man versus a woman can recover after these external shocks vary greatly. Women as the burden bearers and the primary caregivers to children and other vulnerable groups in society, such as the disabled, sick and elderly, are issues to be explored.

2.3.3 Water Resources

As already indicated above, Jamaica has a high rate of female-headed households; this datum indicates the significant responsibility held by females in Jamaica. The need to ensure there is a supply of clean water for the family is one such responsibility, which is particularly significant, in rural areas, where many households are without centralized water supply; women would therefore be expected to bring water because they are mostly in charge of domestic chores requiring water such as cleaning, laundry, cooking, etc. Women are also more often responsible for cooking than men; thus, they face a higher burden of food supply.

Climate change has brought to Jamaica an increase in the frequency of very intense drought periods, which negatively impact the availability of water to households. This has significant implications for the many female-headed households in rural areas which rely on rainwater sources and these severe drought conditions have also recently impacted households in urban areas due to disconnections of the public water supply, on which residents in urban areas such as Kingston and St. Andrew rely.

2.3.4 Energy Sector

There are approximately 2.7 billion people – 40 percent of the world's population –that depend on wood, charcoal or animal waste for basic energy needs such as cooking and heating (UNDP, 2013).

Although Jamaica has a high percentage of public energy usage from the Jamaica Public Service Company Limited, it is important to note that poor and marginalised people tend to rely on locally sourced biomass for their daily energy needs. Any stress on their surrounding ecosystems, climatic or otherwise, is likely to render them increasingly vulnerable to biomass –and hence energy –scarcities. Such scarcities take a significant toll on poor women, especially rural women (UNDP, 2013). This reality will be explored in the TNA process to determine the extent to which this issue applies in the Jamaican context.

Further, as the energy sector in Jamaica expands and diversifies into renewables, it is important to determine the extent to which women are involved in the sector and the expansion. The energy sector is generally known to be largely male-dominated. The TNA process will explore any existing inherent biases that act as barriers within the energy sector.

In 2019, RUBIS Energy Jamaica, Island Grill, Facey Commodity, and the Jamaica Chamber of Commerce became the first in the English-speaking Caribbean to achieve a crucial milestone in their process to secure a Gender Equality Seal globally coordinated by the UN Development Programme (UNDP, 2019). This is a step for Jamaica in the direction to achieve gender equality in the energy sector.

Companies which earn the Gender Equality Seal, at either the Gold, Silver or Bronze level, are those that have demonstrated achievements in gender-equality practices through recruitment, organisational placement, wages, times and working hours, opportunities, care of the vulnerable, sexual harassment protocols and budget allocations for gender activities. The programme aims to address persistent gender gaps in the workplace by encouraging the relevant entities to create equitable conditions for both men and women and establishing environments where women's work and contributions are equally valued (UNDP, 2017). Any further results available from this programme will be explored to inform the TNA.

2.3.5 Gender Analysis in the TNA Process

Gender-balanced stakeholder consultations are therefore crucial to the TNA process to unearth critical gender gaps in all four sectors described above. Already, the TNA process has examined the composition of the sector working groups in an effort achieve gender balance. Each of these sector working groups represents a group of diverse sector-specific stakeholders c xwho have provided inputs into the technology selection, technology fact sheets and the prioritisation of the technology options. Importantly, the Bureau of Gender Affairs for Jamaica will be involved in the consultation process.

As the TNA process continues and the barrier assessment begins, these consultations will seek responses to gender-based questions. This is a critical approach to unearthing inherent gender biases. A few examples of questions are as follows:

1. What do female farmers need to improve agricultural productivity?
2. What do male farmers need to improve agricultural productivity?

3. What are the challenges male-headed households have in accessing potable water?
4. What are the challenges female-headed households have in accessing potable water?
5. Do men have access to the technologies identified for each sector?
6. Do women have access to the technologies identified for each sector?
7. What are the hindrances to men having access to the technologies identified for each sector?
8. What are the hindrances to women having access to the technologies identified for each sector?
9. Are there any past or current programmes relevant to the four sectors that address gender inequalities?

In addition to these stakeholder working groups, gender-based statistics, where available, will be requested and analysed. These may include:

- Updated gender-based data from RADA related to registered farmers and land ownership;
- Gender-based data demographic and household statistics from the Statistical Institute of Jamaica;
- Gender-based data from the Jamaica Survey of Living Conditions as published by the Planning Institute of Jamaica;
- Gender-based data on energy and source of water (if available);
- Gender-based data on fisherfolk (if available);
- Review of the Jamaica National Policy for Gender Equality (NPGE);
- Vision 2030 Gender Sector Plan.

The results from both the consultations and the statistics would be analysed to identify the gender-related barriers associated with each technology in all four sectors. The results of the gender-based barrier assessment will then inform the Technology Action Plan (TAP) for Jamaica. The analysis and the TAP will attempt to answer several key questions, some of which have been outlined below:

- What is the gender-based inequalities, discrimination and denials of rights in each context? How do these issues intersect with other factors of discrimination such as age, ethnicity, disability and class?
- How will gender relations influence the effectiveness and sustainability of the project activity and result? How can project processes and activities be designed to reduce inequalities and increase equality?
- How will the proposed results affect the relative status of women and men? Will they exacerbate or reduce inequalities?
- How will women and men be targeted and reached?
- Are the recommended actions responding to the gender differentiated patterns identified from the barrier analysis?
- How will the project ensure that women and men have equal access to the technologies and opportunities?
- What resources will be required by responsible persons to mainstream gender during the implementation of identified technologies?
- Are there specific activities geared towards addressing capacity building needs during the TAP implementation process?
- Are women and men equally able to benefit from any training sessions recommended?
- Have gender relevant indicators been developed to track gender performance during the implementation of the TAP?

During the technical needs action planning process, gender-balanced sector working groups will again be convened to discuss recommended actions to address technology needs and barriers in each sector. Where necessary, gender-based focus groups will be held. This approach facilitates the mainstreaming of gender fully into Jamaica’s technical needs assessment and action planning process.

Part II – Technology Prioritisation for Adaptation

3 Agriculture Sector

3.1 Existing climate-related Technologies in the Agriculture Sector

Jamaican farmers have developed various strategies to deal with the effects of climate change on their farms. These strategies have emerged through traditional knowledge and experimentation as well as through special training initiatives such as those implemented by RADA and other agencies. These include the Agriculture Disaster Risk Management (ADRM) initiative which has strengthened the understanding of several Jamaican farmers regarding disaster risk reduction and resilience in the process of adapting to climate change across the island (FAO, 2019). Projects like '*Accelerating the Uptake of Climate-smart Agriculture in Jamaica*' are also aimed at strengthening the resilience of farmers to climate extremes, while improving agricultural productivity and incomes of smallholder farmers in Jamaica through the promotion of widespread adoption of climate-smart agriculture (CSA) practices (JIS, 2019). Other major projects train farmers in how to utilise climate-smart techniques including drought mitigation strategies, irrigation (like the drip-irrigation technique), water harvesting, green house production and various soil husbandry operations) (JIS, 2015). Farmers already use improved informal irrigation, mulching for retention of soil moisture, crop diversification and changes in crop planting seasons while also creating water storage options (ODPEM, 2011). In Southern St. Elizabeth, farmers have implemented a variety of adaptation measures to manage drought, including planting quick crops (e.g., escallion); planting drought-resistant crops (e.g., escallion, cassava); scaling down production during dry season; installing edging (e.g., perimeter planting with guinea grass); careful timing of water application; sacrificing proportions of crops; sharing water; using drip irrigation; using trucked water; and the use of black tanks to increase water storage (Cambell, Barker, & McGregor, 2011).

Farmers across Jamaica have also been implementing innovative agricultural techniques such as soil erosion control mechanisms like tyre bonding (embedding old/used tyres into the farm soil to reduce soil erosion, typically along sloped terrains); water management/rainwater harvesting; protective agriculture (greenhouses); selected cropping during the dry season (e.g., some farmers plant gungo peas and cassava in Mavis Bank); and the adjustment of planting seasons (in Bushy Park much cultivation takes place between December and August).

In addition, improved soil and crop management (e.g., use of organic materials), community risk mapping, reforestation, establishment of boundaries/reserves to regulate the forest cover, agroforestry, engagement of the community, data gathering and use, public awareness, training of farmers in climate-resilient best practices and mangrove replanting are all considered suitable coping practices (PPCR, 2011).

Figure 3.1: Tyre bonding as a means to prevent soil erosion on farms

Local community-level adaptation practices among farmers include sharing seeds; requesting food scraps from restaurants and other places to supplement livestock feed; repairing sheds and structures with temporary natural materials (broom thatch, etc.); reducing farm inputs such as fertilizers and pesticides; cutting grass for extra fodder for cattle; switching to dwarf varieties of fruit trees, planting hedgerows around and between high risk/vulnerable crops (such as bananas) to reduce wind impact; and growing root tuber crops during hurricane season (FAO, 2010).

More advanced science and technology-based techniques will soon include impact modelling. This type of modelling will allow an opportunity to test what the future would look like without costly physical experimentation. In agriculture, this may take the form of crop modelling which could include determining the successes that would be achieved if one crop variety was transplanted from one location and replanted in another without having to invest in cultivating the plant itself. In addition, data for agricultural-resilience projects are needed. This can incorporate data on the best crops for particular extremes in particular areas, soil types, the best animal feed in particular climate extremes (e.g., using local materials in the absence of water and grass), and climate information more specific to agriculture (e.g., agricultural drought information specific to particular areas being included in weather reports, rather than vague evaluations of general rainfall distribution across the island).

3.2 Decision Context

In Jamaica, the agriculture sector's contribution to GDP has fluctuated between 6.7% and 4.8% from 1991 to the present (MEGJC, 2018). Currently, it has been estimated that the sector contributes on average 7% to the GDP and employs 18% of the labour workforce (The World Bank, 2013). While Jamaica has seen a recent increase in agricultural production due to government interventions into the sector up to 2011, these have been now reduced due to recent extreme events and climate disasters (MEGJC, 2018).

The agricultural sector in Jamaica has a high potential for exposure to significant adverse impacts related to climate change as indicated in Section 3.1. All parishes across the island are prone to flooding and many of them are subject to experiencing extended periods of drought.

To reduce the overall impacts of climate change on the agricultural sector, several objects must be considered. These objectives should focus on providing considerable investments in agriculture infrastructure; the upscaling of community-based adaptation initiatives in agriculture; capacity building in the agriculture, fisheries and aquaculture agencies; and advancing research and development in crops and livestock (FAO, 2013).

The FAO in their 2013 report, *Climate Change and Agriculture in Jamaica*, identified several priority areas for action for the agriculture section (FAO, 2013). These included:

- Strengthening linkages between local food production and the tourism sector;
- Production and productivity programme for domestic food crops;
- Development and promotion of agricultural systems and practices suitable for agroclimatic conditions;
- Providing value-added climate information services for agriculture;
- Improved water resources development, conservation and management.

Therefore, technology options for the agriculture sector focuses on prioritising technologies which will support these priority areas for action.

3.3 Overview of possible Adaptation Technology Options

A long list of technology options along with briefs was prepared from the reviews of previous TNA Reports, TNA Fact Sheets, online databases and from consultations with stakeholders from the agriculture sector. The long list of technologies is given in Table 3.1.

A short list of technologies was extracted from the long list. This was done by conducting a survey with stakeholders and working group members. The process also allowed for feedback and comments which facilitated the inclusion of additional technologies. The short list identifies 5 to 8 climate change adaptation technologies for the sector. The short list of technologies and descriptions for each is given in Table.2.

Technology fact sheets for each shortlisted technology were also discussed and developed from the review of previous TNA Reports, TNA Fact Sheets, online databases, feedback from stakeholders in the agriculture sector and the working group. The TNA Factsheets for the shortlisted technologies are given in **Appendix III.**

Table 3.1: Long List of Adaptation Technologies for the Agriculture Sector

Agriculture Sector Adaptation Technologies	
Sprinkler and drip irrigation system	Bottle irrigation
Fog harvesting technology	Mist blowers
Rainwater harvesting technology	Shade houses using mesh/shade cloth (but is opened compared to greenhouse)
Slow-forming terraces	Aquaponics/hydroponics
Conservation tillage	Storage for produce

Agriculture Sector Adaptation Technologies		
Integrated nutrient management		Pond liners
Crop diversification and new varieties		Pond water recycling
New varieties from biotechnology		Automatic water storage system
Ecological pest management		Earthen catchment ponds
Seed and grain storage		Micro dams
Livestock disease management		Reforestation/Afforestation
Selective breeding via controlled mating		Pressurised irrigation water from wells
Mixed farming		GIS technology
Agro-forestry		Water channels
Community-based agricultural extension		Nutrient integration
Farmer field schools		Contour drainage
Water user association		Trenches
Reforestation		Drought management training
Sustainable production systems		Increase canopy density
Sustainable crop management		Agroparks
Forestry genetic resources (FGR)		Reduced trunk cutting during harvesting
Sustainable system of animal husbandry		Emulsion
Vetch fields		Open canal river system
Micro-propagation		Animal rest stations
Genetic engineering		Strategic grazing times
Real-time wireless soil moisture monitoring system (IRISTAR Pro2 Plus)		Pest management training
Hydroponics/Soilless agriculture		Crop phenology assessment
Rootstock selection		Early warning systems
Melioration of salinised soils sea-level rise induced saltwater intrusion		Fireproofing
Soil protection from wind erosion		Check dams
Water erosion reduction		Basin cultivation
Surface self-flow with mechanical uplifting of water		Contour barriers
Windbreaks/Shelter belts		Bio stimulants
Drip irrigation		Combination irrigation schemes
Water storage		Intercropping
Reducing water loss by laying grass on land after ploughing		Collaborative measures
Greenhouse		Crop modelling
Silage		Underground cropping
Feed storage		Cover cropping

Table 3.2: Short List of Adaptation Technologies for the Agriculture Sector

	Agriculture Sector Adaptation Technologies	Description
1	**Drip Irrigation Systems**	Drip irrigation involves constant application of a specific and calculated quantity of water to soil crops (localised area). This significantly reduces water runoff through deep percolation or evaporation. Barriers to implement both systems include lack of access to finance for the purchase of equipment, lack of local skills for design, installation and maintenance of the system, and lack of nationally/locally available component parts. May be solar-powered for efficiency.
2	**Rainwater Harvesting Technology**	Ideal for adaptation to restricted water supply in areas where there is no surface water, or where groundwater is deep or inaccessible due to hard ground conditions, or where it is too salty or acidic. Rainwater harvesters induce, collect, store and conserve local surface runoff for agriculture. Implementation is often at the household level.
3	**Mulching**	Mulching refers to utilising the crop grass or plastic mulch to cover soil surfaces to aid in reducing the amount of water and wind movement across the surface of the ground.
4	**Ecological Pest Management**	This involves actively maintaining pest populations at levels below those causing economic injury, while providing protection against hazards to humans, animals, plants and the environment via natural and cultural processes and methods, including host resistance and biological control. The key factors in managing this process include using beneficial organisms that behave as parasitoids and predators through processes which include releasing beneficial insects and providing them with a suitable habitat; managing plant density and structure to deter diseases; cultivating for weed control based on knowledge of the critical competition period; and managing field boundaries and in-field habitats to attract beneficial insects, and trap or confuse insect pests.
5	**Livestock Disease Management for Small Ruminants**	This precautionary measure prevents disease from entering and spreading in livestock populations by putting in strict regulations regarding the movement and housing of livestock under a disease prevention/animal health programme. This preventative plan also controls the spread of infection and hence, reduces loss of cattle by identifying new infections and changes in the ones which already exist.
6	**Reforestation/Afforestation as a form of Agro-Forestry**	The replanting of trees on land which has previously had trees, but which has been recently deforested. Using large fruit-bearing trees around the perimeter of small farms can therefore help boost production, while promoting agro-forestry.

	Agriculture Sector Adaptation Technologies	Description
7	**Agro-Economic Zones**	Farmers are encouraged to cultivate lands on adjoining farmlands to aid in ease of water supply and other resources. The farmers will also benefit from centralised sorting and packaging facilities within the area.
8	**Early Warning Systems**	This refers to 3-month forecast systems which aid farmers in preparing for extreme weather conditions or changes in weather.

3.4 Criteria and Process of Technology Prioritisation

The Multi-Criteria Analysis (MCA) was the methodology used for the prioritisation of the technologies from the shortlist for Jamaica. The consulting team attended the 1st Regional Capacity Building Workshop for the TNA Group of Caribbean countries in Kingston, Jamaica from 20–22 March 2019. The team was trained in the MCA methodology required by the TNA. At the Sector Working Group Session for Agriculture, the MCA was explained to the group and they were guided through the following steps:

I. Technology Fact Sheets: The technology fact sheets were discussed for all the shortlisted technology options. For each technology option, the team had extensive discussions on the capital and operational costs, benefits to farmers, current status of the use of the technologies, disadvantages of the technology options and how the technology could assist the farmers and the sector in adapting to the effects of climate change;

II. Development of Criteria: Criteria were developed and discussed by the working group. Criteria were selected based the broad categories proposed by the TNA, namely, cost, economic, social, environmental and climatic. The approved criteria were used for rating the technology options from the shortlist of technologies. Criteria were also developed within these broad categories (Table 3.3);

III. Development of Weights for each Criterion: The weighting system was discussed, and the working group agreed to the weighting of each criterion. Some further adjustments were made to the weights to ensure the goal of the MCA was being achieved. The weights for each criterion is given in Table 3.3.

IV. Rating each Technology Option: The team was then shown how to rate each technology option based on the criterion giving a score between 0 and 100. The Excel worksheet was given to the working group members for them to complete and send to the consulting team. This became necessary as the working group needed more time to review the fact sheets for the technology options.

The completed sheets were returned to the consulting team; the scores were subsequently aggregated and tabulated using the MCA tool provided by TNA.

Table 3.3: Agreed Criteria and Weights for the Agriculture Sector MCA

Category	Criteria	Description	Weight
Capital Cost	Capital Cost	Fixed one-time cost for the purchasing and setting up of the technology or equipment	25
	Operational and Maintenance Cost	Cost associated with the day-to-day operation and maintenance of the technology or equipment	15
Economic	Increase in Yields for Farmers	Increase in the yields for farmers which will increase their overall income from high productivity	15
	Technology can be adopted across Jamaica	Easy for farmers across Jamaica to adopt and implement, therefore having an overall economic benefit on the agriculture industry	15
	Suitable for vulnerable Farmers	Technology will decrease the vulnerability of farmers to the effects of climate change and therefore will allow for sustainability in the agriculture sector.	5
Social	Increase the Scale of existing Technology	The technology can be easily scaled up to allow for expansion of the farm or to be used on different sized farms.	10
Climate	Adaptation to Climate Change	The technology provides the ability for farmers to adapt to the effects of climate change in Jamaica.	15

3.5 Results of Technology Prioritisation

The MCA was completed by the sector working group on the eight adaptation technology options for the agriculture sector. During the MCA process, consensus was achieved for the scoring and where there was a difference, an aggregated score was used. Weighting adjustments were completed after scoring to ensure that the analysis was accurate. Both the MCA analysis scores, and weighted scores are given in **Appendix IV**. Based on the weighted scores (Table 3.4) the prioritised adaptation technologies for the agriculture sector for Jamaica are:

1. Sprinkler and Drip Irrigation Systems
2. Rainwater Harvesting Systems

Table 3.4: Results of the MCA for Adaptation Technology Options for the Agriculture Sector

Rank	Technology Options	Score
1	Sprinkler and Drip Irrigation	7785
2	Rainwater Harvesting Systems	6813
3	Livestock Disease Management	6633
4	Agro-Economic Zones	6600
5	Reforestation/Afforestation	6180
6	Ecological Pest Management	6345
7	Early Warning Systems	5353
8	Mulching	4800

4 Coastal Resources

4.1 Existing Technologies in Coastal Resources

To adapt to the impacts of climate change on Jamaica's coastal resources, the Government of Jamaica has sought to employ various hard and soft engineering techniques. After Hurricane, Ivan several engineering interventions had to be made to restore roads and to protect them from further wave impacts. Wave attenuation devices (WADs), concrete structures designed to disperse the energy of incoming waves and reduce the erosion on coastal regions, have also been installed. WADs also provide a habitat for fish and marine life and may be seen along the coastal communities of Old Harbour Bay in St. Catherine, Long Bay, Westmoreland and Alligator Pond, in Manchester. This has helped to reduce the effects of coastal erosion and sea-level rise on the communities, while supporting a feeding ground for marine life that adds to the community's fishing industry.

A similar venture, under the North Eastern Coastal Resilience Building Project led by the PIOJ and funded by the GoJ Adaptation Fund Programme, will target the community of Annotto Bay, St. Mary. This will address the retreat of the coastline towards major critical, physical assets within the town; coastal and riverine flooding; and deforestation. The project will ensure the implementation of shoreline protection and ecosystems restoration (reforestation), the drainage system outfall upgrade and capacity building. Activities in Annotto Bay include the installation of 600 m of rock revetment; the installation of 300 m of artificial reef in the form of Wave Attenuation Devices (WADs) or the reclamation of 18,000 m^2 of land and the construction of a new jetty, agro-forestry (300 trees), and realignment of the outfall of the Motherford Drain.

Modelling sea-level rise and storm surges is also a useful tool which is being carried out to assess beach erosion and sea level rise in Long Bay, Negril by the Marine Geology Unit. Based on past data sets, the potential sea level rise and the intensity of storm surges in the future can be determined. This information combined with current settlement configuration and population projections can help to determine the possible damages and distance inshore which will be affected with the influence of the current rate of climate change. It is nearly impossible to remove the residents and businesses inwards from the coastline. Strategies to protect against and minimise the impacts will have to include accommodation and protection strategies. CARIBSAVE collected and analysed primary data to assess the vulnerability of the livelihoods of residents in Port Antonio and coastal communities along Jamaica's northeast coast (Orange Bay, Buff Bay, Hope Bay, Boundbrook to Drapers and Snow Hill) to climate change, then extrapolated this to the rest of Jamaica (CARIBSAVE, 2011). The project also looked at sea-level rise and storm surge impacts on the coast of the parish of Portland. Some adaptation strategies which have been recommended include strict development guidelines for strategic coastal locations which are most vulnerable and offering greater protection from impacts such as flooding, erosion, storms, water shortages and subsidence. PIOJ and Mona Informatics have undertaken research which demonstrates that there will be critical loss of land in coastal areas of Jamaica under different sea-level rise scenarios. If sea level rises by 0.18 m, the predicted loss of land area is 101.9 km^2, while a 1 m increase in sea level is likely to result in a 416.4 km^2 loss of land (CSGM, 2014).

Contractors need to ensure that new and existing building stock is more resilient to climate change impacts and sustainable drainage measures and high standards of water efficiency must be incorporated in both new and existing building stock. There needs to be an increase in flood storage capacity and sustainable new water resources need to be developed. Protection and maintenance of coastal ecosystems (i.e., mangroves and coral reefs) from further degradation are critical preservation strategies and in the case of mangroves, replanting programmes in relevant areas along the coast have been employed. Mangrove replanting projects have been carried out at Portland Cottage in Clarendon and along the Portmore Causeway in St. Catherine. These measures can help to stabilise the coast and restore the protective function of coastal ecosystems.

Shoreline revetment projects involving entities like the National Environment and Planning Agency, the Planning Institute of Jamaica, the National Works Agency, the Office of Disaster Preparedness and Emergency Management, and the Jamaica Social Investment Fund have been carried out on several locations on Jamaica's southern coast (GoJ, 2018). These include Roselle located close to White Horses in St. Thomas, the windward side of the Palisadoes Peninsula, Gordon Cay, Kingston Harbour, and Bluefields in Westmoreland. The placement of groynes along the seashore is an ongoing protective measure that is being carried out at various locations in order to dissipate wave energy and the impact of currents and protect the shoreline from erosion.

A new coral restoration programme has been established in Jamaica. It was implemented by the Sandals Foundation in partnership with the Coral Restoration Foundation and the Bluefields Bay Fishermen's Friendly Society. Under this initiative, a project to install artificial coral reefs at Bluefields Bay in Westmoreland has also been carried out as well as a project to install geo-textile tubing at Portmore to prevent erosion (MEGJC, 2018). Breakwaters have also been installed at various locations on the south coast to prevent coastal erosion. Embankments have also been constructed in some low-lying coastal areas.

A community-centred approach was used by the Caribbean Fish Sanctuary Partnership Initiative (C–FISH), a four-year project implemented by the Caribbean Community Climate Change Centre (CCCCC) and CARIBSAVE that helped with improving the management of 7 fish sanctuaries across Jamaica. C–FISH was successful in improving the management of these fish sanctuaries in Jamaica (with an increase in fish biomass of over 1,400% in the fish sanctuary located in Boscobel, St. Mary) because it has focused on building the capacity and engagement of the local communities. Monitoring and evaluation have continued in these declared fish sanctuaries on Jamaica's north and south coast. Some of the other sanctuaries are showing outstanding performance with increased fish population, species type and the size of fish. The most prominent sanctuaries include the fish sanctuaries in Portland Bight in Clarendon, Bluefields Bay in Westmoreland and San San in Portland (GoJ, 2018).

Development of early warning systems continues and there are also plans to develop legislation to remove settlements located in areas that are highly vulnerable to hurricanes, storms and flooding.

Traditional community adaptation practices/strategies have also been employed. Over the years, people have developed their own strategies to adapt to hazards. Whilst some adaptive measures have been employed and others are underway, additional research is required to determine more reliable assessments so that effective adaptation mechanisms can be developed. These will be critical in reducing the impacts of climate change on the sustainable development of the country.

4.2 Decision Context

The coastal resources of Jamaica are particularly important to the country's environment and economy. The majority of the country's population and economic activity and infrastructure lies along or near the coastline (MEGJC, 2018). Approximately 82% of the population and 70% of all major industries are located within the coastal zone (MEGJC, 2018). The coastal marine environment also supports important marine ecosystems and contributes to the country's GDP through the tourism and fishery industries.

Sea-level rise is expected to have a major impact on Jamaica, with sea level rise projects ranging from 1.43 m-0.6 m along the North coast and 1.05m along the South coast (CSGM, 2016). These changes have already begun to impact Jamaica with many locations across the island experience net erosion of 20.8 m (PIOJ, 2013). Sea surface temperatures around the island is also expected in increase through to the end of the century (MEGJC, 2018), therefore impacting fisheries resources and marine ecosystems. The frequency and intensity of hurricanes and tropical storms as also expected to increase due to climate change.

This will also cause an increase in storm surge. Potential impacts to be considered from climate change on coastal resources include coral bleaching, ocean acidification, changes in sea surface temperatures, loss of breeding areas and nurseries such as mangroves, sea grass beds and coral reefs and a general increase in marine pollution from terrestrial sources.

However, the coastal zone in Jamaica is highly sensitive and vulnerable to climate related hazards, such as hurricanes and storm surges, as well as more slowly occurring changes such as sea level rise. Given the critical importance of the Jamaica's coastal zone to the economy, this vulnerability has serious implications for much of Jamaica's population and economic stability.

Jamaica is now party to over 14 Special Fisheries Conservation Areas which now protects over 15% of Jamaica's archipelagic marine resources (including 1,707 ha of coastline) (MEGJC, 2018). This is in keeping with Aichi target 11, requiring signature countries to protect at least 10% of their coastal-marine areas by 2020. Therefore, technologies for adapting to the effects of climate change for coastal resources in Jamaica should focus on:

1. Protecting coastal infrastructure (beaches, roads, buildings and communities) to the effects of erosion and sea level rise.

2. Supporting marine and coastal ecosystems in adapting to the effects of increasing sea surface temperatures, sea level rise and poor water quality.

4.3 Overview of possible Adaptation Technology\ Options

The long list of technology options and short briefs were first prepared from a review of previous TNA Reports, TNA Fact Sheets, online databases and from consultations with stakeholders in coastal resources. The long list of technologies for coastal resources is given in Table 4.1.

A short list of technologies was extracted from conducting surveys and further consultations with members of the coastal resources working groups. The process was intended to identify at least 5 technologies for the sector. However, one technology (flood-proofing) was removed after further consultation with stakeholders as it was generally considered to be difficult to apply to the existing situation across Jamaica. The short list of technologies and descriptions for each is given in Table 4.2.

Technology fact sheets for each shortlisted technology were also discussed and developed from a review of previous TNA Reports, TNA Fact Sheets, online databases and feedback from stakeholders in the coastal sector. The TNA Factsheets for the shortlisted technologies are given in **Appendix III**.

Table 4.1: Long List of Adaptation Technologies for Coastal Resources

Coastal Resources Adaptation Technologies		
Beach nourishment		Artificial reef and restoration of coral reefs by transplanting
Artificial dunes and dune rehabilitation		Creation of artificial cape
Seawalls		Construction of groynes
Sea dykes		Coastal monitoring sea-level, tide, salinity, sedimentation and coastal erosion
Storm surge barriers and closure dams		Tidal river management (TRM)
Reclaimed land		Tidal barriers (Sluice gates)
Flood-proofing		Rehabilitation or construction of existing or new embankments, dykes and coastal knolls
Wetland and seagrass restoration		Integrated coastal zone management (ICZM)
Floating agricultural systems		Demarcation and Protection of Riparian Buffer Zones
Flood hazard mapping		Rock revetment
Flood warning and response system		Coastal road adjustments
Managed defence realignment		Design predictive modelling
Coastal setbacks		Implementing coastal law
Infiltration trenches		Control saline intrusion

Table 4.2: Short List of Adaptation Technologies for Coastal Resources

	Coastal Resources Adaptation Technologies	Description
1	**Wetland Restoration**	Restoring wetland ecosystems like salt marshes, mangroves and in some cases, seagrass bed communities to act as a first line of defence along the coast This may be done through the transplanting of sprigs, stems, seedlings or plant propagules of typical salt marsh and mangrove species. The lands can then be zoned and protected to minimise degradation.
2	**Coral Reef Ecosystem Restoration**	Man-made, underwater structure built to reduce wave energy entering the coastline and control beach erosion

	Coastal Resources Adaptation Technologies	Description
3	**Beach Nourishment**	This soft engineering approach is used in response to shoreline erosion and flood reduction. It involves the artificial addition of sediment of suitable quality to a beach area that has a sediment deficit. Sand can be placed to create an extension of the beach width or as an underwater deposit which will be gradually moved onshore under the normal action of waves. This is done using trucks or conveyor belts or dredge ships which remove sediment from the seabed; the sediment is then transferred ashore by floating or submerged pipelines or by the 'rainbow method' to transfer ashore directly from the ship.
4	**Rock Revetments**	A revetment is a sloped facing of stone, concrete or other durable materials built to protect a scarp or embankment against erosion by wave action (Baird & Associates – Reef Watch, 2003). Sea walls may be referred to as a revetment or can be viewed as a sloped sea wall. Vertical sea walls reflect wave energy, whereas sloped sea walls (or revetments) also dissipate this energy. Revetments can also be carried out using synthetic geotextile technology in conjunction with vegetation techniques.

4.4 Criteria and Process of Technology Prioritisation

The Multi-Criteria Analysis (MCA) methodology was used for the prioritisation of the technologies from the shortlist for Jamaica. The consulting team attended the 1st Regional Capacity Building Workshop for the TNA Group of Caribbean countries in Kingston, Jamaica from 20–22 March 2019. The team was trained in the MCA methodology required by the TNA. At the Sector Working Group Session for Coastal Resources, the MCA was explained to the group and they were taken through the following steps:

I. Technology Fact Sheets: The technology fact sheets were discussed for all the shortlisted technology options. For each technology, the team had extensive discussions on the capital and operational costs, benefits to residents and fisherfolk, current status of the use of the technologies, disadvantages of the technology options and how the technology could assist the sector in adapting to the effects of climate change;

II. Development of Criteria: Criteria were developed and discussed by the working group. Criteria were selected based the categories proposed by TNA guidelines – i.e., cost, economic, social, environmental and climatic. The approved criteria were used for rating the technology options from the shortlist of technologies. Criteria were also developed within these broad categories (Table 4.3).

III. Development of Weights for each Criterion: The weighting system was discussed, and the working group agreed to the weighting of each criterion.

IV. The team was then shown how to rate each technology option based on the criterion giving a score between 0 and 100. Scoring was completed in the working group session.

Completed sheets were returned to the consulting team where the scores were aggregated and tabulated using the MCA tool provided by TNA.

Table 4.3: Agreed Criteria and Weights for Coastal Resources MCA

Category	Criteria	Description	Weight
Capital Cost	Capital Cost	Fixed one-time cost for purchasing and setting up of the technology or equipment	15
	Operational and Maintenance Costs	Costs associated with the day-to-day operation and maintenance of the technology or equipment	10
Economic	Protection of coastal infrastructure	The technology provides protection to coastal infrastructure therefore protecting property. This will reduce the overall cost for repair and maintenance of property and reduce disruption to business. It will have an overall benefit to the economy of the country.	20
	Restoration and protection of coastal and marine resources	The tourism and fisheries industries depend on both coastal and marine resources. The technology provides protection for these resources which will ensure protection of revenues and overall economic benefit to the industries.	10
Social	Protection of livelihoods	The technology protects coastal resources and therefore preserves jobs and sources of income.	5
	Promotes resilience in coastal communities	Most of the Jamaica's population lives along the coastline. The technology allows these communities to be more resilient and adapt to the effects of climate change. Women, children and vulnerable groups will become more resilient against the effects of climate change.	5
	Protection of coastal property	The technology provides protection of coastal property including homes, businesses and other infrastructure.	5
Environmental	Restoration of coastal and marine ecosystems	The technology will allow for coastal and marine ecosystems to be restored, either by direct rehabilitation of the ecosystem or indirectly by creating an enabling environment for the ecosystem.	20
Climate	Ability to adapt to the effects of climate change	The technology improves the overall ability of the country to adapt to the effects of climate change.	10

4.5 Results of Technology Prioritisation for Coastal Resources

The MCA was completed by the sector working group on the four technology options. During the MCA process, consensus was achieved for the scoring and where there was a difference, an aggregated score was used. The MCA analysis scores, and weighted scores are given in **Appendix IV**. Based on the weighted scores (Table), the prioritised adaptation technologies for the Coastal Resources for Jamaica are:

1. Wetland Restoration
2. Coral Reef Ecosystem Restoration.

Table 4.4: MCA Scores for Adaptation Technology Options for Coastal Resources

Rank	Technology Options	Score
1	Wetland Restoration	7550
2	Coral Reef Ecosystem Restoration	6100
3	Rock Revetments	5775
4	Beach Nourishment	4275

5 – Water Sector

5.1 - Existing Technologies within the Water Sector

Major water resources issues in Jamaica include reduced water access during extensive drought periods and contaminated water during heavy rainfall periods as well as saltwater intrusion along some coastal areas. To adapt to the water scarcity, water storage has been increased particularly with the use of tanks in domestic and commercial settings as well as on farms. There has also been an increased use of rainwater harvesting (Witter, 2007). These measures ensure that even on the driest of days, there will always be a water source, and they have great potential particularly for irrigation purposes.

Suitable water management practices at the individual, community and national levels to improve water use, efficiency and conservation have been encouraged in the 2019 Water Sector Policy and Implementation Plan. The plan provides an update to the 2004 Jamaica Water Sector Policy. It outlines the current situation in the water and wastewater sector, and ensures that the principles, objectives and policy directions for the management of the country's water resources are in line with the Vision 2030 Jamaica National Development Plan. Key additions to the policy include a strong commitment to Integrated Water Resources Management (IWRM), drought mitigation and efforts to ensure adaptation and resilience to climate change and climate variability across the water resources sector (MEGJC, 2019). Adherence to the suggested measures outlined throughout the policy, can result in a reduction in demand on existing sources and infrastructure, reduced costs and reduced vulnerability to drought (MEGJC, 2019). One of the benefits of improved land use management practices is protection of the quality and quantity of water resources. Poor land use and agricultural practices can increase the vulnerability of watershed slopes to soil erosion and sediment transport during heavy rains (CSGM, 2010).

In addition, conservation of water in homes has also played a big role and should continue to be adhered to by Jamaican households. Examples of water-reducing household technologies include low-flush toilets, and reduced water use for showers and other household appliances. Protection of surface and ground water sources from sea water intrusion will be reduced once freshwater supply of natural underground storage areas are kept replenished. The National Water Commission (NWC) has found it necessary to restrict water supplies to households and businesses when freshwater resources are minimal during prolonged drought periods to ensure optimal use of the remaining water supplies until there is enough rainfall to replenish them.

At the beginning of 2009, the Water Resources Authority (WRA), an agency of the MEGJC, handed donated equipment for measuring rain intensity valued at just under JA$1 million, to the National Meteorological Office (Met Office) to aid in watershed management and enable improved monitoring of the effects of climate change (JIS, 2009). The rain gauges and laptop formed part of the equipment supplied under the pilot Vulnerability and Capacity Assessment (VCA) Project within the water sector. Under the project, Jamaica will have improved capabilities to specifically assess how climate change and sea-level rise will impact coastal limestone aquifers, and the feasibility for establishing a wider network of rainfall intensity measuring stations. The study area selected was the limestone aquifer of the Rio Minho Hydrologic Basin, located on the Clarendon and Vere Plains, which are in southern Clarendon along Jamaica's south coast. The intensity gauge was installed within the recharge area of the Rio Minho Hydrologic Basin, the input area of water resources for the Clarendon Plains, and the

Mile Gully-Walderston area in Manchester. The data allowed for more reliable analysis of extreme rainfall events.

Under Section 16 of the Water Resources Act (1995), the WRA is mandated to provide the Minister with a National Water Resources Master Plan, which will include inventories of resources, demand and water balances. Accurate and continuous climate data is most important to the determination of the inventories and water balances as well as marking changes in climate in the island's hydrologic basins. Limited evaporation data is available, hence the decision by the WRA to strengthen the MET Service.

Other projects carried out include a drought-induced stream flow in St. Toolis Spring, the source of irrigation water supply to the Mid-Clarendon District. Consumers were dependent on the water supplied from the spring-fed irrigation system for the production of agricultural produce and crops as well as for livestock farming. The severe drought and lack of irrigation water impacted various agricultural produce and livestock. In order to sustain agricultural production in the area and maintain the livelihoods of the farmers, the National Irrigation Commission (NIC) recommissioned the St. Toolis wells. The wells were inactive for the 12-year period during which there was an ongoing flow of water from the spring. Additionally there was reduced aquifer recharge in the Spring Plain Well, Clarendon, a major water source equipped to provide irrigation water to farmers in the Spring Plain – Ebony Park Agro Parks. Previously, the well would consistently "break suction" because the hydrological regime had changed due to the drought. This resulted in the static water level declining from 27.95 meters below ground level (mbgl) in October 2013 to 30.48 mbgl in October 2015. In order to adapt to the changes in the aquifer level, the pump fitted to the well was lowered by 10ft (3 m) and operated at the licensed rate to allow for recharge of the aquifer.

The National Environment and Planning Agency (NEPA), with whom the management of watershed protection is principally invested, produced a National Watershed Policy to address the most severe constraints to watershed management and to seek to employ strategies to ensure the sustainable use and development of watersheds (NEPA, 2003). A new draft water policy and implementation plan was completed in 2019 and this plan is seen as critical in addressing the prospects of more frequent droughts.

5.2 - Decision Context

Climate change presents several risks for Jamaica which includes, changes in rainfall levels and patterns, changes in temperatures, sea level rise and salt water intrusion, hotter and more intense drought periods and hurricanes (MEGJC, 2019). These climatic changes can potentially impact the water resources in Jamaica. These impacts includes: -

- Impacts on surface water and increase sedimentation due to an increasing the intensity of floods more intense rainfall events, tropical storms and hurricanes.
- Increase stress on water resources due to an increase in the intensity and frequency of droughts.
- Increased rates of sediment erosion in watersheds, therefore affecting the transportation and movement of water.
- Increased sea-level rise will exacerbate saltwater intrusion into coastal acquirers.

The watersheds in Jamaica are important to Jamaica as the source of replenishing potable and non-potable water from surface and underground sources. The adverse impacts from climate change will inevitably have negative implications for sectors including agriculture, energy, mining and quarrying, manufacturing, tourism, housing, sanitation and health services and areas such as natural resource management, urban planning and regional development. Climate change models and projections indicate that changing rainfall patterns, sea-level rise, extreme events and increasing temperatures will have impacts on surface and ground water quantity and quality across Jamaica. Therefore, water resources in Jamaica is highly vulnerable to climate change.

The GoJ has recognized the need for adaptation measures to protect the Jamaica's water resources. Therefore, the GoJ has outlined goals to preserve water resources infrastructure and provide and improve services in the water sector to ensure the safety and reliability of water resources to meet human and environmental needs in Jamaica. This will be done through several initiatives to include -

- The promotion of rainwater harvesting and adequate water storage in areas with adequate but where groundwater and surface water sources are unavailable,
- Increase efficiency in water delivery and water use,
- Planning for the effects of climate change and then range of climate variability on infrastructure, investment and service delivery to adequately manage water resources (MEGJC, 2019).

To aid the GOJ in achieving its goals for the water sector, technologies for adapting to climate change should focus on.

1. Diversification of water sources to minimize the impacts of water shortages during periods of prolonged droughts.
2. Protection of water sources from contamination, saltwater intrusion, increased sedimentation and other pollutants.
3. The efficient use and reuse of water to preserve decreasing sources of water supply, particularly good quality ground water.

5.3 - Adaptation Technology Options in the Water Sector

The long list of technology options and short briefs were first prepared from a review of previous TNA Reports, TNA Fact Sheets, online databases and from consultations with stakeholders in water resources. The long list of technologies for water resources is given in Table 5.1

A short list of technologies was extracted from conducting surveys and further consultations with members of the water resources working groups. This aimed to identify 5 to 8 technologies for the sector. The short list of technologies and descriptions for each is given in

Table 5.2

Technology fact sheets for each shortlisted technology was also discussed and developed from a review of previous TNA Reports, TNA Fact Sheets, online databases and feedback from stakeholders in water resources. The TNA Factsheets for the shortlisted technologies are given in **Appendix III**.

Table 5.1: Long List of Adaptation Technologies for Water Resources

Water Resources Adaptation Technologies	
Boreholes/Tube wells	Fog tower

Water Resources Adaptation Technologies		
Desalination		Artificial raining/ Cloud seeding
Household drinking water treatment and safe storage		Solar Distillation
Improving the use of water-efficient fixtures and appliances		Restoration of minor tank networks
Leakage management Detection and repair in piped systems		Integrated river basin management (IRBM)
Diversification of water supply		Integrated Urban Water Resource Management (IUWRM)
Small reservoirs and micro-catchments		Real-time data monitoring
Rainwater harvesting		Artificial aquifer recharge
Water reclamation and reuse		Water lock-offs
Water safety plans		Large dams/reservoirs
Atmospheric water generator		Flow monitoring
Artificial recharge of aquifers		Barbeque catchment tanks
Wastewater treatment		Water pumping

Table 5.2: Short List of Adaptation Technologies for Water Resources

	Water Resources Adaptation Technologies	Description
1	**Rainwater Harvesting**	This may be done by collecting rainwater from rooftops (which act as the catchment area) and storing it in an appropriate container which may be fitted with a tap for daily usage.
2	**Restoration of Minor Tank Networks**	Tanks which harvest water from surface water bodies, runoff and from direct rainfall, but have been damaged or silted. These can help to diversify water supply, control and capture storm water and aid in groundwater recharge.
3	**Water Reclamation and Reuse**	Using municipal wastewater as a vital resource for agricultural and other irrigation, industrial and domestic uses Wastewater would go through various treatment procedures including secondary clarifiers, filtration basins of various designs, membranes, and disinfection basins to become purified.
4	**Artificial Recharge of Aquifers**	The process of spreading or impounding water on the land to increase the infiltration through the soil and percolation to the aquifer or of injecting water by wells directly into the aquifer Wind and solar energy pumping systems may be used for groundwater extraction.

	Water Resources Adaptation Technologies	Description
5	**Real-time Data Monitoring**	Real time monitoring of stream flow along rivers to assess river flooding along the network

5.4 - Criteria and Process of Technology Prioritisation

The Multi-Criteria Analysis (MCA) methodology was used for the prioritisation of the technologies from the shortlist for Jamaica. The consulting team attended the 1st Regional Capacity Building Workshop for the TNA Group of Caribbean countries in Kingston, Jamaica from 20–22 March 2019. The team was trained in the MCA methodology required by the TNA. At the Sector Working Group Session for Water, the MCA was explained to the group and they were taken through the following steps:

I. Technology Fact Sheets: The technology fact sheets were discussed for all the shortlisted technology options. For each technology, the team had extensive discussions on the capital and operational costs, benefits, current status of the use of the technologies, disadvantages of the technology options and how the technology could assist the sector in adapting to the effects of climate change;

II. Development of Criteria: Criteria were developed and discussed by the working group, and were selected based the categories proposed by TNA, i.e., cost, economic, social, environmental and climatic. The approved criteria were used for rating the technology options from the shortlist of technologies. Criteria were also developed within these broad categories (Table 5.3).

III. Development of Weights for each Criterion: The weighting system was discussed, and the working group agreed to the weighting of each criterion.

IV. Rating each Technology Option: The team was then shown how to rate each technology option based on the criterion giving a score between 0 and 100. Scoring was completed in the working group session.

Completed sheets were returned to the consulting team where the scores were aggregated and tabulated using the MCA tool provided by TNA.

Table 5.3: Agreed Criteria and Weights for Water Resources MCA

Category	Criteria	Description	Weight
Capital Cost	Capital Cost	Fixed one-time cost for purchasing and setting up of the technology or equipment	10
	Operational and Maintenance Costs	Cost associated with the day-to-day operation and maintenance of the technology or equipment	10
Economic	Creates Opportunities for Investment	Creates opportunities for investment by individuals, companies and the government	10

Category	Criteria	Description	Weight
	Reduced Cost of Water to Consumers	An overall cost reduction in the cost of water to the users and consumers of water Lower cost for water will provide overall benefit to women, farmers, small businesses and other vulnerable groups.	25
Social	Improved Access to clean Water	Increases the access to water in communities, to women, children, small farmers and other vulnerable groups	15
Environmental	Promotes efficient Use of Water	Allows for the efficient use of water and water resources This may include the reclamation and reuse of water resources.	25
Climate	Adapting to the Effects of Climate Change	The technology improves the overall ability for the country to adapt to the effects of climate change.	5

5.5 - Technology Prioritisation for the Water Sector

The MCA was completed by the sector working group on the four technology options. During the MCA process consensus was achieved for the scoring and where there was a difference, an aggregated score was used. The MCA analysis scores, and weighted scores are given in **Appendix IV**. Based on the weighted scores (Table 5.4), the prioritised adaptation technologies for the Coastal Resources for Jamaica are:

1. Rainwater Harvesting and Restoring of Barbeque Catchments;
2. Creation and Restoration of Minor Tank Networks;

Table 5.4: MCA Scores for Water Resources Technology Options

Rank	Technology Options	Score
1	Rainwater Harvesting and Restoring of Barbeque Catchments	7506
2	Creation and Restoration of Minor Tank Networks	6956
3	Water Reclamation and Reuse	6313
4	Artificial Recharge of Aquifers	6056
5	Desalination	4431

PART III – Technology Prioritisation for Mitigation

6 – Mitigation Technology Prioritisation for the Agriculture Sector

6.1 - GHG Emissions

In Jamaica, the agriculture sector is the second highest contributor to greenhouse gas (GHG) emissions which influence global climate change. In 2012, the sector contributed to 11% (1.6 Mt CO_2e or 4,336 Gg CO_2e) of the total emissions released by all industries and sectors across the island (Aether Consultancy, 2015). Overall, Jamaica's GHG emissions increased by 0.63 MtCO_2e from 1990 to 2013, with an average annual change in total emissions of 0.5%. Average annual change within the agricultural sector was estimated to be −1.6%, indicating a decrease in emissions between that period (IDB, 2017). Sources of GHG in agriculture and the gases released vary mainly between nitrite and methane with nitrite from manure management accounting for 43% of total crop and livestock emissions (Table 6.). Other major contributions came from nitrite emissions from organic fertilizer and soil leaching.

Table 6.1: Source and Types of GHG emitted from Agriculture in Jamaica with their respective Quantities

Source and Type of GHG Emitted	Quantity
Synthetic N Fertilizer	35.7 Gg NO_2/year, CO_2e
Organic N Fertilizer	1390.7 Gg NO_2/year, CO_2e
Crop Residues	6.6 Gg NO_2/year, CO_2e
Drained/Managed organic Soils	64.4 Gg NO_2/year, CO_2e
Indirect N_2O Emissions: Soils Deposition	4.1 Gg NO_2/year, CO_2e
Soils Leaching/Runoff	459.5 Gg NO_2/year, CO_2e
Emissions of CO_2 from Lime	0.2 Gg CO_2
Emissions of CO_2 from Urea Application	1.5 Gg CO_2
Emissions of CH_4 from Rice Cultivation	0.2 Gg CH_4/year, CO_2e
Emissions of CH_4 from Field Burning	6.0 Gg CH_4/year, CO_2e
Emissions of N_2O from Field Burning	1.9 Gg NO_2/year, CO_2e
TOTAL	**1970.9 Gg CO_2e**
GHG Emissions from Livestock: Grazing Animals	304.3 Gg NO_2/year, CO_2e
Enteric Fermentation (CH_4)	139.9 Gg CH_4/year, CO_2eq
Manure Management (CH_4)	106.9 Gg CH_4/year, CO_2eq
Manure Management (N_2O)	1613.7 Gg NO_2/year, CO_2e
TOTAL	**2104.5 Gg CO_2e**
TOTAL CROPS AND LIVESTOCK	**4075.4 Gg CO_2e**

Source: (IDB, 2017)

Currently, Jamaica does not monitor its own greenhouse gas emissions and progress to develop a centralised database has been slow due to limited capacity and resources. However, with the establishment of a government operated Climate Change Division, this process is expected to be accelerated.

6.2 Existing Mitigation Technologies within the Agriculture Sector

Whilst no monitoring of GHG emissions is being carried out, farmers and businesses within the agriculture sector have been moving increasingly towards installation of renewable energy systems, particularly solar and wind power. The objective is to reduce emissions and to benefit from reduced electricity costs and the associated increase in profits. However, the initial cost to engage in the use of solar power and wind turbines on farms is too high for most small farmers across Jamaica. Therefore, financial assistance is required to fulfil the need for wider use of solar and wind energy, particularly on pig farms, and poultry farms; and also, for water pumping, retrofitting storage facilities and accessing shallow wells for water. Some assistance has been provided by climate financing institutions like the Green Climate Fund and Global Environment Facility. Without this assistance, most farmers within the sector will have to continue using fossil fuels, even though they desire to make the move towards renewable energy so as to be more energy-efficient and to keep costs down.

Some aquaculture farmers in St. Catherine have been using solar and wind power to operate the pumps connected to ponds. The most recent large-scale farm to be retrofitted with solar power was the Monymusk Sugar Factory where the irrigation machinery is now solar-powered.

The use of biomass and waste to generate energy by farmers is a viable means of renewable energy in Jamaica. Under this process, a portion of the manure from Jamaica's four most common livestock animals can be redirected to anaerobic digesters to produce biogas for power generation. These animals include all cattle (dairy or other), chickens (layer, broilers), swine (market or breeding), and goats. The digesters encourage methanogenesis, converting 80% of the available energy in the effluent into methane (NGGIP, 2006), resulting in a 65% methane-by-volume biogas (WBGMI, 2016).

6.2 - Decision Context

In 2012, the agriculture sector in Jamaica contributed to 11% (1.6 Mt CO_2e or 4,336 Gg CO_2e) of the total emissions released by all industries. The average annual change within the agricultural sector was -1.6%, therefore, this indicates that there has been a decrease in emissions from 1990 to 2013. GHG from the agriculture sector. The agriculture sector also contributed the largest amount of CH4 emissions preliminary from fermentation and manure management and these emissions has increased be 16% of total CH4 emissions from 2006 to 2012. The sector also accounted for 98% of N2O emissions in 2012 mainly from manure management, agriculture soils and other indirect emissions.

The GoJ has employed mitigation actions within the agriculture sector as a measure to reduce GHG emissions. The GoJ aims to deploy animal waste digestion power to generate some 28.2 MW of electricity. This will be done through the use of anaerobic digesters to produce biogas suing livestock manure. The biogas will be used to generate electricity. This is one technology which will aim in decreasing the GHG emissions from the Sector. Generally, technologies to mitigate against GHG emissions should concentrate on: -

1. Decreasing the sources of GHG in agriculture
2. Containing the different types of gases released from agricultural practices and cattle farming.

6.3 - Mitigation Technology Options

A long list of technology options along with briefs were prepared from the reviews of previous TNA Reports, TNA Fact Sheets, online databases and from consultations with stakeholders from the agriculture sector. The long list of mitigation technologies is presented in Table 6.2.

A short list of mitigation technologies was extracted using results of surveys and further consultation with members of the sector working groups. This aimed to prioritise three technologies for the sector. The short list of technologies and descriptions for each is presented in Table 6.3.

Technology fact sheets for each shortlisted technology were also discussed and developed from review of previous TNA Reports, TNA Fact Sheets, online databases and feedback from stakeholders in the agriculture sector. The TNA Factsheets for the shortlisted technologies are given in **Appendix III**.

Table 6.2: Long List of Mitigation Technologies for the Agriculture Sector

Agriculture Mitigation Technologies		
Carbon dioxide reduction		Off-field crop residue management
Nitrous oxide (N_2O) reduction		Organic agriculture
Advanced Bio-hydrocarbon Fuels		Solar dryer
Aerobic biological treatment (composting)		Soil mulching
Agriculture for biofuel production		Natural pesticides
Agro-forestry		Using cow dung as fertilizers
Bioethanol from sugar and starch-based crops		Solar-powered water pumps for irrigation
Biomethane compressed natural gas hybrid fuel		Biodigester
Biorefinery		Solar-powered irrigation pumps from pressurised well systems
Cellulosic ethanol		Fodder banks and feeding fields
Concentrating solar power		Solar-powered mating parlours
Covering manure storage facilities		Vermi-composting
Household biogas digesters		Recycling cane trash
Irrigation		Intercropping
Livestock management		Solar-powered insulated cooling system
Microalgae for mitigating carbon dioxide		Cow milking machine operated by biofuel

Table 6.3: Short List of Mitigation Technologies for the Agriculture Sector

	Agriculture Sector Mitigation Technologies	Description
1	**Cropping Systems**	Alternating cash crops with legume plants which helps to fix nitrogen This includes mixed-cropping, inter-cropping, cover cropping and crop rotation.

	Agriculture Sector Mitigation Technologies	Description
2	**Irrigation**	CO_2 emissions can be reduced with effective irrigation by increasing yields and crop residues which can enhance carbon sequestration.
3	**Fodder Banks and Feeding Fields**	Fields are grown specifically to produce grass for cattle; this, in turn, reduces soil erosion, soil exposure, nutrient loss and ensures GHG in soils do not escape into the atmosphere. Grass is then cut and stored for feeding particularly during dry periods when lack of rain reduces the accessibility to naturally grown grass on pasture fields
4	**Concentrating Solar Power**	Concentrates the energy from the sun for electricity production by heating fluid which is then used to raise steam to a conventional turbine for on and off-grid electricity provision This reduces carbon emissions and helps farmers save against high electricity costs.
5	**Solar-Powered Water Pumps for Irrigation**	Pressurised deep well pumps consume a lot of electricity, but when combined with solar power, it greatly reduces the cost of water to farmers.
6	**Aerobic Biological Treatment (composting)**	The biological degradation under controlled aerobic conditions The waste is decomposed into carbon, water and the soil amendment or mulch which is integrated back into the soil. Carbon storage also occurs in the residual compost.

6.4 - Criteria and Process of Technology Prioritisation

The Multi-Criteria Analysis (MCA) methodology was used for the prioritisation of the technologies from the short list for Jamaica. At the Sector Working Group Session for Agriculture, the MCA was explained to the group and they were taken through the following steps:

I. Technology Fact Sheets: The technology fact sheets were discussed for all the shortlisted technology options. For each technology, the team had extensive discussions on the capital and operational costs, the benefits, the current status of the use of the technologies, the disadvantages of the technology options and how the technology could assist in mitigating GHGs;

II. Development of Criteria: Criteria were discussed by the working group, and selected based on the categories proposed by TNA, that is, cost, economic, social, environmental and climatic. The approved criteria were used for rating the technology options from the shortlist of technologies. Criteria were also developed within these broad categories (Table 6.4);

III. Development of Weighting for each Criterion: The weighting system was discussed, and the working group agreed to the relative weighting of each criterion. Some further adjustments were made to the weights to ensure the goal of the MCA was achieved;

IV. The team was then shown how to rate each technology option based on the criteria giving a score between 0 and 100. The Excel Worksheet was given to the working group members for them to complete and send to the consulting team. This was done as the working group needed more time to review the fact sheets for the technology options.

Completed sheets were returned to the consulting team; the scores were subsequently aggregated and tabulated using the MCA tool provided by TNA.

Table 6.4: Agreed Criteria and Weights for the Agriculture Sector MCA

Category	Criteria	Description	Weight
Capital Cost	Capital Cost	Fixed one-time cost for purchasing and setting up of the technology or equipment	25
	Operational and Maintenance Costs	Cost associated with the day-to-day operation and maintenance of the technology or equipment	15
Economic	Increase in yield for farmers	Increase in the yields for farmers which will increase their overall income due to high productivity	15
	Technology can be adopted across Jamaica.	Easy for farmers across Jamaica to adopt and implement, therefore having an overall economic benefit to the agriculture industry	5
	Suitable for vulnerable farmers	Technology will be suitable for vulnerable farmers to implement without implications for cost or causing economic harm.	5
Social	Increases the scale of an existing technology	The technology can be easily scaled up to allow for expansion of the farm or to be used on different sized farms.	10
	Ease of adoption by farmers across Jamaica	The technology can be adopted by farmers of different genders, diverse ages, with different sized farms, and farm types. It is not limited to any particular farmer nor does it require advanced learning or knowledge of the technology.	10
Environmental	Mitigation or adaption to climate change	The technology provides the ability for farmers to mitigate against climate change.	15

6.5 - Results of the MCA for Mitigation Technology Options for Agriculture

The MCA was completed by the sector working group on the 6 mitigation technology options for the agriculture sector. During the MCA process, consensus was achieved for the scoring and where there was a difference, an aggregated score was used. Adjustments to weights were completed after scoring to ensure analysis was accurate. The MCA analysis scores, and weighted scores are given in **Appendix IV**. Based on the weighted scores (Table 6.5), the prioritised mitigation technologies for the agriculture sector included:

1. Concentrating Solar Power;
2. Aerobic Biological Treatment;

Table 6.5: Results of the MCA for Mitigation Options for the Agriculture Sector

Rank	Technology Options	Score
1	Concentrating Solar-Powered Systems	6575
2	Aerobic Biological Treatment (composting)	6500
3	Solar-Powered Irrigation and Cooling Systems	6400
4	Fodder Banks and Feeding Fields	6400
5	Irrigation	6350
6	Cropping Systems	6300

7 – Mitigation Technology Prioritisation for the Energy Sector

7.1 - GHG Emissions and existing Technologies

Jamaica is a net importer of fossil fuel energy sources principally for electricity, heat and transport applications. Jamaica's Third National Communication (TNC) under the United Nations Framework Convention on Climate Change (UNFCCC) indicates that Jamaica's GHGs are significant compared to other small states. In 2013, Jamaica's total GHG emissions were 10.3 Mt CO2e, amounting to 0.02% of global GHG emissions (USAID, n.d.) and the main sources of harmful emissions are from the combustion of fossil fuels from the electricity sector, transportation, and the industrial sector. Other contributing factors to greenhouse gas emissions include open burning of materials in cane fields, waste dumpsites and backyards, as well as the burning of synthetic or man-made chemicals. The aluminium/bauxite industry, in particular, is responsible for the high energy intensity in Jamaica being comparable on that of most developing countries. This is reflected in the country's carbon emissions statistics.

Electricity is the most significant consumer of energy and most generation systems are powered by fossil fuels (Figure 7.1). A further breakdown of types of energy sources in the generation subsector indicates that the electricity grid is supplied from petroleum (45%), natural gas (37%) and renewables (18%), which include solar, wind and hydropower (Figure 7.2).

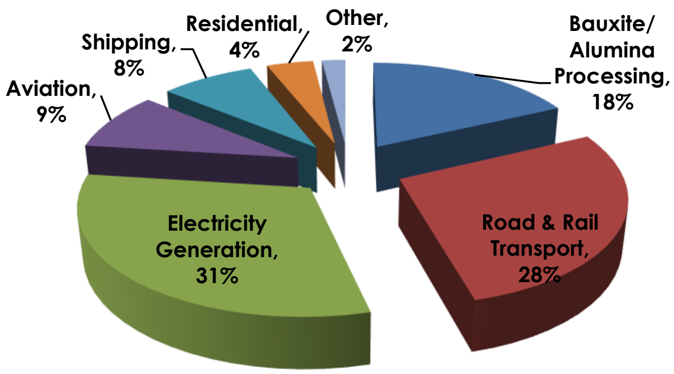
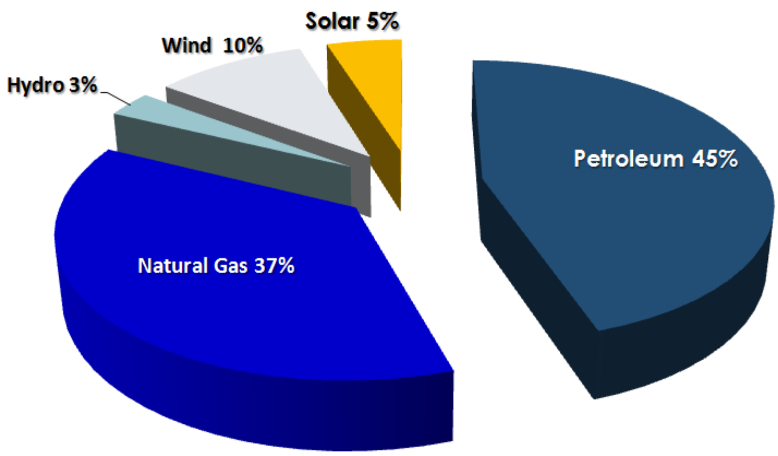


Figure 7.1: Energy Consumption in Jamaica by Category (TNC, 2018)



Source: MSET Sectoral Presentation, 2019

Figure 7.2: Installed Electricity Capacity in Jamaica by 2020

Most fossil fuel plants owned by the utility company are over 30 years old and inefficient, however, these are being replaced on a schedule beginning with the supply of natural gas to the Bogue, Montego Bay 120 MW plant gas combined cycle turbine (GCCT) plant and a new 190 MW natural gas turbine plant in south-east Old Harbour (Table 7.1). The high proportion of inefficient fossil-based plants directly and adversely influences Jamaica's high GHG emission levels.

Of the remaining fossil fuel imports, motive applications for local road and rail consume 28% of imported fossil fuels, while the minerals industry (bauxite) is the third highest consumer of fossil fuels at 18% for heat and power. The presence of a significant bauxite sector contributes to Jamaica's high energy index relative to energy intensity rates in Latin America and the Caribbean. A rapid assessment conducted by Sustainable Energy for All (SE4All, 2013), attributed this elevated energy index partly to the high energy use of the bauxite and alumina sector and to Jamaica's general inefficiency in the use of energy. The bauxite and alumina sector is therefore targeted for greater energy efficiency and will be utilising natural gas and more efficient energy and heat technology applications to improve energy and emissions performance.

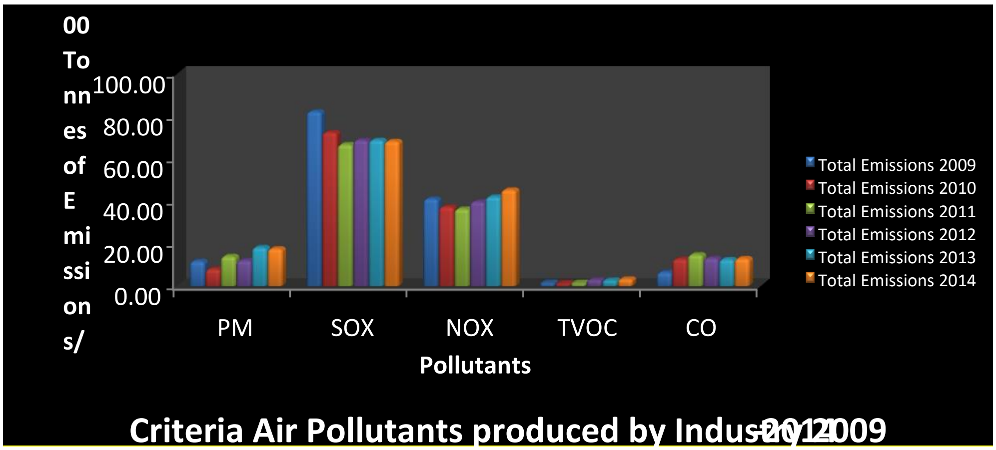
Electricity and heat generation is a significant contributor to GHG emissions in Jamaica (Figure 7.3). Emissions data from industries available for 2014 from NEPA indicate that sulphur oxides (SO_x) and nitrogen oxides (NO_x) represent over 80% of the emissions from major and significant sources (NRCA, 2006).

The on-road transportation subsector is a significant fossil fuel user and contributor to GHG emissions (Figure 7.4, Figure 7.5 and Figure 7.) with a significant vehicle stock estimated to be 580,994 (including motorcycles) in 2016 with a purchase rate of 52,046 vehicles per year (Johnson, Koebrich, & Singer, 2018). The vast majority is privately-owned motor cars (69%). To mitigate emissions, Jamaica's NDC goal is to reduce transportation petroleum use 10% below business-as-usual (BAU) levels by 2030 (Table 7.2 and Table 7.3).

Table 7.1: Generation Plants on the Jamaica Transmission and Distribution Grid by Fuel

	2013	2014	2015	2016	2017
Steam Generation	262	262	262	262	262
Hydro Generation	22.27	29.52	29.52	29.52	29.52
Wind Power	3	3	3	3	3
Slow-speed diesel	40	40	40	40	40
Gas Turbines	151.5	151.5	151.5	151.5	151.5
Combine Cycle Technology	114	114	114	114	114
JPS Total	**592.77**	**600.02**	**600.02**	**600.02**	**600.02**
Wind Power	38	38	38	98.3	98.3
Medium-speed diesel	189.5	189.5	189.5	189.5	189.5
Steam Turbine (Jamalco)	11	11	11	11	11
Slow-speed diesel	61.3	61.3	61.3	61.3	61.3
Solar				20	20
IPP Total	**299.8**	**299.8**	**299.8**	**380.1**	**380.1**

Source: (JPS, 2018)



Key:PM – particulate matter; SOx- sulphur oxides; NOx – nitrogen oxides
TVOC – total volatile organic compounds; CO – carbon monoxide

Figure 7.3: Emissions from major and significant Sources in Jamaica (NEPA, n.d.)

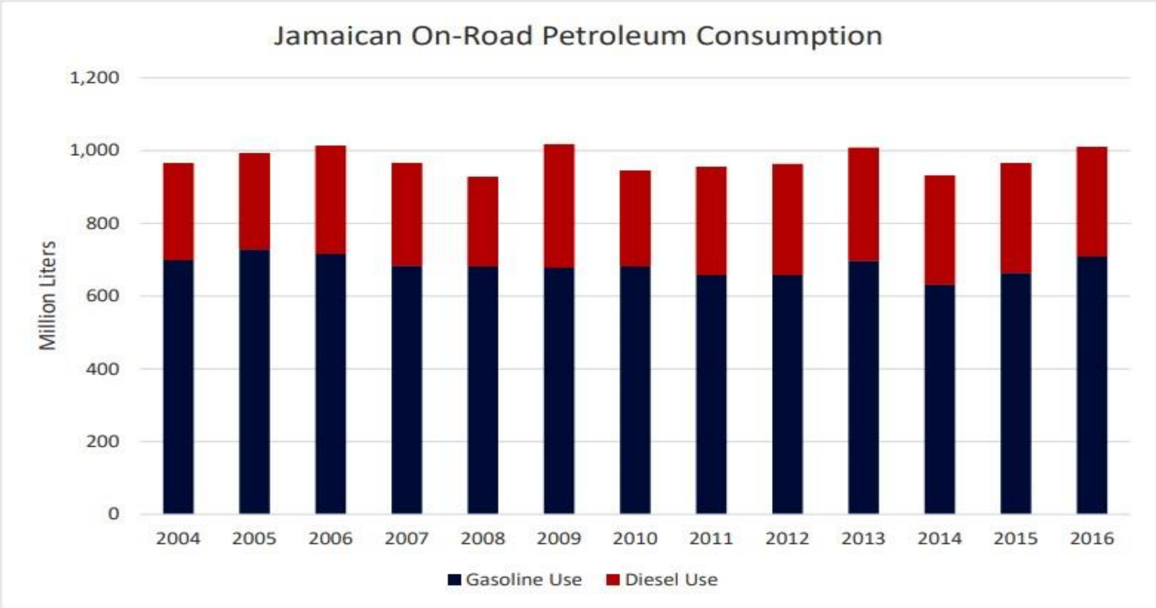


Figure 7.4: Jamaica on-road petroleum consumption (Technical Report, National Renewable Energy Laboratory)(Johnson, Koebrich, & Singer, 2018)

Table 7.2: Jamaica on-road Vehicle Imports by Fuel (2016 – 2017)

2016–2017 Jamaican On-Road Vehicle Imports by Fuel Type

	Gasoline	Diesel	Other
LDV	91%	9%	0.2%
MDV/HDV	9%	90%	0.8%
All Vehicles	88%	12%	0.2%

Source: (Johnson, Koebrich, & Singer, 2018)

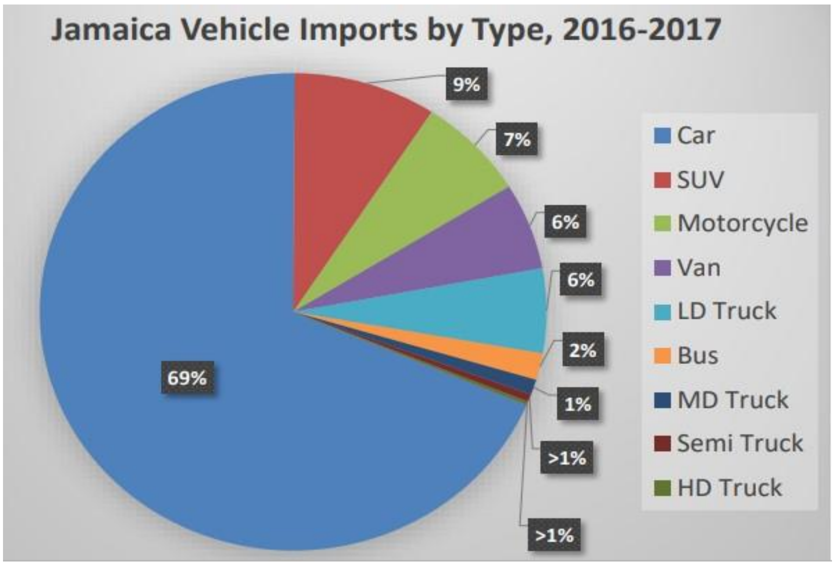


Figure 7.5: Jamaica Vehicle Imports by Type of Vehicle (2016 – 2017) (Technical Report, National Renewable Energy Laboratory) (Johnson, Koebrich, & Singer, 2018)

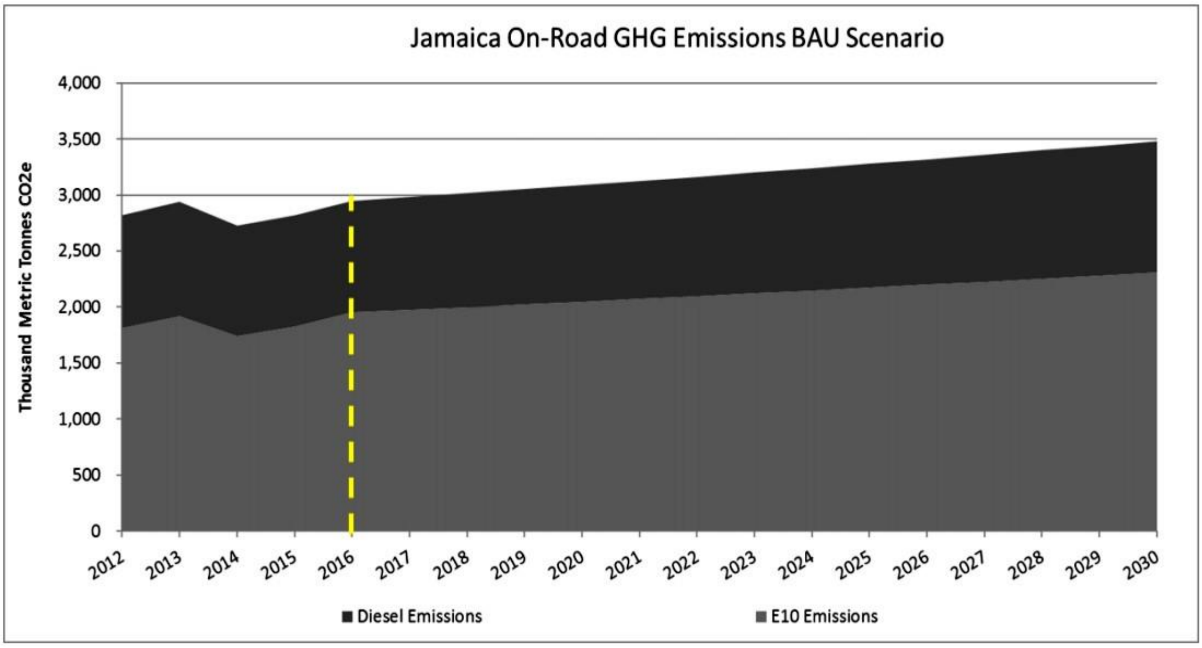


Figure 7.6: Jamaica on-road GHG Emissions BAU Scenario 2016 – 2030 (Johnson, Koebrich, & Singer, 2018)

Table 7.3: Emissions Reduction Goals for the on-road Transportation Sector

Transportation Subgoal - Predicted GHG Reduction, and Percent Contribution to Overall Goals

Transportation Subgoal (from 2030 BAU)	Thousand Metric Tons (TMT) CO_2e Reduced	Percent of Overall Goal
9% reduction in VKT of LDVs through walking, biking, using public transit, ridesharing, and telecommuting	206.8	58.6
7% improvement in fuel economy for new LDVs	64.8	18.4
All diesel contains 5% biodiesel	57.9	16.4
Traffic-flow is smoothed so that 1.5% of road kilometers are converted from city drive cycle to highway drive cycle	12.9	3.7
HDV idle time reduced 45 minutes per vehicle per day	6.1	1.7
12% of new LDV purchases to be electric	4.5	1.3

CO_2e – carbon dioxide equivalent

Reducing Jamaica's GHG emissions by 10% below the 2030 BAU scenario is possible for the road transportation sector. This can be achieved by reducing vehicle kilometres travelled by 59%; adding a further 18% reduction from fuel economy improvements; adding B5 biodiesel would lead to a further reduction of 16%; traffic-flow improvements would result in a reduction of 3.7%; and an additional 3% reduction split between reducing idle time for heavy-duty vehicles and increasing the purchase of light-duty electric vehicles (EV).

In 2007, Jamaica released 4.74 tonnes of CO_2 per capita – slightly above the world average of 4.38 tonnes of CO_2 per capita and greater than the average for Latin America and the Caribbean of 2.21 tonnes of CO_2 per capita. Emissions data show that the energy sector in particular is responsible for over 86% of CO_2 emissions released into the atmosphere, with the remainder coming from land use changes that remove trees and other vegetation (National Policy for the Trading of Carbon Credits 2010–2030 – Proposed Strategic Framework, October 2010).

Electricity and heat generation alone contributes over 70% of Jamaica's total emissions over multiple years. In 2014, Jamaica was estimated to have generated emissions of 10.2 Mt CO_2e per annum from energy consumption, industrial processes, land use changes, forestry, agriculture and waste. The highest estimated emission of 14 Mt CO_2e was in 2006 and has since trended downward to 10 Mt CO_2e in 2014. Energy alone was estimated to have contributed 85.7% of total emissions in 2006 and 74% in 2014 (Table) (IPCC, 2006). The NDC has therefore assigned target emission reductions shown in Table .

In a BAU scenario, Jamaica will generate emissions of 14.5 Mt (CO_2e) in 2030, however, with interventions, Quantified Emission Targets with Unconditional Contributions, Jamaica is expected to achieve emissions of 13.4 Mt (CO_2e), a 7.8% reduction from the BAU 2030 scenario. With international support in regard to the Quantified Emission Targets with Conditional Contributions, Jamaica is expected to achieve a 10% reduction in emissions below the BAU 2030 scenario of 13.0 Mt (CO_2e) (Figure 7.7).

Jamaica's Nationally Determined Contributions (NDCs) therefore aim to mitigate the equivalent of 1.1 million metric tons of carbon dioxide per year by 2030 (or 7.8%) of emissions versus the BAU scenario in the energy sector (IPCC, 2018). This outcome is predicated on the current level of implementation of the National Energy Policy and the existing pipeline of renewable energy projects. With the provision of international support, Jamaica will conditionally increase its ambition to a reduction of GHG emissions of 10% below the BAU scenario. The period for implementation is from 2005 to 2030 (with an interim target in 2025). Specific emissions of interest include CO_2, CH_4, N_2O, NOx, CO, non-methane volatile organic compounds (NMVOCs), and SO_2 as related to the named critical GHG emissions. The Kigali Amendment also indicates that Jamaica should also consider reducing refrigerants with global warming potential (GWP) as part of its overall efforts in climate change mitigation and a National Cooling Strategy is being developed to remove or replace ozone depleting refrigerants and inefficient cooling systems. The NDC is therefore expected to result in lower emissions equivalent to 4.7 Mt CO_2 per person by 2030, versus an equivalent of 5.1 Mt CO_2 per person under the current BAU scenario. Jamaica will therefore implement its NDC through the Climate Change Policy Framework and the National Energy Policy 2009–2030 as the two main instruments available since at this time Jamaica does not have climate change-related laws.

As the long-term energy strategy, Jamaica's 2009–2030 National Energy Policy has included harnessing indigenous energy resources concurrent with preserving and enhancing economic, social, and environmental capital. This Policy is in line with the Climate Change Framework which aims to achieve emissions reduction of 10% below the BAU scenario, subject to the provision of international support. This reduction target is based on enhanced implementation of the National Energy Policy. Part of the focus is mitigation through the application of renewable energy generation and energy-efficiency initiatives in the electricity and transportation sectors. In particular, the Office of the Prime Minister has mandated increasing the number of renewables in the energy mix from 20% to a more ambitious target of 50% by 2030, supported by NDC targets, CC targets, and a goal for 100% electrification island wide in line with the UN's development goal of Sustainable Energy for All. The Energy Policy also seeks to reduce emissions at the points of power generation (Table 7.6).

Renewable generation on the national grid stands at approximately 18% of gross electricity generation as of 2019. Critical to achieving this were Independent Power Purchase (IPP) agreements for 24 megawatt (MW) with the Wigton III wind farm, 36.8 MW with Blue Mountain Renewables (BMR), 20 MW from Content Solar and Eight Rivers/Paradise Park/Neoen Company (EREC) with a 37 MW solar photovoltaic plant. This would be equivalent to a reduction of GHG emissions of more than 457,800 tonnes of CO_2 per year. An additional 12 MW of energy being generated by residential and commercial customers will also contribute to reduced GHG emissions. The NAMA for the scaling up of renewable sources of electricity will be central to the full implementation of the NDC. The linkages between the two initiatives are shown in Table .

The bauxite sector, a significant consumer of fossil fuels for power and heat, has retrofitted their plants and is currently taking steps to transition to liquefied natural gas and more energy-efficient equipment in order to reduce emissions and be more commercially viable.

Through two key projects on energy efficiency and conservation, namely, the Energy Efficiency and Conservation Programme and Energy Security Efficiency and Enhancement Project as well as other initiatives in public sector facilities, a total of 1,954 barrels of oil, equivalent to 2,514 tonnes of CO_2, have been reduced. The Inter-American Development Bank (IDB), the Japan International Cooperation Agency (JICA) project and the Energy Management and Efficiency Programme (EMEP) will also significantly reduce GHG emissions **(**Emissions Policy Framework, 2017).

Table 7.4: Jamaica's Historical GHG Emissions (2006 and 2014)

EMISSION SOURCES	EMISSIONS (CO_2e)	
	2006	**2014**
Energy	12 Mt	7.4 Mt
Industrial Processes	660 kt	950 kt
Land Use Change & Forestry	770 kt	780 kt
EMISSION SOURCES	EMISSIONS (CO_2e)	
Agriculture	680 kt	620 kt
Waste	430 kt	420 kt
Gross Absolute Values	**14 Mt**	**10 Mt**

Source: (Climate Watch, 2019)

Table 7.5: Jamaica's Nationally Determined Contribution Targets

Year	BAU	NDC (unconditional) (7.8% reduction)	NDC (conditional on international support) (10% reduction)
2025	13,443 kT CO_{2e}	12,370 kT CO_{2e}	12,099 kT CO_{2e}
2030	14,401 kT CO_{2e} (5.1 metric tonnes CO_2 per person)	13,368 kT CO_{2e} (1.1 million metric tonnes of CO_2 per year or 4.7 metric tonnes CO_2 per person)	13,043 kT CO_{2e}

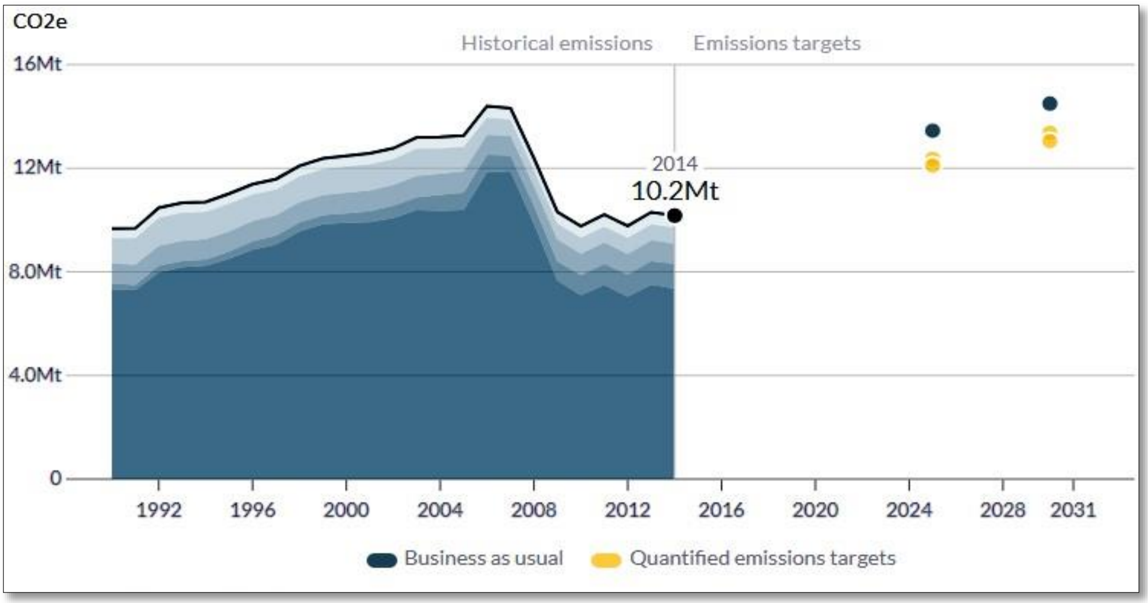


Figure 3.7: GHG Emissions and Emissions Targets (Climate Watch, 2019)

Table 7.6: Energy Sector Indicators and Targets

Sector Indicators	2008	2012	2015	2030
Energy Intensity Index (EII) BTU/US$1 Unit of Output (Constant Year 2000; $US)	15,392	14,000	12,700	6,000
Percentage of Renewable Energy Scenario (REN) in Energy Mix	**5.6%**	**11%**	**12.5%**	**20%**
Percentage of Total Households with Electricity (%)	92	94	100	-
Sector Indicators	2008	2012	2015	2030
GHG Emissions (Mt per annum)	5	5	4.5	3.5

Source: Jamaica National Energy Policy 2009–2030, Renewable Energy Sub-Policy

Table 7.7: Provisions of the NDC and the NAMA

Initiative	Jamaica Renewable Energy Nationally Appropriate Mitigation Action	Nationally Determined Contribution
Objective	30% participation of renewable energy in electricity generation by 2030 To promote the incorporation of renewable energy-based electricity generation, assisting in the creation of an enabling environment for early development of the renewable energy industry	Increase the share of renewable sources of energy in the primary energy mix to 20% by 2030 Reduce emission of the equivalent of 1.1 million metric tons of carbon dioxide per year by 2030 versus the business-as-usual (BAU) scenario. i.e., a 7.8% reduction of emissions compared to BAU
Timeframe	2030	2005–2030 with an interim target in 2025
Scope of gases included	CO_2	CO_2, N_2O, CH_4, NOx, CO, NMVOC, SO_2
Sectors covered	Energy/Electricity/Renewable Energy	Energy (including transport) (as defined in IPCC's 2006 Guidelines)
Base year	2008	2005
BAU emissions in target year		2025 – 13.445 kT CO_2eq 2030 – 14,492 kT CO_2eq

Initiative	Jamaica Renewable Energy Nationally Appropriate Mitigation Action	Nationally Determined Contribution
Mitigation scenario in target year		Unconditional contribution 7.8% below BAU by 2030 2025:12,370 kT CO_2eq 2030:13,368 kT CO_2eq
Policies	• Vision 2030 Jamaica – National Development Plan • Special Initiative for Low Carbon Development – Climate Change Policy Framework • National Energy Policy Action Plan (draft)	• Climate Change Policy Framework, 2015 • National Energy Policy, 2009–2030
Institutional arrangements	MSET – coordination of the implementation of the NAMA Political/Policy Board – to deal with renewable energy and mitigation NAMA Board	Climate Change Division, MEGJC – coordination of actions of MDAs to implement the NDC and creation of an enabling environment for necessary private action

7.2 - Decision Context

Jamaica's total GHG emissions were 10.3 MtCO_2e in 2013 or 0.02% of Global GHG emissions. While this is a small contribution to Global GHG, the GoJ has proceeded with fulfilling its international obligation and mitigation commitments for GHG emissions. The GoJ aims for a 205 of renewable energy in the energy mix by the year 2010. This is outlined in the National Energy Policy 2009-2030 and the draft national Renewable Energy Policy 2010-2030. In keeping with this vision, Jamaica has seen significant investment in the renewable energy sector since 2012 (MEGJC, 2018). Additionally, the GoJ, has promoted renewable energy use at the consumer, with incentives for solar water heaters and PV systems through a series of loans, grants and tax exemptions.

Jamaica’s conditional NDC goals require abetment target of 1.124 MtCo2e by 2030 for the energy sector. This is expected to be achieved through potential and planned GHG reduction initiatives in the production and consumption of energy throughout many sectors including, residential and commercial buildings, manufacturing industry, transportation, public utilities, electricity generation, agriculture, solid waste management, water and wastewater.

Mitigation technologies for the energy sector should, therefore, support the GoJ mitigation initiatives outlined in the National Energy Policy 2009-2030 and the draft national Renewable Energy Policy 2010-2030.

7.3 - Mitigation Technology Options for the Energy Sector

A long list of technology options along with briefs were prepared from the reviews of previous TNA Reports, TNA Fact Sheets, online databases and from consultations with stakeholders from the agriculture sector. The long list of mitigation technologies is given in Table .

A short list of mitigation technologies was extracted from conducting surveys and further consultations with members of the sector working groups. This aimed to identify at least 5 technologies for the sector. The short list of technologies and descriptions for each is given in Table 7.9.

Technology fact sheets for each shortlisted technology were also discussed and developed based on a review of previous TNA Reports, TNA Fact Sheets, online databases and feedback from stakeholders in the energy sector. The TNA Factsheets for the shortlisted technologies are given in **Appendix III.**

Table 7.8: Long List of Mitigation Technologies for the Energy Sector

Energy Mitigation Technology		
Wind turbine systems		Biogas
Combined heat and power (CHP) plants		Calcpos Rotary Burner (CRB)
Integrated gasification combined cycle		Super Boilers
Anaerobic bio-digestion		Seawater Air Conditioning (SWAC)/District Cooling (DC)
Refuse-derived fuel production		Flue Gas Based Fuel Dryer for Biomass Combustors
Micro hydropower		Advanced Pulverized Coal (Single and Double Unit)
Solar Photovoltaic system		Smart grid Technology
Biodiesel		Production and use of molten salt in thermodynamic solar plants
Bioethanol from sugar and starch-based crops		Biofuel
Extraction turbine		Solar Dryers
Geothermal water heating		

Table 7.9: Short List of Mitigation Technologies for the Energy Sector

	Energy Sector Adaptation Technologies	Description
1.	**Refuse-derived Fuel Production**	Fuel produced from various types of waste such as municipal solid waste (MSW), industrial waste or commercial waste

	Energy Sector Adaptation Technologies	Description
2.	**Concentrated Solar Power**	Concentrates the energy from the sun for electricity production by heating fluid which is then used to raise steam to a conventional turbine for on- and off-grid electricity provision This reduces carbon emissions and helps farmers save against high electricity costs.
3.	**Seawater Air Conditioning (SWAC)**	Seawater district cooling is an alternative cooling strategy which draws cold water from a source and exchanges the heat (heat exchanger) from the occupied environment with this cold water to affect the cooling. It uses no refrigerants therefore has no adverse CC impacts from refrigerants. In Jamaica, cooling opportunities exist in the proximity of the Cayman Trench due to access to an inexhaustible source of cold deep-sea water. In this context, a seawater air conditioning (SWAC) system might draw cold seawater from great depths (>800 m) to a cooling station. This chilled water can then be used to absorb heat from buildings and then returned the warmer water to the ocean, usually at a shallower depth. Several buildings can be connected to the chilled freshwater loop creating an option to conventional air conditioning and which requires no refrigerants. For this reason, SWAC is sometimes referred to as District Cooling because of the connectivity of multiple cooling loads near the SWAC plant.
4.	**Biogas**	Biogas is the mixture of gases produced by the breakdown of organic matter in the absence of oxygen. It is produced from raw materials like agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. Biogas is a renewable energy source which may be used for heating, electricity and efficient stoves.
5.	**Above Ground Light Rail Transit (LRT)***	Light rail or light rail transit (LRT) is a form of urban rail public transportation that generally has a lower capacity and lower speed than heavy rail and metro systems. The term is typically used to refer to rail systems with rapid transit-style features that usually use electric rail cars operating mostly in private rights-of-way such as above ground railway systems. Therefore, there is no mixing of traffic and the railway system.

	Energy Sector Adaptation Technologies	Description
6.	**Natural Refrigerants**	The use of natural substances (Carbon dioxide, ammonia, petroleum derived compounds, oxygen compounds, nitrogen compounds and elemental gases) instead of hydrofluorocarbon (HFC), hydrochlorofluorocarbon (HCFC) and chlorofluorocarbon (CFC) refrigerants
7.	**Solar Air Conditioning**	Air conditioning systems which are powered by solar photovoltaic systems

7.4 - Criteria and Process of Technology Prioritisation for the Energy Sector

The Multi-Criteria Analysis (MCA) methodology was used for the prioritisation of the technologies from the shortlist for Jamaica. The consulting team attended the 1st Regional Capacity Building Workshop for the TNA Group of Caribbean countries in Kingston, Jamaica from 20–22 March 2019. The team was trained in the MCA methodology required by the TNA. At the Sector Working Group Session for Energy, the MCA was explained to the group and they were taken through the following steps:

I. Technology Fact Sheets: The technology fact sheets were discussed for all the shortlisted technology options. For each technology, the team had extensive discussions on the capital and operational costs, benefits, current status of the use of the technologies, disadvantages of the technology options and how the technology could assist in mitigating GHGs;

II. Development of Criteria: Criteria were developed and discussed by the working group. Criteria were selected based the categories proposed by TNA, cost, economic, social, environmental and climatic. The approved criteria were used for rating the technology options from the shortlist of technologies. Criteria were also developed within these broad categories (Table 7.10);

III. Development of Weights for each Criterion: The weighting system was discussed, and the working group agreed to the weighting of each criterion. Some further adjustments were made to the weights to ensure the achievement of the MCA goal;

IV. Rating of each Technology: The team was then shown how to rate each technology option based on the criterion, giving a score between 0 and 100. The Excel Worksheet was given to the working group members for them to complete and return to the consulting team. This was done as the working group needed more time to review the fact sheets for the technology options.

Completed sheets were returned to the consulting team; the scores were subsequently aggregated and tabulated using the MCA tool provided by the TNA project.

Table 7.10: Agreed Criteria and Weights for the Energy Sector MCA

Category	Criteria	Description	Weight
Capital Cost	Capital Cost	Fixed one-time cost for purchasing and setting up of the technology or equipment	15
	Operational and Maintenance cost	Cost associated with the day-to-day operation and maintenance of the technology or equipment	12
Economic	Improves consumer cost or energy	Reduces the cost of energy to consumers	3
	Promotes opportunities for investment	Creates opportunities for investment from the private sector	9
	Creates positive externalities	Creates opportunities of positive returns indirectly related to the energy sector. That is can create downstream industries which depend on energy or lower energy cost.	5
Social	Improves quality of life	Improves the quality of life for communities, particularly women, children and vulnerable groups.	3
	Creates greater access to energy	Allows women, children, vulnerable groups and communities greater access to energy across Jamaica.	3
	Positive impact on local towns and communities	Crates a positive social impact on communities (e.g. community lighting may cause reduction in crime)	3
	Promotes energy security in Jamaica	Communities become less vulnerable to international shocks in the energy markets	10
Environmental	Reduction in GHG emissions	Allows for the reduction in GHG emissions for Jamaica	10
	Promotes the protection of the environment (land and marine ecosystems)	Protects the environment or does not cause any negative impacts on the environment.	12
Climate Related	Ability to mitigate against climate change	Allows Jamaica to reduce GHG emissions in the aid of mitigation against the effects of climate change.	15

7.5 - Results of Technology Prioritisation for the Energy Sector

The MCA was completed by the sector working group on the 7 mitigation technology options for the energy sector. During the MCA process, consensus was achieved for the scoring and where there was a difference, an aggregated score was used. The MCA analysis scores, and the weighted scores are given in **Appendix IV**. Based on the weighted scores (Table), the prioritised adaptation technologies for the Water Resources for Jamaica are:

1. Biogas
2. Natural Refrigerants

Table 7.11: Results of the MCA for Mitigation Technology Options for the Energy Sector

	Technology Options	Score
1	Refuse-Derived Fuel Production	5873
2	Biogas	6528
3	Seawater Air Conditioning (SWAC)	3205
4	Solar Air Conditioning	5250
5	Above-ground Light Rail	4060
6	Concentrated Solar Power	5675
7	Natural Refrigerants	6210

Part IV – Summary and Conclusion

8 - Summary and Conclusions

The Technology Needs Assessment for Jamaica represents the first deliverable (Multi-Criteria Analyses – MCA) of a three-step process that seeks to identify and create *climate technology pathways for implementation of the Paris Agreement*. A Consulting team was trained through a Capacity Building Workshop held in Jamaica in 2019. The TNA Multi-Criteria Analysis was shared for the prioritization of climate change adaptation and mitigation technologies for Jamaica. The Consulting Team was also supported and guided by the TNA Coordinator (CCD) who also serves as the National Designated Authority (NDA) with respect to the UNFCCC Technology Mechanism in Jamaica. The CCD was further supported by a National Project Steering Committee, and provided the consulting team with overall vision, leadership support, communication and guidance.

A mapping process of stakeholders for each sector was first completed by the Consulting Team which considered stakeholders from the public sector, private sector, academia and others. Gender balance was considered during the stakeholder mapping and the selection of the working groups for each sector. This was guided by the TNA Guidance for Gender-Responsiveness (2018). Selected stakeholders contributed throughout the entire TNA process and through a series of stakeholder consultations which included interviews, online surveys and working group meetings.

Interviews were conducted with stakeholders to identify known and available climate related technologies and to validate an initial long list of technologies developed by the National Consultants. The Working Groups for each sector were also determined from the stakeholder mapping exercise with consideration for gender balance. Sector Working Groups were initially engaged through a survey and interviews which allowed for the determination of a short list of technologies and technologies descriptions.

Technology Fact Sheets were then prepared for each shortlisted technology. This was done through consultations with professionals within each sector with knowledge of the technologies, through review of Technology fact Sheets from other countries and additional research of technology options.

The Sector Working Groups ultimately prioritized climate technologies from the short list of technologies using the TNA MCA methodology. This was done through sector working group meetings, where members,

- Discussed the Technology Fact Sheets for all the short-listed technology options, including the capital and operational cost, benefits, current status of the use of the technologies, disadvantages of the technology options and how the technology can assist the sector in adapting to the effects of climate change. Some adjustments were made based on stakeholder's recommendations.
- Developed Criteria based on cost, economic, social, environmental and climatic benefits. The approved criteria were then used for rating the technology options from the short-list of technologies.
- Developed Weights for each Criterion, for each technology.
- Rate/score each technology option based on the criteria and weighting using MCA worksheet template provided.

Additional sensitivity analyses was also completed using the criteria and scoring developed from the working group consultations. Ten technologies for climate change adaptation and mitigation for

Jamaica were eventually prioritized using this process. The identification of climate technologies in each sector general aligns with national development objectives and goals for sustainable development. The prioritized technologies are given in Table 8.1 below. These technologies will be further analysed in the second step of the TNA Process, the Barrier Analysis and Enabling Framework.

Table 8.1: Prioritized technologies for climate change adaptation and mitigation for Jamaica

Technologies for Adaptation	
Agriculture Sector	1. Sprinkler and Drip Irrigation for crop farmers
	2. Rainwater Harvesting Systems and water storage for the agriculture
Coastal Resources	3. Wetland Restoration (mangrove)
	4. Artificial Coral Reef and Coral Reef Ecosystem Restoration
Water Resources	5. Rainwater Harvesting and Restoring of Barbeque Catchments
	6. Creation and Restoration of Minor Tank Networks
Technologies for Mitigation	
Agriculture Sector	7. Concentrating Solar Power Systems
	8. Aerobic Biological Treatment (composting)
Energy Sector	9. Refuse Derived Fuel Production
	10. Biogas

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Appendices

Appendix I: List of stakeholders involved and their contacts

Agriculture Sector

	Company/Organization	Stakeholder Groupings	Contact Person/Member First Name	Surname	Position	Phone Contact	E-mail	Address
1	Ministry of Industry, Commerce, Agriculture and Fisheries	Public Sector/Civil Society	Stephen	Smikle	Head of Agriculture & Fisheries	(876) 923-8811	sgsmikle@micaf.gov.jm	Marcus Garvey Dr, Kingston
2	Ministry of Industry, Commerce, Agriculture and Fisheries	Public Sector	I.V.	Wilson	Manager, Climate Adaptation Fund	8766187102	Ivwilson@micaf.gov.jm	Hope Gardens, Kingston 6
3	UWI Department of Life Sciences	Academia	Jane	Cohen	Professor Biotchnology	8769771828	jane.cohen@uwimona.edu.jm	UWI, Mona Campus
4	UWI Department of Chemistry	Academia	Michael	Coley	Lecturer	8769771910	michael.coley@uwimona.edu.jm	UWI, Mona Campus
5	UWI Department of Physics	Academia	Michael	Taylor	Professor Climate Change	8769272480	michael.taylor@uwimona.edu.jm	UWI, Mona Campus
6	College of Agriculture, Science and Education	Academia	Mark	Gooden	Dean of Agriculture	8769935436		Passley Gardens, Port Antonio
7	UTECH College of Science and Sports	Academia	Adonna	Jardine - Comrie	Head of Environmental Science Division	8769271680-8 (ext 3151)		
8	National Commission on Science and Technology	Public Sector	Patricia	Lewin	Senior Technology Officer	8769068433	plewin_ncst@mstem.gov.jm	36 Trafalgar Road, Kingston 10
9	Scientific Research Council	Public Sector	Sean	Lee		(876)929-8990-9	info@mset.gov.jm	PCJ Building, 36 Trafalgar Road, Kingston 10.
10	Agri and Industrial Supplies	Private Sector	Hugh	Grey	Owner	(876) 926-7601	agriindpacking@gmail.com	38 Lyndhurst Rd, Kingston 5, Jamaica W. I.
11	Jamaica Broilers Group (Ja Egg Services & CB Chicken)	Private Sector	Robert / Sean	Levy / Lindo	CEO	(876) 943-4376 (get whitemarl #)		McCook's Pen, St. Catherine
12	Jamaica Producers Group	Private Sector	Jeffery	Hall	Managing Director	(876) 926-3503 (ext 1311)		4 Fourth Avenue, Newport West, Kingston 13. Jamaica
13	AG-CHEM (Agricultural Chemicals Plant)	Private Sector	Graham	Dunkley	General Manager	(876) 901-0905 (need other number)		2E Ashenheim Rd, Kingston

	Company/Organization	Stakeholder Groupings	Contact Person/Member First Name	Surname	Position	Phone Contact	E-mail	Address
14	Agro Investment Corporation	Private Sector	Kadiana	Ramballi	CFO	876 764 8071	info@agroinvest.gov.jm	AMC Complex, 188 Spanish Town Road Kingston 11. PO Box 144.
15	Carib-Agro Distributors	Private Sector	Desmond	Ashman	Managing Director	876-8178831, 876-2856151	dashman@caribagrodistributors.com	Lot C, 226 Spanish Town Road, Kingston 11, Jamaica
16	Jamaica Agricultural Society	Civil Society	Josephine	Hamilton	Parish Manager	8764176639	jhamilton@jas.gov.jm	67 Church Street, Kingston
18	Jamaica Agriculture Commodity Regulatory Authority	Civil Society	Gary	Watson	Field Coordinator	(876) 376-9259	gwatson@jacra.org	1 Willie Henry Drive, P.O. Box 508. Kingston 13
19	Sugar Industry Authority	Civil Society	George	Callaghan	CEO	876-926-5930	sia@cwjamaica.com	5 Trevennion Park Road, Kingston
20	Rural Agricultural Development Agency	Civil Society	Marina	Young	Principal Director of Technical Services	8768186019	youngm@rada.gov.jm	Hope Gardens Kingston 6
21	Banana Industry Board	Civil Society	Oral	Lewis	Extension Officer	(876) 922–5347/8764399504	bananaboard@cwjamaica.com	10 South Avenue, Kingston 4
22	All-Island Jamaica Cane Farmers Association (call back at 12)	Civil Society	Nigel	Myrie		(876) 922-7076	nigel.myrie@allcanejamaica.com	4 North Avenue - Kingston 4
23	Marion Cormack Farming	Private Sector	Marion	Cormack	Small Farm Owner	8762980869	has no email	Mount Olive District, Lawrence Tavern P.O.
24	Fender and Company Farming	Private Sector	Maxine	Fender	Small Farm Owner	8763779432	maxinefender@gmail.com	Woodford, St. Andrew
25	Salisbury Grange	Private Sector	Peter	Scott	Part Owner	8765779646	petscott@hotmail.com	Salisbury Plain, West Rural St. Andrew
26	Taylor and Company	Private Sector	Robert	Taylor	Small Farm Owner	8762971910	has no email	Mavis Bank, East Rural St. Andrew
27	Elisabeth Levy	Private Sector	Elisabeth	Levy	Farmer	8768808679	lizlevy15@gmail.com	Amity Hall Agro Park, Old Harbour Road, St. Catherine
28	Aqua Wilson	Private Sector	Maurice	Wilson	Aquaculture Small Farm Owner	8765389608	mauricewilson50@gmail.com	Hill Run, St. Catherine
29	Eagle Aquaculture Farm	Private Sector	Garfield	Christy	Aquaculture Small Farm Owner	8763280815	eagleaquaculture@ymail.com	Lot #292 Hill Run, Williams Boulevard, St. Catherine
30	Frederick Lyn Aquaculture Farm	Private Sector	Frederick	Lyn	Aquaculture Small	8763825854	marcialyn84@yahoo.com	Lot # 303, Hill Run, St Catherine

	Company/Organization	Stakeholder Groupings	Contact Person/Member First Name	Surname	Position	Phone Contact	E-mail	Address
					Farm Owner			
31	H & H Farms Jamaica Ltd.	Private Sector	Howard	Hill	Aquaculture Small Farm Owner	8769901412	hill2farms@hotmail.com	Lot # 269, Hill Run, St Catherine
32	Murrmaid Aquaculture Farm	Private Sector	Francis	Murray	Aquaculture Small Farm Owner	8768064899	francis_dsaint@yahoo.com	Lot #348-10 Hill Run, St. Catherine
33	Eglin Hope Farms	Private Sector	Emile	Spence	Farm Owner	8763839617	egspence@gmail.com	49 Keble Crescent, Kingston 6, St. Andrew
34	Lewis Dairy	Private Sector	Christene	Lewis	Farm Owner	8765428519	davianduncan@yahoo.com	Lot 3, Luana Farm, Black River PO Box 54, St/ Elizabeth Jamaica
35	Maos Farms	Private Sector	Oshane	Saunders	Farm Owner	8763567493	oshane.saunders@yahoo.com	Llandovery, St. Ann
36	Spring Common Dairy	Private Sector	Derrick	Walker	Farm Owner	8764010942	gracejbu986@gmail.com	Rhymesbury P.O Box 194 May Pen
37	DBLU Farms Produce (Ground provisions)	Private Sector	Michael	Donegan	Owner	8763981104 OR 8768599751	mike.37@live.com charmstar01.sd@gmail.com	Lot 149 Las Brown Drive, Colbeck Old Harbour, St. Catherine
38	Thomas Farms	Private Sector	Gregory	Thomas	Farm Owner	8768696297	megregorythomas@yahoo.com	Pancho Lane, Heartease District, Yallahs, St. Thomas
39								
40	CSG		dale	rankin				
41	National Irrigation Commission	Public Sector	Glenmore	Young	Regional Operations System Manager	8769842334	glenmorey@nicjamaica.com	
42	National Irrigation Commission	Public Sector	Rohan	Stewart	Director of Engineering and Technology Services	8769840625	rohans@nicjamaica.com	
43	National Irrigation Commission	Public Sector	Emile	Myers	Manger Energy Department	8766818145		
44	Jamaica Dairy Development Board		Everton	Parkes		876-276-9314/876-618-7107		

Coastal Resources

	Company/Organization	Stakeholder Groupings	Contact Person/Member First Name	Surname	Position	Phone Contact	E-mail	Address
1	Ministry of Economic Growth and Job Creation	Public Sector				(876) 926 1590 OR (876) 926-1690-3	info@megjc.gov.jm	25 Dominica Drive, Kingston 5
2	Jamaica Environment Trust	Public Sector	Suzanne	Stanley	CEO	(876) 960-3693 (876) 906-9385	sstanley.jet@cwjamaica.com	123 Constant Spring Road, Unit 5, Kingston 8, Jamaica W.I.
3	UWI Department of Enginnering	Academia	Nicolas	McMorris	Head of Civil Engineer	(876) 927-1640 (ext 2405)	nicolas.mcmorris@uwimona.edu.jm	4 St. John's Close, The University of the West Indies, Mona Rd, Kingston
4	UWI Department of Geology and Geography	Academia	Simon	Mitchell	Scientific Officer	(876) 927-2129	simon.mitchell@uwimona.edu.jm	UWI, Mona
5	Port Royal Marine Lab	Academia	Hugh	Small		(876) 967-8344	hugh.small@uwimona.edu.jm	Port Royal, Kingston
6	Discovery Bay Marine Lab	Academia	Camillo	Trench	Chief Scientific Officer	8768692953	camillo.trench@uwimona.edu.jm	Discovery Bay, St. Ann Jamaica
7	Centre for Marine Sciences	Academia	Mona	Webber	Director	8769358835-6	mona.webber@uwimona.edu.jm	1 Anguilla Close, UWI, Mona. Kingston 7
8	Planning Institute of Jamaica	Public Sector	Roxine Lehome	Valentine Johnson	Climate Change Division	(876) 960-9339	info@pioj.gov.jm	16 Oxford Road, Kingston 5
10	Smith Warner International	Private Sector	Lia Elizabeth	Nicholson Mondon	Climate Change Adaptation and Mitigation Specialist Coastal Engineer	(876)978-8950 or (876)978-7415		Unit 13 Seymour Park, 2 Seymour Ave Kingston 10
11	CEAC Solutions	Private Sector	Kristopher	Freeman	Enginner	876-946-2210 / 876-946-9263	kfreeman@ceacsolutions.com	20 Windsor Avenue, Kingston 5
12	Port Authority Jamaica	Private Sector	Mervis	Edgill	Supervisor of Engineering and Port Development	876-922-0290		15 -17 Duke Street, Kingston

Water Resources

	Company/Organization	Stakeholder Groupings	Contact Person/Member First Name	Surname	Position	Phone Contact	E-mail	Address
	Ministry of Economic Growth and Job Creation	Public Sector						
1	National Water Commission	Public Sector	Naveed	Samuda	Hydrologist	876-929-3540-5	naveed.samuda@nwc.com.jm	4 Marescaux Road, Kgn 5
3	National Irrigation Commission	Public Sector	Mark	Richards	CEO	8769774022/8769776727		191 Old Hope Road, Kingston 6
4	Office of Utilities Regulation	Public Sector	Winston	Robotham	Deputy Director General	(876) 968-6053	consumer@our.org.jm	3rd Floor PCJ Resource Centre, 36 Trafalgar Road, Kingston 10
5	Rural Water Supply	Public Sector	Douglas	Wilson		908-2955	info@rwslja.com	25 Dominica Dr, Kingston
6	UWI Department of Physics	Academia	Tannecia	Stephenson	Climate Change Specialist		tannecia.stephenson02@uwimona.edu.jm	Dept Physics, UWI Mona
7	UWI Department of Geology and Geography	Academia	Arpita	Mandal	Hydrogeologist		arpita.mandal@uwimona.edu.jm	Dept of Geology, UWI, Mona
8	UWI Department of Chemistry	Academia						
9	Water Resources Authority	Private Sector	Geffery	Marshall	Chief Hydrologist	(876) 927 – 0077	gmarshall@wra.gov.jm	Hope Gardens, P.O. Box 91, Kingston 7
10	Jamaica Wells and Services Limited	Private Sector	Richard	Simpson		(876) 929-8544-5	info@jamaicawells.com	3 & 5 Ballater Avenue, Kingston 10
11	Premier Land and Water Development	Private Sector	Demali	Cohen		need new number	premierlwdevelopment@gmail.com	Unit 5, 13 West Kings House Road, Kingston 10. St. Andrew
12	Instant Save Conservation Solutions	Private Sector	Leanne	Spence	Owner	8764243855/(876) 630-3360/(876) 754-9030	contact@instantsaveja.com	26 Haining Road, Kingston 6
13	Chem-Quip Water Treatment Limited	Private Sector	Leon	Sutherland	Services Manager	8763475244		2A Ashenheim Rd, Kingston 11, Jamaica, W.I.
14	Jamaica Water Treatment Co Ltd	Private Sector	AJ	Brown		876-754-8298	ajbrown@cwjamaica.com	Suite 7, 33 Lyndhurst Road, Kingston 5
15	Yallahs Irrigation Specially Authorized Society	NIC				8764898912		
16	Colbeck Water Users Irrigation Specially Authorized Society	Public Sector (NIC)	Glenmore	Young	Regional Operations System Manager	8764898912	glenmorey@nicjamaica.com	

Energy Sector

	Company/Organization	Stakeholder Grouping	Contact Person/Member First Name	Surname	Position	Phone Contact	E-mail	Address
1	Ministry of Science, Energy and Technology	Public Sector	Horace	Buckley	Manager Special Projects	876 908 3622 876 567-9097/876 551 4569	hbuckley@mset.gov.jm	
2	Jamaica Public Service Company Ltd	Public Sector	Dionne	Nuent	Head – Generation Special Projects	(876)878-3934		
3	Office of Utility Regulations	Public Sector	Cedric	Wilson	Deputy Director General	(876) 968-6053	consumer@our.org.jm	3rd Floor PCJ Resource Centre, 36 Trafalgar Road, Kingston 10
4	UWI Department of Physics	Academia						
5	UTECH College of Science and Sports	Academia						
6	National Commission on Science and Technology	Public Sector	Patricia	Lewin	Senior Technology Officer	8769068433	plewin_ncst@mstem.gov.jm	36 Trafalgar Road, Kingston 10
7	Scientific Research Council	Public Sector	Cliff	Riley	Caribbean Climate Innovation Centre	876-389-9774	cliff2@src-jamaica.org	P.O. Box 350, Hope Gardens, Kingston 6
8	JPS Energy Store	Private Sector	Emanuel	DaRosa	CEO		calljps@jpsco.com	6 Knutsford Boulevard, Kgn. 5
9	Power Tech Jamaica	Private Sector				876-908-0196-9, 876-381-6100	info@powertechjamaica.com	17 Carvalho Drive, Kingston 10
10	BoilerCo	Private Sector				(876) 924-2803, (876) 925-4418, (876) 969-7929	boilerco@cwjamaica.com	14 Dunrobin Avenue, P.O. Box 340, Kingston 10
11	Doctorbird Power Facility (Jamaica Energy Partners)	Private Sector						
12	Jamaica Private Power Company	Private Sector				(876) 938-3983		
13	Conserve IT	Private Sector						
14	SolarBuzz Jamaica	Private Sector	Jason	Robinson	Managing Director	8769064693	jason@solarbuzzjamaica.com	6 Haining Rd, Kingston
15	Isratech Jamaica	Private Sector						17 Carvalho Drive, Kingston 10
16	Alternative Power Service	Private Sector	Damian	Lyn	CEO	876 960-4886/876 527-8130	damian.lyn@apsja.com	4 Strathairn Avenue, Kingston 10
17	West Kingston Power Partners	Private Sector						
18	GetSol Warehouse	Private Sector						
19	Alternative Energy Plus	Private Sector						

	Company/Organization	Stakeholder Grouping	Contact Person/Member First Name	Contact Person/Member Surname	Position	Phone Contact	E-mail	Address
20	Atlantic Industrial Electric Supply Company Limited	Private Sector						
21	CARISOL	Private Sector						
22	Anthing Solar	Private Sector						
23	RTA BIZ Energy Solutions	Private Sector						
24	Green Energy Savings Solutions	Private Sector						
25	Alternex Energy	Private Sector						
26	Electro-Energy Design and Construction Services Limited	Private Sector						
27	Enersave Solutions	Private Sector						
28	Modern Power and Cooling Technology	Private Sector						
29	Solar King	Private Sector						
30	Sun Source Technology	Private Sector						
31	Iree Solar	Private Sector	Alex	Hill	Vice-President/Managing Director	876 564 9900/(876) 371-4733	alex@ireesolar.com	
32	Solar and More	Private Sector						
33	Solar Direk	Private Sector						
34	Nac Energy Solutions	Private Sector						
35	Estech Energy	Private Sector						
36	Burton Steer Energy Solutions	Private Sector						
37	Automatic Control Engineering (ACE) Solar	Private Sector						
38	Petroleum Corporation of Jamaica	Private Sector	Brian	Richardson	Acting Managing Director/Manager, Oil and Gas	876 929 5380-9 ext-288		36 Trafalgar Road, Kingston 10, Jamaica
39	Jamaica Solar Energy Association	Private Sector	Alex	Hill	Vice-President/Managing Director	876 564 9900/(876) 371-4733	alex@ireesolar.com	29 Burlington Avenue, Kingston 10

Appendix II: Working Groups

Agriculture Sector

	Name/Position	Company	Organization Type	Contact	Response	Gender
1	Gary Watson	Jamaica Agricultural Commodity Regulatory Authority	Government	876 376-9259 gwatson@jacra.org	Accepted	M
2	Marina Young Principal Director Technical Services	Rural Agricultural Developmen t Authority	Government	876 818 6019 876-977-1158/62	Accepted	M
3	Howard Hill	H & H Aquaculture Farms Jamaica Ltd	Private	hill2farms@hotmail.c om 876-990-1412		M
4	Everton Parkes Farming Systems Specialist	Jamaica Dairy Developmen t Board 4 St. Lucia Avenue Kingston 5	Government	birdp22@yahoo.com 876-276-9314/876-618-7107	Accepted	M
5	Dr. Jane Cohen Lecturer	Department of Life Sciences University of the West Indies	Academic	jane.cohen@uwimona. edu.jm ntp_reid@yahoo.com		F
6	Fazel Huie Lecturer Faculty of education	College of Agriculture, Science and Education Passley Gardens Port Antonio	Academic	education@case.edu.j m		M
7	Annabel Williams Farm Owner	Kew Park Estate	Private	annabel@kewpark.co m 876-383-5474		F
8	Elisabeth Levy Farm Owner	Crop Farm	Private	Lizlevy15@gmail.com 876-880-8679		F

WG Composition – Male (62%) Female (38%)

Coastal Resources

	Name/Position	Company	Organization Type	Contact	Response	Gender
1	Dr. Theresa Moodie Manager Environmental Management Services	Environmental Solutions Limited 7 Hillview Avenue Kingston 10	Private		Accepted	F
2	Dr. Shakira Khan Instructor Broward College	Consultant Instructor	Private and Academic	shakira_k@yahoo.com	Accepted	F
3	Ms Delahaye	Port Authority of Jamaica 15 – 17 Duke Street Kingston	Public/Government	medghill@portjam.com 876-922-0290		F
4	Prof. Mona Webber	Centre for Marine Sciences University of the West Indies Mona Campus Kingston	Academic	mona.webber@uwimona.edu.jm 876-935-8835	Accepted	F
5	Dr. David Smith	Smith Warner International Limited Unit 13 Seymore Avenue Kingston 10	Private	david@smithwarner.com 876-978-8950	Accepted	M
6	Mr Francis	B & D Trawling 1 Port Royal Street Kingston	Private	rickgfrancis@bdtrawling.com 876-922-4150		M
7	Dr Carey Wallace Executive Director	Tourism Enhancement Fund 60 Knutsford Boulevard Kingston	Public/Government	876-926-8684	Accepted	M

WG Composition – Male (43%) Female (57%)

Water Resources

	Name/Position	Company	Organization Type	Contact	Response	Gender
1	Glenmore Young	National Irrigation Commission 191 Old Hope Road	Public/Government	glenmorey@nicjamaica.com 876 984 2334 876-965-0714 876-489-8801	Accepted	M
2	Geoffery Marshall Chef Hydrologist	Water Resources Authority Old Hope Road	Public/Government	gmarshall@wra.gov.jm 876-927-0077	Accepted	M
3	Leanne Spence Director	Instant Save Conservation Solutions 26 Haining Road Kingston 5	Private	876-424-3855 876-630-3360 876-754-9030	Accepted	F
4	Douglas Wilson General Manager Engineering	Rural Water Supply 25 Dominica Drive Kingston	Public/Government	876-908-2955	Accepted	M
5	Claire Bernard	Planning Institute of Jamaica 16 Oxford Road	Public/Government	cbernard@pioj.gov.jm 876-935-5054 876-832-1293		F
6	Mark Barnett President	National Water Commission 28 Barbados Avenue	Public/Government	mark.barnett@nwc.com.jm	Accepted	M
7	Ian Gage Engineer and Director	Water and Sanitation Engineer Environmental Solutions Limited	Private		Accepted	M
8	Christopher Madden HSE Manager	Wisynco Lakes Pen St Catherine	Private	christopherm@wisynco.com	Accepted	M
9	Ms. Caveen Murray Director	Isratech Jamaica Limited Unit 17 The Trade Center Red Hills Road, Kingston	Private	caveen@isratech.com 876-754-5443		F
10	Dr. Arpita Mandal Lecturer	Hydrologist Department of Geography and Geology University of the West Indies	Academic	mandalarpitaster@gmail.com 1-876-297-7380	Accepted	F

WG Composition – Male (60%) Female (40%)

Energy Sector

	Name/Position	Company		Contact	Response	Gender
1	Damian Lyn CEO	Alternative Power Sources	Private	damian.lyn@apsja.com 876 960-4886 876 527-8130	Accepted	M
2	Edson Galbraith General Manager Loan Origination & Portfolio Management	Development Bank of Jamaica	Financial	egalbraith@dbankjm.com 876 929-400 876 619-400	Accepted	M
3	Alex Hill Vice-President Managing Director	Jamaica Solar Energy Association 29 Burlington Avenue, Kingston 10 Kingston, Jamaica	Private	alex@ireesolar.com 876 564 9900 876 371-4733		M
4	Dionne Nugent Head Generation Special Projects	Jamaica Public Service Company Ltd	Private	876 878-3934 dnugent@jpsco.com	Accepted	F
5	Brian Richardson Acting Managing Director Manager, Oil and Gas	Petroleum Corporation of Jamaica 36 Trafalgar Road Kingston 10, Jamaica	Government	876 929 5380-9 ext-288 Brian.richardson001@gmail.com	Interested	M
6	Horace Buckley Manager Special Projects	Ministry Science Energy and Technology	Government	hbuckley@mset.gov.jm 876 908 3622 876 567-9097 876 551 4569		M
7	Jason Robinson Managing Director	Solar Buzz	Private	jason@solarbuzzjamaica.com 876 875 9542	Accepted	M

	Name/Position	Company		Contact	Response	Gender
	Cheyenne McClarthy Environmental Manager	Airports Authority of Jamaica		cmcclarthy@gmail.com 876-352-1757 876-924-8452-6		F
	Ava Tomlin Regional Director	BMR Energy		atomlin@bmrenergy.com 876-469-4609 876-656-8445		F

WG Composition – Male (67%) Female (33%)

Appendix III: Technology Fact Sheets

Adaptation

Agriculture Sector

Technology: Sprinkler and Drip Irrigation for small and medium sized farmers	
Sector: Agriculture Sector	
Subsector: Irrigation	
Technology Characteristics	
Introduction	Sprinkler and drip irrigation technologies can improve water efficiency and contribute substantially to improved food production. *Sprinkler Irrigation* involves a type of pressurized irrigation that consist of applying water to the soil surface using mechanical and hydraulic devices that simulate natural rainfall. *Drip irrigation* involves the constant application of a specific and calculated quantity of water to soil crops (localized area). This significantly reduces water runoff through deep percolation or evaporation.
Technology Characteristics/Highlights	• Sprinkler and drip irrigation technology is a more efficient use of water for irrigation in agriculture. • Eliminates use of water conveyance channels therefore reducing water loss. • Distributes water more evenly across crops, thus helping to avoid wastage and increases crop yields • Most suitable for rows, field and tree crops that are grown closely together. These include sugarcane, groundnut, cotton, vegetables, fruits, flowers, spices and condiments.
Institutional and Organizational Requirements	Capacity building is required for farmers and at the institutional levels. Farmers need to understand how these systems work the benefits of these systems. Institutional capacity building will be required for research, financing and development for the technology.
Operation and Maintenance	Day-to-day operations can be carried out by farmers and do not require skilled labour. Basic maintenance can be done by farmers and owners of the systems, Pressured systems may require some skilled labour for maintenance.
Endorsement by Experts	
Adequacy for Current Climate	Under the conditions of increased water stress resulting from climate change the benefits of the technology is significant.
Scale/Size of Beneficiaries Group	The scale of the drip irrigation technology is highly flexible making it appropriate for use by all crop farmers.
Disadvantages	Barriers to implement both systems include lack of access to finance for the purchase of equipment, lack of local skills for design, installation and maintenance of the system and lack of

	nationally/locally available component parts. May be solar- powered for efficiency.
Capital Cost	
Cost to Implement Adaptation Technology	Medium to high cost.
Development Impacts, Direct and Indirect Benefits	
Reduction of Vulnerability to Climate Change (Indirect)	
Environmental Benefits (Indirect)	• Lowered water withdrawal from ground water resources, particularly during more sensitive dry months, drip technology prevents depletion of ground water table and pollution from infusion of saline and other contaminants. • Increased use efficiency of chemical fertilizer through fertigation prevents resource waste and development of water pollution problems. • Reduce use of agricultural chemicals such as weedicides and pesticides minimizes adverse environmental impacts such as pollution of water bodies and biodiversity loss. • Reduces soil degradation and erosion associated with flood irrigation. Therefore reducing water sources degradation and siltation of runoff.
Local Context	
Opportunities and Barriers	To be effective drop and sprinkler irrigation systems require periodic maintenance. This includes water quality analysis to determine if precipitate or other contaminants are present hat could affect the operation of the irrigation system.
Market Potential	Large market across Jamaica.
Status	The technology is currently used in the country by some farmers; however, it is not widely used due to the high capital cost.
Timeframe	
Acceptability to Local Stakeholders	Yes, this technology is widely accepted by local stakeholders.

Technology: Rainwater Harvesting for irrigation	
Sector: Agriculture Sector	
Subsector: Irrigation	
Technology Characteristics	
Introduction	For adaptation to restricted water supply in areas where there is no surface water, or where groundwater is deep or inaccessible due to hard ground conditions, or where it is too salty or acidic. Rainwater harvesters induce, collect, store and conserve water from rainfall or runoff from rainfall for irrigation uses. Therefore, systems requires little to no water treatment.
Technology Characteristics/Highlights	The technology can help to collect and store water for use during low water periods.
Institutional and Organizational Requirements	Initial cost for these systems can be high and these costs are generally for infrastructure and installation. Requires rooftop or clear area to collect rainwater. The size of the collection area plays an important role in the amount of water that can be collected. Requires land area for water storage in tanks or micro dams. The amount of area and size of storage tanks required to ensure water is available for times of water shortages or droughts is usually significant.
Operation and Maintenance	The size of the system will determine the level of skills required. Simple collection systems using roof top collection and regular storage tanks are easy to operate and maintain. Large systems which may use dams or cisterns for water storage may require more skilled labour for operation and maintenance.
Endorsement by Experts	The technology is approved by experts across Jamaica and has been promoted as an alternative water source.
Adequacy for Current Climate	Collection and storage of rainwater can provide a convenient and alternate source of water for irrigation during seasonal dry periods and droughts.
Scale/Size of Beneficiaries Group	Rainwater harvesting and storage systems can be easily scaled. Additions to the system can be made relatively easy and do not require significant modification from the original system. Since the system is scalable at all levels it can be used by farmers of all size and types.
Disadvantages	Requires rainfall which is not available during long periods of droughts. Requires large areas of land for storage of water.
Capital Cost	

Cost to Implement Adaptation Technology	Constriction and material cost varies widely for the technology. Smaller systems can cost several thousand Jamaican dollars while larger systems can be in excess of a several million Jamaican dollars.
Development Impacts, Direct and Indirect Benefits	
Reduction of Vulnerability to Climate Change (Indirect)	Contributes to water security by increasing water sources and availability.
Environmental Benefits (Indirect)	Reduces stormwater runoff from property and therefore reduces contamination of surface water with pesticides, sediments, metals and fertilizers. Excellent source of water for plans and landscape irrigation since it has no chemicals such as fluoride and chlorine. Reduces over exploitation of other sources of water.
Local Context	
Opportunities and Barriers	Initial cost is expensive Opportunity to provide financing mechanisms for farmers for the implementation of rainwater harvesting and storage systems.
Market Potential	Has market potential nationwide.
Status	Already used in some areas across Jamaica, however, the adoption rate has been generally low.
Timeframe	
Acceptability to Local Stakeholders	Rainwater harvesting has been promoted across Jamaica by main stakeholders. RADA and Rural Water Development has been implementing rainwater harvesting systems in Jamaica.

Technology: Livestock Disease Management for small ruminants	
Sector: Agriculture Sector	
Subsector: Livestock	
Technology Characteristics	
Introduction	Livestock diseases contribute to problems associated with livestock production and can have great effects on animal welfare, productivity, food security and uncertainty, loss of income and negative impacts on human health. The effects of climate change can exacerbate these problems along with introducing new diseases and hot temperatures will also cause additional stresses on livestock. Livestock disease management is made up of two key components • Prevention measures in susceptible herds • Control measures taken once infection occurs Preventing disease from entering and spreading in livestock populations by putting in strict regulations regarding the movement and housing of livestock under a disease prevention/animal health programme. Controlling the spread of infection to reduce loss of herds by identifying new infections and changes in the ones which already exist.
Technology Characteristics/Highlights	Benefits of livestock disease prevention and control include: - • Higher production (as morbidity is lowered and mortality or early culling is reduced) • Avoiding future cost of treatment and control • Prevents spread of diseases to other animals and herds
Institutional and Organizational Requirements	Livestock and animal health policy would have to be developed for both commercial and pastoral sectors and include interventions to support the most vulnerable farmers. May require government support/investment in infrastructure (including early warning systems, roads, abattoirs, holding pens, processing plants etc), vaccination programmes and research and development. Will require education and sensitization programmes for farmers of small ruminants.
Operation and Maintenance	n/a
Endorsement by Experts	Stakeholders within the agriculture sector support the idea of livestock disease management programmes particularly for ruminants
Adequacy for Current Climate	The impacts of climate change on livestock diseases have been largely vector-borne diseases. Increasing temperatures have supported the expansion of vector populations and increase in vector populations during wet periods. Climate change could also influence disease distribution indirectly through changes in the distribution and treatment of livestock. Therefore, improving livestock disease control and management is an effective technology for climate change adaptation.

Scale/Size of Beneficiaries Group	Can be effective for very small ruminant farmers or large-scale farmers.
Disadvantages	May require large capital investments and this will not be suitable for small farmers.
Capital Cost	
Cost to Implement Adaptation Technology	Cost varies and may include: • Cost for construction of facilities • Cost associated with testing and screening • Veterinary services and vaccinations • Training for farmers and livestock keepers • Cost associated with cultural changes in farming practices
Development Impacts, Direct and Indirect Benefits	
Reduction of Vulnerability to Climate Change (Indirect)	Allows farmers additional knowledge on controlling the spread of animal diseases which may be exacerbate by climate change
Environmental Benefits (Indirect)	
Local Context	
Opportunities and Barriers	A lack of strong institutions and political will to monitor diseases effectively. Small-scale backyard producers are difficult to monitor, control and eradicate diseases. Infected wildlife can pose a challenge to controlling and monitoring diseases Insufficient support or compensation for farmers who may be required to cull or slaughter livestock, particularly for small-scale produce.
Market Potential	Small, medium and large ruminants’ farmers across the island
Status	
Timeframe	
Acceptability to Local Stakeholders	

Technology: Agro-Economic Zones (AEZ)	
Sector: Agriculture Sector	
Subsector:	
Technology Characteristics	
Introduction	A self-sustaining economic zone which helps in the development of the area where it is set up and creates employment opportunities locally, there by contributing to the overall GDP of the national economy (Chinmaya, 2011)
Technology Characteristics/Highlights	Key elements on an AEZ include: - • Water management and irrigation facilities • Procurement of modern farm equipment • Allows for closer research in agriculture • Capacity building for farmers • Allows for storage infrastructure • Allows for branding and marketing
Institutional and Organizational Requirements	Stakeholders within the economic zone will be the local farmers, or business owners, consumers of goods and the government.
Operation and Maintenance	
Endorsement by Experts	Stakeholders within the Agriculture industry in Jamaica believe that AEZ should be expanded. AEZs have proven successful in Jamaica to date and other parts of the world, including India.
Adequacy for Current Climate	Allows farmers more variety for use and sale of their produce. That is, in an AEZ, different crops or grades can be used in the production of processed goods/foods.
Scale/Size of Beneficiaries Group	AEZ can benefit small and medium sized farmers within a region or zone.
Disadvantages	Large capital investment required, and this usually must be provided by Government Requires organization and corporation by many stakeholders
Capital Cost	
Cost to Implement Adaptation Technology	High capital cost for the setup of the AEZ. These costs are usually associated with: - • Construction and installation of improved irrigation systems • Construction and installation of agro-processing and storage facilities which may sometimes include cold storage units.
Development Impacts, Direct and Indirect Benefits	
Reduction of Vulnerability to Climate Change (Indirect)	
Environmental Benefits (Indirect)	Promotes the efficient use of the resources. Can allow for use of all grades and products, therefore reducing wastage in farms.
Local Context	
Opportunities and Barriers	Benefits of an AEZ include: • Creating employment opportunities • Improving the necessary amenities in the area

	• Contributes to economic growth and development
Market Potential	
Status	AEZ has been implemented in several areas across Jamaica largely supported by the Government.
Timeframe	
Acceptability to Local Stakeholders	

Technology: Reforestation/Afforestation	
Sector: Agriculture Sector	
Subsector:	
Technology Characteristics	
Introduction	Reforestation and afforestation is the direct human induced conversion of non-forest areas to forest areas through planting and seeding. Planting, seeding or the promotion of natural seed sources leads to increase in biomass, dead organic matter which acts as carbon pools. This also creates soil carbon pools. Afforestation can also create substantial soil stocks and carbon pools over time in areas which have low soils initially.
Technology Characteristics/Highlights	Not only does reforestation/afforestation provide options for adapting to climate change. It also have benefits for mitigating against climate change. Afforestation/Reforestation result in reduced greenhouse gas emissions, it also results in a variety of socio-economic development and environmental protection benefits to include enhanced biodiversity conservation; increase in the connectivity of forests and increase mobility options of species and habitats. It also promotes water and soil conservation, provides income through the provision of forest products (fuelwood, fibre, lumber) and can create employment.
Institutional and Organizational Requirements	Will require support from the government, and the Forestry Department, In Jamaica a lot of the land is privately owned, and incentives are given for persons who keep private lands under forest conditions. However, this scheme is not widely adopted.
Operation and Maintenance	Require little maintenance and operation over the long term.
Endorsement by Experts	This technology has been endorsed and promoted by experts and expert ecologist
Adequacy for Current Climate	The technology is appropriate given the effects climate change will have on Jamaica.
Scale/Size of Beneficiaries Group	Scalability is limited to the amount of available land area that can be reforested/afforested.
Disadvantages	Can also promote a decline in carbon stock and biomass if areas are not managed properly.
Capital Cost	
Cost to Implement Adaptation Technology	Initially cost implications include: - • Purchase of seeds or seedlings • Cost associated with planting and caring for plants in the early growth stages.

Development Impacts, Direct and Indirect Benefits	
Reduction of Vulnerability to Climate Change (Indirect)	Allows for the creation of habitats to help ecosystems and species expand habitats that might be threated due to the effects of climate change.
Environmental Benefits (Indirect)	Will promote covering of barren and degraded land, increases vegetation cover and promotes the protection and expansion of local ecology and ecosystems.
Local Context	
Opportunities and Barriers	Barriers Include: - • Start up capital for seeds, seedlings and plant nursery • Requires land to be converted to forestry, therefore limiting lands used for development
Market Potential	Large market potential across Jamaica
Status	Widely used across the world and in many areas across Jamaica. Forestry Department in Jamaica has promoted afforestation and reforestation and regularly give free seedlings/plants to the public.
Timeframe	Lifetime
Acceptability to Local Stakeholders	Technology is accepted by most stakeholders

Technology: Ecological Pest Management	
Sector: Agriculture Sector	
Subsector:	
Technology Characteristics	
Introduction	Actively maintaining pest populations at levels below those causing economic injury while providing protection against hazards to humans, animals, plants and the environment via natural and cultural processes and methods, including host resistance and biological control. Particularly, by using beneficial organisms that behave as parasitoids and predators through processes which include releasing beneficial insects and providing them with a suitable habitat, managing plant density and structure to deter diseases, cultivating for weed control based on knowledge of the critical competition period, managing field boundaries and in-field habitats to attract beneficial insects, and trap or confuse insect pests.
Technology Characteristics/Highlights	
Institutional and Organizational Requirements	
Operation and Maintenance	
Endorsement by Experts	
Adequacy for Current Climate	Coastal erosion is being exacerbated by climate change and areas with existing coral reefs are seeing coral reef degradation due to high sea temperatures. Therefore, creating and restoring coral reefs with different varieties of corals which can withstand higher temperatures can help to decrease coastal erosion and create marine coral reef environments.
Scale/Size of Beneficiaries Group	Coastal communities where there is large depends on coastal landscape. This may include fishermen, coastal infrastructure, hotels and the tourism industry.
Disadvantages	High capital cost to implement and high maintenance cost Requires great deal of technical studies to determine best location, type of material to be used and details of the reef to be built. Will require regulatory approvals.
Capital Cost	
Cost to Implement Adaptation Technology	
Development Impacts, Direct and Indirect Benefits	
Reduction of Vulnerability to Climate Change (Indirect)	
Environmental Benefits (Indirect)	Artificial reefs and restores reefs will form a more effective barrier with respect to wave action and erosion along the coastline. Will provide shelter for other marine organisms and therefore improve the overall stability of the reef and ecosystems, therefore preserving biodiversity.
Local Context	
Opportunities and Barriers	Opportunities: • Project could provide employment opportunities to persons involved in coastal construction sector, coastal zone management and the tourism industry. • Can create fishing habitats which can also benefit fishermen. • Creates an environment for academics and researchers. Barriers: • High cost for implementation, monitoring and maintenance. This is because this will require technical research and

	modelling to determine best characteristics for reef and coral reef restoration. May include high cost for growing and transplanting suitable corals, monitoring of coral reef and cleaning and maintenance of the reef system. • Insufficient or lack of motivation and knowledge of the coastal and marine resource utilisers on the importance of sensitive coastal marine ecosystems and their sustainable utilization. • Reluctance of coastal communities to acquire new knowledge and to accept changes in practices.
Market Potential	
Status	Coral transplanting and restoration has been successful in other countries. It has also been done on smaller scales in the Caribbean and Jamaica. Therefore, this can be adopted on a larger scale at other sites across Jamaica.
Timeframe	Project can take up to 3 years Year 1 – Research, training, site survey and selection. Planting of corals in coral nursery. Year 2 – Development of hard structures for artificial reef and transplanting of corals. Year 3 to 4 – Monitoring and evaluation of success of coral reefs and changes in coastal erosion.
Acceptability to Local Stakeholders	Research, academics, hotels and tourism industry personnel will accept this technology. Some coastal communities may oppose the technology. Fishermen may or may not be opposed the introduction to the technology.

Technology: Early Warning Systems	
Sector: Agriculture Sector	
Subsector:	
Technology Characteristics	
Introduction	Putting in place 3, 6 and 12 month forecast systems to aid farmers in preparing for extreme weather conditions or changes in weather. The data will be presented in a less detailed format which can be easily understood by farmers. Farmers should be able to access this information through various sources. These should include: - • The use of mobile application • Text messaging • Toll-free hotline • Community bulletin boards
Technology Characteristics/Highlights	Data and forecast are already done by many local and international agencies. The Meteorological Office of Jamaica also provides this information; however, it rarely reaches the farmers in time for them to make decisions. The technology will allow farmers to have this data in advance of planting seasons, therefore they can make informed decisions and therefore minimize loss to flooding or drought.
Institutional and Organizational Requirements	Requires corporation and data from the Meteorological Services of Jamaica. Will require additional interpretation and forecasting of data and presentation of data for farmer needs. Require farmers to have access to information possible through one or more means. That is, they will have to travel to community centre or nearby offices to access information or have access to mobile or data services.
Operation and Maintenance	System will require skilled labour for the operation and maintenance.
Endorsement by Experts	
Adequacy for Current Climate	Many farms are vulnerable due to the changing weather patterns caused by climate change, longer and hotter drought periods and more intense rainfall events of short duration. Therefore, farmers require advance reliable information for planning and decision making.
Scale/Size of Beneficiaries Group	Can be used by all size farms and farmers across Jamaica. This include small back-yard farms to large commercial farms.
Disadvantages	Requires significant capital for the operation and maintenance of the system. It is usually costly to operate and maintenance applications and send text messages to everyone.
Capital Cost	

Cost to Implement Adaptation Technology	Capital and operationally cost intensive
Development Impacts, Direct and Indirect Benefits	
Reduction of Vulnerability to Climate Change (Indirect)	Allows farmers to access information critical for crops and livestock farming. Therefore, improving their decision-making ability and promotes an overall decrease in vulnerability to climate change.
Environmental Benefits (Indirect)	Will promote the efficient use of resources and decrease wastage.
Local Context	
Opportunities and Barriers	Capital and operational cost intensive
Market Potential	
Status	RADA currently has a system in place for notification to farmers by text messages about severe weather events, however, due to budget constraints, they are unable to continuously provide updates and, they do not reach all or the majority of farmers.
Timeframe	
Acceptability to Local Stakeholders	Access to reliable information at the right time is critical for the farming industry and therefore stakeholders endorse this technology.

Technology: Mulching	
Sector: Agriculture Sector	
Subsector: Crops	
Technology Characteristics	
Introduction	This technology is popular in areas that are water-intensive, arid or have heavy evaporation or soils. Inputs from this technology include the use of foliage and post-harvest by products.
Technology Characteristics/Highlights	• Promotes the reuse and recycling of agriculture waste material • Protects and promotes soil quality • Efficient use of limited water resources Overall provides an increase in crop yields
Institutional and Organizational Requirements	Capacity building required for farmers
Operation and Maintenance	
Endorsement by Experts	Endorsed by experts
Adequacy for Current Climate	
Scale/Size of Beneficiaries Group	Can be use on all size farms
Disadvantages	• Decaying material may cause odours which are unpleasant • May promote pest and insects
Capital Cost	
Cost to Implement Adaptation Technology	Cost can vary depending on the farm and type of inputs. However, the incremental cost is low when changing from other farming practices
Development Impacts, Direct and Indirect Benefits	
Reduction of Vulnerability to Climate Change (Indirect)	
Environmental Benefits (Indirect)	• Increase fertilizer efficiency • Reduced nitrogen volatilization and nitrous oxide emissions • Controls weeds • Protects farm environment
Local Context	
Opportunities and Barriers	Difficult to change traditional practices Time and resource intensive
Market Potential	Potential for large-scale application in coastal sandy lands, which have low levels of organic content and nutrients, or in drought prone areas at the beginning of dry periods. Can also be applied to step arable lands.
Status	Not widely used across Jamaica
Timeframe	
Acceptability to Local Stakeholders	Some farmers may be opposed to the idea as it time and resource intensive and also had negative impacts such as harbouring pest and decaying material.

Coastal Resources

Technology: Wetland (Mangrove) Restoration	
Sector: Coastal Resources	
Subsector: Coastal Protection	
Technology Characteristics	
Introduction	Wetland habitats are important because they perform essential functions in terms of coastal flood and erosion management. They induce wave and tidal energy dissipation (Brampton, 1992) and act as a sediment trap for materials, thus helping to build land seawards. The dense root mats of wetland plants also help to stabilise shore sediments, thus reducing erosion (USACE, 1989). Wetland restoration re-establishes these advantageous functions for the benefits of coastal flood and erosion protection. Techniques have been developed to reintroduce coastal wetlands to areas where they previously existed and to areas where they did not, if conditions will allow. The diversity of wetland types means there are numerous methods for restoring wetlands. The method adopted will depend on the habitat which is being restored. In Jamaica, one of the primary wetland restoration objectives should be to achieve natural recruitment of the four species of mangrove trees: Red Mangrove (*Rhizophora mangle*), Black Mangrove (*Avicennia germinans*), White Mangrove (*Laguncularia racemose)* and Button Mangrove (*Conocarpus erectus*). The depth and salinity of water are two critical components of restoration success. Restoration sites should preferably undergo site preparation that allows for 0.5 to 2.5m of inundation, unobstructed tidal flows, calm water to allow seeds to establish roots and mixing of fresh and saline waters to achieve a salinity between 5 and 35ppt.
Technology Characteristics/Highlights	The most restored wetland ecosystems for coastal protection are salt marshes and mangroves. Sea grass may also be employed as a coastal defence, to dampen waves but on their own seldom considered an adequate shore protection alternative. Salt marshes are widely re-established: • through managed realignment schemes. • whilst maintaining the present coastline position through vegetative transplants from healthy marshes, and • may require the site’s elevation to be raised using appropriate fill material. Mangrove restoration includes: • collecting plant propagules from a sustainable source, • preparation of the restoration site for planting at regular intervals at an appropriate time of year • Establishment of nurseries to stockpile seedlings for future planting • Planting dune grasses. These grasses provide a stable, protective substrate for mangroves to establish their root systems in.
Institutional and Organizational Requirements	At a local level, proactive measures can be implemented to ensure wetland habitats are maintained and used in a sustainable

	manner. This will preserve habitats into the future, reduce or even avoid the cost of restoration and planting schemes and avoid the many potential problems encountered in the course of wetland restoration efforts. It is important that the multiple agencies involved in shoreline management avoid providing conflicting guidance. At a larger scale, it is useful for governments to adopt proactive coastal management plans to protect, enhance, restore and create marine habitats. Without such a framework, action to restore wetlands is likely to be fragmented and uncoordinated.
Operation and Maintenance	In contrast to hard defences, wetlands are capable of undergoing 'autonomous' adaptation to SLR, through increased accumulation of sediments to allow the elevation of the wetland to keep pace with changes in sea level. Provided wetlands are not subjected to coastal squeeze, and the rate of SLR is not too rapid to keep pace, wetlands can adapt to SLR without further investments.
Endorsement by Experts	The restoration and recreation of wetlands can also reduce or even reverse wetland loss as a result of coastal development. This is important in terms of maintaining the global area of wetlands and in sustaining wetlands in the face of climate change. Wetland creation may also fulfil legal obligations for the compensation of habitats lost through development, treatment of wastewater and reduction on non-point pollution. Evidence from the 12 Indian Ocean countries affected by the 2004 tsunami disaster suggested that coastal areas with dense and healthy mangrove forests suffered fewer losses and less damage to property than those areas in which mangroves had been degraded or converted to other land use (Kathiresan & Rajendran, 2005).
Adequacy for Current Climate	Fits well, both for present and expected climate.
Scale/Size of Beneficiaries Group	Wetland creation can bring about various economic, social, and environmental benefits to local communities.
Disadvantages	The disadvantages of wetland restoration are minimal. One possible disadvantage is the space requirement in locations which are often of high development potential (but also increasingly high flooding potential). Wetland restoration is also likely to require a degree of expertise, especially in locations where wetland re-colonisation must be encouraged by transplanting wetland plants and wetland habitats are difficult to recreate.
Capital Cost	
Cost to Implement Adaptation Technology	Different types of wetland will require different restorative measures with varying costs and labour requirements. which are likely to contribute toward variations in costs: • Type of wetland to be restored, expertise availability, and • consequent chances of success • Degree of wetland degradation and consequent restoration requirements • Intended degree of restoration (for example, it may not be possible to restore all the ecosystem functions of a wetland if it is in a highly industrialised/urbanised environment and the planned restoration measures may be less ambitious) • Land costs if land purchase is required to convert to wetlands • Labour costs • Transportation distance between seedling source and planting site • Seedling mortality rate between collection and planting

	• Cost of raising specific species in nurseries before transplantation because they cannot be directly planted on mud flats due to strong wind and wave forces In general, restoring wetlands costs US$3,500 to $80,000 per acre (http://www.bnl.gov/erd/peconic/factsheet/wetlands.pdf)
Development Impacts, Direct and Indirect Benefits	
Reduction of Vulnerability to Climate Change (Indirect)	Reduction in physical damage to property, source of sustainable materials and reduction in human casualties in case of large waves caused by storms.
Environmental Benefits (Indirect)	Given the importance of the fishing sector in many coastal communities in developing countries, coastal wetlands are highly beneficial. Improved fishing effect may increase incomes of local communities and contribute toward local sustainable development. Other goods and services provided by wetlands, such as the provision of wood and fibers could also prove highly beneficial to local communities, especially in developing countries. Wetland recreation can also create opportunities for eco-tourism and increase recreational opportunities.
Local Context	
Opportunities and Barriers	Opportunities: There is an opportunity to implement wetland restoration or creation together with hard defences such as dikes or seawalls. In such a case, the presence of wetlands on the seaward side of the defence leads to lower maintenance costs over the lifetime of the structure. The technology has an 80% success rate Barriers: The establishment of wetlands which provide full coastal flood and erosion protection takes time, and the approach does not offer immediate benefits. As such, wetland recreation may not be practicable where coastal management is reactive and focused on hard defenses. A desire to improve wetland habitats also needs to exist before the strategy can go ahead. This may involve raising public awareness of the benefits of wetland restoration and (re)creation, the lack of which is itself one of the most significant barriers. The tourism model for Jamaica especially along the north coast does not facilitate/incorporate the use of mangroves Limited areas in Jamaica which has been declared or identified for wetland restoration.
Market Potential	The technology has been in use for past 20-30 years worldwide. The market for learning from successful implementation and management restoration and protection projects exists locally and worldwide.

Status	Wetland restoration has been used as a solution but agencies as a programme for development projects which may destroy wetlands in other areas.
Timeframe	Medium term to Long Term
Acceptability to Local Stakeholders	Without additional understanding, local communities might oppose the restoration of coastal wetlands, seeing it as a loss of land with development potential.

Technology: Coral Reef Ecosystem Restoration	
Sector: Coastal Resources	
Subsector: Coastal Zone	
Technology Characteristics	
Introduction	Man-made, underwater structure built to reduce wave energy entering the coastline and control beach erosion. The artificial reef acts as a wave breaker and can create an environment for marine life such as algae, fish and shellfish. The reefs can be made from a variety of materials; however, concrete has been used in other areas and has been successful. The artificial reefs will be constructed on-land and transported and set into place. This technology can also be done in places where coral reefs have been degraded. Artificial structures can be installed to enhance the reef building mechanisms. Varieties of corals used should be fast growing corals that can manage high sea temperatures. Coral gardening, or asexual coral propagation, methods use fragments of corals from donor colonies or wild populations generated by disturbances (e.g., fragments broken from storms, anchoring, or vessel grounding). Fragments are transported to a nursery where they are grown for several months (approximately 6-12 months depending on the species), and then propagated to create new material for nursery expansion or “outplanting”. Once the stock and capacity of the nursery has increased, coral colonies are transported and outplanted onto natural reefs to grow and become reproductive, spawning members of the population.
Technology Characteristics/Highlights	Facilitates the preservation of the beach by reducing erosion while keeping the seashore landscape undistorted as the reefs are not visible on the sea surface. Artificial reefs contribute to the creation of natural environment for seaweeds, shellfish, fish and other marine life. Can facilitate the creation of diving in selected areas of the reef if managed correctly. Artificial selection for the reef
Institutional and Organizational Requirements	Will require permits from local agencies, such as NEPA Will require details technical studies from academic and research institutes. Technical reports and modelling will also be required.
Operation and Maintenance	Day-to-day maintenance may be required depending on the site of for both the nursery and the artificial reef. Maintenance will require over a longer period and this will require specialized skills. High operation cost
Endorsement by Experts	Artificial reefs have been successfully implemented in other parts of the world.

	Coral transplanting is accepted worldwide for the restoration of coral reefs and the creation of artificial reefs.
Adequacy for Current Climate	Coastal erosion is being exacerbated by climate change and areas with existing coral reefs are seeing coral reef degradation due to high sea temperatures. Therefore, creating and restoring coral reefs with different varieties of corals which can withstand higher temperatures can help to decrease coastal erosion and create marine coral reef environments.
Scale/Size of Beneficiaries Group	Coastal communities where there is large depends on coastal landscape. This may include fishermen, coastal infrastructure, hotels and the tourism industry.
Disadvantages	High capital cost to implement and high maintenance cost. Requires great deal of technical studies to determine best location, type of material to be used and details of the reef to be built. Will require regulatory approvals.
Capital Cost	
Cost to Implement Adaptation Technology	Capital cost may vary depending on the size of the reef required and material used. Technical studies will also be required which can be costly.
Development Impacts, Direct and Indirect Benefits	
Reduction of Vulnerability to Climate Change (Indirect)	Will play an important role in the protection of coastal areas and wetlands as they are threatened by increasing sea-level rise and storm surge.
Environmental Benefits (Indirect)	Artificial reefs and restores reefs will form a more effective barrier with respect to wave action and erosion along the coastline. Will provide shelter for other marine organisms and therefore improve the overall stability of the reef and ecosystems, therefore preserving biodiversity.
Local Context	
Opportunities and Barriers	Opportunities: • Project could provide employment opportunities to persons involved in coastal construction sector, coastal zone management and the tourism industry. • Can create fishing habitats which can also benefit fishermen. • Creates an environment for academics and researchers. Barriers: • High cost for implementation, monitoring and maintenance. This is because this will require technical research and modelling to determine best characteristics for reef and coral reef restoration. May include high cost for growing and transplanting suitable corals, monitoring of coral reef and cleaning and maintenance of the reef system. • Insufficient or lack of motivation and knowledge of the coastal and marine resource utilisers on the importance of sensitive coastal marine ecosystems and their sustainable utilization.

	• Reluctance of coastal communities to acquire new knowledge and to accept changes in practices. • Sustainable funding • Scale of restoration may not match the size of the problem being solved.
Market Potential	Areas on the north coast of Jamaica for tourism South coast for livelihoods (eg.g. fishermen).
Status	Coral transplanting and restoration has been successful in other countries. It has also been done on smaller scales in the Caribbean and Jamaica. Therefore, this can be adopted on a larger scale at other sites across Jamaica.
Timeframe	Project can take up to 3 years Year 1 – Research, training, site survey and selection. Planting of corals in coral nursery. Year 2 – Development of hard structures for artificial reef and transplanting of corals. Year 3 to 4 – Monitoring and evaluation of success of coral reefs and changes in coastal erosion.
Acceptability to Local Stakeholders	Research, academics, hotels and tourism industry personnel will accept this technology. Some coastal communities may oppose the technology. Fishermen may or may not be opposed the introduction to the technology.

Technology: Rock Revetments	
Sector: Coastal Resources	
Subsector:	
Technology Characteristics	
Introduction	A revetment is a sloped facing of stone, concrete or other durable materials build to protect a scarp or embankment against erosion by wave action (Baird & Associates – Reef Watch, 2003). Some reference may be is made to sea walls, as a revetment can be viewed as a sloped sea wall. Vertical sea walls reflect wave energy, whereas sloped sea walls (or revetments) also dissipate this energy. Revetments can also be carried out using synthetic geotextile technology in conjunction with vegetation techniques
Technology Characteristics/ Highlights	Depends on the underlying embankment for support. Can be considered as flexible as the structure can endure some settlement or other movement without failing. The size of the material depends on the severity of the current or wave attack. Revetments are primarily intended to control the erosion of the backshore (i.e. the land behind the structure) due to direct wave attack. This will block the dynamic removal and return of dune material during and following a storm. If appropriately designed, revetments and sea walls have a high amenity value – in many countries, seawalls incorporate promenades which encourage recreation and tourism. Potentially long-lived structures provided they are adequately maintained. Direct economic benefit by growth in material and construction expertise demand. (Baird & Associates – Reef Watch, 2003)
Institutional and Organizational Requirements	At present, the advice given in developing countries for modern seawall construction appears to be informal, if given at all. If effective design and construction is to occur; local communities must be given at least basic design guidance. This may come from government or voluntary organizations. The design and construction of revetments is relatively straightforward for experienced practitioners. Additionally, contractors can achieve good outcomes, as can land manager works teams with general civil experience supervised by an experienced coastal engineer. Some complexities and sensitivities in design include: • estimating design conditions (wave or flow dominance) • consideration of existing bank conditions and history of change • selection and specification of filter layers and geotextiles • ensuring the toe is well founded and risk of undermining is low • appropriate crest height with consideration of overtopping scour, amenity and drainage • specification of locally available materials

	• site access • maintaining public access (Swan River Trust, 2009)
Operation and Maintenance	The design life of revetments depends on the initial design conditions and maintenance regime. A robustly designed and constructed revetment should have a design life in excess of 20 years, with a modest degree of maintenance. Generally, a significant maintenance exercise would be required in the first few years of construction as the structure settles and is bedded down. Inspections undertaken biannually and following severe storms and floods would determine the ongoing maintenance requirements. Maintenance of well designed and constructed revetments should be limited to occasional repacking and replacement of armour. Other types of structures may be more dependent on the maintenance regime for their intended design life. Responsive approaches to a severe erosion event (emergency works) often result in poorly sized and poorly interlocked dumped rock revetments. These structures may meet the immediate needs of the foreshore manager but require a high level of ongoing maintenance or significant upgrade to meet engineering standards, provide a reasonable design life and maintain the amenity of the foreshore (Swan River Trust, 2009).
Endorsement by Experts	Rock revetments are a well-accepted method of coastal protection worldwide.
Adequacy for Current Climate	Adequate for current climate. May support dune and vegetation preservation and restoration.
Scale/Size of Beneficiaries Group	Variable depending on location. Beneficiaries may be villages, touristic developments, cultural sites, coastal infrastructures such as roads.
Disadvantages	Revetments do not address the root cause of erosion. The underlying erosion process will continue unabated and any beach that is present will gradually diminish in width and eventually disappear altogether. Beach loss may be accelerated by wave reflection from the structure (Baird & Associates – Reef Watch, 2003). By encouraging development, hard defences necessitate continued investment in maintenance and upgrades, effectively limiting future coastal management options. Although authorities may not have a responsibility to continue providing protection, the removal of defences is likely to be both costly and politically controversial. In the absence of a seawall (or revetment), natural shoreline erosion would supply adjacent stretches of coastline with sediment, through a process known as longshore drift. Once a seawall is constructed however, the shoreline is protected from erosion and the supply of sediment is halted. This causes sediment starvation at sites located alongshore, in the direction of longshore drift and this has the capacity to induce erosion at these sites. The down-drift end of the seawall (or revetment) is also typically subjected to increased erosion as a result of natural processes. This flanking effect can cause undermining and instability of the wall in extreme cases.

	Seawalls increase security by reducing the risk of flooding and erosion. However, the coastal zone remains a high-risk location not least due to the presence of residual risk. To combat unwise development of the coastal zone, future developments need to be carefully planned.
Cost to Implement Adaptation Technology	Construction costs (particularly at the time of writing) are highly variable and can escalate rapidly. Factors influencing price include proximity of quarry, availability of required size range, demand, site access and complexity of design. Not expensive Unit rates for the construction plant and operators can vary depending on needs for smaller bobcats to larger excavators and loaders. A price schedule for a larger revetment should typically include the following items. • Preliminaries: insurances; mobilisation of plant and equipment; site establishment; survey; construction management plans. • Materials (supply, deliver and place): armour (various size ranges or classes) core; geotextile. • Plant hire: excavator; loader • Reinstatement works as-constructed survey; demobilisation; and site clean-up. (Swan River Trust, 2009) The cost of carrying out revetments with synthetic geotextile technology has been estimated to be around one third of the cost of conventional rock revetments, while providing the similar level of protection. (http://www.geofabricsinternational.com/webfiles/GeofabricsInternationalAU/files/TPCost_effective_coastal_protection_works_using_sand_filled_geotextile_containers.pdf)
Reduction of Vulnerability to Climate Change (Indirect)	Reduction in physical damage to property, infrastructure and economic output (caused by evacuated facilities).
Environmental Benefits (Indirect)	Creation of jobs: • For leisure, touristic or other commercial activities on the amenities provided necessary agreements are made or permits are issued. • Supporting associated operations, such as quarry operations or construction of infrastructures and operating loading equipment. • For the implementation of complementary coastal protection technologies. Can create investment in: • Supplying equipment and service in installation. • Specialist coastal erosion studies for guiding maintenance, upgrade and complementary operations.

Opportunities and Barriers	Opportunities: Seawall construction is one of several options available when high value land cannot be protected in other ways. The approach provides a high level of protection to valuable coastal areas although the long-term sustainability of the approach should also be taken into account. Less technologically advanced designs can be implemented at local levels, utilising local knowledge and craftsmanship. This requires less investment and a reduced need for involvement of large organisational bodies such as national or sub-national government or non-governmental organisations (NGOs). While ad-hoc implementation is possible, technological guidance from expert organisations is desirable to ensure sufficient levels of protection. Seawalls can also be implemented as part of a wider coastal zone management plan which employs other technologies such as beach nourishment and managed realignment. Placement of seawalls inland, following managed retreat, reduces interference with coastal zone processes and creates a buffer zone to protect against coastal flooding and erosion (French, 2001). The seawall therefore acts as a last line of defence. Use of seawalls in conjunction with beach nourishment can also address some of the negative impacts of seawall construction, such as beach lowering and down drift erosion. Barriers: Cost: The design of an effective seawall requires good quality, long-term environmental data such as wave heights and extreme sea levels. This is frequently unavailable in developing countries and can be costly to collect. Secondly, because seawalls are frequently exposed to high wave loadings, their design must be highly robust, requiring good design, significant quantities of raw materials and potentially complicated construction methods. In locations of high energy waves, additional cost must be expended on protective measures such as rip-rap (Wide-graded quarry stone normally used as a protective layer to prevent erosion (Coastal Research, 2010)) to protect the structure's toe. French (2001) recommends proactive construction of seawalls at some distance inland. This reduces interference with coastal processes and creates a buffer zone to protect against coastal flooding and erosion. A key barrier to this type of approach lies in convincing and educating landowners of the necessity for, and benefits of, these measures (Mimura & Nunn, 1998).
Market Potential	Yes, construction contractors may develop expertise with this technology and bid for works tendered.
Status	Practiced widely across coastal areas in Jamaica
Timeframe	Short term, with long term maintenance and upgrades.
Acceptability to Local Stakeholders	Seawalls (or revetments) may reduce beach access for handicapped people and for emergency services. This can be problematic if the beach fronting such structures is to be used for recreation. The appearance of seawalls can be aesthetically displeasing which can further negatively affect beaches dependent upon a tourist economy.

Technology: Beach Nourishment	
Sector: Coastal Resources	
Subsector:	
Technology Characteristics	
Introduction	Soft engineering approach for use in response to shoreline erosion and flood reduction. It involves the artificial addition of sediment of suitable quality to a beach area that has a sediment deficit. Sand can be placed to create an extension of the beach width or as an underwater deposit which will be gradually moved onshore under the normal action of waves. This is done by trucks or conveyor belts or dredge ships which remove sediment from the seabed, and which is then transferred ashore by floating or submerged pipelines or by the 'rainbow method to transfer ashore directly from the ship.
Technology Characteristics/Highlights	Method of beach nourishment include placement by dredging, trucks or conveyor belts. Sand can be places to create an extension of the beach width or as an underwater deposit which will be gradually moved onshore under the normal wave action. Supply of nourishment material by offshore dredging is often favoured because it allows for large quantities and this method is currently practiced in many other countries. It is possible in Jamaica where offshore sand deposits are available but can be very costly and may have environmental impacts on marine life and ecosystems.
Institutional and Organizational Requirements	Will requires corporation from many stakeholders, particularly beach users and stakeholders with a marine interest. Research and technical studies will be required by research institutions, academics and engineers. Permits will be required from local agencies, including NEPA.
Operation and Maintenance	May require little to no maintenance. Nourished beach will require more sand in about 10 years.
Endorsement by Experts	Beach nourishment is considered a soft dense technology and works best to complement hard protection measures such as seawalls, and groynes. It has been practiced worldwide and generally has been successful in many areas. Wide sandy beaches can generally provide protection from erosive waves reaching coastal infrastructure.
Adequacy for Current Climate	Beach nourishment alone may not be adequate as a stand-alone technology and will require hand structures such as groynes and sea walls. Sea grass and dune vegetation restoration may also be required as other soft defences which may complement beach nourishment. However, the technology is acceptable as a solution for protection from erosion and inundation due to sea-level rise, especially in beaches which are have economic importance.
Scale/Size of Beneficiaries Group	May benefit beaches with economic importance in Jamaica. This may include: • Persons involved in the hotel and tourism industry.

	• Persons using beaches for recreational activities. • Persons using the beaches for economic activity, e.g., fishing. •
Disadvantages	Onshore sands have high silt content
Cost to Implement Adaptation Technology	High capital cost
Reduction of Vulnerability to Climate Change (Indirect)	Control beach erosion and slr
Environmental Benefits (Indirect)	Beach nourishment will provide protection for the land and coastal environments. It may also provide shelter and additional breeding sites for turtles, sea birds and other endangered and ecologically important organisms and the sand burrowing organisms, which would in turn improve the biodiversity in the sandy and dune habitats.
Opportunities and Barriers	Opportunities: • Provide more opportunities to local and foreign tourist for recreational activities which in turn helps to maintain good healthy conditions. • Coastal scientist and sedimentologist will get an opportunity to use their experience and knowledge when extracting offshore sand deposits for beach nourishment. Barriers: • High cost incurred for beach nourishment. • Insufficient or lack of motivation and knowledge of certain sections of the coastal communities for conversation and sustainable management and maintenance of beaches. • If used alone, beach nourishment may not be successful.
Market Potential	Many beaches in Jamaica has been eroding or receding. This has greatly affected beaches for recreational use, hotels and the tourism industry. Therefore, there is a need for soft and hard sea defences to protect coastal interest.
Status	Knowledge for the use of the technology can be found locally by experts. The technology has been successfully used on some beaches in Jamaica in the past.
Timeframe	Site selection and technical studies, 3 to 6 months Implementation of beach nourishment, 2 to 3 months Evaluation and monitoring, 1 to 5 years
Acceptability to Local Stakeholders	Some stakeholders may accept the use of the technology as they perceive it to be beneficial and can create opportunities.

	There is as strong possibility that some stakeholders may find the technology destructive to the environment. Particularly in the area where the beach sand is being sourced from.

Water Resources

<table>
<tr><td colspan="2">Technology: Rainwater Harvesting and Restoration of Barbeque Catchments</td></tr>
<tr><td colspan="2">Sector: Water Resources</td></tr>
<tr><td colspan="2">Subsector: Water Supply</td></tr>
<tr><td colspan="2">Technology Characteristics</td></tr>
<tr><td>Introduction</td><td>Harvesting (collecting) and storing rainwater from rooftops of houses, other larger facilities (schools, hospitals and industrial buildings) and community barbeque catchments as primary and secondary water for portable

Jamaica is experiencing long drought periods and short periods of intense rainfall. Rainwater harvesting has been widely promoted in Jamaica as a source of non-potable water. Rainwater harvesting from rooftops of homes, schools, hospitals, large industrial buildings and barbeque catchments can therefore help collect and store water to supplement other water sources. Untreated rainwater is usually for non-portable uses such as landscaping, washing of cars and flushing toilets.

If the harvested rainwater is treated it can be used for portable uses. Typically, treatment of water ranges from use of bleach to boiling. However, these methods are usually not done correctly and therefore poses a health risk. Technologies are available to increase water storage and water treatment options. These also range in scale from household levels to community level. Methods for rainwater treatment include: -
Filtration Systems
UV Treatment Systems
Ozone Treatment Systems

Old barbeque catchment in Manchester Jamaica</td></tr>
<tr><td>Technology Characteristics/Highlights</td><td>Rainwater Harvesting contributes can help adapt to climate change in the following: -
Diversification of potable water supply
Creates new sources of water
Increases stormwater control and capture
Increase water storage
Setup Cost varies with complexity of the system; however, the system is easily scalable, and components can be added over time.
Technology can be simple and easily maintained without specialized persons.</td></tr>
</table>

Institutional and Organizational Requirements	Awareness programmes and training required should be conducted by local experts. • Construction and maintenance of the system should be done/managed by household/owners. • Households can be easily advised through knowledge sharing platforms and communication channels, such as local health authorities and municipal corporations • Technical advice from local experts and skilled persons for more advance or complex systems. • Testing for water quality should be done by professionals.
Operation and Maintenance	The day-to-day operation of a rainwater harvesting system can be done by the property owner. Simple systems for household uses and non-portable uses do not require skilled labour. Large systems may require a plumber or some expert advice. Daily maintenance can be done by property owner; however, upgrades and long-term maintenance may require more skilled persons.
Endorsement by Experts	Experts view rainwater harvesting as useful technology for supplementing primary water supply sources. In some areas rainwater harvesting is seen as the optimal solution as a primary water supply. However, there is rarely enough storage to last through long drought periods, and insufficient water treatment methods for potable uses. Therefore, increase storage capacity and water treatment methods are largely required.
Adequacy for Current Climate	Currently main areas in Jamaica, especially Kingston and St. Andrew are experiencing water shortages. Short intense rainfall events do occur and therefore rainwater harvesting systems can help to collect and store water for future use. In rural areas of Jamaica where water supply networks (pipes) may be limited, rainwater harvesting is seen as useful as a primary source of water.
Scale/Size of Beneficiaries Group	Small rainwater harvesting systems can be used on the household levels. Large systems at schools, hospitals and industrial facilities can benefit the school's population and the wider community.
Disadvantages	Poses health risk if water is not stored properly. This may lead to breeding of mosquitoes, algae and other pest. Requires roofs and storage tanks to be cleaned often. System may be useless in periods of long drought as many places do not have the area and water storage capacity to store large amounts of water for long periods of drought.
Capital Cost	
Cost to Implement Adaptation Technology	Provided suitable rooftop is available: Capital Cost: US$500 to US$10,000+ Operating life of a rooftop rainwater harvesting system is 20+ years.

Development Impacts, Direct and Indirect Benefits	
Reduction of Vulnerability to Climate Change (Indirect)	Rainwater harvesting can contribute to climate change adaptation by diversifying the sources of water supply.
Environmental Benefits (Indirect)	Reduce exploitation and dependency on groundwater and surface water therefore having benefits to the environment. Helps preserve current freshwater supplies therefore maintaining ecological flows of surface and ground water. Can act as a buffer to steam stormwater discharge and flooding.
Local Context	
Opportunities and Barriers	Opportunities: • Diversification of water supply. • Reduce dependency on groundwater and surface water sources. • Reduce stormwater flow. Barriers: • May not be useful during periods of long severe droughts. • Systems cannot be used on unsuitable roofs. • Requires large areas for water storage • Not suitable in areas with high levels of air pollution
Market Potential	High potential for households and other facilities to invest in systems for water capture and storage. Jamaica has been experiencing water shortages over most of the island and therefore there is a market for the introduction of technologies to increase water supply, storage and treatment.
Status	Rainwater harvesting is used in many areas across Jamaica, including, homeowners, schools and other commercial facilities, however, the overall adaptation rate, especially in urban areas is generally low.
Timeframe	Construction of Rainwater harvesting system can take less than 1 month to 6 months.
Acceptability to Local Stakeholders	The majority of stakeholders see rainwater harvesting as acceptable.

Technology: Creation and Restoration of Minor Tank Networks	
Sector: Water Resources	
Subsector: Water Supply	
Technology Characteristics	
Introduction	Creation and Restoration of tanks which harvest water from surface water bodies, runoff and from direct rainfall. Restoration of tanks that have been damaged or silted. These tanks can provide water for domestic, agricultural and livestock needs. These tanks are large and usually gravity feed to houses or to a communal pipe. They are large enough to support small communities. Water will require some treatment for potable uses.  Image source: https://www.mentalfloss.com/article/64577/how-do-water-towers-work
Technology Characteristics/Highlights	Diversification of water supply Control and capture of storm water
Institutional and Organizational Requirements	Technical assessments will be required to determine the location, size and for the design and construction of tanks. Local government agencies such as municipal corporations and NWC will have to play a role in coordination and implementation. Skilled community members could be trained to assist with general cleaning and maintenance of the system.
Operation and Maintenance	Minor tanks can be managed by communities and farmer organizations with technical support from agencies such as NWC and NWA.
Endorsement by Experts	This technology has been used in the past in Jamaica and other countries.
Adequacy for Current Climate	Adequate for areas which may have periods of short heavy rainfall and long periods of no rainfall. May be useful for rural communities which may not have water supply from Municipal sources.
Scale/Size of Beneficiaries Group	Can be beneficial to small rural communities and rural farmers
Disadvantages	High cost for repair and maintenance Cost for water treatment for potable use Cost of water quality monitoring may be high
Capital Cost	
Cost to Implement Adaptation Technology	High Cost for Construction Construction cost range from US$20,000 to US$60,000
Development Impacts, Direct and Indirect Benefits	

Reduction of Vulnerability to Climate Change (Indirect)	Storage of water during drought periods Diversification of sources of water Capture of stormwater which may reduce flooding
Environmental Benefits (Indirect)	Will have a positive impact on the control of storm water control Positive impact on communities for diversification of water supply positive impacts on ground water quality and quantity
Local Context	
Opportunities and Barriers	Opportunities: Agencies, communities and farmers see the need for greater water storage and diversification of water supply. Barriers: High cost to repair and maintain the minor tank networks. High evaporation loss due to open tanks
Market Potential	Can be adequate for use in rural communities.
Status	Was used in the past in rural communities in Jamaica.
Timeframe	Technical and feasibility studies 6 to 12 months Construction can take 6 to 12 months Monitoring and Evaluation 2 years
Acceptability to Local Stakeholders	This will be acceptable to the majority of local community stakeholders as it would provide water during times of drought and can help control storm water

<table>
<tr><td colspan="2">Technology: Water Reclamation and Reuse in Large Facilities</td></tr>
<tr><td colspan="2">Sector: Water resources</td></tr>
<tr><td colspan="2">Subsector: Water Supply and Sanitation</td></tr>
<tr><td colspan="2">Technology Characteristics</td></tr>
<tr><td>Introduction</td><td>Using wastewater from schools, hotels and large industries for landscaping. Wastewater would go through various treatment procedures including secondary clarifiers, filtration basins of various designs, membranes, and disinfection basins to become purified.

Sustainable uses of reclaimed water include:
• Substituting for applications which do not require potable water
• The use of reclaimed water uses the same treatment technologies as conventional wastewater treatments</td></tr>
<tr><td>Technology Characteristics/Highlights</td><td>Reclaimed water can be used for applications which do not require potable water.

Allows for an additional water source to assist in meeting both current and future needs.

Ensures compliance with environmental regulations by the creating better management of water consumption and wastewater discharges.

Helps to store water for use during low water periods.

Efficient use of water.</td></tr>
<tr><td>Institutional and Organizational Requirements</td><td>Small scale water reclamation and reuse does not require any permits.

Larger scale plants for large hotels may require permits for the construction and operation of water treatment facility.</td></tr>
<tr><td>Operation and Maintenance</td><td>Operations generally consist of daily monitoring.

Does not require engineers or professional for general cleaning of the system.

Does not require engineers or professional for day-to-day maintenance.

May require engineers or professional for large maintenance. This may only be required in the medium to long term.</td></tr>
<tr><td>Endorsement by Experts</td><td>Water recycling and reuse is seen as an efficient use of water.</td></tr>
<tr><td>Adequacy for Current Climate</td><td>With current water shortage issues being experienced across Jamaica, the reclamation and reuse of water will decrease the demand for freshwater for landscaping.</td></tr>
<tr><td>Scale/Size of Beneficiaries Group</td><td>Benefit schools, hotel owners and industry.</td></tr>
<tr><td>Disadvantages</td><td>Socio-political and cultural barriers for the use of reclaimed water
Requires strict water quality testing which can be costly.</td></tr>
</table>

Capital Cost	
Cost to Implement Adaptation Technology	The financial cost for implementing water reclamation, treatment and reuse facilities can vary significantly. The approximate capital cost could range from US$4,000 to US$20,000.
Development Impacts, Direct and Indirect Benefits	
Reduction of Vulnerability to Climate Change (Indirect)	Water reclamation and reuse can contribute to climate change adaptation by diversifying the sources of water supply for landscaping.
Environmental Benefits (Indirect)	Reduce exploitation and dependency on groundwater and surface water therefore having benefits to the environment. Helps preserve current freshwater supplies therefore maintaining ecological flows of surface and ground water.
Local Context	
Opportunities and Barriers	Opportunities: • Less dependency on one source of water. • Reduction in the use of portable water for landscaping. • Reduction in the use of municipal water and water bill. Barriers: • High cost for setting up the system. • Potential cultural and social issues for the reuse of water.
Market Potential	Not regularly seen in schools, industry or on the household level.
Status	Water reclamation and reuse is already used in some hotels in Jamaica.
Timeframe	Construction Phase may take 3 to 6 months.
Acceptability to Local Stakeholders	Already acceptable by some stakeholders such as hotels. May be easily acceptable by other stakeholders.

Technology: Artificial Recharge of Aquifers	
Sector: Water Resources	
Subsector:	
Technology Characteristics	
Introduction	The process of spreading or impounding water on the land to increase the infiltration through the soil and percolation to the aquifer or of injecting water by wells directly into the aquifer. This allows for water to be stored in the underground aquifer for use in times water shortages. Wind and solar energy pumping systems may be used for groundwater intrusion and extraction.
Technology Characteristics/Highlights	Storing water in the aquifer which can be used in the future. Reducing water loss due to surface runoff and evaporation. Improving water quality. Management and reversal of saltwater intrusion.
Institutional and Organizational Requirements	Technical studies and feasibility studies will be required. Water Resources Authority will be a major partner in implement and the operations. May require some coordination with Ministry of Health and NEPA.
Operation and Maintenance	Day-to-day operations do not require professionals. Upgrades and maintenance will require engineers and professionals.
Endorsement by Experts	Professionals view this as suitable technology for groundwater recharge, it has been used in some parts of Jamaica.
Adequacy for Current Climate	Capture of stormwater can provide some relief from flooding. Water storage for future use during drought periods. Improve water quality from infiltration and percolation. Prevent and reverse saltwater intrusion.
Scale/Size of Beneficiaries Group	Benefit to entire communities.
Disadvantages	Large areas required for capture and storage of surface water.
Capital Cost	
Cost to Implement Adaptation Technology	Capital cost for construction of water bund or storage area can be costly. Land for water storage may be costly. High capital cost for water injection pumps if required.
Development Impacts, Direct and Indirect Benefits	

Reduction of Vulnerability to Climate Change (Indirect)	Storage of water underground which can be used for periods of water shortages. Help captures stormwater runoff during periods of intense rainfall.
Environmental Benefits (Indirect)	Improved groundwater quality. Reduce downstream flooding and traps sediment from flowing downstream and into the coast areas, therefore protecting marine and coastal ecosystems. Reduces and revers saltwater intrusion.
Local Context	
Opportunities and Barriers	Opportunities: • Improves quantity of water from underground sources. • Can improve water quality form underground water sources. • Reduce flooding from storm water runoff. Barriers: • Requires other technical and management solutions to be implemented. • Not feasible in all areas across Jamaica. • No direct financial or economic benefit. • Requires detail technical studies.
Market Potential	May not be suitable for urban areas because of the space required where groundwater sources are depleted and degraded. May be useful in rural areas and agricultural areas. Storm water can be trapped, and this will prevent flooding of farms, water can be stored in aquifers and refused on the farms during periods of droughts.
Status	Not widely used in Jamaica.
Timeframe	Technical studies could take 3 to 6 months. Construction Phase take 3 to 6 months. Monitoring and evaluation required for 2 years.
Acceptability to Local Stakeholders	Would be acceptable to local stakeholders, especially farmers in rural areas.

Technology: Desalination	
Sector: Water Resources	
Subsector: Water Supply	
Technology Characteristics	
Introduction	Desalination plants remove sodium chloride and other dissolved constituents from seawater, brackish waters, wastewater, or contaminated freshwater to produce freshwater. There are several processes used in desalination including reverse osmosis or electrodialysis. The process of desalination requires large amounts of energy and therefore the process is sometimes expensive, however, in areas where there is water stress or scarcity, it may be a suitable alternative. This process may also be done using renewable energy sources. The use of desalination has been successful in many areas across the world as a source of freshwater in areas with water scarcity, in areas with water stressed populations, areas with high rural to urban migration and to adapt to changes in water supply due to climate change.
Technology Characteristics/Highlights	Desalination can be done by difference processes which includes, thermal Desalination or membrane desalination. Technologies have advanced so that desalination is less expensive and can use brackish water rather than seawater.
Institutional and Organizational Requirements	Technical studies will be required for the feasibility, water quality, water quantity, source of brackish/ seawater. Environmental Assessments and Permits will be required for the construction and operation of the desalination plant. License required from Water Resources Authority for the extraction of water. Agreements for sale of water to National Water Commission.
Operation and Maintenance	Day-to-day operation and maintenance requires engineers and highly skilled personnel.
Endorsement by Experts	With expected changes in precipitation and extend period of drought, surface and ground water sources are becoming less reliable and scare. Therefore, experts see desalination as a viable option for the diversification of water supply in water scarce and water stressed areas.
Adequacy for Current Climate	Jamaica is an island whose water resources will be greatly impacted by climate change. The island has been experiencing changes in rainfall patterns and longer drought periods. Areas such as Kingston and St. Andrew has high water demands, however, inadequate water supply, therefore desalination can provide freshwater for large coastal cities.
Scale/Size of Beneficiaries Group	Water scarce urban coastal areas such as Kingston and St. Andrew, St. Ann’s Bay and Port Antonio. Beneficiaries groups include general population, hotels and industrial facilities.

Disadvantages	Environmental impacts from concentrated brine as a by-product from the desalination process. Requires energy therefore can contribute to GHG emissions if fossil fuels used in the production of electricity. May increase the cost of providing water.
Capital Cost	
Cost to Implement Adaptation Technology	Cost includes capital cost for construction of the desalination plant and associated facilities and maintenance cost for the operation of the plant. Capital Cost – US$8 Million to US$10 Million for large coastal plant (600,000 Imperial Gallons per Day).
Development Impacts, Direct and Indirect Benefits	
Reduction of Vulnerability to Climate Change (Indirect)	Water from desalination can contribute to climate change adaptation by diversifying the sources of water supply. Provides resilience to water quality degradation as freshwater can be produced from highly contaminated water sources.
Environmental Benefits (Indirect)	Reduce exploitation and dependency on groundwater and surface water therefore having benefits to the environment. Helps preserve current freshwater supplies therefore maintaining ecological flows of surface and ground water.
Local Context	
Opportunities and Barriers	**Opportunities:** Provide potable water for domestic, commercial and industrial use. Helps preserve current freshwater supplies therefore maintaining ecological flows of surface and ground water. **Barriers:** High capital cost for the construction of desalination plant. High operating cost for desalination plant. High energy demand for the desalination process.
Market Potential	Opportunities for investment is high not only due to climate change but also due to the need for alternative water sources as the demand on the limited amount of freshwater is increasing over time.
Status	Desalination has not been used in Jamaica on a large scale, however, it is practiced at small scale in some industrial facilities and hotels.
Timeframe	Will require feasibility and other technical studies – 6 to 8 months Construction Phase – 1 to 1.5 years.
Acceptability to Local Stakeholders	People may have issues with the taste of desalinated water

Mitigation

Agriculture Sector

TECHNOLOGY FACT SHEET
CONCENTRATED SOLAR POWER

1. **Sector:** Energy

2. **Introduction:**

Jamaica's 2009–2030 National Energy Policy is the long-term strategy for achieving 'developed nation' status and includes harnessing indigenous energy resources concurrent with preserving and enhancing economic, social, and environmental capital (currently the electricity grid is supplied by petroleum 45%, natural gas 37% and renewables 18% solar, wind and hydropower).
The Government has set a mandate for 50% renewables on the grid, supported by NDC targets, CC targets, and a goal for 100 % electrification islandwide in line with UN's aspirations of Sustainable Energy for All. The Energy Policy also seeks to reduce emissions at the points of power generation.

One potential technology which has no GHG emissions during operation and can provide electrical power to the grid is concentrated solar power (CSP). CSP technologies use curved (parabolic) mirrors to reflect and concentrate sunlight on to receivers that focus solar energy and convert it to heat. This thermal energy can then be used to produce electricity via a steam turbine or heat engine driving a generator for on- and off-grid electricity provision. These systems can also provide heat, either at high temperatures directly for processing, or as a by-product for desalination plants or cooling systems.
These systems require clear open spaces for optimal conditions and therefore may have some constraints on location or co-location with other activities.

3. **Technology Name:** Concentrated Solar Power (CSP)

4. **Technology Characteristics:**

CSP technologies use mirrors to reflect and concentrate sunlight onto receivers, then convert the energy to electrical or heat energy. The CSP energy can also be stored before or while powering a steam generator and therefore can be used either as a flexible provider of electricity, that is, as a "peaker" plant, or as a base load source of electricity similar to a traditional nuclear or coal plant, but without the GHG emissions.

There are three basic designs for CSP, all using curved mirrors to concentrate solar energy onto a thermal receptor vessel (gas or liquid filled) to power a steam turbine (Dell and Rand, 2004). The transfer of heat to water generates high temperature and high pressure steam which turns a generator and alternator, finally producing electricity. The following provides an overview of the three basic CSP designs:

I. **Simple parabolic dish** which focuses the sun's energy onto a thermal receiver mounted at the focal point of the dish. Temperatures greater than 1000°C can be reached. Due to its limited size, the output from one dish is about 25 kilowatts (kW) at maximum;
II. **Central receiver or solar tower** uses thousands of mirrors to track the movement of the sun and focus the light rays on a tall central tower to produce temperatures in the range of 300–1000°C in heat transfer fluids (e.g., a molten salt, air, water/steam, liquid sodium). The heated fluids transfer heat to water to make steam which turns turbines to generate electricity with power outputs in the range of 30–200 MW (air can be used at 1000°C in a gas turbine, thus replacing natural gas);

III. **Parabolic troughs** have mirrors up to 100 m long which may be used to track the sun to focus its rays on heat pipes containing water. The water is heated to temperatures of 200–400°C to produce steam and power outputs ranging from 30 to 350 MW.

The electricity generated can be sent to the grid to offset the use of fossil fuel.

5. Country Specific/Applicability:

The total solar energy resource, evaluated on the annual solar radiation on the entire national territory, has been calculated to have the potential to achieve 2.2 x 1012 kilowatt-hours (kWh). The potential solar energy varies from 1,200 kWh/m2/year to 1,600 kWh/m2/year in the different regions of Mongolia. According to the "Master Plan Study on Rural Power Supply" by Renewable Energy in Mongolia, up to 20 percent of the country's electrical power energy will be supplied from renewable energy sources by the end of 2020. The huge potential for solar energy in Mongolia makes it possible to implement CSP technology. However, it is important to secure international support in order to build the solar thermal power plants and access international grants or soft loans to finance the project. Forty (40) MW CSP capacities have been considered to replace 20 MW conventional coal-based power plants in general. The capacity utilisations of CSP and conventional coal power plants are 35% and 70% respectively. The replacement capacity is based on an equivalent energy output by both power plants. The CSP plant will not produce direct GHG emissions.

6. Status of Technology in the Country and its Future Market Potential:

7. Barriers:

The appropriateness of a CSP system is significantly linked to the plants' locations.

Selected locations require high direct normal solar radiation, hence the direct normal intensity (DNI) of the sun's energy should be high. Jamaica would have such conditions, however, occasional clouds would affect energy production in similar ways to solar photovoltaics (PV).

CSP systems require contiguous parcels of land to accommodate plants of the sizes of 100 MW and higher for efficient and cost-effective energy production. Essentially a typical CSP plant requires 5 to 10 acres of land per MW of capacity. The larger acreage is needed to accommodate thermal energy storage.

These large open spaces also mean the investment could be vulnerable to the annual risk of high intensity storms.

CSP plants require access to water resources for the heat transfer liquid, for cooling small amounts to wash collector and mirror surfaces. Regular cleaning is necessary due to the highly polished mirrors and the potential for accumulation of dust, bird droppings and rainfall sediments which could negatively impact the reflection of the sun's energy, and consequently, the plant efficiency. Some CSP plants, however, can utilise wet, dry, and hybrid cooling techniques to maximise efficiency in electricity generation and water conservation.

Because of the vast tracts of land needed, agreements between the owner of the power plant and land owner(s) can sometimes be a barrier to implementation, or change the economics of the project significantly. Land owners may only have access to the value of their sale or lease, as agricultural co-location would be prohibited due to the possibility of damage to infrastructure during agricultural land preparation, planting or harvesting. Also, some crops may attract birds (droppings).

Capital costs can be high and project financing can be a barrier to utility-scale solar power. Projects require significant funds for long-term, low-interest debt for projects which commercial banks are hesitant to offer.

Local expertise would have to be developed for this new technology.

8. Benefits:

- No GHG during operation;

- Addition of REN on the grid.

9. Operations:

10. Cost:

The capital cost of CSP is about 2,500 USD/kW and 5,000 USD/kW respectively for options without storage and options with molten salt storage tank systems including equipment and construction, planning with generation costs of approximately US$ 0.11 to US$ 0.18/kWh without storage and with storage respectively. The annual operational and maintenance costs of the CSP plant is US$ 12 million. These costs are higher than a conventional coal-based power plant, and 3 to 2.5 times more higher compared to a solar photovoltaic plant, hence, CSPs can be difficult to finance.

References:
Fact Sheet - TNA Report – Technology Needs Assessment for Climate Change Mitigation– Mongolia. You can access the complete report from the TNA project website http://tech-action.org/
Fact Sheet-TNA Report – Technology Needs Assessment and Technology Action Plans for Climate Change Mitigation– Rwanda. You can access the complete report from the TNA project website http://tech-action.org/

http://climatetechwiki.org/technology/csp

TECHNOLOGY FACT SHEET

1. **Sector:** Agriculture

2. **Introduction**: The biological degradation occurs under controlled aerobic conditions and the waste is decomposed into carbon dioxide, water and the soil amendment or mulch which is integrated back into the soil. Carbon storage also occurs in the residual compost.

3. **Technology Name:** Aerobic Biological Treatment (Composting)

4. **Technology Characteristics:** There are two major methods to composting, active and passive:

   Active Composting is done under ideal conditions allowing aerobic bacteria to thrive. This requires the composting material to be kept warm, insulated and moisturized to ensure the bacteria is kept within the ideal conditions.
   Passive Composting which requires a level of physical intervention is minimised.

   The process of composting requires several steps which include, waste collection, sorting, piling and sprinkling.

5. **Country Specific/Applicability**: In Jamaica, composting can be easily implemented especially in rural areas where the practice can be done away from residential buildings. Waste materials from farms and residential households can be used in the process, therefore minimising overall waste.

   The mulch or soil amendment from the compost can be used in farming as manure, therefore reducing the need chemical fertilizers.

6. **Status of technology in the country and its future market potential**: Composting a not practised widely across Jamaica, however, there is the potential for this to be adopted across the island by farmers.

7. **Barriers:** Generally, the barriers to composting include lack of knowledge and experience of farmers about the process and methods of composting and also the financial and time investment required. The proliferation of cheaper alternatives for fertilizers also hinders the practice of composting and the use of compost manure. Compost manure quality is also variable and therefore may pose challenges for farmers.

8. **Benefits:** Waste composting can result in economic, social and environmental benefits for Jamaica. It can reduce the overall need for the generally expensive waste collection process in rural areas which is likely to have an inevitable impact on economics. The sorting and reuse of bio-degradable waste will mean that waste management authorities can focus more efforts and resources on the management of non-biodegradable waste, therefore contributing to an overall cleaner environment.

   Natural decomposition which takes place under anaerobic conditions results in the emission of methane gas. Composting, however, results in the emission of carbon dioxide instead of methane. Carbon dioxide is thirty times less potent as a greenhouse gas than methane. Therefore, composting contributes overall to climate change mitigation.

9. Operations:

10. **Cost:** The cost associated with composting highly depends on the size and type of composting. Small operations which can be done by small farmers and householders are usually inexpensive as most of the labour required can be done by farm owners. In larger commercial facilities, some basic equipment may be required, however, the capital and maintenance costs are usually low.

TECHNOLOGY FACT SHEET
SOLAR-POWERED WATER PUMP STORAGE FOR IRRIGATION

1. **Sector:** Agriculture

2. **Introduction:**

Agriculture is a major contributor to the Jamaican economy and for 2018, Jamaica's agricultural product exports totalled just over US$ 217 million.. There are approximately 220,000 farmers including many female owners and employees. With a wide range of soil types and micro-climates, a variety of tropical products can be grown. The chief economic crops are sugar, bananas, citrus, cocoa and coconuts. Non-traditional crops are also grown including Irish potatoes, onions, red peas, cassava, dasheen, ginger, garlic, castor beans, sweet potatoes, pineapples, strawberries, sweet yam, hemp (not industrial), bamboo, and soon to be joined by cannabis. Sugar cane production alone utilises around 45,000 hectares which is about 4% of the total land area of Jamaica, however, the Ministry of Industry, Commerce, Agriculture and Fisheries indicated that some 24,000 hectares of former sugar-cane lands are to be placed into other areas of agricultural production.

Agriculture in Jamaica requires irrigation for small to large commercial farms. In this regard, farmers may receive water in pipelines or canals through the National Irrigation Commission, or from surface water sources or wells. Pumping is required to meet water requirements for commercial production and pumps, whether pressurised deep well pumps or surface pumps, consume a lot of electricity from the grid. The methodology for water distribution is also inefficient being surface flooding, supply to open channels or in more efficient farms, via drip irrigation. The farms are severely affected during annual drought cycles and over time, the volume of available water of irrigation becomes less and has, in some cases, caused farms to fail.

The grid source for water pumping is currently fuelled by 82% fossil fuel sources and 18% by renewable sources and there is over 18% technical online loss.

With the anticipation of more intense drought periods, current high electricity costs and an expected growth in agriculture, the current technology proposal to irrigate farms considers using a Solar Photovoltaic In-line Micro or Pico Hydro Pump-Storage Hybrid System where off-grid Distributed Generation (DG) systems are used to pump water on local farms, but also used to pump water to storage ponds or tanks when not in irrigation mode. Depending on the elevation of the storage systems, water can be returned to the farms by gravity for irrigation but may also generate some power for the farms' operations by inline hydropower pumps. The technology would therefore reduce operational costs, store water for drought periods, and avoid the use and wastage of fossil fuels and the consequent emissions of GHGs.

3. **Technology Name:** Solar Photovoltaic In-line Micro or Pico Hydro Pump-Storage Hybrid System

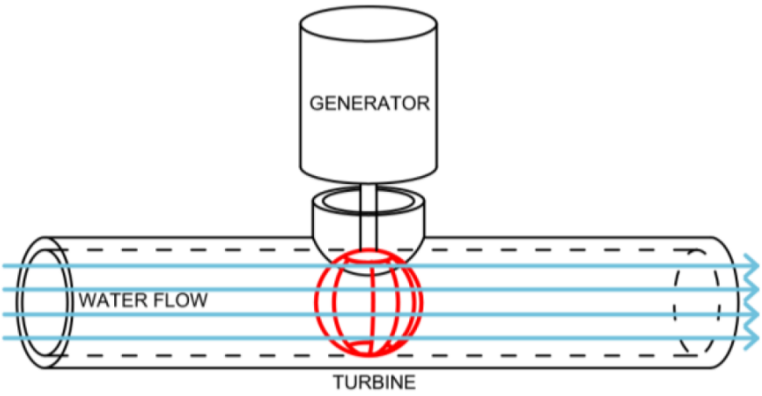
4. **Technology Characteristics:**

Solar photovoltaic power generation converts sunlight into direct current electricity by using semiconductors.

The proposed inline hydropower system falls within the category of "micro-hydro" (up to 100 kW) and "pico-hydro" (up to 5 kW). They can be utilised for gravity-fed and pressurised water transmission and distribution lines and in particular, micro-hydro systems may be located in irrigation systems using different, but common piping materials. In-pipe hydro systems are akin to clean base load energy without the intermittency of wind and solar and without GHG emissions.

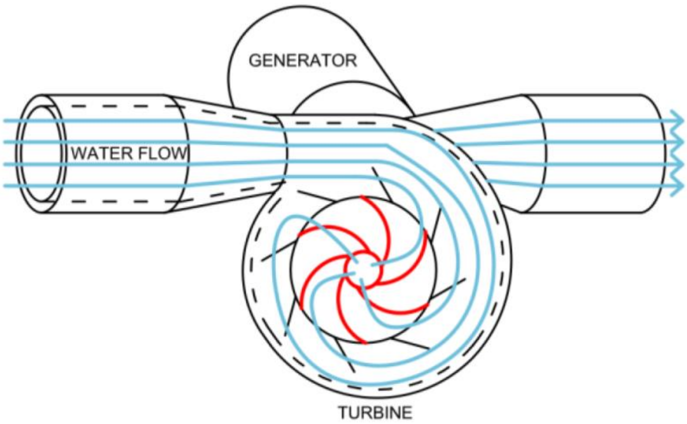
Piped water systems can also recover energy using in-line hydroelectric generation and reduce net energy consumption, greenhouse gas emissions, and operating costs. In pipe hydropower systems can be divided in two main designs:

1. Internal systems with turbines wholly inside the pipe section with generator protruding from the conduit as illustrated below;



Source: Marco Casini, 2015

2. External systems have the turbine contained in a secondary conduit that bypasses the main water line as illustrated below.



Source: Marco Casini, 2015

Regarding the turbine types, turbines suitable to recover energy from the differential pressure and flow inside a pressure-controlled water supply system could include a Francis turbine and a reverse-acting pump (or pump-as-turbine – PAT). The PAT had a number of other advantages over other types of hydro turbines, including:

- Simple design and ease of application
- Similar operational and maintenance considerations to regular pumps
- Availability for a large range of heads and flows
- Available in a large number of standard sizes
- Lower costs
- Availability of spare parts
- Ease of installation
- Ease of integration within an existing system
- Direct coupling of turbine/generator resulting in lower friction loss, longer bearing life, and less maintenance.

(*Source*[4]).

The total hybrid technology would involve the following components:

[4] https://www.wateronline.com/doc/in-line-turbines-harness-energy-for-water-utilities-0001

Renewable Energy Power Generation:	**Storage Systems:**
• Solar Photovoltaic systems for day time pumping • In-line Micro or Pico Hydro Pump system for night-time gravity flow and potential energy conversion and power generation	Natural or membrane-lined ponds or storage tanks (at elevations if topography permits)
Piping: Normal as suitable to the crop's irrigation	**Pumping:** DC pumps interconnected with the in-line hydro or solar PV systems

5. Country Specific/Applicability:

Many farms which are at risk from more frequent drought events, inability to recover quickly due to under capitalisation and financial challenges in paying high electrical costs for pumping and irrigation are small farms. Some are located in off-grid areas. The Ministry of Industry, Commerce, Agriculture and Fisheries (MICAF) will engage agro-parks – lands within a geographical area sometimes contiguous that have roads, and water for irrigation and other infrastructure to support such farms. Whether in the agro-park context or as isolated farms, this solar PV-hydro-storage hybrid system would provide a buffer against increasing drought events, while providing clean power for operations.

The Government has set a mandate for 50% renewables on the grid, supported by NDC targets, CC targets, and a goal for 100 % electrification islandwide in line with the UN's Sustainable Energy for All aspirations. This project will advance these mandates:

- CO_2 emission reductions can be achieved at the point of generation (JPS plants);
- The State is also active in reducing public sector spending for electricity;
- By inserting micro hydro turbines generators (<100 kW) or Pico-hydro (up to 5kW) in the main delivery pipeline to farmers, the National Irrigation Commission (NIC) can generate electricity, while supplying farm acreages by gravity flow without a significant pressure drop;
- With this technology, NIC will not require pay for some electricity for water storage and supply and will generate clean renewable electricity which can be sold to the grid which uses fossil fuels;
- Alternatively, the electricity can be used to boost pumping needs or the electricity demands of a pumping station.

The entire system would be modular and could be replicated on multiple farms or to supply shared water channels in urban communities.

6. Status of Technology in the Country and its Future Market Potential:

No solar PV pump storage has been applied in agriculture to date, however, this technology has significant potential for further uptake in the public sector and private sector contexts. The National Irrigation Commission (NIC) consumes electricity for agricultural water supply islandwide, and sometimes to remote urban areas with no grid access. Pumping water for irrigation is expensive and this is required most during daily on-peak demand hours (highest tariffs). Electric pumps are expensive to operate and require electricity from the grid which is > 80% fossil-based.

For the private sector, an example is one company in Jamaica's significant sugar cane industry which has already initiated a private sector joint venture project. Monymusk Sugar Factory in Clarendon is preparing to have 50% of the power required for its irrigation system to be powered by solar photovoltaic source. A memorandum of understanding (MoU) was signed between Sugar Company of Jamaica (SCJ) Holdings Ltd and Blue Mountain Renewables (BMR) Energy LLC. Monymusk will therefore reduce the consumption of electricity from the fossil fuel-dominant (>80%) electricity grid, reduce its pumping costs and utilise more clean renewable energy. With the utilisation of a low volume, low-pressure pump powered by solar PV, the sugar company will be able to pump water to various remote acreages or alternatively pump water to storage tank(s) at a high elevation during the days using clean renewable energy. The water from tanks can be released during the days or at nights when needed.

Regarding future projects, MICAF will implement agro-parks which will increase pumping of water using the national grids. The technology will enable the parks to be irrigated at lower electricity rates, using of REN energy, while reducing GHG emissions: an adaptation in anticipation of more frequent drought periods.

7. Barriers:

- Initial cost for set up;
- Initial technical capacity to design and install systems.

8. Benefits:

- Reduction of GHG;
- Contribution of RE to National 2030 REN targets, NDA targets and climate mitigation mandates;
- Operational cost reductions;
- Adaptation to future drought events;
- Economic productivity and sustainability;
- Increased employment;
- Food security and sustainability.

9. Operations:

10. Cost:

In the past, Campari's property of 2,400 acres of arable land had costs ranging JA$800,000 and JA$1.5M (US$ 6,000 – US$11,000) per month for electricity to operate two big pumps and two smaller pumps which pumped water from four productive springs on the property.

This proposed hybrid system would enable lower cost pumping operations (To be added).

References:

Casini, Marco (2015). Harvesting energy from in-pipe hydro systems at urban and building scale. International Journal of Smart Grid and Clean Energy.

TECHNOLOGY FACT SHEET

- **Sector:** Agriculture

- **Introduction:** Fields grown specifically to produce grass for cattle; this, in turn, reduces soil erosion, soil exposure, nutrient loss and ensures that GHG in soils do not escape into the atmosphere. Grass is then cut and stored for feeding particularly during dry periods when lack of rain reduces the accessibility to naturally grown grass on pasture fields.

- **Technology Name:** Fodder Banks and Feeding Fields

- **Technology Characteristics:**
    - High-quality fodder can be used to maintain healthy productive animals;
    - Can aid in the control and management of diseases and pest;
    - Can be utilised year-round as excess feed during the dry periods can be cut and stored for dry periods and drought;
    - Fodder banks usually consist of trees, shrubs and legumes which have deeper roots that allow them to reach soil moisture, therefore, these plants can access and retain water during dry periods.

- **Country Specific/Applicability**: There are many small medium-sized farms that are affected during drought periods. During these times, farmers usually struggle to find nutrient-rich grass or feed. This is especially the case for small farmers who practise free-range feeding.

- **Status of technology in the country and its future market potential:** Fodder banks have been used in some areas across the island, particularly to augment the feeding of diary and beef cattle, thereby mitigating the impacts on the farmers during periods of severe drought. The technology is, however, not widely used and therefore can be expanded across the island to benefit more farmers.

- **Barriers:**
    - Intensive farming and managing of fodder fields is time-consuming and resource-intensive;
    - The process fragments livestock raising making it difficult to use fodder fields;
    - Requires controlled storage for feed during periods of drought.

- **Benefits:**
    - Free-range feeding is common practice and culturally accepted;
    - Can augment feeding for cattle during periods of drought or low grass yields;
    - Can assist in providing a balanced diet for cattle which will improve the overall cattle productivity;
    - Requires little processing and therefore operational costs are generally low.

- **Operations:**

- **Cost:**

TECHNOLOGY FACT SHEET

1. **Sector:** Agriculture

2. **Introduction:** CO_2 emissions can be reduced with effective irrigation by increasing yields and crop residues which can enhance carbon sequestration. Water efficiency in irrigation techniques can be improved by:
   - Understanding the crop type and needs
   - Scheduling irrigation
   - Type of irrigation methods used
   - Enhancing soil quality
   - Source of water.

3. **Technology Name**: Irrigation (efficient)

4. **Technology Characteristics:** The principal feature of the technology is to use all the elements outlined in providing enough water to the field during certain periods of growth.

5. **Country Specific/Applicability**:

6. **Status of technology in the country and its future market potential**: Farmers rarely calculate the amount of water required for crops and they usually provide inadequate water or flood the fields, causing excess flooding and runoff.

7. **Barriers:** The systems of fields and associated infrastructure, drainage and irrigation systems are usually expensive. The technology and knowledge required are also usually or can be somewhat advanced and may require calculations.

   Many farmers are located far away from water sources and therefore water transportation is very costly.

   Communities and farmers are not always aware of the importance and quality of water sources.

8. **Benefits**:
   - Reducing water costs, enhancing fertilizer efficiency, increasing tilling rates and improving crop yields;
   - Lower methane emissions compared to flood irrigation in every growth stage.

9. **Operations:**

10. **Cost:** Setup and maintenance costs are usually high. Requires high cost for research, development training and knowledge transfer. High costs are also associated with the construction or renovation of irrigation systems.

TECHNOLOGY FACT SHEET

1. **Sector:** Agriculture

2. **Introduction:** This is a transformation from the system of inter-cropping with three crops to double cropping and shrimp/fish/poultry.

3. **Technology Name:** Cropping Systems (Double cropping and shrimp/fish/poultry)

4. **Technology Characteristics:**

5. **Country Specific/Applicability:** Many farmers already practise some form of inter-cropping, however, they lack the knowledge to integrate aquaculture into their production.

6. **Status of technology in the country and its future market potential:** This technology is practised on a very small scale in Jamaica, however, there is room for further development and use across the country.

7. **Barriers:** Requires knowledge of inter-cropping systems.

8. **Benefits**:
   - Can generate higher income than growing three crops;
   - Leads to reduction in the amount of pesticides and fertilizers required;
   - Promotes recycling of agricultural residue as inputs for aquaculture;
   - Prevents eutrophication in fish farms due to excess food and faecal waste from fish or shrimp, thus preventing diseases.

9. **Operations:**

10. **Cost:** Implementation and technology application costs
    - The cost depends on the kind of technology that farmers choose and can be very high if good infrastructure and long-term investment are required.

TECHNOLOGY FACT SHEET
REFUSE-DERIVED FUEL PRODUCTION

1. Sector: Waste Management/Energy

2. Introduction:

Jamaica produces in excess of 900,000 tonnes of municipal solid waste (MSW) annually, with high moisture content, high organic content especially from garden cuttings, furniture, textiles and paper-derived packaging. The MSW also contains significant amounts of plastics and rubber tyres.

Waste Characterization Studies (MPM, WPM, SPM & NEPM)

Composition of Household Solid Waste Collected (MPM) 2013

Waste Fraction	Percentage (%) Generated
Compostable	62.22
Paper	9.27
Plastic	12.2
Metal/Tin	2.38
Cardboard	5.46
Glass	2.81
Textile	5.09
Other	0
E-Waste	0.04
Wood/Board	0.53
Total	***100***

Despite many attempts made to manage this material in an acceptable manner, only a tiny fraction of this material is properly utilised incurring enormous cost, occasional fires and toxic emissions and health issues in open MSW locations.
Many attempts made to convert MSW into energy have not materialised as it has been considered that the combustible volumes are small, livelihoods may be affected, tipping fees would be held by the state, and government ministries have not determined the lead and beneficiary agency for such systems.
In the proposed technology, MSW may be converted into a Residue-Derived Fuel (RDF) to reduce the volume of permanent solid waste and the space required for the far future, generate electricity and maintain livelihoods.

3. Technology Name: Refuse-Derived Fuel

4. Technology Characteristics:

There are many technology options for RDF as outlined in the following table:

Technology	Advantages	limitations
1. Incineration	• Highly flexible waste type; various waste can be burnt at the same time • Reduce a lot of mass and volume • Short treatment time • High energy yield • Require small space for the system.	• High investment, operation, and maintenance cost. • The facility should have the capacity greater than 250 tons per day to be cost effective. • Advanced and emerging technology;
2. Anaerobic Digestion, AD	• Clean technology • Large amount of biodegradable waste • Simple technology; can be developed easily	• Have to campaign the organic waste separation from the beginning. • Require the development of microbial species enable to digest waste at various environmental conditions and produce high gas yield. • Require soil conditioner marketing to increase the revenues of the system.
3. Landfill Gas to Energy	• Decrease the release of methane (GHG) to the atmosphere • Decrease risk of explosion or fire hazard from landfill • Simple technology; can be developed easily in the country	• The volume of waste in landfill must be greater than 1 million ton for cost effectiveness • Hard to predict the gas generation rate due to complex phenomena governed by various factors.
4. Refuse Derived Fuel	• Clean technology • Capable of using with pyrolysis / gasification • The RDF can be stored and used when needed • Require small space for the system • Simple technology; can be developed easily in the country.	• Unable to complete the waste destruction; need a further waste treatment to complete the treatment/destruction process. • No market for the RDF just yet.

5. Gasification	• Clean technology • Reduce a lot of mass and volume • Short treatment time • High energy yield • Require small space for the system	• Must be used with a basis waste destruction process such as RDF. • Require high investment, operation and maintenance cost. • Advanced technology; cannot be developed in the country
6. Plasma Arc	• High heating temperature increases waste destruction efficiency. • Residual of the high temperature process is slag, which stabilizes hazardous substances generally found in the residual of low temperature such as ash.	• High investment, operation, and maintenance cost. •
7. Plastic waste into fuel processing technology.	• Liquid fuel can be transported easily and economically. • The fuel can be stored to use when needed. • Require small space for the system • Simple technology; can be handled by the country	• Require the effective plastic waste separation process. • Require cleaning process for the plastic waste.

(*Source*: Fact Sheet, TNA Report – Technology Needs Assessments Report For Climate Change Mitigation – Thailand)

In Jamaica's scenario, landfill gas extraction, and very high temperatures, RDF and gasification/pyrolisis technologies are options which would satisfy waste disposal MSW volume constraints for the technology, access to technology, sustainable livelihoods and desired environmental outcomes (emissions). Dual fuel technologies can be added to facilitate supplemental, alternative fossil sources such as natural gas.
The production of RDF from MSW would involve:

1. Manual and mechanised sorting – Preliminary, manual sorting and recovery of recyclable, reusable and non-combustible items such as glass bottles and metals;
2. Combustible materials such as paper, hardboard, wooden items, plastics, etc. would be retained for energy;
3. Power generation via gasification or pyrolysis, from combustible solids.

5. Country Specific/Applicability:

The solid waste facilities are islandwide, but all in close proximity to the electricity grid for the potential of grid interconnection.

Solid Waste Management Data - Jamaica

Disposal Site	Acreage	Type of Solid Waste	Volume of Solid Waste Annually Tons (2014)	Commencement of Operations	Owned By	Operated By	Current Operational Status
Riverton	106	Municipal & Hazardous	390,585	1983	UDC/KSAC	NSWMA	Active
Church Corner	3	Municipal	17,760	1980's	St. Thomas Parish Council	NSWMA	Active
Doctorswood	7.4	Municipal	17,522	1980's	Issa et al	NSWMA	Active
Hadden	9	Municipal	25,053	1980's	UC Rosal	NSWMA	Active
Tobolski	12.2	Municipal	8,342	1980's	St. Ann Bauxite Company	NSWMA	Active
Myresville	9	Municipal	15,348	1980's	Alpart Bauxite Company	NSWMA	Active
Martin's Hill	19	Municipal	61,976	1980's	UC Rosal	NSWMA	Active
Retirement	27	Municipal	153,222	1985	St. James Parish Council	NSWMA	Active

Note: Average Per Capita Generation Rate is 1kg

All sites with the exception of Doctorswood all are located in close proximity to electricity infrastructures

Jamaica is currently experiencing a solid waste crisis where continued deposition of MSW intrudes into community living spaces, pollutes ground water sources, accumulates toxic materials and produces other public health hazards and occasional fires from combustible materials cause hospitalisation of citizens in neighbouring communities and slows traffic.
The electricity supply will also be expanded and the state has a 50% renewable mandate for the grid by 2030. RDF or waste to energy has been invited as a technology for new base load generation.
Proposals to effect composting are not feasible due to low volumes of combustible materials; costliness of ventures to the state as such projects are labour-intensive; possible land constraints,; health risks from sorting the waste; and uncertainty of the commercial value of the products.
RDF will convert high volumes of the MSW and destroy toxic and hazardous materials, while incorporating the workforce in the manual sorting process, and at managerial and technical levels.

6. Status of Technology in the Country and its Future Market Potential:

Currently, there is no RDF facility in Jamaica, however, the upcoming Integrated Resource Planning process will add REN technologies and Waste-to-Energy (WTE) has been considered in a previous 115MW renewable energy generation bid.
Currently, RDF options remain the best MSW solution for Jamaica.
Norman Manley International Airport has an incinerator and can be possibly used as pilot of waste to energy.
Interest is high for local companies on the small to medium scale (20MW), government and energy producers.

7. Barriers:

- State indecision on a lead government agency;
- Unwillingness to apply the tipping fees to investors and developers of the technology;
- Environmental lobby against WTE technologies due to lack of confidence in the air pollution controls;
- Resistance by citizens involved with sorting and recycling solid waste at the waste sites;
- Hesitance to invest by technology companies due to past bid failures;
- Political interference in some of the communities around the dumps/landfills (e.g., Riverton).

8. **Benefits:**
   - Significantly resolves the solid waste problem in the country;
   - 80%-efficient conversion process;
   - Reduction of GHG emissions and overall cleaner air from fewer spontaneous fires;
   - Smaller solid waste management problem;
   - Economic benefits from lower electricity costs;
   - Energy security from use of more local energy sources;
   - New or continued employment;
   - Reduced public health impacts;
   - New expertise to be developed;
   - Additional income for municipalities.

9. **Operations:**
   High operational maintenance cost

10. **Cost:**

   USD $1,900/kW

References:

TNA Report – Technology Needs Assessment Reports For Climate Change Mitigation – Lebanon

TECHNOLOGY FACT SHEET
BIOGAS (ANAEROBIC DIGESTION)

1. **Sector:** Waste/Energy

2. **Introduction:**

The anaerobic digestion is decomposition of biodegradable material by micro-organisms in the absence of oxygen. Anaerobic digestion is often used for industrial or domestic purposes to manage waste streams. Three principal products are produced through the process of anaerobic digestion. First, the process produces a biogas, consisting mainly of CH_4 (up to >60%) and CO_2, which can be used for energy production and some moisture. Biogas is therefore the mixture of gases produced by the breakdown of organic matter in the absence of oxygen. The second product is a nutrient-rich digestate. Finally, the process results in liquid liquor that can be used as a fertilizer.
Biogas is produced from raw materials like agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. Biogas is a renewable energy source which may be used for heating, electricity and efficient stoves.

3. **Technology Name:** Biogas (Anaerobic Digestion)

4. **Technology Characteristics:**

A biogas facility with an anaerobic digester has three main components:

1. A waste collection system;
2. Anaerobic digester for the production of the biogas consisting of methane and CO_2;
3. Biogas handling system – A device that puts the biogas to use such as a combined heat and power plant. There are two basic types of digesters – Batch and Continuous:
   a. Batch-type digesters whose operation consists of loading the digester with organic materials and allowing it to digest (breakdown). The retention time depends on temperature and other factors. Once the digestion is complete, the effluent is removed and the process is repeated;
   b. Continuous digester where organic material is constantly or regularly fed into the digester. The material moves through the digester either mechanically or by the force of the new feed pushing out digested material. Continuous digesters produce biogas without the interruption of loading material and unloading effluent. They may be better suited for large-scale operations. Proper design, operation, and maintenance of continuous digesters produce a steady and predictable supply of usable biogas.

Many different variations of anaerobic digesters exist. The most common variations are:

1. Covered lagoon;
2. Completely enclosed mixed reactor;
3. Plug-flow anaerobic digester;
4. Induced blanket reactor.

5. **Country Specific/Applicability:**

The recovery of biogas through anaerobic digestion systems is a proven technology worldwide using animal waste streams or agricultural wastes. Jamaica has an abundance of both at the sites where electricity is needed and plants can be established.

6. **Status of Technology in the Country and its Future Market Potential:**

Anaerobic digestion has been practised in Jamaica for decades and the Scientific Research Council has patented options of the technology.

The technology has been used particularly on animal farms, and as other farms increase in number and complexity, their waste flow and energy requirements will also increase.

7. Barriers:

- Odour can be a problem where biogas is produced. Local air quality at such facilities is poor and a strong odour is produced by the open lagoons in particular.

8. Benefits:

The sector in which the technology is mainly applied is the agriculture sector, which is significant in the Jamaican economy. Projects using anaerobic digestion technology improve the viability of these rural enterprises. The technology is therefore capable of strengthening the backbone of the economy and subsequently, improves social development. The current waste stabilisation technique most often used at farms and industrial locations are completely enclosed mixed reactors.
The technology avoids the emission of methane as the fuel is combusted for heat or electricity.
The implementation of an anaerobic digester facility makes existing farm workplaces safer and healthier and local air quality is significantly improved.
Several economic development benefits arise from the energy production of the technology. National energy self-sufficiency is increased due to the local energy production. This also would reduce Jamaica's dependency on other countries for fossil fuel imports, which, in turn, would lead to an improved economic balance sheet of the country and a higher level of energy security.
Large amounts of animal waste can create serious environmental concerns. When animal manure enters rivers, streams or groundwater supplies, it can have environmentally detrimental effects. In addition, decomposing manure causes air quality concerns associated with ammonia emissions, and the contribution of methane emissions to global climate change. The implementation of an anaerobic digestion offers a number of air and water quality benefits. Digester systems isolate and destroy disease causing organisms that might otherwise enter surface waters and pose a risk to animal and human health. Moreover, anaerobic digesters help protect groundwater. Synthetic liners provide a high level of groundwater protection for manure management systems (EPA, 2002).
The concrete or steel in plug-flow and complete mix digesters also effectively prevent untreated manure from reaching the ground water. Biological treatment of waste, such as composting and anaerobic digestion, reduces volume of waste and therefore lowers landfill requirements. Recycling of the residual solids as fertilizer further reduces waste volume.
Climate change mitigation benefits of this technology is the prevention of methane emissions associated with conventional manure management practices. In addition, the energy produced by the biogas facility offsets the energy derived from fossil fuels. Therefore, anaerobic digesters with a biogas recovery system can help reduce overall quantities of CO_2.

9. Operations:

10.Cost:

Systems constructed in the US can have average costs of US$ 470 per cow. More generally, anaerobic systems for digestion, solids processing, and generation are expected to cost US$ 500 to US$ 800 per cow in the US.

Operating and capital costs of European Digester Systems

	Large 1 MW 5000 Cow Facility	Small 25 kW 125 Cow farm
Capital Cost	US $ 9.113.000,-	US $ 500.000,-
Annual Operating Cost	US $ 643.000,-	US $ 8.800,-
Power Sale Rate $/kW	US $ 0.06	US $ 0.06
Heat Sale $/kW	US $ 0.01	US $ 0.01
Solids Sales	US $ 700.000,-	US $ 20.000

References:

TNA Report – Technology Needs Assessment and Technology Action Plans for Climate Change Mitigation– Bhutan

TECHNOLOGY FACT SHEET
SEAWATER AIR CONDITIONING (SWAC) / DISTRICT COOLING (DC)

1. **Sector:** Cooling/Air Conditioning

2. **Introduction**:

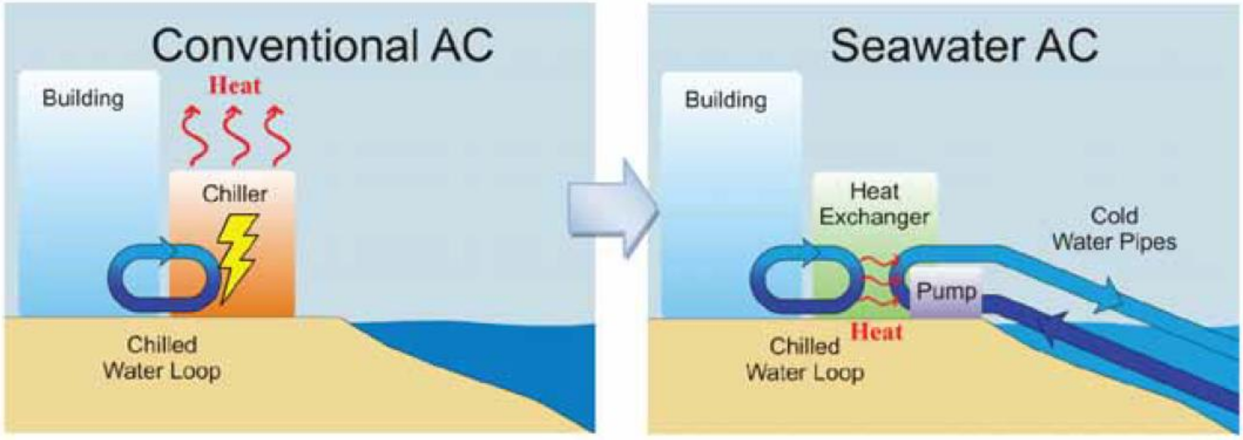
Air conditioning is typically the most energy-consuming demand for commercial buildings, especially in tropical countries where comfortable ambient air conditions are critical for many reasons, including wellness and low mortality; cold chains that preserve food and medication; improvement in learning performance; workplace productivity and safety; and business success including the hospitality sector. Space cooling needs are typically accomplished either by central air handling systems for larger buildings, or self-contained units for individual zones in smaller buildings.
Electricity consumption for cooling can often is continuous over 24 hours and so selection of more energy-efficiency cooling systems and systems with low climate impacts are desirable.
With predicted changes in the climate due to anthropogenic sources, the increase in hot weather will be disproportionately worse in developing countries, and the greatest burden of heat stress is expected. More air conditioning will become more of a necessity for mobile and stationary cooling needs.
Conventional air conditioning utilises a low-boiling point refrigerant which can undergo phase changes (liquid/gas), and remains chemically unchanged while being moved by a mechanical system throughout various pieces of equipment in a closed continuous loop. The refrigerant phase changes occur as it receives or releases heat from the occupied space where the closed system is exposed as it is compressed or depressurised. Other components, such as blowers/fans, then circulate the cooler air.
Many of these refrigerants have global warming potential (GWP) thousands of times higher than CO_2 and are being phased out for climate change (CC) benefits and protection of the ozone layer.
Seawater air conditioning (SWAC)/district cooling(DC) is an alternative cooling strategy which draws cold water from a source and exchanges the heat (heat exchanger) from the occupied environment with this cold water to effect the cooling. It uses no refrigerants and therefore, has no adverse CC impacts from refrigerants. In Jamaica, SWAC opportunities exist in the proximity of the Cayman Trench due to access to an inexhaustible source of cold, deep-sea water. In this context, a seawater air conditioning (SWAC) system might draw cold seawater from great depths (>800 m) to a cooling station. This chilled water can then be used to absorb heat from buildings and then return the warmer water to the ocean, usually at a shallower depth. Several buildings can be connected to the chilled fresh water loop, creating an option to conventional air conditioning and which requires no refrigerants. For this reason, SWAC is sometimes referred to as District Cooling because of the connectivity of multiple cooling loads in close proximity to the SWAC plant.

3. **Technology Name**: Seawater air conditioning (SWAC)/district cooling (DC)

4. **Technology Characteristics:**

The technology requires significant cold water resources near shore, high pressure pumps to suck this cold water into a heat exchanger, onshore delivery pipelines and significant off-take loads in close proximity (district). The SWAC can be linked to large water-cooled centrifugal chillers or be used as a heat sink for conventional chillers or direct cooling source.

Schematic Showing Major Conventional AC System (Left) Compared to a SWAC System (Right)



(*Source*: Development Bank of Latin America (Corporación Andina de Fomento – CAF), 2015

Seawater air conditioning has several advantages over conventional cooling. These advantages include:

- Improved energy efficiency – SWAC uses 10%–20% of the electricity of conventional cooling. This significantly reduces the operating cost and allows a SWAC developer to sell cooling at a price that is insensitive to prevailing energy costs;
- Reduced CO_2 emissions as a climate change mitigation opportunity;
- No use of refrigerants;
- More predictable operating costs over the long term, and most of the cost is in the invested capital;
- Reduced dependence on imported fuels which require foreign exchange and generate GHGs.

5. Operational Necessity:

Without this technology, air conditioning growth will take place using more refrigerants with high GWP in smaller mini-spilt and multi-split systems in the rapidly developing business and tourism sectors in Montego Bay. Electricity demand would also increase rapidly, and be fuelled by natural gas and petroleum which contribute adversely to climate change impacts.

6. Country Specific/Applicability:

An analysis of a proposed SWAC in the northern section of Jamaica was done by CAF – Development Bank of Latin America in 2015 for Montego Bay; the project shows promising returns on the investment. In the Montego Bay zone, there are large luxury hotels, new Business Process Outsourcing (BPO) operations, an airport and new housing developments which could provide a cluster of cooling load within Montego Bay.

SWAC could also utilise tariffs that favour shifting electricity loads from on-peak to off-peak hours (Time of Use tariff) and reduce the need to urgently add more fossil fuel plants as base load.

7. Status of Technology in the Country and its Future Market Potential:

Currently, SWAC does not exist in Jamaica as a cooling alternative, however, it has a future market potential due to the rapidly expanding tourism and business sectors in close proximity to cold deep water sources. SWAC is also a viable Energy as a Service (EaaS) option which shifts capital and maintenance risks from the client to the service provider. This facilitates the economical investment in air conditioning.

8. **Barriers**:

A significant disadvantage of SWAC, however, is the large up-front capital cost. SWAC is 6–9 times more expensive than conventional cooling, which represents a significant risk to a developer.

Financial analysis for a SWAC system in Montego Bay is estimated to have a capital cost of about US$ 100 million and supplies about 7,600 tons of cooling. The cooling load would therefore have to

be significantly large for viability and therefore, potential users would have to agree to costs before a project can be implemented.
SWAC systems are sensitive to natural disasters such as hurricanes and earthquakes; however, the north west of Jamaica has a lower risk profile in his regard.
An important tool in mitigating these risks is high-confidence cost estimates by obtaining as much detailed information as available on components such as:

- High-resolution bathymetry;
- Environmental risk analysis (storms incidence, earthquakes, other, etc.);
- Design and construction costs;
- Cooling load demand;
- Environmental permitting requirements and challenges;
- Electricity prices and tariffs;
- Any contingency costs.

9. Benefits:

SWAC would have significant impacts on reducing global warming by the avoidance of refrigerant use. It also shifts power demand to off-peak times, reduces electricity demand through greater efficiency, and delays the addition of new fossil fuel plants.
SWAC is often delivered as an EaaS investment allowing the client to apply resources to core operations.

The technology is modern and efficient therefore reducing energy consumption and fossil fuel consumption along the northern belt of large luxury hotels.
The lower operating costs will improve operation costs for cooling within the hotel sector, the BPO industry and other entities, thereby increasing profitability, and encouraging further development and employment.

10. **Operations**:

11.Cost:

An analysis of a proposed SWAC in the northern section of Jamaica was conducted by CAF – Latin America Development Bank in 2015 for Montego Bay. The evaluation indicated that a SWAC system in Montego Bay was estimated to have a capital cost of about US$100 million and supply about 7,600 tons of cooling. Levelized costs at US$3,458/ton/year are, however, estimated to be 34% lower than conventional AC systems for which levelized costs are estimated at US$5,247/ton/year. This levelized cost of SWAC in Montego Bay indicates that the city is a good candidate site for SWAC development. The simple payback period for SWAC varies from 8.7 years at the minimum electrical rate (US$0.25/kW-hr) to 4.8 years at the maximum rate (US$0.45/kW-hr).
The operating cost for conventional cooling is 4.4 times higher than that for SWAC, with over US$20 million per year spent on electricity.

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TECHNOLOGY FACT SHEET
SOLAR AIR CONDITIONING

1. **Sector:** Energy and Cooling Subsectors

2. Introduction:

Air conditioning is typically the most energy-consuming demand for commercial buildings, especially in tropical countries where comfortable ambient air conditions are critical for many reasons including wellness and low mortality; cold chains that preserve food and medication; improvement in learning performance; workplace productivity and safety; and business success, including the hospitality sector. Space cooling needs are typically accomplished either by central air handling systems for larger buildings, or self-contained units for individual zones in smaller buildings.
Electricity consumption for cooling can often is continuous over 24 hours and so selection of more energy-efficiency cooling systems and systems with low climate impacts are desirable.
With predicted changes in the climate due to anthropogenic sources, the increase in hot weather will be disproportionately worse in developing countries, and the greatest burden of heat stress is expected. Air conditioning will therefore become more of a necessity for mobile and stationary cooling needs.
However, meeting cooling needs can have adverse impacts on climate change due to the characteristics of the refrigerants and the efficiency of the equipment used to achieve the cooling effect. Vast amount energy is required to operate typical cooling equipment, such as air conditioners and refrigerators. Moreover, many refrigerant gasses have a high global warming potential (GWP); when these gasses leak into the atmosphere, they have a significant impact on greenhouse gas emissions. Many of these refrigerants have global warming potential (GWP) thousands of times higher than CO_2 and are being phased out for climate change (CC) benefits and protection of the ozone layer. With high electricity prices and reliance on imported fossil fuels, residents and businesses suffer from expensive power bills, utilities struggle to meet peak energy demand, and governments are saddled with increasing dependence on imported energy (with prices that fluctuate).
Solar air conditioning systems use both electrical power from the grid and the sun's energy to effect the cooling cycles with similar performance to traditional air-conditioners, but with less electricity demand from the grid. Eighty-two percent (82%) of the grid's energy supply comes from fossil fuels which produce polluting GHGs.

3. Technology Name: Solar air conditioning

4. Technology Characteristics:

Conventional air conditioning utilises a low-boiling point refrigerant which can undergo phase changes (liquid/gas), remains chemically unchanged while being moved by a mechanical system throughout various pieces of equipment in a closed continuous loop. The refrigerant phase changes occur as it receives or releases heat from the occupied space where the closed system is exposed and as it is compressed or depressurised. Other components such as blowers/fans then circulate the cooler air.
Solar air conditioning systems use both electrical power to operate fans and electric control components and the solar thermal energy as the thermal source to evaporate the refrigerant liquid in the condenser, and maintain the refrigeration cycle while the compressor cycles off.
These solar sources reduce the amount of electrical energy from the grid required to run the compressor by absorbing thermal solar energy via a solar thermal collector (glass tubes) with copper heat conducting inner coils then releasing it to effect the phase change in the refrigerant. Some systems also utilise solar PV panels to supplement the source of electrical energy.
The collector, compressor and the condenser have been designed to work in tandem to allow a smaller compressor to be used. The smaller compressor consumes less electricity and combined with the solar collector, the air conditioners optimise energy savings and reduce running costs. Solar-assisted air conditioners can therefore save 30%–50 % of electricity relative to traditional air conditioners.

5. Country Specific/Applicability:

It has a wide target market – hotels, restaurants, hospitals, factories, schools, convention centres, and high-end residential units. It requires minimal direct sunlight exposure, ambient heat and heat blown by the condenser is also utilised.

6. Status of Technology in the Country and its Future Market Potential:

The technology is available in Jamaica primarily from CARISOL, however, most sales are related to traditional air conditioner systems with refrigerants of high GWP such as HFC–143a with GWP of 5,000 over a 20-year duration.

COMPANY	**AC SIZES**
Caribbean Solar Energy Ltd (Carisol)	9000BTU 12000BTU 18000BTU
	24000BTU 36000BTU 60000BTU

The future market is significant as cooling services are essential for achieving many desirable human and developmental outcomes and becoming more critical with increasing temperatures due to climate change. Air conditioning will continue to be needed for controlled indoor conditions – hospitals, schools, office buildings, factories, and so on. It improves comfort, productivity and safety. These positive outcomes have favourable impacts on overall national development objectives.

In addition, Jamaica is committed to phasing out of Ozone Depleting Substances (ODSs) under the Montreal Protocol of 1993 and under the K*igali Amendment* project the Government, the cooling industry, and users have demonstrated a significant will to migrate towards more energy- efficient technologies which have lower environmental atmospheric impacts, through the use of policy, legislation, and international collaborations. So, Jamaica is pursuing cooling which is efficient, with low climate impacts by collaborating with UN Environment's United for Efficiency's (U4E) in the development of a National Cooling Strategy (JNCS). The JNCS has been prepared with a view of key trends for cooling technologies and best practices, taking into account the complex interplay of energy, climate, ozone and pollution considerations. The strategy includes solar air conditioners.

Hybrid thermal systems which have been used in Jamaica (Digicel building) and has been proven to operate efficiently.

7. Barriers:

8. Benefits:

- Reduction in the use of refrigerants with high GWPs;
- Energy efficiency leading to reduced energy use and lower reliance on the fossil fuel-dominant grid.

9. Operations:

10. Cost:

References:

TECHNOLOGY FACT SHEET
ABOVE GROUND LIGHT RAIL TRANSIT (LRT)

1. Sector:

2. Introduction:
In Jamaica, the roadways are dominated by private vehicles at a ratio of 188 motor vehicles per 1,000 and 138 passenger cars per 1,000 people leading to regular traffic build-ups during three main peak hours each day. There is also a public transportation system in the form of buses and licensed motor cars; however, they are also subject to traffic jams with high emissions while idling. Existing aboveground trains are currently dedicated to transportation of industrial products like bauxite and alumina, limestone, alcohol and molasses and other large volume products.

Light rail or light rail transit (LRT) is a form of urban rail public mass transportation that generally has a lower capacity and lower speed than heavy rail and metro systems. The term is typically used to refer to rail systems with rapid transit-style features that usually use electric rail cars operating mostly in private rights-of-way such as above ground railway systems or dedicated right-of-way lanes. Therefore, there is no mixing of traffic and the railway system.

Mass transit, such as LRT, can move large numbers of people at less cost to the individual and society. It has been observed that cities and countries that have high rates of mass transit spend much less on transport overall than others. Mass transit also makes it easier for people who can't afford private vehicles, or can't drive them. Mass transit also operates in a smaller space, thus saving space and allowing greater urban density and a denser city's infrastructure costs less per resident. A good mass transit system provides services that are frequent, fast, punctual, safe, comfortable, clean and affordable. Mass transit, like LRT, leads to greater equality and social inclusion as more people can use it to meet their needs, that is, to get to health and other services, social connections and work.

3. **Technology Name:** Above Ground Light Rail Transit (LRT)

4. Technology Characteristics:
There are variations in mass transit options utilising the light rail transit modality. The engines are driven by electric motors powered from the grid via overhead electrical lines. Power supply systems vary, but the voltages are nominal and vary depending on load and distance from the substations.

Many are supplied by DC current and modern trams and trains use on-board solid-state electronics to convert these supplies to run three-phase AC induction motors. Where AC supplies are used, they are single-phase, except where marked three-phase. Conductors are typically overhead lines or a conductor ground rail which is a third rail to one side of the running rails. The conductor rail can be:

- Top contact: oldest, least safe, affected by water, ice, snow and debris;
- Side contact: newer, safer, less affected by water, ice, snow and debris like leaves;
- Bottom contact: newer, safer, least affected by water, ice, snow, and leaves.

The transit system has a few coaches to allow flexibility in the urban space. They often carry the equivalent to 2 or 3 automobiles in one trip and so require much less fuel/energy to move each person and with less emissions. Emissions from internal-combustion engines are generally proportional to fuel consumption, and therefore, a full LRT will produce less pollution per person/trip than an automobile, especially as they do not share the same ground space as the traffic and have less idle time. LRT coaches may run on metal or rubber wheels.

5. Country Specific/Applicability:
Jamaica's traffic challenges are highlighted by main routes often coming to a standstill for periods up to an hour and commuters opt to begin their journey very early in the mornings or later after working hours to avoid the delays. This affects the level of work productivity by employees.

Motor vehicles are expensive, and though there are attractive loans for purchase, meeting the criteria for affordability is not possible for the majority of commuters.
The bus system is functional, however, they share the same routes where traffic occurs and commuters have longer wait times in bus depots which are inconvenient for working commuters. This affects the level of employee productivity.

The road taxi services are often not comfortable and drivers are commonly less sensitive to safety concerns. These are also often caught in traffic.

LRT in the Jamaican context would avoid the traffic delays; have no emissions from operation (and little idle time) as they are electrically powered. Light rail transit can be powered by renewable energy on dedicated electrical lines, thus further reducing the contribution to GHGs and with DC, conductors are more efficient in transmission of electricity than the central grid.

6. Status of Technology in the Country and its Future Market Potential:
No LRT exists, but the current infrastructural build-out of wide lane main corridors may be able to accommodate the addition of dedicated right-of-ways and move large numbers of commuters between distant and populous locations.

7. Barriers:
LRT has the following challenges that should be taken into account:
- Public acceptance of the LRT and awareness of the diverse benefits (social, environmental, etc.) are unknown;
- Appropriate consideration of non-technical aspects, such as which routes, will be selected for LRT. Also, Jamaican roads are limited in the number of lanes and adding a dedicated lane may aggravate traffic congestion or disrupt business during construction of dedicated right-of-ways;
- Careful planning is critical, for example, in order to avoid bus overcrowding during peak periods, an issue which occurs frequently;
- Possible resistance by existing bus operators, with negative consequences on the initial implementation. This has occurred when buses in the public bus service were increased in number and size;
- High safety issue due to the risk of electrocution on conductors;
- Many mass transit options are not profitable in the traditional commercial sense, so they may be seen as undesirable by planners, however, the positive gains on common good, such as national productivity, clean air, convenience and affordability to the commuters, are strong reasons for consideration. These benefits have to be promoted strongly for successful implementation;
- Private motor vehicle ownership is associated with personal ambitions and status and may be a psychological barrier to optimal use by potential commuters.

8. Benefits:
Mass transit is one of the main components in a sustainable, low-carbon transport future. Since mass transit moves more people at less cost, it leads to reduced private vehicle use, thereby causing reductions in greenhouse gas emissions and traffic congestion. LRTs can therefore make an important contribution to a sustainable urban transport system. It is more energy-efficient than conventional bus systems per person-kilometre due to the higher speeds and higher capacity buses.

Also, it may improve the modal split between private vehicles and public transportation, towards more use of public transport. Thereby, it contributes to the following aspects of sustainable development:
(i) Reduction of air pollution (clean air) and national health;
(ii) Reduction of GHG emissions;
(iii) Congestion reduction;
(iv) Increase in energy supply security, due to reduction for imported oil;
(v) Social equality and poverty reduction by providing affordable high-quality transport;
(vi) Economic prosperity by reducing travel times and congestion;
(vii) National work productivity, commuter convenience;

(viii) Increased energy supply security due to use of REN and reduction of imported oil or gas for the grid.

9. Operations:

Operation is expensive due to the need to ensure public safety as it pertains to sanitation, electrical risks and accidents; reliability of the LRT to maintain preference as a transportation mode and thus optimal use; grid or power generation charges/tariffs; and maintenance of conductors.

Technical and specialised staff will also be needed.

The costs for operations may not be recouped from fares charged and therefore, state budget allocations should be expected.

10.Cost:

When assessing the benefits and costs of mass transit, many factors need to be taken into account. These factors include an assessment of travel time savings, reductions in fuel, pollution and accidents, and space saved. Transit systems can be financed and managed through public-private-partnerships, with private partners building the system, operating it, or both. Public funds may also be available through the international development banks, regional development banks or bilateral development cooperation arrangements. In addition, climate change funding mechanisms may fund transit projects. Transit operating costs can, of course, be at least partially covered by passenger fares. Almost all modern public transit systems are subsidised by government, and each city or locality must decide the amount of subsidy it can afford to provide. Higher capacity systems cost more to put in, but offer much more potential reduction in total transport costs and GHG emissions.

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TECHNOLOGY FACT SHEET
NATURAL REFRIGERANTS

1. **Sector:** Energy and Cooling Subsectors

2. Introduction:
Air conditioning is typically the most energy-consuming demand for commercial buildings, especially in tropical countries where comfortable ambient air conditions are critical for many reasons, including wellness and low mortality; cold chains that preserve food and medication; improvement in learning performance; workplace productivity and safety; and business success, including the hospitality sector.

Space cooling needs are typically accomplished either by central air handling systems for larger buildings, or self-contained units for individual zones in smaller buildings.

Electricity consumption for cooling can often is continuous over 24 hours and so selection of more energy-efficiency cooling systems and systems with low climate impacts are desirable.

With predicted changes in the climate due to anthropogenic sources, the increase in hot weather will be disproportionately worse in developing countries where the greatest burden of heat stress is expected. Air conditioning will become more of a necessity for mobile and stationary cooling needs.

However, meeting cooling needs can have adverse impacts on climate change due to the characteristics of the refrigerants and the efficiency of the equipment used to achieve the cooling effect. Vast amount energy is required to operate typical cooling equipment, such as air conditioners and refrigerators. Moreover, many refrigerant gasses have a high global warming potential (GWP), and when these gasses leak into the atmosphere, they have a significant impact on greenhouse gas emissions. Many of these refrigerants have global warming potential (GWP) thousands of times higher than CO_2 and are being phased out for climate change (CC) benefits and protection of the ozone layer. With high electricity prices and reliance on imported fossil fuels, residents and businesses suffer from expensive power bills, utilities struggle to meet peak energy demand, and governments are saddled with increasing dependence on imported energy (with prices that fluctuate).

The use of natural substances (carbon dioxide, ammonia, petroleum-derived compounds, oxygen compounds, nitrogen compounds and elemental gases) instead of hydrofluorocarbon (HFC), hydrochlorofluorocarbon (HCFC) and chlorofluorocarbon (CFC) refrigerants can avoid contributions to anthropogenic climate change.

3. Technology Name: Natural Refrigerants

4. Technology Characteristics:
Conventional air conditioning utilises low-boiling point artificial refrigerants especially HCFCs, HFCs, and CFCs which can undergo phase changes (liquid/gas) and remain chemically unchanged while being moved by a mechanical system throughout various pieces of equipment in a closed continuous loop. The refrigerant phase changes occur as it receives or releases heat from the occupied space where the closed system is exposed and as it is compressed or depressurised. Other components, such as blowers/fans, then circulate the cooler air.

Natural refrigerants are primarily natural molecules found in the environment and which can be utilised as refrigerants due to their similar characteristics of low-boiling points, chemical stability, and the ability to undergo phase changes, while absorbing and releasing thermal energy. They are particularly beneficial, having zero ozone depletion potential (ODP) and very low or zero global warming potential (GWP) (See table below).

Common Natural Refrigerants

REFRIGERANT	ASHRE NUMBER	MOLECULAR FORMULA	GWP	ODP
CARBON DIOXIDE	R-744	CO_2	1	0
PROPANE	R-290	C_3H_8	3.3	0
ISOBUTANE	R-600a	C_4H_{10}	4	0
PROPYLENE	R-1270	C_3H_6	1.8	0
AMMONIA	R-717	NH_3	0	0
WATER	R-718	H_2O	-	0
AIR	R-729	N/A	-	0

Source: Modified from https://natref.carel.com/what-are-natural-refrigerants, (2019).

These natural refrigerants are all considered alternatives to synthetic refrigerants.

Carbon Dioxide:

Since carbon dioxide (R-744) is produced as a by-product from industrial processes, it technically does not contribute to global warming.

The refrigerant (R-744) is non-flammable, non-toxic and safe; has an excellent coefficient of thermal transfer; and is extremely low viscosity and completely compatibility with normal lubricants. On the downside, system-operating pressures are very high, presenting technical challenges for compressors, valves, and piping.

R-744 is available on the cooling market at low prices and is popularly used as an alternative to synthetic refrigerants in supermarket refrigeration, heat pump water heaters, commercial refrigerated vending machines, industrial and transport refrigeration systems or vehicle air conditioning systems.

Hydrocarbons:

Hydrocarbons refrigerants are flammable, non-toxic, harmless to the ozone layer and have a very low GWP. High flammability is the major challenge with hydrocarbon refrigerants. The most common hydrocarbons used in heating, ventilation, air conditioning, and refrigeration (HVAC/R) applications are propane (R-290), isobutane (R-600a) and propylene (R-1270). Hydrocarbon blends (e.g., R-441A) are also well known.

Hydrocarbons are particularly beneficial as they operate at standard working pressures and have excellent thermodynamic properties, leading to high energy efficiency with performance expected to be equal to or better than R-410A. The latent heat of vaporisation of hydrocarbons is almost two times higher than that of the most common HFC refrigerants (e.g., R-134a, R-404A and R-507). The result would be a higher cooling/heating effect for the same refrigerant mass flow. Pure R600a and isobutene mixtures can replace R12 and R134a.

Pure hydrocarbons and blends have wide applications including air conditioning, chillers, domestic and industrial refrigeration, beverage coolers, vending machines, mobile refrigeration, heat pumps and water heaters.

Ammonia:

Ammonia (R-717) is a mildly flammable, toxic substance and corrosive refrigerant. R-717 is easily detected by its strong pungent odour. ODP and GWP values are both zero.

R-717 is also widely available on the cooling market at very low prices and a good substitute for banned R22. At standard operating pressures, it has good thermodynamic properties, and among refrigerants, it has the highest energy efficiency for both medium and low temperature operations. Ammonia is cost-effective for large capacity units in the commercial and industrial refrigeration and district heating applications (e.g., vapor compression chillers, absorption systems) and some restricted residential and light commercial AC equipment.

Water:

Water (R-718) as a refrigerant, is utilised in developmental chillers; it requires large spaces and the use of complex compressor technology.

5. Country Specific/Applicability:

Natural refrigerants have a wide target market potential for large HVAC systems such as in hotels, restaurants, hospitals, factory, schools and convention centres, and high-end residential units.

Jamaica has a significant tourism and hospitality sector with large all-inclusive hotels. The business processing outsourcing industry is also growing rapidly. Such sectors can utilise natural refrigerants to mitigate the impacts of artificial refrigerants.

6. Status of Technology in the Country and its Future Market Potential:

Industries typically use artificial refrigerants.

The future market is significant as cooling services are essential for achieving many desirable human and developmental outcomes and is becoming more critical with increasing temperatures due to climate change. Air conditioning will continue to be needed for controlled indoor conditions hospitals, schools, office buildings, factories, and similar type facilities. It improves comfort, productivity and safety. These positive outcomes have favourable impacts on overall national development objectives.

In addition, Jamaica committed to phase out of Ozone Depleting Substances (ODSs) under the Montreal Protocol in 1993 and under the K*igali Amendment*, the Government, the cooling industry, and users have demonstrated a significant will to migrate towards more energy efficient technologies which have lower environmental atmospheric impacts, through the use of policy, legislation, and international collaborations. Jamaica is therefore pursuing cooling which is efficient and has low climate impacts by collaborating with UN Environment's United for Efficiency's (U4E) in the development of a National Cooling Strategy (JNCS). The JNCS has been prepared to reflect a range of key trends for cooling technologies and best practices, taking into account the complex interplay of energy, climate, ozone and pollution considerations. The strategy includes natural refrigerants.

7. Barriers:

Some of the natural refrigerants are hazardous (especially for compounds such as ammonia and hydrocarbon blend refrigerants) and the cooling industry is not accustomed to handling them, therefore, practical hands-on training is needed for service technicians. Training institutions will also require capacity development intervention. In smaller refrigeration systems, for example, where hydrocarbon options (such as R290 which is refrigerant grade propane) are often flammable, toxic or classified as high-pressure refrigerants, training should include methods for safe handling. With the risk of fires or explosion with improper handling, proper training of customs officers, RAC technicians, manufacturers, operators, trainers of trainers and waste handlers, special sensitisation will be required. For larger commercial systems used for storage, alternatives such as ammonia are considered a high health hazard because it is corrosive to the skin, eyes, and lungs. Extreme exposure (300 ppm) is potentially fatal or dangerous, and ammonia is flammable at concentrations of approximately 15% to 28% by volume in air, especially when mixed with lubricating oils.

8. Benefits:

Reduction in the use of refrigerants with high GWPs and therefore reduced contributions to CC

9. Operations:

10. Cost:

References:

Appendix IV: Multi-Criteria Scores for the Technology Needs Assessment for Jamaica

MCA Scores for the Technology Options for the Agriculture Sector (Adaptation)

	Costs		Benefits				
			Economic			Social	Climate
	Capital Cost	Operational and Maintenance Cost	Increase in yeild for farmers	Technology can be adoted across Jamaica	Suitable for vulnerable farmers	Increases the scale of an exisitng technology	Adaption to climcate change
1. Sprinkler and Drip Irrigation System	87.5	25	75	82.5	90	92.5	99
2. Rainwater Harvesting Technology	60	20	55	95	97.5	85	95
3. Mulching	45	40	37.5	55	72.5	27.5	70
4. Ecological Pest Management	65	62.5	30	98	50	52.5	72.5
5. Livestock Disease Management	75	47.5	60	72.5	69	55	77.5
6. Reforestation/Afforestation	75	30	17.5	85	93.5	42.5	95
7. Agro-Ecological Zones	77.5	75	47.5	65	42.5	77.5	57.5
8. Early Warning System	40	30	22.5	82.5	65	69	87.5
	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
Criterion weight	25	15	15	15	5	10	15

MCA Weighted Scores for the Technology Options for the Agriculture Sector (Adaptation)

	Costs		Benefits					Total score
			Economic			Social	Climate	
	Capital Cost	Operational and Maintenance Cost	Increase in yeild for farmers	Technology can be adoted across Jamaica	Suitable for vulnerable farmers	Increases the scale of an exisitng technology	Adaption to climcate change	
1. Sprinkler and Drip Irrigation System	2187.5	375	1125	1237.5	450	925	1485	7785
2. Rainwater Harvesting Technology	1500	300	825	1425	487.5	850	1425	6813
3. Mulching	1125	600	562.5	825	362.5	275	1050	4800
4. Ecological Pest Management	1625	937.5	450	1470	250	525	1087.5	6345
5. Livestock Disease Management	1875	712.5	900	1087.5	345	550	1162.5	6633
6. Reforestation/Afforestation	1875	450	262.5	1275	467.5	425	1425	6180
7. Agro-Economic Zones	1937.5	1125	712.5	975	212.5	775	862.5	6600
8. Early Warning System	1000	450	337.5	1237.5	325	690	1312.5	5353
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
Criterion weight	25	15	15	15	5	10	15	100

MCA Scores for Technology Options for Coastal Resources (Adaptation)

	Costs		Benefits						
			Economic		Social			Environmental	Climate related
	Capital Cost	Operational and Maintenance Cost	Protection of coastal infrastructure	Restoration and protection of coastal and marine resources	Protection of livelihoods	Promotes resilience in coastal communities	Protection of coastal property	Restoration of coastal and marine ecosystems	Ability to adapt to the effects of climate change
1.Coral Reef Ecosystem Restoration	60	20	60	80	70	50	60	82.5	45
2.Wetland Restoration	80	60	90	65	80	75	85	60	90
3.Beach Nourishment	20	30	70	55	55	60	50	20	50
4. Rock Reventments	50	90	90	20	70	70	85	10	80
	0=very high cost --> 100=very low cost	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
Criterion weight	15	10	20	10	5	5	5	20	10

MCA Weighted Scores for Technology Options for Coastal Resources (Adaptation)

	Costs		Benefits							Total score
			Economic		Social				Climate related	
	Capital Cost	Operational and Maintenance Cost	Protection of coastal infrastructure	Restoration and protection of coastal and marine resources	Protection of livelihoods	Promotes resilience in coastal communities	Protection of coastal property	Restoration of coastal and marine ecosystems	Ability to adapt to the effects of climate change	
1.Coral Reef Ecosystem Restoration	900	200	1200	800	350	250	300	1650	450	6100
2.Wetland Restoration	1200	600	1800	650	400	375	425	1200	900	7550
3.Beach Nourishment	300	300	1400	550	275	300	250	400	500	4275
4. Rock Revetments	750	900	1800	200	350	350	425	200	800	5775
Criterion weight	15	10	20	10	5	5	5	20	10	100

MCA Scores for Technology Options for Water Resources (Adaptation)

	Costs		Benefits				
			Economic		Social	Environmental	Climate related
	Capital Cost	Operational and Maintenance Cost	Creates Opportunities for Investment	Reduce Cost of Water to Consumers	Improved access to clean water	Promotes efficient use of water	Adapting to the effects of climate change
1. Desalination	10	10	35	23.75	77.5	70	75
2. Artifical Recharge of Aquifers	45	70	26.25	47.5	72.5	78.75	80
3. Creation and Restoration of Minor Tank Networks	65	71.25	28.75	66.25	63.75	88.75	95
4. Rainwater Harvesting and Restoring of barbeque networks	77.5	77.5	40	76.25	63.75	88.75	95
5. Water Reclamation and Reuse	35	41.25	40	61.25	61.25	90	90
	0=very high cost --> 100=very low cost	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
Criterion weight	10	10	10	25	15	25	5

MCA Weighted Scores for Technology Options for Water Resources (Adaptation)

	Costs		Benefits					Total score
			Economic		Social		Climate related	
	Capital Cost	al and Mainten	pportunites for In	ost of Water to C	d access to cleo a	tes efficient use o	fpting to the effects of climate ch	nge
1. Desalination	100	100	350	593.75	1162.5	1750	375	4431
2. Artifical Recharge of Aquifers	450	700	262.5	1187.5	1087.5	1968.75	400	6056
3. Creation and Restoration of Minor Tank Networks	650	712.5	287.5	1656.25	956.25	2218.75	475	6956
4. Rainwater Harvesting and Restoring of barbeque networks	775	775	400	1906.25	956.25	2218.75	475	7506
5. Water Reclamation and Reuse	350	412.5	400	1531.25	918.75	2250	450	6313
Criterion weight	10	10	10	25	15	25	5	100

MCA Scores for Technology Options for the Agriculture Sector (Mitigation)

	Costs		Benefits					
			Economic			Social		Environmental
	Capital Cost	Operational and Maintenance Cost	Increase in yield for farmers	technology can be adopted across Jamaica	Suitable for vulnerable farmers	Increases the scale of an existing technology	Ease of adoption by farmers across Jamaica	Mitigation or adaption to climate change
1. Cropping Systems	20	20	80	100	60	100	100	100
2. Irrigation	80	10	80	100	80	30	30	100
3. Fodder Banks and Feeding Fields	30	10	80	100	60	100	100	100
4. Concentrating Solar Power	90	50	0	10	5	100	100	100
5. Solar-Powered Water Irrigation	90	50	0	10	50	80	80	100
6. Aerobic Biological Treatment (Composting)	20	10	100	100	70	100	100	100
	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 low --> 100= Very high
Criterion weight	25	15	15	5	5	10	10	15

MCA Weighted Scores for Technology Options for the Agriculture Sector (Mitigation)

Decision Matrix: Weighted Scores									
	Costs		Benefits						Total score
			Economic			Social			
	Capital Cost	al and Mainten	ase in yeild for fa	can be adoted acr	for vulnerable	cale of an exisif	ion by farmers a	adaption to clir	
1. Cropping Systems	500	300	1200	500	300	1000	1000	1500	6300
2. Irrigation	2000	150	1200	500	400	300	300	1500	6350
3. Fodder Banks and Feeding Fields	750	150	1200	500	300	1000	1000	1500	6400
4. Concentrating Solar Power	2250	750	0	50	25	1000	1000	1500	6575
5. Solar-Powered Water Irrigation	2250	750	0	50	250	800	800	1500	6400
6. Aerobic Biological Treatment (Composting)	500	150	1500	500	350	1000	1000	1500	6500
Criterion weight	25	15	15	5	5	10	10	15	100

MCA Scores for Technology Options for the Energy Sector (Mitigation)

	Costs		Benefits									
			Economic			Social				Environmental		Climate related
	Capital Cost	Operational and Maintenance Cost	Improves consumer cost of energy	Promotes opportunities for Investment	Creates positive externalities*	Improves quality of life in Jamaica	Creates greater access to energy	Positive impact on local towns and communities	Promotes Energy security in Jamaica	Reduction in GHG Emissions	Promotes the protection of the environment (land and marine ecosystems)	Ability to mitigate against climate change
1. Refuse Derived Fuel Production	12.5	7.5	55	95	75	80	60	85	95	70	75	65
2. Biogas	25	30	55	90	92.5	80	80	90	95	75	65	75
3. Seawater Air Conditioning (SWAC)	0	10	45	40	40	60	15	40	55	70	10	45
4. Solar Air Conditioning	45	60	35	35	35	70	50	35	55	70	60	55
5. Above-ground Light Rail	5	25	5	45	50	80	5	70	30	75	50	60
6. Concentrated Solar Power	5	45	50	50	55	50	45	45	90	90	70	75
7. Natural Refrigerants	30	60	5	50	90	90	20	85	5	100	95	90
	0=very high cost --> 100=very low cost	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 low --> 100= Very high	0= Very low --> 100= Very high	0= Very low --> 100= Very high
Criterion weight	15	12	3	9	5	3	3	3	10	10	12	15

MCA Weighted Scores for Technology Options for the Energy Sector (Mitigation)

	Costs		Benefits										Total score
			Economic			Social			Environmental			Climate related	
	Capital Cost	Operational and Maintenance Cost	Improves consumer cost of energy	Promotes opportunities for Investment	Creates positive externalities*	Improves quality of life in Jamaica	Creates greater access to energy	Positive impact on local towns and communities	Promotes Energy security in Jamaica	Reduction in GHG Emissions	Promotes the protection of the environment (land and marine ecosystems)	Ability to mitigate against climate change	
1. Refuse Derived Fuel Production	187.5	90	165	855	375	240	180	255	950	700	900	975	5873
2. Biogas	375	360	165	810	462.5	240	240	270	950	750	780	1125	6528
3. Seawater Air Conditioning (SWAC)	0	120	135	360	200	180	45	120	550	700	120	675	3205
4. Solar Air Conditioning	675	720	105	315	175	210	150	105	550	700	720	825	5250
5. Above-ground Light Rail	75	300	15	405	250	240	15	210	300	750	600	900	4060
6. Concentrated Solar Power	75	540	150	450	275	150	135	135	900	900	840	1125	5675
7. Natural Refrigerants	450	720	15	450	450	270	60	255	50	1000	1140	1350	6210
Criterion weight	15	12	3	9	5	3	3	3	10	10	12	15	100