Jamaica

BARRIER ANALYSIS AND ENABLING FRAMEWORK REPORT

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Barrier Analysis and Enabling Framework

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BARRIER ANALYSIS AND ENABLING FRAMEWORK

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Abbreviations

BAEF	Barrier Analysis and Enabling Framework
CAF	Customs Administrative Fee
CARDI	Caribbean Agricultural Research and Development Institute
CASE	College of Agriculture, Science and Education
CCD	Climate Change Division
CET	Common External Tariff
CH_4	Methane
CMS	Centre for Marine Sciences
CO_2	Carbon Dioxide
CO_{2e}	Carbon Dioxide Equivalent
CSGM	Climate Studies Group Mona
CSP	Concentrated Solar Power
DBJ	Development Bank of Jamaica
DEFRA	Department for Environment, Food and Rural Affairs
DTU	Technical University of Denmark
EFJ	Environmental Foundation of Jamaica
EfW	Energy from Waste
ESL	Environmental Solutions Limited
EST	Environmentally Sound Technology
FAO	Food and Agriculture Organization
FIT	Feed-in Tariff
GCT	General Consumption Tax
GDP	Gross domestic product
GEF	Global Environment Facility
Gg	Giga tonnes
GHG	Greenhouse Gas
GoJ	Government of Jamaica
GWh/yr	Gigawatt hours per year
IDB	Inter-American Development Bank
IRP	Integrated Resource Plan
IWEco Project	Integrating Water, Land and Ecosystems Management in Caribbean Small Island Developing States
JAMIN	Jamaica Awareness of Mangroves in Nature
JCA	Jamaica Customs Agency
JCCCP	Japan Caribbean Climate Change Partnership
JPSCo	Jamaica Public Service Company
JSIF	Jamaica Social Investment Fund
kg	Kilogram
kJ	Kilojoule
KMA	Kingston Metropolitan Area
kW	Kilowatt
kWe	Kilowatt-electric
kWh	Kilowatt-hour
MCA	Multi-Criteria Analysis
MEGJC	Ministry of Economic Growth and Job Creation
Met Office	Meteorological Office of Jamaica
MGD	Mines and Geology Department
MICAF	Ministry of Industry, Commerce, Agriculture and Fisheries
MJ	Megajoule

MLGCD	Ministry of Local Government and Community Development
MOHW	Ministry of Health and Wellness
MSW	Municipal Solid Waste
Mt	Mega tonnes
MW	Megawatt
MWh	Megawatt-hour
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
NEP	National Energy Policy
NEPA	National Environment and Planning Agency
NEPT	Negril Area Environmental Protection Trust
NIC	National Irrigation Commission
N_2O	Nitrous oxide
NSWMA	National Solid Waste Management Authority
NWA	National Works Agency
NWC	National Water Commission
OHS	Occupational Health and Safety
OUR	Office of Utilities Regulation
PCJ	Petroleum Corporation of Jamaica
ppt	Part per thousand
PV	Photovoltaic
RADA	Rural Agricultural Development Authority
R&D	Research and Development
RDF	Refuse Derived Fuel
RFP	Request for Proposal
ROI	Return on Investment
RWH	Rainwater Harvesting
RWSL	Rural Water Supply Limited
SDC	Social Development Commission
SWTP	Soapberry Wastewater Treatment Plant
TAP	Technology Action Plan
TEF	Tourism Enhancement Fund
The UWI	The University of the West Indies
TNA	Technology Needs Assessment
TNC	Third National Communication
UDP	UNEP DTU Partnership
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UTech, Ja	The University of Technology, Jamaica
UK	United Kingdom
UV	Ultraviolet
WHO	World Health Organization
WRA	Water Resources Authority
WTE	Waste-to-energy

EXECUTIVE SUMMARY

This Barrier Analysis and Enabling Framework (BAEF) Report identifies and summarises potential barriers to the deployment and diffusion of adaptation and mitigation technologies identified for Agriculture, Water Resources, Coastal Resources, and the Energy Sector in Jamaica. These four sectors were identified by the Technology Needs Assessment (TNA) Steering Committee of the Government of Jamaica in accordance with the sectors identified in the National Climate Change Policy (2015) as particularly vulnerable to the impacts of climate change. The first step in the TNA process is the identification of technologies to meet adaptation and mitigation interventions deemed priorities for the selected sectors.

The climate technologies identified and prioritized through an extensive process of stakeholder consultations, document review, and TNA Multi-Criteria Analysis are presented below in Table ES-1.

Table ES-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 Irrigation
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

The second stage of the TNA process entailed analysis and prioritization of potential barriers and measures to overcome the challenges to implementation. Sector working group consultations and expert advice guided prioritization as well as market categorization and identification of root causes. Cross-sectoral discussions further assisted the formulation and outline of the enabling framework to overcome the identified barriers.

Market categorization of barriers relates to the potential cost and funding of the proposed intervention. Categorization of the technologies is shown below in Table ES-2. Barriers were further analysed in terms of financial and non-financial categories, and root causes of problems were identified to inform crafting of the enabling framework for overcoming barriers.

Adaptation technologies were selected for the Agriculture Sector, Water Resources and Coastal Resources. Mitigation technologies were selected for the Agriculture Sector and the Energy Sector.

Table ES-2: Market Categories for the prioritized technologies

Sector	Prioritized Technologies	Technology Market Categorization
Agriculture Sector	1. Drip and Sprinkler Irrigation	Consumer Good
	2. Rainwater Harvesting for Irrigation	Consumer Good
Water Resources	3. Community Scale Rainwater Harvesting Systems	Publicly Provided Good
	4. Minor Water Tank Networks for Communities	Publicly Provided Good
Coastal Resources	5. Mangrove and Seagrass Restoration	Publicly Provided Good
	6. Coral Reef Restoration	Publicly Provided Good
Agriculture Sector	7. Concentrated Solar Power for Medium and Large Farmers	Capital Good
	8. Aerobic Biological Treatment (Composting)	Consumer Good
Energy Sector	9. Refuse Derived Fuels	Capital Good
	10. Biogas	Capital Good

Agricultural Sector

Targets for **Agricultural Adaptation** measures relate to water management, conservation, and crop diversification towards food security and export in Jamaica. This is in the light of the projected variability and reduced rainfall associated with climate change, and the resulting extended dry periods causing stress to crops and livestock. Because more than 80% of the small and medium-sized farmers in Jamaica depend on rainfall as their primary source of water for irrigation (Young, 2020), water management practices and technologies are critical for the agriculture sector to adapt to climate change. Table ES-3 presents the prioritised technologies and preliminary targets.

Table ES-3: Preliminary targets for the prioritized technologies for the agriculture sector

Prioritized Technologies	Preliminary Targets
Drip and Sprinkler Irrigation	Implement sensitization and awareness programmes across farming districts in Jamaica and provide support for vulnerable smaller farmers operating ¼ acre farms to install "starter" drip and sprinkler irrigation systems, at a rate of twenty farms per year from 2021–2023 and expand to include twenty larger farms (¼ – 5 acres) per year thereafter (vulnerable farms in need of support to be identified through the Rural Agricultural

Prioritized Technologies	Preliminary Targets
	Development Authority (RADA) and other agricultural support entities).
Rainwater Harvesting for Irrigation	Implement sensitization and awareness programme in farming districts across Jamaica through the establishment of 3 selected pilot areas per year from 2021–2023 and install sustainable harvesting systems, providing access to vulnerable farmers in each of the 3 areas over the specified period.

Barriers to diffusion of the technologies were determined as financial and non-financial and within each of these, relevant effects were identified.

Four (4) significant financial barriers included:

1. Access to finance for capital expenditure
2. Perception of risk by lending agencies and high interest rates
3. Possession of documentation to facilitate conducting business with financial institutions and lending agencies.
4. Disconnect between repayment schedules stipulated by lenders and farming cycle revenue earned from farming/crop cycle.

These barriers are interconnected as they relate to small and medium-sized farmers not having the required capital/financing to purchase and install systems to improve water capture, storage, and use.

With respect to the non-financial barriers, safety, and security of rainwater harvesting system, sprinkler and drip irrigation have been a concern for farmers, as well as for financial institutions, and donor agencies. Farmers report that equipment is often stolen from farms. Other important non-financial barriers include cultural norms and practices, knowledge, environment, and technical assistance.
The enabling framework presented in Table ES-4 below incorporates measures identified to overcome the barriers.

Table ES-4: Enabling Framework to Overcome Barriers Identified

Enabling Framework	
Financial	Ministry of Finance and the Public Service can make provisions and/or provide support and guidance to the Development Bank of Jamaica and other financial institutions for them to be able to provide loans and financial support to farmers while reducing the risk to the lending agency/bank. The loans should consider the farming cycle, and the effects that climate change will have on small and medium-sized farmers and their ability to produce. Keeping in mind that such loans and financial support towards technologies, such as integrated water management systems and solutions for farmers, will allow farmers to become more resilient to the effects of climate change.

Enabling Framework	
Technical	Small and medium-sized farmers will need assistance in the use of new technologies for accessing information (products available, understanding the use of technology, weather information). These must be able to deliver to the farmers in ways and formats which the farmers can easily understand. Additionally, building confidence and competence for farmers in the use of smart digital technology may therefore be a means to enable more efficient collection and management of the limited water collected in rainwater harvesting systems. With the use of new technologies, programmes geared towards building capacity and changing cultural behaviour are important and very critical to support the use of new technologies. This is important to ensure the selection of the appropriate technology that will bring maximum benefit based on the type of crops grown and site characteristics. These programmes can introduce farmers to additional technologies and best practices to facilitate optimal water use such as seed/crop selection based on location, the use of shade housing, intercropping, etc. This will foster the integrated approach which is necessary to optimize agricultural output in the face of a changing climate. Introducing new farming technologies is an important way to combat climate change issues. Technologies such as rainwater harvesting, water storage (tanks/ponds), sprinkler and drip irrigation are all linked within the broader category of integrated water management. Therefore, these solutions should be provided to farmers as integrated water management solutions for farmers and stand-alone systems. One example is that water management solutions for a farmer could incorporate water capture, storage, and efficient use. Additionally, farmers who are open and able to embrace non-traditional techniques such as aquaponics can also be encouraged. Investing in technologies and modernizing agriculture can further facilitate farming as a good investment in the face of climate change. This should be supported by post-harvest programmes that can provide various options that minimize loss from “farm to fork” and maximize profits through value-added products. Capacity building support is important as with increased knowledge farmers may be in a better position not just to determine their needs for additional technologies but also to identify beneficial linkages geared towards a more market informed farming. This can encourage diversification of production to satisfy market needs.
Institutional	No single government agency has responsibility or accountability for promoting, installing, or maintaining rainwater harvesting (RWH) systems. Organizational responsibility should be determined, and a cross-sectoral approach applied.

Enabling Framework	
Security	Farmers should be sensitized and trained in how to improve farm security. Municipal Corporations, Local Police and the Praedial Larceny Prevention Unit should be sensitized to play a bigger role in controlling theft within the agriculture sector.

Water Sector

Examination of the **Water Sector** underscored the need for climate adaptation as the sustainable supply of quality water has become an increasing challenge across the island. The prioritized technologies selected - i) community-scale rainwater harvesting systems and ii) minor water tank networks for communities, focuses on water capture and storage and will be essential in ensuring the availability of a consistent and reliable water supply particularly in rural areas. Prioritised Technologies and Targets are presented in Table ES-5 below

Table ES-5: Prioritised Technologies and Targets for the Water Sector

Prioritized Technology	Preliminary Target
Community-scale Rainwater Harvesting Systems	The target for rainwater harvesting systems is to increase existing coverage by approximately 50% in non-utility supplied rural communities over the three-year period of 2021–2024. Currently, there are 353 community-scale rainwater harvesting systems across Jamaica. This target is in keeping with the GoJ's National Water Sector Policy and Implementation Plan 2019, which includes Rainwater Harvesting. The GoJ seeks "*to promote the rehabilitation and maintenance of community catchment tanks, where Municipal Corporations, Local Authorities, or communities themselves wish to take on the responsibility of maintaining these systems*" (GoJ, 2019).
Minor Water Tank Networks for Communities	The target for minor tank networks is to increase water storage and distribution systems for potable uses by 20% in non-utility supplied rural communities by 2024. This target is in keeping with the National Water Sector Policy and Implementation Plan 2019 which outlines the GoJ's goal to provide potable water access to everyone by 2030 (GoJ, 2019).

Although the barriers are mainly financial, several issues relate to non-financial considerations viz. cultural/behavioural, environmental, technical, security-related, regulatory, institutional political and economic.

Stakeholders have identified the following as the most significant issues:

1. Financial resources required by Municipal Corporations and the Rural Water Supply Ltd. to build, operate, and maintain Rainwater Harvesting Systems and Minor Storage Tanks are not provided through the Ministry of Local Government and Rural Development.
2. Community systems are often vandalized and much of the equipment is stolen. This has resulted in a reluctance to setup these systems without additional security measures.
3. No single agency is responsible for the development of rainwater as a source of potable and non-potable water for Jamaica. Rural Water Limited has undertaken activities on rainwater harvesting, but this is only a small part of the Agency's wider mandate.

To overcome the barriers, the enabling measures have been suggested as presented below in Table ES-6

Table ES-6: Suggested Enabling Measures to overcome barriers.

Financial	Municipal Corporations and by extension the GoJ should provide funding for the construction, rehabilitation and operation of community scale water harvesting and management systems.
Institutional	An agency should be designated with the mandate for the safe collection and distribution of rainwater, to facilitate sustainability of supply as a public good. Create a special water licencing scheme which will allow for private entities to set up rainwater harvesting, storage and distribution networks for communities. This approach will need cooperation between the private sector and various public agencies such as the Water Resources Authority (WRA), the National Water Commission (NWC), the Ministry of Health and Wellness (MOHW), the Office of Utilities Regulation (OUR) and the National Environment and Planning Agency (NEPA).
Security	Central government, municipal corporations, local police, communities, and the private sector should create partnerships to allow for great security and safety of the community water capture, storage, and distribution systems. Community organizations should play a critical role, especially in rural locations. The use of technologies to enhance security measures will be critical, especially in rural communities.

<u>Coastal Resources</u>

Over the past several decades, coastal ecosystems in many areas around Jamaica have been undergoing stress from anthropogenic activities, and the removal of mangroves, seagrass beds, and coral reefs associated with multi-purpose use of the coastal zone. This has increased Jamaica's vulnerability to hurricanes and storm surges and has been posing a major threat to coastal ecosystems and marine life.

The technologies which have been selected for prioritization are:

i. Wetland (mangrove) and Seagrass restoration and protection.

ii. Coral reef restoration and protection.

Preliminary targets for the application and diffusion of (i) Wetland (mangrove and seagrass) Restoration and (ii) Coral Reef Restoration are presented in Table ES-7 below:

Table ES-7: Prioritised Technologies and Preliminary Targets for Coastal Resources

Prioritized Technology	Preliminary Target
Wetland Restoration	Over a five-year period, 2021–2026, complete the enhancement and/or replacement of 20% of critical wetland areas across Jamaica, based on a list of critical areas identified in consultation with NEPA
Coral Reef Restoration	Over a five-year period, 2021–2026, complete coral reef restoration at two sites Site selection, method, implementation, and monitoring should be done in consultation with NEPA

The barriers associated with the implementation and diffusion of the two prioritized technologies both fall within the broader category of ecosystem restoration and are both considered to be 'blue/green' adaptation technologies. Identified Financial barriers are articulated in Table ES-8 below.

Table ES-8: Identified financial barriers for Coastal Resources.

Direct	
1	Capital and operational costs for coral reef restoration is particularly high. This is because there is a relatively high cost associated with the initial research and development, as well as the cost for operating and maintaining a coral nursery.
Indirect	
2	Generally, seagrass, mangrove and coral reef restoration activities offer little guarantee of success and return on investment. Therefore, developers and investors see little financial benefit for engaging with these kinds of activities.
3	Coral reef restoration occurs over a long period and requires continued financial input into managing the site. Therefore, it is usually seen as an ongoing expense.

The non-financial barriers relate to knowledge gap, environment, technical capacity, regulatory and institutional environments, political decision-making, and social factors.

To overcome these barriers, the following enabling framework presented in Table ES-9 has been suggested by stakeholders consulted.

Table ES-9: Suggested Enabling Framework to overcome Financial and Non-Financial barriers

Enabling Framework Measures	
Financial	Government should create a tax or bond that businesses which receive a permit or licence to operate along the coast must pay on a yearly basis. The purpose of these

Enabling Framework Measures	
	taxes/bonds will be for the management of coastal resources including restoration and coastal monitoring activities. The established fund can be managed in such a way that resources are allocated to access the best available technology/data to improve decision-making on where to focus ecosystem-based interventions. Incentives and fiscal support should be provided to coastal developers who endeavour to avoid disturbance/destruction of coastal wetlands and the marine environment. Such support should consider favourable terms for importation of equipment or materials which are proven to support healthy natural resources; tax benefits or fees reduction to compensate for designs which avoid disturbance/destruction of the natural environment; and more selective approvals for smaller customized developments versus large developments which employ wide-scale land clearance. Increase funding initiatives for organizations that promote the sustainable use of coastal resources through the implementation and management of various projects and programmes. This additional funding should improve the capacity of these organizations to not only effectively manage and monitor coastal areas, but also to allow them to extend these activities to other vulnerable coastlines across Jamaica.
Institutional	Capacity building is required for the regulatory agencies. There is a need to improve the knowledge and experience of staff through training, research, and development. These should cover the areas for new methods in wetland and coral reef restoration, and improve technologies in the monitoring of coastal zones, and coastal zone management. Regional tertiary academic institutions in partnership with selected private sector entities and international partners could support scholarships for professional programmes which deliberately incorporate coastal environmental protection and alternative building designs into development type activities.
Legislative	Legislation needs to be changed /created to remove optionality in development in and around wetlands and coastal zones as discretionary perspectives will continue to yield inconsistent and deleterious outcomes. Concomitant regulations should selectively/expressly disallow building permit approvals for development which includes destruction of wetlands and coastal resources, or supposed alternatives of replanting wetland species, where neither the science nor the historical outcomes, locally or regionally, have supported success of this alternative.

The synergy between reef and wetland restoration is important to the reduction of wave energy in the coastal zone. By removing barriers to coral reef and wetland restoration, it is possible to enhance the success of beach and wetland restoration projects across Jamaica. This will allow the communities, developments, and users of the coastal zone to become more resilient to the effects of climate change.

Technologies for Mitigation

Technologies for Mitigation were identified and prioritized for the **Agriculture and Energy Sectors.**

Several **Agricultural** practices and management systems release greenhouse gases (GHG) that contribute to global warming and climate change. This is associated with most, if not all stages of both the production and post-harvest processes involved in crop cultivation and livestock rearing. Methane (CH_4) and Nitrous Oxide (N_2O) are two prominent gases released by farming processes. Carbon Dioxide (CO_2) is also emitted directly from the use of farm equipment (e.g., diesel or gasoline pumps), heavy machinery (e.g., tractors) and general light or heavy transportation. Indirectly, there is CO_2 contribution from the 24-hour use of electricity for pumping, motors, lighting, and heavy-duty fans (e.g., wind tunnel methods for poultry rearing). As such, a reduction in the use of fossil fuels to power machinery with the incorporation of renewables for energy, innovative techniques for food production, better manure/waste management and more efficient application of fertilizers have been targeted areas for reduction of emissions by stakeholders involved in the sector. The mitigation technologies prioritized by stakeholders and the associated targets are presented in Table ES-10 below.

Table ES-10: Mitigation technologies and Preliminary Targets for Agriculture

Prioritized Technology	Preliminary Target
Concentrated Solar Power (CSP)	To reduce GHG emissions from the multi-dimensional agricultural sector through the implementation of Concentrated Solar Power (CSP) where there is demand for electricity. CSP systems up to 5 megawatts (MW) may be applicable for large commercial farms with large power demands for water pumping, electrical equipment (e.g., cold storage), conveyors, external security lighting and offices, etc. Due to the cost for the CSP technology, focus will be placed on 3 opportunities: • A 100kW CSP Stirling engine system (4 x 25 kilowatt-electric [kWe]) at one (1) of the 9 Agro Parks[1]. Agro Parks operate under a cooperative structure with multiple users, so power demand within the Park boundary will be continuous throughout various crop cycles therefore improving the commercial viability of the investment. • 100kW CSP Stirling engine system each at 2 private sector farms.
Aerobic Biological Treatment of	To allow for an effective system for handling agricultural waste while contributing to the reduction of greenhouse gases from decomposition of the organic matter

[1] *An Agro Park is an area of intensive, contiguous, parcel of land for agricultural production which seeks to integrate all facets of the agricultural value chain from pre-production to production, post harvesting and marketing.*

Prioritized Technology	Preliminary Target
Agricultural/Organic Waste (Composting)	Small farmers are already composting in small containers, used barrels and wooden troughs at a subsistence level. It is recommended that at least a 1 acre of commercial composting operations be established in each of the 3 counties of Jamaica (Cornwall, Middlesex and Surrey, i.e., 3 in total) to demonstrate the feasibility of commercial composting and give easier access to visits and observation for interested parties across the island. Agro Parks, with their mixed cropping, could be ideally used as various crops mature at different times, hence the possibility of year-round organic material based on crop cycles. Also, the compost can be utilized at the same location by the farmers or the excess sold.

The barriers related to Concentrated Solar Power are mainly financial and are both direct and indirect as presented in Table ES-11 below.

Table ES-11: Direct and Indirect Barriers to Diffusion of Concentrated Solar Power

		Score/10
Direct		
1	CSP requires high capital and operating costs.	9
Indirect		
2	There is a high permit fee for users to produce electricity and have it sold back to the grid.	8
3	Fossil fuel costs are lower and fluctuating.	4

The non-financial barriers relate mainly to knowledge of the system and applicability within the Jamaican environment.

Regarding measures to overcome the barriers, given the high capital and operating cost, innovative and favourable financing and fiscal measures would be required. Implementation would also need to be promoted by the GoJ to support the Nationally Determined Contribution (NDC) for GHG emission reduction. Competition for land space is also a consideration in that, production of solar power could be in direct competition with the same land space for agricultural enterprise. Therefore, the farmer will have to decide about how much space to allocate for electricity production as opposed to agricultural activity.

The financial barriers associated with anaerobic digestion/composting are indirect in that:

- The process to complete composting is seen as labour intensive to the farmer and since there is no return, the farmer will prefer to do other tasks, which may have some immediate material benefit.
- There is limited ability to scale up from a small compost to larger compost for use on a farm. That is because composting require inputs and land areas which are not readily available to small and medium-sized farmers.

The prioritized technologies for **the Energy Sector** are in alignment with the GoJ's strategy outlined in the National Energy Policy (NEP), and they also address issues with waste management in Jamaica. The technologies and targets are presented in Table ES-12.

Table ES-12: Prioritised Technologies and Preliminary Targets for the Energy Sector

Prioritized Technology	Preliminary Target
Refuse Derived Fuels	One (1) power 10 MW plant at a waste facility is proposed for this mitigation technology, producing lower GHG emissions than a typical fossil fuel plant. Pre-sorting and critical temperature pyrolysis for energy production will reduce the solid waste burden at all national disposal sites, reduce spontaneous combustion and inadvertent release of GHG (by removing combustibles), while contributing useful power within the national Integrated Resource Plan's (IRP) projected demand. The draft National Energy-from-Waste Policy (GoJ, 2010) estimates that for each tonne of municipal solid waste (MSW) combusted rather than landfilled, the overall carbon dioxide reduction can be as high as 1.3 tonnes of CO_2 per tonne of MSW when both the avoided landfill emissions and the avoided use of fossil fuel are considered. Also, it estimates that thermal treatment of MSW results in the generation of 500-600 kWh of electricity per tonne of MSW combusted. A feasibility analysis in 1995/6 for waste at the Riverton City waste site reported an average calorific value of the waste disposed at the site as 8.87 megajoules (MJ) per kilogram (kg) per day and an estimated annual energy output of 67,500 megawatt-hours (MWh) with about 9 MW available for export to the national grid (thermal efficiency of about 25%). In 2009, the Petroleum Corporation of Jamaica (PCJ) entered into an agreement with a private sector company to establish two waste-to-energy co-fired plants using new technologies, with capacities of 45 MW at the Riverton facility (358 gigawatt hours per year [GWh/yr]) and one 20 MW facility at the Retirement facility (141 GWh/yr). If methane energy content recovered from the Riverton facility of 222,424,440 x 105

Prioritized Technology	Preliminary Target
	kilojoules (kJ) per year was considered, it could potentially serve[2] over 3,000 homes. Additionally, from the sugar companies the Energy from Waste (EfW) Policy indicates that the cogeneration potential from bagasse for the period 2008 to 2030 is estimated to range between 20 and 63 MW. Refuse derived fuel (RDF) as a result will reduce competition for land as per modus operandi for solid waste management, reduce vermin hosting, and offer continued employment for healthier and productive basic livelihoods of persons currently using the disposal sites for an income (improved occupational health and safety [OHS] conditions). Pre-sorting of solid waste will also improve feedstock quality to the scrap market for specific by-products, for example, scrap metals or new feedstock such as ash for cinder blocks. Refuse derived fuel/Waste-to-energy (RDF/WTE) will be included in the next generation of Requests for Proposals (RFPs) based on the 2019 Integrated Resource Plan.
Biogas (large scale)	At least one (1) medium commercial scale biodigester facility is being targeted as a catalyst for development at other sewerage sites island wide. A system this scale could be tested at any of the nearly 100 sewerage (wastewater) treatment plants operated by the National Water Commission island wide. The largest single sewerage treatment plant is in Greater Portmore (18,180 m^3/day). The proposed system should receive approximately 100,000 – 200,000 m^3 of wastewater/annum, with the potential to generate enough biogas for approximately 4,000 MWh_e/annum[3]. A system such as this has the potential to save 2,500t CO_{2e}/annum. A continuous digester may be best suited for sewage operations, where the organic material can be constantly or regularly fed into the enclosed digester. Of special interest for immediate intervention would be the Soapberry Wastewater Treatment Plant (SWTP) and associated sewerage

[2] According to Jamaica Public Service Company (JPSCo), the average requirement per household is 1,869 kWh per year. Therefore, based on the estimated conversion of 3.6 x 106J = 1kWh, the energy produced can serve over 3,300 homes (Model: Emcon Associates-Henry 1989 study, Model: Zsuzsa- Hungarian – biogas)

[3] Bio-engineering Installations – HoSt Holding B.V. 2020. https://www.host.nl/en/biogas-plants/sludge-biogas-plants/?gclid=CjwKCAiArIH_BRB2EiwALfbH1NadycAC4sewP7buB0XA3_lgfd4Wqh4vjYGlSEaTx5cc3E8KN8bZixoCe5EQAvD_BwE

Prioritized Technology	Preliminary Target
	infrastructure (i.e., Pumping Stations and Transmission mains), for which NWC has an 85% shareholding, and is now required to expand its current treatment capacity from 75,000 m^3/day to 150,000 m^3/day, in order to meet the medium-term requirement for treatment of wastewater collected by NWC in the Kingston Metropolitan Area (KMA). In the expansion, it is envisaged that the output from SWTP will be reused for agricultural purposes to offset the current use of potable water sourced from the Rio Cobre. It is mandated that in privatization, the SWTP should have the climate change mitigation and adaptation designs via new technologies and renewable energy solutions. For this purpose, an invitation for consultancy to provide advisory services for the "Expansion and Privatization of the Soapberry Wastewater Treatment Plant in Jamaica" was posted on 18 November 2020[4]. Part of this consultancy is to give attention to the potential value of treated effluent and/or any other by-products and/or derivate from the plant that could provide financial (via complementary revenue streams) and economic benefits, that is, recycling, renewables. These objectives align well with an anaerobic biodigester coupled to a renewable biogas combined cycle power plant.

The financial barriers relate directly to large capital investment and infrastructure upgrades to be integrated into the current waste disposal system in Jamaica. Indirectly, consideration was given to the cap usually placed on lending from funding agencies which is lower than the capital investment required for large scale energy projects. These projects are generally driven by private investors who may receive a high risk with "unproven technologies". Further, the economics and return on investment for these technologies are lower than other technologies such as solar photovoltaic (PV) and wind energy.

Limitations

A cost benefit exercise was attempted to support diffusion of the prioritized technologies and the proposed enabling measures to overcome the identified barriers. However, the data required as inputs to enable quantification of identified benefits of diffusing the technologies was not available. It is recommended that the action plan toward project design include as part of the monitoring and evaluation component, a structured process of relevant data collection to inform project implementation in an iterative way as well as to build a database to support evidence-based decision-making going forward.

[4] Summary Terms of Reference Assignment Title: Engagement of Transaction Advisory Services for the Expansion and Privatisation of the Soapberry Wastewater Treatment Plant

Part I Introduction

1 Purpose

This report presents the analysis of potential barriers to the implementation of prioritized technologies for adaptation and mitigation to climate change in the four sectors selected by the Government of Jamaica (GoJ), namely, **Coastal Resources, Water Resources, Energy, and Agriculture**. The document is the second deliverable in the Technology Needs Assessment (TNA) Project for Jamaica. It outlines the process followed to identify and prioritize barriers and presents measures and an enabling framework for overcoming the identified barriers.

The prioritised technologies were presented in **Report I** entitled **Identification, Assessment and Prioritization of Technologies** submitted in February 2020 as stated below.

1.1 Overview of the Global TNA

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 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. In that regard, the TNA is intended 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. 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.

1.2 Objectives of the TNA

The main objectives of the TNA Project are:

1. To identify and prioritize through country-driven participatory processes, technologies that can contribute to the adaptation and mitigation goals of the participating countries, while meeting the national sustainable development goals and priorities.
2. To identify barriers hindering the acquisition, deployment, and diffusion of prioritized technologies, followed by the identification of enabling frameworks to overcome these barriers.
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 participating countries.

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

1.3 Prioritized Technologies for Jamaica

The first deliverable of the Technology Needs Assessment Project for Jamaica was completed in February 2020. The report identified and prioritized technologies for diffusion and implementation in Jamaica for the adaptation to and mitigation of climate change. Prioritization was done through a process of stakeholder and working group consultations and document review. 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 (De Groot, 2018).

A long list of technologies was first developed from research, and this was shortened based on stakeholder consultations via an online survey. Technology Fact Sheets were then prepared for each shortlisted technology, incorporating findings from consultations with respective technology-savvy professionals within each sector; through review of Technology Fact Sheets from other countries; and additional research of technology options.

The prioritization of climate technologies was completed by the working groups using the TNA Multi-Criteria Analysis process. Members of the respective groups undertook the following:

1. Discussed the Technology Fact Sheets for all the short-listed technology options, including capital and operational costs, benefits, 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 stakeholders' recommendations.
2. 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.
3. Developed weights for each criterion, for each technology.
4. Rated/scored each technology option based on the criteria and weighting using the Multi-Criteria Analysis (MCA) worksheet template provided.

Ten technologies for climate change adaptation and mitigation for Jamaica were prioritized using this process. The identification of climate technologies in each sector were aligned with Vision 2030 national development objectives and the sustainable development goals of Jamaica. The prioritized technologies are presented in Table 1-1.

Table 1-1: Prioritized technologies for climate change adaptation and mitigation for Jamaica

Technologies for Adaptation	
Agriculture Sector	Sprinkler and Drip Irrigation for crop farmers
	Rainwater Harvesting Systems and water storage for irrigation
Coastal Resources	Wetland Restoration (mangrove)
	Artificial Coral Reef and Coral Reef Ecosystem Restoration
	Rainwater Harvesting and Restoring of Barbeque Catchments

Water Resources	Creation and Restoration of Minor Tank Networks
Technologies for Mitigation	
Agriculture Sector	Concentrating Solar Power Systems
	Aerobic Biological Treatment (composting)
Energy Sector	Refuse-Derived Fuel Production
	Biogas

2 Process for the Identification of Barriers

The Barrier Analysis and Enabling Framework (BAEF) is the second step in the Technology Needs Assessment (TNA) process. The objective of the BAEF is *to analyse market conditions for each selected technology, identifying the barriers to their enhanced deployment, followed by the identification of enabling frameworks to support their deployment and diffusion in Jamaica.*

The BAEF for the prioritized technologies for adaptation and mitigation in the four sectors for Jamaica (Table 1-1) was developed following the guidelines provided in the various TNA guidebooks. These included:

1. TNA Step by Step: A guidebook for countries conducting a Technology Needs Assessment Action Plan (Haselip, Narkevicicute, Rogat, & Traerup, 2019);
2. Overcoming Barriers to the Transfer and Diffusion of Climate Technologies, Second Edition (Nygaard & Hansen, 2015);
3. Guidance for a gender-responsive Technology Needs Assessment (De Groot, 2018).

2.1 The Process for Jamaica

The BAEF process for Jamaica was completed on a review of key documents and stakeholder consultations. Prioritization of barriers, market categorization, and identification of root causes were completed through sector working group consultations and expert advice. Findings from the individual sectors were shared with a cross-sector working group to contextualize the intersectoral conditions for technology diffusion. This process guided the formulation and outline of the enabling framework to overcome the identified barriers.

Consultations were completed over a four-week period and entailed brainstorming and open discussions through a combination of (i) face-to-face group meetings, (ii) individual face-to-face meetings, (iii) individual phone meetings, and (iv) Zoom group meetings. Overall, consultations occurred with over 25 persons with sector-specific and cross-sector knowledge and experience. A list of sector specialists consulted is given in **Appendix I.** The consultant's attendance to other project stakeholder consultations allowed for additional feedback from over thirty-five (35) farmers and community members. This assisted in understanding barriers within the agriculture sector and water resources.

Market categorization of technologies was first discussed among the consultants, followed by discussion and validation with the sector specialists. Market categories were determined based on the market characteristics of the technology in Jamaica. The market categories and definitions were based on those provided in the guidebook "Overcoming barriers to the Transfer and Diffusion of Climate Technologies" (Table 2-1) (Nygaard & Hansen, 2015). An overview of the market classifications for the prioritized technologies is presented in Table 2-2. The market categorization was used to guide the barrier analysis and was instrumental in defining the targets for each of the prioritized technologies.

Table 2-1: Technology categories and their market characteristics (Nygaard & Hansen, 2015)

Categories	Description	Market Characteristics	Technology Examples
Consumer goods	Goods specifically intended for the mass market; households, businesses, and institutions	• A high number of potential consumers • Interaction with existing markets and requiring distribution, maintenance, and installer networks in the supply chain. • Large and complicated supply chains with many actors, including producers, assemblers, importers, wholesalers, retailers, and end consumers. • Barriers may exist in all steps in the supply chain. • Demand depends on consumer awareness and preferences and on commercial marketing and promotional efforts	Solar home systems, compact fluorescent lamps (CFLs), energy-efficient air conditioners, drip irrigation tubes, seeds for drought-resistant crops
Capital goods	Machinery and equipment used in the production of goods, for example, consumer goods or electricity	• A limited number of potential sites/consumers • Relatively large capital investment • Simpler market chain, i.e., few or no existing technology providers • Demand is profit-driven and depends on demand for the products the capital goods are used to make.	Utility technologies, such as biomass plants, small-scale hydropower plants, or technological parts thereof Could also be machinery used in agriculture, and technologies used in industrial process
Publicly provided goods	Technologies in this category are (although not always) publicly owned, and production of goods and services	• Very few sites • Large investment, government/donor funding • Public ownership or ownership by large companies • Simple market chain: technology procured through	Sea dykes, infrastructure (roads and bridges, sewage systems), mass transport systems (metros)

Categories	Description	Market Characteristics	Technology Examples
	are available (free or paid) to the public or to a large group or persons.	national or international tenders. • Investment in large-scale technologies tend to be decided on at the government level and heavily dependent on existing infrastructure and polices.	
Other non-market goods	Non-tradable technologies transferred and diffused under non-market conditions, whether by governments, public or non-profit institutions, international donors or NGOs	• Technologies are not transferred as part of a market but within a public non-commercial domain. • Serves overall political objectives, such as energy saving and poverty alleviation. • Donor or government funding	Early warning systems for drought, seasonal

Table 2-2: Categories for the prioritized technologies for Jamaica

Sector	Prioritized Technologies	Technology Market Categorization
Agriculture Sector	Drip and Sprinkler Irrigation	Consumer Good
	Rainwater Harvesting for Irrigation	Consumer Good
Water Resources	Community-scale Rainwater Harvesting Systems	Publicly Provided Good
	Minor Water Tank Networks for Communities	Publicly Provided Good
Coastal Resources	Mangrove and Seagrass Restoration	Publicly Provided Good
	Coral Reef Restoration	Publicly Provided Good
Agriculture Sector	Concentrated Solar Power for Medium and Large Farmers	Capital Good
	Aerobic Biological Treatment (Composting)	Consumer Good

Sector	Prioritized Technologies	Technology Market Categorization
Energy Sector	Refuse Derived Fuels	Capital Good
	Biogas	Capital Good

Ranking of each barrier was completed by the consultants. Each barrier was rated according to the perceived significance linked to preventing the implementation or the diffusion of the technology across Jamaica. A barrier is considered **Most Significant** if it has a total score ranging from 8 – 9. This indicates that the barrier could be a '*showstoppe*r' and could possibly prevent the technology from being widely disseminated and used across Jamaica if significant interventions are not made. These barriers are also highlighted in red in the barrier analysis. A **Significant** barrier (Total Score ranging from 6 – 7) is one that will partially prevent the dissemination and use of a technology across Jamaica; however, it is possible to overcome these barriers with some additional effort, resources, and support. **Least significant** barrier (Total Score ranging from 3 – 5) is considered a barrier which can have some effect on the dissemination and use of a technology, however, these barriers can easily be addressed. Barriers with a Total Score ranging from 0 – 2 have been considered as **'Not Significant but Present.'** This indicates that these barriers are present but will not widely affect the dissemination and use of the technology across Jamaica.

Only one of the **Most Significant** barriers were considered in this assessment as these are considered the most important challenge to the widespread diffusion and use of the prioritized technologies in Jamaica. Therefore, the Identified Measures and Enabling Framework focus on overcoming the most significant barriers. Measures to these barriers were first identified during the stakeholder consultations and these were further developed through policy research, expert experience, and technology/sector specific consultations with key personnel. Problem trees were also used to help identify the root causes of the most significant barriers identified.

Indicative Cost and Benefits for the prioritized technologies and the proposed measures are presented, but the process is incomplete. It is important to note that there is a lack of quantitative data to complete such analysis effectively and accurately. In the absence of such data, economic modelling will be required to effectively quantify the benefits of the prioritized technologies and proposed measures. It is recommended that a system for gleaning relevant data be included in the action plan for project design.

Part II Technologies for Adaptation

3 Agriculture Sector

The prioritized technologies for **climate change adaptation** within Jamaica's agriculture sector are (i) Drip and Sprinkler Irrigation Technologies and (ii) Rainwater harvesting for irrigation. These technologies fall within the broader definition of water management and conservation.

Water availability is an increasingly important issue for the agriculture sector in Jamaica which accounts for up to 75% of the local water demand (CSGM, 2016). Over 80% of small and medium-sized farmers in Jamaica depend on rainfall as their primary source of water for irrigation (Young, 2020). The effects of climate change are already manifested in the current increasing unpredictability and variability in annual rainfall patterns and increasing temperatures. Of added significance are the rainfall projections for Jamaica which indicate that by the end of the century, there may be an overall reduction in precipitation of up to 40% and increased temperatures of up to 3.2°C above 1986 – 2005 base levels (CSGM, 2016). These projections portend possible aggravated dry conditions which could have devastating effects on the agriculture sector. Water management practices and technologies are therefore imperative currently, and into the future.

In this section, implementation targets for two water management technologies in the agriculture sector are outlined. Through extensive stakeholder consultation, barriers hindering the potential transfer of these technologies were identified. The barriers have been categorized as financial or non-financial with further sub-categories (such as, legal, social, technical), however, linkages between these categories exist. This allowed for a broader analysis and presentation of enabling framework measures to overcome these barriers.

Of significance is the impact of the Covid-19 Pandemic which began to affect Jamaica in March 2020, and which was not considered at the beginning of the TNA process. The effects exposed some of the strengths and weaknesses within the agriculture sector and highlighted the need for more diversified markets and technological innovations to reduce the vulnerability of the sector to reduced income.

Impacts of the Covid-19 pandemic on the agriculture industry have varied across Jamaica. Overall, the availability of food to local consumers and manufacturers has not been interrupted (Hall-Hanson, 2020), as farmers continued their daily operations, and domestic supply and distribution chains for food and agricultural products were not severely disrupted. Adequate planting materials and agricultural inputs were also available to continue local production. However, one significant challenge faced by the sector was triggered by the reduction in business operations within the tourism industry, which led to a surplus of produce. The pandemic highlighted the large number of farmers who were solely dependent on demand from hotels and restaurants. Many farmers were faced with an excess of harvested crops as the demand from the hotel industry vanished, resulting in acres of spoilt produce. Some estimates project that Jamaican farmers will experience an annual hit of USD$1.68 million, given the loss of markets.
From the perspective of sellers, demand from local consumers was not reduced significantly, but access to produce became constrained for periods due to imposed restrictions and curfews which reduced opening times for market vendors and shopping times for consumers.

3.1 Preliminary Targets for Technology Transfer and Diffusion

Table 3.1 highlights the preliminary targets for the transfer and diffusion of the prioritized technologies for climate change adaptation for the agriculture sector in Jamaica.

Table 3-1: Preliminary targets for the prioritized technologies for the agriculture sector

Prioritized Technology	Preliminary Target
Drip and Sprinkler Irrigation	Implement sensitization and awareness programmes across farming districts in Jamaica and provide support for vulnerable smaller farmers operating ¼ acre farms to install "starter" drip and sprinkler irrigation systems, at a rate of twenty farms per year from 2021–2023 and expand to include twenty larger farms (¼ – 5 acres) per year thereafter (vulnerable farms in need of support to be identified through RADA and other agricultural support entities).
Rainwater Harvesting for Irrigation	Implement sensitization and awareness programme in farming districts across Jamaica through the establishment of 3 selected pilot areas per year from 2021–2023 and install sustainable harvesting systems, providing access to vulnerable farmers in each of 3 areas over the specified period.

3.2 Barrier Analysis for Sprinkler and Drip Irrigation Systems

3.2.1 General Description of Sprinkler and Drip Irrigation Systems

Sprinkler and drip irrigation technologies allow for enhanced efficiency in the application of water for irrigation in agriculture and reduce loss of water through traditional conveyance channels. Drip systems apply water and minerals evenly across crops, thus helping to reduce wastage and increase crop yields.

Drip irrigation involves the application of water at a determined rate to the root zone of crops. This significantly reduces water run loss through deep percolation or evaporation. Required minerals can also be added to the water, thus allowing for increased efficiency, minimized oversaturation, and improved productivity. Drip irrigation is most suitable for rows, field and tree crops that are grown closely together (Figure 3-1). These include sugarcane, bananas, groundnut, cotton, vegetables, fruits, flowers, spices, and condiments.

Sub-canopy or micro-sprinkler irrigation involves a type of pressurized aerial irrigation that consists of applying water to the soil surface from above using mechanical and hydraulic devices that simulate natural rainfall (Figure 3-2**)**. This system of irrigation is more suitable on slopes in the Jamaican environment where drip irrigation is not possible.

Figure 3-1: Drip irrigation system in crops grown in rows in Spring Plain Agro Park, Clarendon, Jamaica

Figure 3-2: Sprinkler irrigation system in grass mulch field in New Forest/Duff-House Agro Park, St. Elizabeth, Jamaica

The benefits of each of these technologies include: -

- Supply of water to farms whenever required by crops, thereby reducing dependence on rainfall.
- Efficient drawdown on water thereby minimizing loss and conserving resources. Where groundwater is the source, efficient irrigation systems can reduce withdrawal particularly during more sensitive dry months, thus minimizing depletion of ground water levels and reducing saline intrusion in the case of coastal aquifers.
- Drip irrigation which increases the efficiency of chemical fertilizer application through fertigation and prevents resource waste and pollution of waterways from chemical residue. In general, it minimizes adverse environmental impacts such as pollution of water bodies and biodiversity loss. The improved efficiency of fertigation is also particularly beneficial to small and medium-sized farmers.
- Reduction in soil degradation and erosion associated with channel and flood irrigation, thereby reducing water sources degradation and siltation of runoff.

In Jamaica, the technologies are well known, and local supply chains are present for the supply and installation of sprinkler and drip irrigation technologies. However, there is generally low uptake by small and medium-sized farmers.

3.2.2 Identification of Barriers

Sprinkler and drip irrigation have been categorized as 'consumer goods' (see Table 2-1 for definitions) as there are over 230,000 small and medium-sized farmers in Jamaica (MICAF, 2020). Local retailers also provide a full service for the supply, installation, and maintenance of the sprinkler and irrigation systems. However, many of the components can be accessed from local retailers and hardware stores. Do-it-yourself (DIY) systems can also be purchased from select local suppliers or directly imported. These imports are subject to all local taxes, duties, and fees. Despite these options, there has been a very low use of the sprinkler and drip irrigation technology in medium and small-scale farms in Jamaica. This barrier analysis aims to identify direct and indirect contributors in the categories of financial and non-financial reasons for this.

3.2.2.1 Economic and financial barriers

Economic and financial barriers were identified from stakeholder consultations and were scored and ranked to determine which barriers were most significant. The barriers and scores are given in Table 3-2.

Table 3-2: Identified economic and financial barriers for sprinkler and drip irrigation systems.

Identified economic and financial barriers		Score/10
Direct		
1	Small and medium-sized farmers rarely have enough capital required for the initial investment for mini-sprinkler and drip irrigation systems. Additionally, they also lack the financial resources to cover the operating and maintenance costs, for sprinkler and drip irrigation systems.	7
2	Small and medium-sized farmers are unable to access financing for the initial capital to purchase the hardware for sprinkler and drip irrigation systems.	9

Identified economic and financial barriers		Score/10
Indirect		
3	Small and some medium-sized farmers lack the required documentation, such as, land titles, financial records, and financial references. This restricts them from conducting business with financial institutions and lending agencies to obtain capital for investment in irrigation systems.	8
4	Loans for the purchase of equipment for small farmers within the agriculture sector are generally seen as high risk and sometimes have a high interest rate. Therefore, it requires a higher return on investment (ROI) which is not typical for small and medium-sized farmers.	8
5	Lending agencies rarely ever consider the farming cycle or crop cycle; therefore, loan arrangements are usually unsuitable for farmers. For example, a loan may require fortnightly or monthly repayments soon after the loan is accessed; however, most farmers only receive revenue after the crop cycle is completed, which may be 3 to 4 months or longer.	8

3.2.2.2 Non-financial barriers

The non-financial barriers were identified from stakeholder consultations and scored to determine which barriers were most significant. The barriers and scores are given in Table 3-3.

Table 3-3: Identified non-financial barriers for sprinkler and drip irrigation systems.

Identification of non-financial barriers		Total/10
Cultural/Behavioural		
1	Farmers tend to have a low level of trust for financial and banking institutions. Small farmers do not trust the banking system and government.	5
2	Small farmers are generally perceived as resistant to change and to accepting new ideas or new technologies.	5
Knowledge		
3	Farmers have a good understanding of finances that are relevant to agriculture and crop cycles. However, they lack understanding of general financing for loans and grants from lenders and agencies. They also misunderstand terms and conditions of these financing arrangements.	5
4	There is limited transfer of knowledge from research and development institutions and the private sector to small and medium-sized farmers. This is particularly so, in available technologies for increased production; efficient technologies; optimizing use of the technology; and promoting a greater understanding of the benefits of these technologies.	3
5	Farmers generally lack access to information; this is because they usually lack required technologies to keep up with how information is shared in the world today. Additionally, small, and medium-sized farmers tend to have	3

Identification of non-financial barriers		Total/10
	communication preferences (such as face-to-face, community meetings, etc.) which are different from those used by many institutions and agencies.	
Environmental		
6	Topographic constraints militate against use of drip irrigation on slopes. Combination with sub-canopy/mini- sprinkler is therefore desirable for some areas. Additionally, warmer temperatures increase evapotranspiration rates, thus possibly reducing the effectiveness of sprinkler systems.	4
Technical		
7	Technical assistance is generally unavailable for small and medium-sized farmers to setup and operate rainwater harvesting, sprinkler, and drip irrigation systems. Many farmers are unaware of the proper use of the technology; how to install and maintain the systems for the efficient collection and use of water; and the application for optimizing production.	4
8	Technical assistance may be available through private suppliers of these technologies, but this assistance may come at a cost to the farmer.	4
9	There are limited hands-on training programmes for farmers in operating water management systems suitable for small or medium-sized farms.	4
Security		
10	The safety and security of the systems for sprinkler and drip irrigation have been a concern for farmers, as well as for lending and donor agencies. There have been many reports that equipment is often stolen from farms. Therefore, additional resources are required to safeguard these systems.	8

3.3 Barrier Analysis for Rainwater Harvesting for Irrigation

3.3.1 General Description of Rainwater Harvesting Systems for Irrigation

Rainwater harvesting systems for agriculture to collect, store and conserve water from direct rainfall or runoff for irrigation purposes. The systems require little to no water treatment which can be expensive for small and medium-sized farmers. The technology is particularly important for areas which experience long periods of drought; areas with limited surface water; or areas where groundwater is deep or inaccessible due to hard ground conditions or where it is saline or acidic.

The technology can help to collect and store water in tanks or ponds for future use and allow less reliance on rainfall. Black plastic water tanks can be used for water storage and are readily available across Jamaica. They come in various sizes and are relatively easy to transport. Farmers can also store water in ponds, dug and lined using pond liners, to create water storage. It is essential that the storage systems be developed to accompany water harvesting.

Initial costs for infrastructure and installation can be high. Rainwater harvesting systems also require rooftops or clear areas to collect rainwater and the size of the collection area plays an important role in determining the amount of water that can be collected.

The overall benefits for rainwater harvesting include: -

- Provision of a convenient and alternate source of water for irrigation during seasonal dry periods and droughts.
- The option of making relatively easy additions without significant modification to the original design as systems are easily scaled.
- The system is scalable at all levels and therefore can be used by farms of all sizes and types.
- Contribution to water security by increasing water sources and availability.
- Reduction in stormwater runoff from property and the likelihood of contamination of surface water with pesticides, sediments, metals, and fertilizers.
- Excellent source of water for plants and landscape irrigation since it has no chemicals such as fluoride and chlorine (and may contain nitrates).
- Reduction in exploitation of other sources of water.

The technology is widely accepted across Jamaica and has been promoted by key stakeholders in the agriculture sector, RADA, and Rural Water Development. They have been implementing rainwater harvesting systems for agricultural development, including 15 rainwater harvesting installations under the Adaptation Fund Programme (MICAF, n.d.). Additionally, the Government of Jamaica developed a Policy Guideline on Rainwater Harvesting (GoJ, n.d.) as part of its national plan and policies for addressing climate change. This was done to guide members of the public, developers and authorities on standards, criteria and requirements for rainwater collection and use (GoJ, 2015). However, key stakeholders have expressed a need for significant expansion across the island, especially for harvesting, storage and use within the agriculture sector.

3.3.2 Identification of Barriers

Rainwater harvesting for irrigation has been categorized as a 'consumer good' (see Table 2-1 for definitions) as this technology could benefit all crop and livestock farmers in Jamaica. Rainwater harvesting has always been part of the agriculture sector in Jamaica; however, these were rudimentary systems which usually occurred on a very small scale. Therefore, the systems were inadequate to address the needs of small farmers or strengthen resilience to the effects of climate change. Recently, several rainwater harvesting projects have been implemented, specifically for small and medium-sized farmers. The Food and Agriculture Organization (FAO) has setup several pilots and demonstrations in south St. Elizabeth, Jamaica, to improve the management of water and the overall productivity of small farmers. The project also provided on-farm training and support in agronomy, system operations and maintenance to over 100 small and medium-sized farmers.

Additionally, in 2019 the Japan Caribbean Climate Change Partnership (JCCCP) trained and donated rainwater harvesting and irrigation systems to over 70 institutions across the country. This included students as young as six years, unattached youth, and prisoners. The project was implemented by the United Nations Development Programme (UNDP), Jamaica and the Jamaica 4H Clubs.

3.3.2.1 Economic and financial barriers

Economic and financial barriers were identified from stakeholder consultations and scored to determine which barriers were most significant. The barriers and scores are given in Table 3-4.

Table 3-4: Identified economic and financial barriers for rainwater harvesting for irrigation

Identified economic and financial barriers		Total/10
Direct		
1	Small and medium-sized farmers rarely have enough capital required for the initial investment for rainwater harvesting and storage systems.	7
2	Small and medium-sized farmers are unable to access financing for the initial capital to purchase the hardware.	9
Indirect		
3	Small and some medium-sized farmers lack the required documentation, such as land titles, financial records, and financial references. This restricts them from conducting business with financial institutions and lending agencies.	8
4	Loans for the purchase of equipment within the agriculture sector for small farmers are generally seen as high risk and sometimes have a high interest rate. Therefore, it requires a higher return on investment (ROI) which is not typical for small and medium-sized farmers.	8
5	Lending agencies rarely ever consider the farming cycle or crop cycle; therefore, loan arrangements are usually unsuitable for farmers. For example, a loan may require fortnightly or monthly repayments soon after the loan is accessed; however, most farmers will not receive any revenue until the crop cycle is completed, which may be 3 to 4 months or longer.	8

3.3.2.2 Non-financial barriers

The non-financial barriers were identified from stakeholder consultation and scored to determine which barriers were most significant. The barriers and scores are given in Table 3-5.

Table 3-5: Identified non-financial barriers and scores for rainwater harvesting for irrigation

Identification of non-financial barriers		Total/10
Cultural/Behavioural		
1	In some communities, there is a general tendency to purchase rather than harvest water. This may be due to prevailing circumstances such as low incidence of rainfall, and limited space to store water.	3
2	Farmers tend to have a low level of trust in financial and banking institutions. Small farmers do not trust the banking system and government.	5

Identification of non-financial barriers		Total/10
3	Small farmers are generally perceived as resistant to change and the acceptance of new ideas or new technologies.	5
Knowledge		
4	Farmers have a good understanding of finances that are relevant to agriculture and crop cycles. However, they lack understanding of general financing for loans and grants from lenders and agencies. They also mis-understand terms and conditions of these financing arrangements.	5
5	There is limited transfer of knowledge from research and development institutions and the private sector to small and medium-sized farmers. This is particularly so in available technologies for increased production; efficient technologies; optimizing use of the technology; and promoting a greater understanding of the benefits of these technologies.	3
6	Farmers generally lack access to information; this is because they usually lack required technologies to keep up with how information is shared in the world today. Additionally, small, and medium-sized farmers tend to have communication preferences which are different from those used by many institutions and agencies.	3
Environmental		
7	Many small or medium-sized farmers do not have the land area to accommodate such rainwater harvesting and large water storage systems.	7
Technical		
8	Limited technical assistance is generally unavailable for small and medium-sized farmers to setup and operate rainwater harvesting, sprinkler, and drip irrigation systems. Many farmers are unaware of the proper use of the technology; how to install and maintain the systems for the efficient collection and use of water; and application for optimizing production.	4
9	Technical assistance may be available through private suppliers of these technologies, but this advice may come at a cost to the farmer.	4
10	Limited hands-on training programmes for farmers in operating water management systems suitable for small or medium-sized farms.	4

3.4 Linkages of the Barriers Identified

The prioritized technologies for the agriculture sector in Jamaica are closely related as they both deal with water management. Rainwater harvesting is one of many solutions for adapting to variability in water supply and severe drought conditions. Drip and sprinkler irrigation systems promote water efficiency in the agriculture sector and seek to reduce water demand. This is particularly important as the GoJ seeks to increase agriculture food production. However, investment in water supply, storage and efficient infrastructure and technology remains low in Jamaica and throughout the Caribbean for small and medium-sized farms. The barrier analysis identified the most significant barriers to the diffusion and use of these technologies across Jamaica. This section seeks to link these barriers under common themes. This allows for identifying broad measures across the sector to reduce/illuminate the effects of these barriers.

Economic and Financial

One of the most significant barriers identified for the technologies is directly or indirectly related to economics and financing of the technologies. Small and medium-sized farmers are unable to access financing for the initial capital to purchase the hardware for rainwater harvesting and sprinkler and drip irrigation systems. While there are loans and grants available to these farmers through various entities such as RADA, the Ministry of Industry, Commerce, Agriculture and Fisheries (MICAF) and the Development Bank of Jamaica (DBJ), small and medium-sized farmers do not meet the criteria to access these opportunities. This is because they lack the required documentation, such as land titles, financial records, and financial references. This restricts them from conducting business with financial institutions and lending agencies. Getting documentation such as land titles is a very difficult, lengthy, and expensive process.

Loans for the purchase of equipment within the agriculture sector for small farmers are generally seen as high risk and sometimes have a high interest rate. Therefore, it requires a higher return on investment (ROI) which is not typical for small and medium-sized farmers.

A problem tree analysis was carried out to determine the root cause why small and medium-sized farmers lack the required capital (Figure 3-2). The root cause analysis indicated the following: -

I. There is limited use of production technology in small and medium-sized farms, therefore, they generally produce on a small scale for sale on local markets. This makes them susceptible to environmental and economic impacts.
II. Small and medium-sized farmers have limited access to or opportunities for further education to learn finances, economics, and banking. Therefore, they lack the knowledge required to understand and appreciate the banking system and apply for financing options or grant opportunities.
III. Small and medium-sized farms also lack required documentation to access and obtain grants and loans. In many cases, the farmers do not have official titles for their properties or other documentation such as birth certificates and so on. The process for obtaining many of these documents are sometimes lengthy and expensive, particularly regarding land valuation and titles.

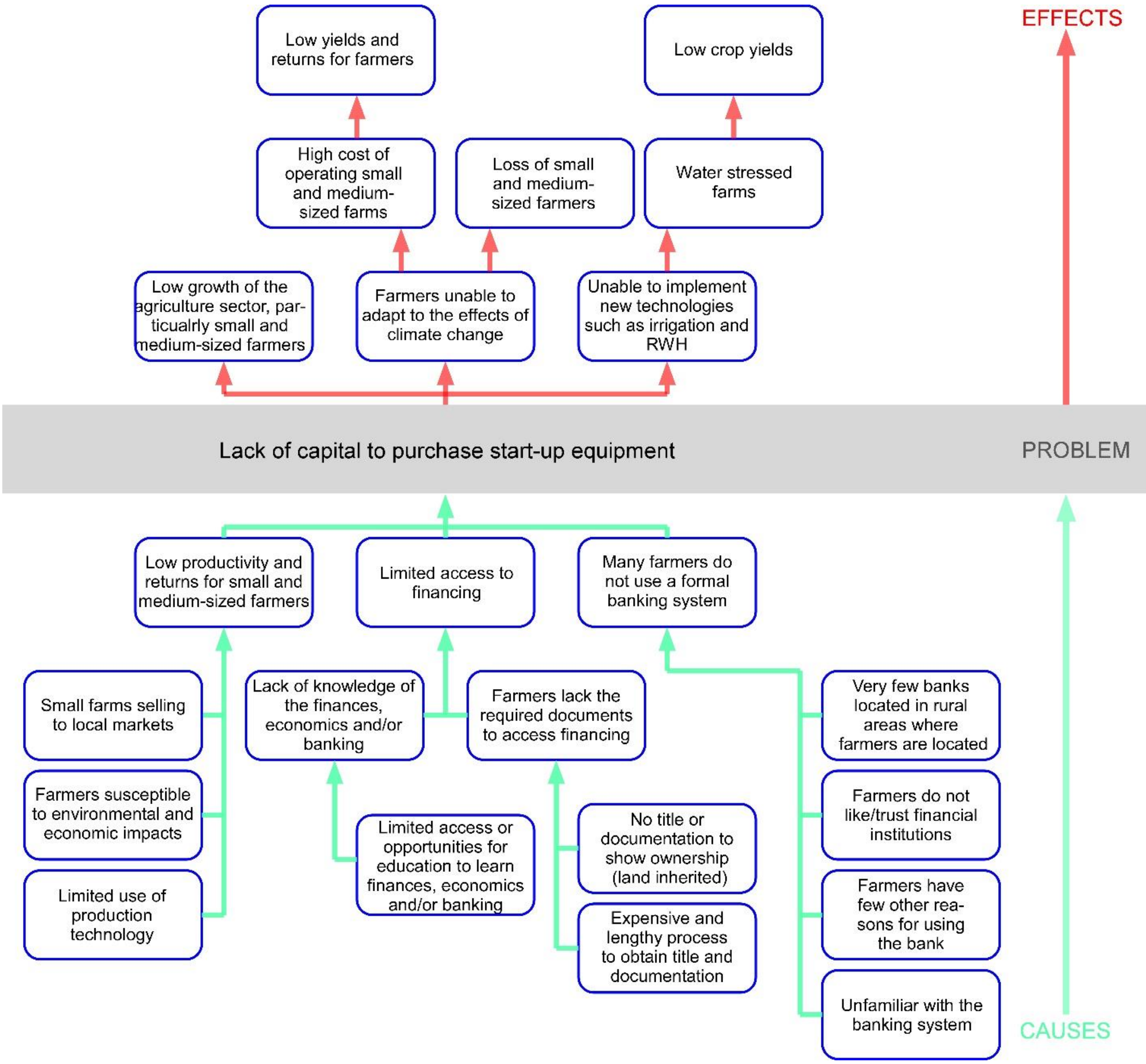

Figure 3-3: Problem tree for small and medium-sized farmers in the agriculture sector

3.5 Identified Measures

Table 3-6 outlines the proposed measures for overcoming the most significant barriers for the two prioritized technologies for the agricultural sector in Jamaica. Some additional measures have also been presented in Table 3-7 for the less significant barriers identified.

Table 3-6: Proposed measures for more significant barriers for the agriculture sector

Overarching Barrier	Proposed Measures
Lack of capital to purchase equipment	• Provision of special grants or subsidy on initial cost of installation. It has been preferred by some stakeholders that Government offer

	grants to fund starter *Sprinkler and Drip Irrigation Systems* for ¼ acre of properties operated by small and medium-sized farmers. Access to such a grant for a starter installation would assist the farmer to improve productivity and earning which would, in turn, facilitate further investment by the farmer and the ultimate expansion of farm output from the remaining sections of the property. The value of such a grant would be site/region-specific, but an average could probably be calculated by the Rural Agricultural Development Agency (RADA) and related agencies. Further access to the grant would also be determined through RADA and related agricultural support entities such as the National Irrigation Commission (NIC). Such an initiative would require a supporting Government of Jamaica (GoJ) policy and institutional framework. • Provision of low interest or interest-free loans for purchase and installation of equipment • Provision of tax incentives and the reduction of import duties on component parts for systems to reduce capital costs for adoption and installation. • Financial incentives through the National Irrigation Commission (NIC) to encourage optimal use of water using water-efficient irrigation systems. • The Ministry of Industry, Commerce, Agriculture and Fisheries, its subsidiaries and related institutions need to re-examine the reasons for slow/lack of uptake when funds are supposedly made available to small and medium farmers, and to develop innovative mechanisms to facilitate change. This could begin with consultations with and among farmer organizations and with public financial entities and private lending agencies regarding the imperative for accessible finance for climate-smart technologies to expand agricultural output toward local food security and export earnings. • A policy and institutional framework need to be negotiated and established by the Government with specific lending agencies to provide farm financing at discounted rates for capital and operating expenses that consider the farming/crop cycle for repayment schedules. The policy framework may consider Government guarantees. • Establishment of a funding policy/financial framework that would enable the Government of Jamaica, through RADA or the Ministry of Industry, Commerce, Agriculture and Fisheries to provide guarantees to selected lending institutions for providing credit to private entities

	to supply sprinkler and drip irrigation systems to local farmers who meet the determined criteria. • The cost of appropriate security systems should be included in the financing package for capital costs of the drip and sprinkler irrigation works. This cost would have to be calculated on a site-specific basis.
High levels of larceny in the agriculture sector preventing additional investment in technology and equipment	• Increased patrols for public security services (Police), the Praedial Larceny Prevention Unit and private security entities in rural areas

Table 3-7: Proposed measures identified for less significant barriers in the agriculture sector

Overarching Barrier	Proposed Measures
Lack of knowledge	• Establish ongoing capacity building programmes for farmers to include business planning, financing, introduction to new technologies and climate change adaptation. • Formulate a Government initiative to position this technology as the part of a larger investment in horticulture to increase overall production in that segment of the agricultural sector. Promotion of this technology and knowledge will generate increased interest in the technology and efficient micro-irrigation systems. • Strengthen farmer-field-schools to allow for greater scale and reach. Specifically, focus should be placed on in-the-field training for farmers, taking account of the farmers' knowledge, capacity and resources. • Train farmers on how to use real-time climate and soil-based information to determine crop water requirement and irrigation water management and irrigation scheduling (when and how much to apply). • Develop practical guidelines for micro-irrigation system design and management. • Organize farmer exposure trips to demonstration site(s) to expose farmers to implementation of the technologies and provide them with all the information regarding the products, suppliers, costs, and economic benefits.
Resistance to change from cultural/behavioural norms	• Provide information to farmers about the financial benefits to be derived from using of these technologies. The training sessions should be designed to highlight how the technology is going to contribute towards the wellbeing/ empowerment of both male and female farmers.

Overarching Barrier	Proposed Measures
	• Training of water users and service providers in design, installation, operation, and maintenance.
Institutional	• Government could include adoption of these technologies in larger agricultural special investment projects so as to improve production and market competitiveness. • Agricultural training entities should be encouraged to include in its curriculum research and development (R&D) as it relates to the application and benefits of the climate-smart technologies for water management. • Farmers need to be included in all stages of the farm/agricultural development process, collection of data, planning and the execution of projects. This will facilitate understanding and engagement with new or improved climate adaptation irrigation technologies. • Reduce perception of risk through demonstration plots, and the identification or creation of markets.

3.5.1 Cost-Benefit of proposed Measures for the Agriculture Sector

A simple cost-benefit analysis was conducted for the implementation of the identified measures (Table 3-8). The cost-benefit analysis was completed with the best available information. While the prioritized technologies identified for the agriculture sector in Jamaica are not new, there is limited research and data to effectively quantify the benefits of these technologies. Such an analysis is required to develop effectively a full quantitative financial model outlining the expected benefits these systems will have on the agricultural sector in Jamaica.

Table 3-8: Simple cost-benefit analysis for the proposed measures for the agriculture sector

Overarching Barriers	Proposed Measures	Expected Costs	Expected Benefits
Lack of capital to purchase equipment	Provision of special grants or subsidy on initial cost of installation. It has been proposed by some stakeholders that Government offer grants to fund starter *Sprinkler and Drip Irrigation Systems* for ¼ acre of properties for small and medium-sized farmers. Access to such a grant for the starter installation would assist the farmer to improve productivity and earnings which would, in turn, facilitate further investment by the farmer and the ultimate expansion of farm output from the remaining sections of the property. The value of such a grant would be site/region-specific, but an average could probably be calculated by the Rural Agricultural Development Agency (RADA) and related agencies. Further access to the grant would also be determined through RADA and related agricultural support entities such as the National Irrigation Commission (NIC). Such an initiative would require a supporting Government of Jamaica (GoJ) policy and institutional framework.	Grants should cover the cost for the implementation of a small RWH or efficient irrigation system. • **Rainwater Harvesting System** Requires roof area for water collection, water tank for storage, guttering and accessories. Average cost ranges from US$1,000 to US$2,000 to collect and store 600 gallons to 2,000 gallons of water. • **Micro-Sprinkler** Cost for purchase and installation of a micro-sprinkler irrigation system for a ¼ acre property is US$150 to US$400. • **Drip Irrigation System** Cost for purchase and installation of a drip irrigation system for a ¼ acre is US$200 to US$500. • **Training and Development** Cost for farmers to use rainwater harvesting and sprinkler and drip irrigation	• Rainwater harvesting system allows for a diversification of water supply and decrease in cost of water purchased from other sources. The benefit varies widely and is highly dependent on site/area and specific rainfall patterns. In general, a small system can save farmers on average US$50 to US$150 per month on water-related costs. • Availability of water and irrigation systems can also allow for increased production and expansion of land under agriculture. • Irrigation systems can be automated; therefore, it is less time-consuming for farmers. • Micro-Sprinkler Irrigation allows for more efficient use of water compared to traditional flood irrigation methods. • Sprinkler irrigation allows for more effective use of water

Overarching Barriers	Proposed Measures	Expected Costs	Expected Benefits
		systems is estimated at US$200 per farmer.	resources on farms situated on hillsides or sloped terrain. • Drip irrigation systems will decease water loss due to evaporation or runoff.
	Provision of low-interest or interest-free loans for purchase and installation of equipment		• Increase in use of rainwater harvesting and irrigation systems by small and medium farmers
	Provision of tax incentives and reduction of import duties on component parts for systems to reduce capital costs for adoption and installation	Farmers can receive a 50% discount on General Consumption Tax (GCT) for the purchase of rainwater harvesting and irrigation systems.	• Increase in use of rainwater harvesting and irrigation systems by small and medium farmers
	Financial incentives through the National Irrigation Commission (NIC) to encourage optimal use of water using water-efficient irrigation system		• Increase in use of rainwater harvesting and irrigation systems by small and medium farmers
	The Ministry of Agriculture, its subsidiaries and related institutions need to re-examine the reasons for slow/lack of uptake when funds are supposedly made available to small and medium farmers, and to develop innovative mechanisms to facilitate change. This could begin with consultations with farmers and among farmer organizations and also with public financial entities and private lending agencies regarding the imperative for accessible finance for climate-smart technologies to expand	**Consultant fees for audit/assessment of financial incentives and recommendations of national standards and guidelines –** Estimated lump sum cost: US$40,000.	• Improved financial incentives, grants, and loan packages for small and medium farmers. • Increased uptake of financial incentives from small and medium farmers • Increase in use of rainwater harvesting and irrigation systems by small and medium sized farmers

Overarching Barriers	Proposed Measures	Expected Costs	Expected Benefits
	agricultural output with the goal being local food security and increased export earnings.		
	A policy and institutional framework needs to be negotiated and established by the Government with specific lending agencies to provide, at discounted rates, farm financing for capital and operating expenses that takes into account the farming/crop cycle for repayment schedules. The policy framework may consider Government guarantees.		• Increased uptake of financial incentives from small and medium farmers • Increase in use of rainwater harvesting and irrigation systems by small and medium farmers
	Establishment of a funding policy/financial framework that would enable the Government of Jamaica through RADA or the Ministry of Agriculture to provide guarantees to selected lending institutions for providing credit to private entities to supply sprinkler and drip irrigation systems to local farmers who meet the determined criteria.		• Improved financial incentives, grants, and loan packages for small and medium farmers. • Increase in uptake of financial incentives from small and medium farmers. • Increase in use of rainwater harvesting and irrigation systems by small and medium farmers
	The cost of appropriate security systems should be included in the financing package for the capital costs of the drip and sprinkler irrigation works. This cost would have to be calculated on a site-specific basis.		• Increased security for water supply and distribution systems • Ensure reliability and resilience in regard to water supply to communities.

Overarching Barriers	Proposed Measures	Expected Costs	Expected Benefits
			• Reduction in repair and replacement costs of property and equipment
High levels of larceny in the agriculture sector preventing additional investment in technology and equipment	Increased patrols for public security services (Police), the Praedial Larceny Prevention Unit and private security entities in rural areas		• Increased security for water supply and distribution systems • Ensure reliability and resilience in water supply to communities. • Reduce repair and replacement costs of property and equipment.
Lack of knowledge	Establish ongoing capacity building programmes for farmers to include business planning, financing, introduction to new technologies and climate change adaptation. Government should position this technology as the part of a larger investment in the horticultural sector with the objective of increasing overall production. Promotion of this technology and knowledge will create increased interest in the technology and efficient micro-irrigation systems.	**Capacity building workshops in business planning, financing, and climate change and technologies for small and medium farmers** Estimated cost: US$10,000 to develop workshop content and material. US$3,000 per workshop	• Increase uptake of financial incentive, grant, and loan packages for small and medium farmers. • Increase in use of rainwater harvesting and irrigation systems by small and medium farmers
	Strengthen farmer-field-schools to allow for greater scale and reach. Specific focus	**Additional funding required for the expansion of farmer field schools**	• Increase in the knowledge of farmers about rainwater

Overarching Barriers	Proposed Measures	Expected Costs	Expected Benefits
	should be given to in-the-field training for farmers, taking into account of the farmers' knowledge and capacity and resources.		harvesting and irrigation systems. • Increase in use of rainwater harvesting and irrigation systems by small and medium farmers
	Capacity building for farmers on how to use real-time climate and soil-based information to determine crop water requirements, irrigation water management and irrigation scheduling (that is, when and how much to apply)	**Capacity building workshops for small and medium farmers.** Estimated cost: US$10,000 to develop workshop content and material. US3,000 per workshop	• Increased knowledge of farmers about real-time data gathering and information. • Proper use of rainwater harvesting and irrigation systems. • Increased water efficiency and use due to improved management of rainwater harvesting and irrigation systems. • Increased crop yield and productivity per acre of agricultural land
	Develop practical guidelines for micro-irrigation system design and management.	**Consultant fees for development of national standards and guidelines re use of irrigation system design and management.** Estimated lump sum cost: US$60,000.	• Proper use and management of irrigation systems • Increased water efficiency and use due to improved management of irrigation systems.

Overarching Barriers	Proposed Measures	Expected Costs	Expected Benefits
			• Increased crop yield and productivity per acre of agricultural land
	Organize farmers' exposure trip on demonstration site to expose farmers to implementation of the technologies and provide them with all the information of the products, suppliers, cost, and economic benefits.	**Field class for small and medium farmers to introduce them to successful use of rainwater harvesting and irrigation systems.** Estimated cost: US$5,000 US$3,000 per field class	• Increase in the knowledge of farmers re rainwater harvesting and irrigation systems. • Increase in use of rainwater harvesting and irrigation systems by small and medium farmers.
Resistance to change from cultural/behavioural norms.	Provide information to farmers about the financial benefits of the use of these technologies. Education should be in a way that it highlights how the technology is going to contribute towards the well-being/ empowerment of both male and female farmers.	**Advertising and marketing campaign geared towards small and medium farmers on the use of rainwater harvesting and irrigation systems.** Estimated cost for advertising campaign: US$50,000 to US$100.00	• Increase in the knowledge of farmers about rainwater harvesting and irrigation systems. • Increase in the use of rainwater harvesting and irrigation systems by small and medium farmers.
Institutional	Training of water users and service providers in design, installation, operation, and maintenance	**Capacity building workshops to train water users and service providers** Estimated cost: US$5,000 to develop workshop content and material. US$3,000 per workshop	• Proper design, installation, use and management of rainwater harvesting and irrigation systems. • Increased water efficiency and use due to improved management of rainwater harvesting and irrigation systems.

Overarching Barriers	Proposed Measures	Expected Costs	Expected Benefits
	Government could include adoption of these technologies in larger agricultural special investment projects to improve production and market competitiveness.		
	Agricultural training entities should be supported to include R&D as it relates to the application and benefits of climate- smart technologies for water management.	Create and improve linkages between agricultural training entities and research and development institutes such as CARDI, The UWI, UTech, Ja, CASE, etc.	• Increase knowledge, data collection and information of rainwater harvesting and irrigation systems
	Farmers need to be included in all stages of the farm/agricultural development process, collection of data, planning and the execution of projects. This will facilitate understanding and engagement with new or improved climate adaptation irrigation technologies.		• Increase in the knowledge of farmers about rainwater harvesting and irrigation systems. • Improved understanding of farmer needs and challenges, therefore increased responses use of rainwater harvesting and irrigation systems. • Increased use of rainwater harvesting and irrigation systems by small and medium farmers
	Reduce perception of risk through demonstration plots, and identification or creation of markets.	**Field class for small and medium farmers to introduce them to successful use of rainwater harvesting and irrigation systems** Estimated cost: US$3,000 to US$5,000 per field class	• Increase in the knowledge of farmers about rainwater harvesting and irrigation systems.

Overarching Barriers	Proposed Measures	Expected Costs	Expected Benefits
			• Increased use of rainwater harvesting and irrigation systems by small and medium farmers

3.6 Enabling Framework for Overcoming the Barriers

Small and medium-sized farmers in Jamaica are extremely vulnerable to climate change. Additionally, global shock events (fuel prices and pandemics) have heightened the need for food security in Jamaica. Therefore, it is important that adaptation measures be focused on reducing farmers' vulnerability to the effects of climate change.

Two prioritized technologies (rainwater harvesting and sprinkler and drip irrigation) for Jamaica seek to reduce farmers' vulnerabilities and risk associated with the effects of climate change. However, several major barriers have been identified which prevent small and medium-sized farmers from accessing these technologies.

The GoJ should make provisions and/or provide policy support and guidance to the Development Bank of Jamaica (DBJ) and financial institutions for them to be able to provide loans and financial support to farmers while reducing the risk to the lending agency/bank. The loans should consider the farming cycle, and the effects that climate change will have on small and medium farmers and their ability to produce. Hence, these loans and financial support towards the acquisition and Master of Technologies, such as integrated water management systems and solutions for farmers, will allow farmers to become more resilient to the effects of climate change.

Small and medium farmers will need assistance in the use of new technologies for accessing information (products available, understanding the use of technology, weather information). It is therefore critical to deliver these new technology-based products to the farmers in ways and formats which the farmers can easily understand. Additionally, building confidence and competence for farmers in the use of smart digital technology may therefore be a means to enable more efficient collection and management of the limited water collected in rainwater harvesting systems.

As the farmers embark on the use of the new technology-based products, programmes geared towards building capacity and changing cultural behaviour are very critical to support their diffusion. This is important to ensure the selection of the appropriate technology that will bring maximum benefit based on the type of crops grown and site characteristics. These programmes can introduce farmers to additional technologies and best practices to facilitate optimal water use such as seed/crop selection based on location, the use of shade housing, intercropping, and so on. This will foster the integrated approach that is necessary to optimize agricultural output in the face of a changing climate.

Responsibility for RWH for agriculture in the rural areas needs to be placed under an agency which will be accountable for the management of the diffusion of the technology. The agency entitled Rural Water Supply Limited (RWSL), a GoJ water supply entity, has been installing large systems in rural schools and public facilities across the island. It is proposed that the RWSL be established as the focal agency for expanding deployment of this technology to rural farmers.

Government, municipal corporations, local police and the Praedial Larceny Prevention Unit should play a bigger role in controlling praedial larceny and theft within the agriculture sector. Improving farmers' awareness and knowledge on how to improve farm security should also be a priority of the GoJ, in an effort to improve national food security.

4 Water Resources

The importance of strengthening water security for Jamaica has been a long-standing issue over several years, and the conflation of climate change impacts and the Covid-19 pandemic has heightened the urgency. Remarkable changes in annual precipitation patterns and associated stormwater runoff and aquifer recharge coupled with warming temperatures and sea level rise have all significantly affected sustainability and the quality of water supply. More specifically, within the last decade, Jamaica has experienced a reduction in rainfall with subsequent increases in temperature and the length of the dry season. This trend is expected to continue as the mean annual temperature for Jamaica is projected to increase between a range of 0.7 to 1.8°C by the 2050s, while changes in rainfall are expected to range between -44% to +18% by the 2050s (CSGM, 2012). These changes have led to prolonged drought in most areas, and coupled with markedly lower and flashy river flow, have resulted in a reduction in both groundwater recharge and the distribution of water across river basins and watersheds.

With respect to the COVID-19–19 pandemic, suggested approaches to mitigating the outbreak involved increased sanitation and improved hygiene practices which required increased use of water resources during an intense drought period as the country faced its annual dry season. Therefore, the main issue faced by the sector was the growing demand for water at a time when water supply was becoming limited. The need for consistent access to clean water in homes became even more crucial during the lockdown and work-from-home periods. This coincided with the time of year when water lock-off restrictions would typically be employed, so the issues of water availability and security therefore became a greater cause for concern.

Whilst the issues related to climate change adaptation for the water sector were not developed as a result of the high demand for water due to the COVID-19–19 pandemic, the virus highlighted the need to combat the issues of water scarcity by employing technologies best suited for water storage in homes, healthcare facilities, schools and commercial businesses. It also emphasized the need to ensure that current technologies can support the increased demand for water supply, as the ability to curtail the spread of the virus would be impacted by the lack of water.

Frequent water restrictions have become the “go-to response” for managing limited water supply, but in providing suitable technologies, and encouraging the sustainable use of water resources, Jamaica may be able to ease the strain associated with meeting the demand for adequate water supply, particularly during a health crisis. To start this process, the GoJ has sought to establish a water fund to provide financial support in managing watersheds, and as a more immediate approach the Ministry of Economic Growth and Job Creation (MEGJC) and the Ministry of Local Government and Community Development (MLGCD) have implemented a Trucking of Water Programme to help relieve persons during water lock-off periods.

Water is a critical input for most economic sectors, as well as for household, sanitation, and health services. Approximately 15% of Jamaicans, especially those in rural communities, depend directly on rainfall catchment systems and rivers as their main source of water (GoJ, 2019). The urban areas which house more than 50% of the population depend on river diversion, reservoirs, and dams for piped water to satisfy domestic and commercial needs. Additionally, the Covid-19 Pandemic has heightened the need for access to water for sanitation and hygiene as there has been considerable emphasis on washing hands and additional cleaning and sanitation, as part of the health and safety protocols. The technologies which have been selected for prioritization for climate change adaptation within the water resources sector in Jamaica are:

i. Community-scale rainwater harvesting systems.
ii. Minor water tank networks for communities.

Prioritized technologies which focus on water capture and storage will be essential in ensuring the availability of a consistent and reliable water supply. These technologies will allow citizens to capture and store water from seasonal rainfall as well as from the increasing occurrence of short duration high intensity rainfall events.

4.1 Preliminary Targets for Technology Transfer and Diffusion

Preliminary targets for the transfer and diffusion of the prioritized technologies were identified and discussed during stakeholder consultations. The targets for the technologies are given in
Table 4-1.

Table 4-1: Preliminary targets for the prioritized technologies for water resources

Prioritized Technology	Preliminary Target
Community-scale rainwater harvesting systems	The target for rainwater harvesting systems will be to increase in non-utility supplied rural communities by approximately 50% of existing coverage over a three-year period, 2021–2024. Currently, there are 353 community-scale rainwater harvesting systems across Jamaica. This target is in keeping with the GoJ's National Water Sector Policy and Implementation Plan 2019, which includes Rainwater Harvesting. The GoJ seeks "*to promote the rehabilitation and maintenance of community catchment tanks, where Municipal Corporations, Local Authorities, or communities themselves wish to take on the responsibility of maintaining these systems*" (GoJ, 2019).
Minor Water Tank Networks for communities	The target for minor tank networks is to increase water storage and distribution systems for potable uses by 20% in non-utility supplied rural communities by 2024. This target is in keeping with the National Water Sector Policy and Implementation Plan 2019 which outlines the GoJ's goal to provide potable water access to everyone by 2030 (GoJ, 2019).

4.2 Barrier Analysis for Rainwater Harvesting System for Community Water Supply

4.2.1 General Description of Rainwater Harvesting Systems for Community Water Supply

Currently, many areas in Jamaica have inadequate water supply. Rainwater harvesting is being widely promoted especially in rural areas where water supply networks (pipes) may be limited, and where collection is seen as a useful primary source for both potable and non-potable uses. Water is collected from rooftops of larger facilities (schools, hospitals, and industrial buildings) and community barbeque catchments and stored in drums and tanks as sources of primary and secondary water or to supplement other sources (Figure 4-1).

Untreated rainwater is usually stored for non-potable uses such as landscaping, irrigation, washing and flushing toilets. However, if the harvested rainwater is treated, it can be used for potable uses (drinking and bathing). Typically, treatment of water ranges from use of bleach to boiling at the household level. New technologies are available to increase water storage and water treatment options. Methods for rainwater treatment include Filtration, Ultraviolet (UV) and Ozone Treatment Systems. The GoJ proposes to treat harvested water at the community level to meet the standards of the Ministry of Health Wellness and World Health Organization (WHO) before it is consumed.

Figure 4-1: Disused barbeque catchment system in Manchester, Jamaica

Rainwater harvesting can help to adapt to the effects resulting from climate change in Jamaica as it allows for:

- Diversification of potable water supply by simple water collection and treatment methods.
- Creation of new sources of water for water-stressed areas.
- Increase in stormwater control and capture.
- Increase in water storage.
- Simple systems with low setup costs and which are scalable by adding components over time.
- Use of technology which can be easily maintained without specialized persons.

Some private and public entities have designed and constructed rainwater harvesting systems across Jamaica. However, there is rarely enough storage to last through long drought periods, and water treatment methods for potable uses is inadequate. Therefore, increased water capture capacity, storage capacity and water treatment methods are largely required.

4.2.2 Identification of Barriers

The rainwater harvesting system for community water supply has been classified as a 'Publicly Provided Good' (see Table 2-1 for definitions) as these systems are expected to provide potable water to the public (non-utility supplied communities). However, in Jamaica these systems are usually built and managed by the GoJ, government agencies, municipal cooperation, and non-profit organizations.

Several large community size catchments were once used across rural areas of Jamaica, but due to lack of maintenance after other more "reliable sources" of water (truck and piped) were introduced, most of these systems were abandoned. However, as water problems have been increasing in recent times, there has been a renewed effort to reintroduce the use of large harvesting systems.

Rural Water Supply Limited, a GoJ water supply entity, has been installing large systems in rural schools and public facilities across the island. Additionally, similar rainwater harvesting systems have been implemented at schools across Jamaica by the UNDP. However, these installed systems do not generally provide potable water for the wider communities. Therefore, there needs to be an increased effort to expand the installation of these larger rainwater harvesting systems using schools and other large facilities which have suitable roofs and space for large water storage tanks. Additionally, efforts should include water treatment to potable standards.

Barriers have been identified for the two prioritized technologies for the water resources sector as direct and indirect and include economic and financial as well as non-financial barriers. Both technologies have similar constraints for diffusion, resulting in some repetition in the listing of barriers. The issues are repeated in the interest of "stand alone" documentation for each technology.

4.2.2.1 Economic and financial barriers

Economic and financial barriers were identified from stakeholder consultation and scored to determine which barriers were most significant. The barriers and scores are given in Table 4-2.**Error! Reference source not found.**

Table 4-2: Identified economic and financial barriers for community-scale rainwater harvesting for potable water uses

Identified economic and financial barriers		Total/10
Direct		
1	Municipal Corporations within the Ministry of Local Government and Community Development currently oversee community Rainwater Harvesting System. However, they lack the financial resources to build, operate and maintain these systems. Additionally, maintenance is done on an ad hoc basis and there is generally no specific department or budget allocation for these activities.	8
2	High capital and maintenance cost for treating community-scale harvested rainwater for potable use	4
3	The NWC is the main provider of potable water for Jamaica, however, community size rainwater harvesting systems pose a particular challenge for the agency as these	6

Identified economic and financial barriers		Total/10
	systems are extremely costly to build and operate compared to the return they will receive for the water.	
Indirect		
4	Cost of water from NWC is much more affordable than collection and treatment of water from rainwater harvesting systems.	7

4.2.2.2 Non-financial barriers

Non-financial barriers were identified from stakeholder consultations and scored to determine which barriers were most significant. The barriers and scores are given in Table 4-3.

Table 4-3: Identified non-financial barriers for rainwater harvesting for potable water uses

Identified non-financial barriers		Total/10
Cultural/Behavioural		
1	The use of untreated rainwater harvesting is not accepted by some groups as suitable for potable uses.	4
2	Collecting and using rainwater is generally seen as something only done by lower class persons and communities and therefore, some individuals shun the idea. Pipe-borne water from public supply more of a *status symbol*.	4
3	Historically, many rural communities benefit from water projects which have been donated, and they rarely pay for the water supplied. Therefore, there is some resistance from community members to pay for supply of water provided by any managed system such as harvested water or water stored in community tanks.	5
4	Bottled water has become widely available across Jamaica, and purchase has become popular for potable uses.	3
5	Many people in rural communities believe water is a public good that should be provided by the government/state, therefore there is resistance to pay for the commodity.	7
Environmental		
6	In some areas there is not enough rainfall for the use of rainwater harvesting due to longer periods of drought. Therefore, the rainwater harvesting system will not be used for the majority of the year.	6
Technical		
7	There is a lack of technical expertise for water treatment.	6
8	Limited or no use of chemicals for the treatment of water for potable and non-potable uses, therefore the water is considered unsafe.	6
9	No maintenance of several existing systems. They have therefore become dysfunctional and out of use.	7
Security		

Identified non-financial barriers		Total/10
10	Community systems are often vandalized and much of the equipment is stolen. There is therefore some reluctance to setup these systems without additional measures for security. Theft of pipes, water pumps, electrical equipment and other fittings are under threat of being stolen.	8
Regulatory		
11	The institutional and regulatory framework for the handling of water resources in Jamaica lies with multiple agencies and there are sometimes conflicting responsibilities and accountabilities. Therefore, rainwater harvesting is done on an ad hoc basis with limited consideration for rainfall dynamics, water quality and water use.	8
12	There is no local regulation or guidelines specific to Jamaica for the safe collection and use of rainwater. Therefore, many systems suffer from poor water quality and often left abandon over time due to poor design considerations. Therefore, regulation is required to ensure water quality and safety standards are met.	3
13	Lack of integrated water resource planning at the community level.	5
Institutional		
14	There is no agency responsible for the development of rainwater as a source of potable and non-potable water for Jamaica. Rural Water Limited has focused activities on rainwater harvesting, but this is only a small part of their wider mandate. Therefore, little attention is paid to the development of rainwater harvesting for communities.	8
15	The NWC is the main provider of potable water for Jamaica, however, community size rainwater harvesting systems pose a particular challenge for the agency as these systems are extremely costly to build and operate compared to the returns, they will receive for producing potable water.	6
Political		
16	Promises of access to piped water are sometimes associated with 'vote getting' during periods of election. Rainwater harvesting and use have therefore not been traditionally promoted in some areas.	5
17	Political motives can dictate the type of projects which are to be implemented in areas. In many instances, other projects are given priority, such as road repair and construction of box drains, etc.	5
18	Political representatives are not likely to support introduction of payment for water in areas where this does not currently exist as there may be political backlash. Such fees for water use are critical for the maintenance of the rainwater harvesting systems, particularly when the water is treated for potable use.	5

4.3 Barrier Analysis for Creation and Restoration of Minor Tank Networks

4.3.1 General Description for the Creation and Restoration of Minor Tank Networks

The creation and restoration of community /minor water tank systems which collect water from piped supplies, surface water bodies, runoff, direct rainfall, or trucks may be suitable for some communities. Minor tanks usually gravity feed to houses or to a communal pipe and the water is used for domestic, agricultural and livestock needs. These community water tanks allow for diversification of water supply for rural communities and increase access to safe water. Instances where water is collected from surface runoff, can also aid in storm water control and capture.

4.3.2 Identification of Barriers

Creation and restoration of minor tank networks have been categorized as a 'Publicly Provided Good' (see Table 2-1) as these systems are expected to provide potable water for the benefit of the general population which resides in non-utility supplied communities. Such larger systems were usually built and managed by the GoJ, government agencies, municipal cooperation, and/or the National Water Commission. Community-scale minor tank network systems were once used in many rural communities. Many tanks still exist today (Figure 4-2), but several need major repair. Many of these systems have also passed their expected lifetime. This coupled with lack of maintenance has rendered them useless. Additionally, the size of these community tanks is no longer adequate to provide for the basic needs of the residents. Many of the community water tanks in Jamaica are operated by the NWC. Others are operated by the Municipal Corporation as minor water supply networks, and are usually limited in scale, and distribution. These systems are also generally not revenue-generating, therefore there is little cash flow to provide upgrades and maintenance of the system.

Figure 4-2: Large storage tank in Northern Clarendon used for the collection of water and distribution to the nearby community

The NWC sometimes mandates the use of community water tanks for new housing developments, however, this is usually for new developments with large water demand. It is also important to note, however, that there are no guidelines for the total storage capacity for these tanks. In general, developers usually provide capacity to last a development for 0.75 to 2 days of water demand.

In Jamaica, there needs to be a larger effort for the repair and creation of minor water tank networks, especially in rural communities where access to NWC piped water supply is limited or unavailable. This may be due to topography, geological risk, and cost. Minor tank networks provide a source of water for communities; however, the water storage and treatment systems also improve the resilience of the communities.

4.3.2.1 Economic and financial barriers

Economic and financial barriers were identified from stakeholder consultations and were scored to determine which were most significant. The barriers and scores are given in Table 4-4.

Table 4-4: Identified economic and financial barriers for creation and restoration of minor tank networks

Identified economic and financial barriers		Total/10
Direct		
1	Municipal Corporations that lie within the Ministry of Local Government and Community Development currently oversee community Minor Storage Tanks. Generally, they lack the financial resources to build, operate and maintain these systems.	8
2	High capital and maintenance costs for water treatment systems for potable use	4
3	The NWC is the main provider of potable water for Jamaica, however, community-scale minor tanks networks pose a particular challenge for the agency as these systems are extremely costly to build and operate compared to the return, they will receive for producing potable water.	6

4.3.2.2 Non-financial barriers

Non-financial barriers were identified from stakeholder consultations and were scored to determine which were most significant. The barriers and scores are given in Table 4-5.

Table 4-5: Identified non-financial barriers for creation and restoration of minor tank networks

Identified non-financial barriers		Total/10
Cultural/Behavioural		
1	Historically, many rural communities benefit from water projects which have been donated, and they rarely pay for the water supplied. Therefore, there is some resistance from community members to pay for supply of water provided by any managed system such as harvested water or water stored in community tanks.	5

Identified non-financial barriers		Total/10
2	Bottled water has become widely available across Jamaica, and purchase has become popular for potable uses.	3
3	Many people in rural communities believe water is a public good that should be provided by the government/state, therefore, there is resistance to pay for the commodity.	7
Technical		
4	There is a lack of technical expertise and limited use of chemicals for water treatment. Water may be considered unsafe for potable use.	6
Security		
5	Community systems are often vandalized and much of the equipment is stolen. There is therefore some reluctance to set up these systems without additional measures for security. Theft of pipes, water pumps, electrical equipment and other fittings are under threat of being stolen.	8
Regulatory		
6	The institutional and regulatory framework for the handling of water resources in Jamaica lies with multiple agencies and there are sometimes conflicting responsibilities and accountabilities. Therefore, rainwater harvesting is done on an ad hoc basis with limited consideration for rainfall dynamics, water quality and water use.	8
7	There are no local regulations or guidelines specific to Jamaica for the safe collection and use of rainwater. Therefore, many systems suffer from poor water quality and are often left abandoned over time due to poor design considerations. Therefore, regulation is required to ensure water quality and safety standards are met.	3
8	There is lack of integrated water resource planning at the community level.	5
Political		
9	Political representatives are not likely to support the introduction of payment for water in areas where this does not currently exist as there may be political backlash. Such fees for water use are critical for the maintenance of the rainwater harvesting systems, particularly when the water is treated for potable use.	5

4.4 Linkages of the Barriers Identified

The GoJ has identified that approximately 15 percent of Jamaicans live in Non-Utility Service Areas (GoJ, 2019). The GoJ intends to use technologies such as spring entombments, small-piped gravity-fed or solar-powered systems, and community or individual rainwater harvesting (catchment tanks) systems. The two prioritized technologies and targets outlined for water resources in Jamaica are associated with increasing the availability of water to non-utility supplied rural communities across Jamaica. This is in keeping with the GoJ's target outlined in the Water Sector Policy and Implementation Plan of access to potable water for everyone by 2030.

The barrier analysis has identified the major barriers to increasing the availability of water on non-utility supplied rural communities across Jamaica for the two prioritized technologies. The barriers identified are similar for the technologies as they are both focused on water supply. This section seeks to link these barriers under common themes. This allows for identifying broad measures across the sector to reduce/eliminate the effects of these barriers.

Economic and Financial

One of the most significant economic and financial barriers identified for the two prioritized technologies for water resources is the general lack of financial resources to build, operate and maintain these systems. Additionally, maintenance is done on an ad hoc basis and there is generally no specific department or budget allocation for these activities. A problem tree root cause analysis (Figure 4-3) indicated the following: -

1. Agencies and government entities, such as Parish Councils and Water User Groups/Associations do not have the required finances to build, operate and maintain large water capture, storage, and distribution systems on a community scale.
2. While technical expertise is available across the country for the design of community- scale water systems, local government agencies and water user groups/association do not have the required capacity to implement and manage these systems/projects. Outsourcing this can be expensive as these large systems require specialist skills.

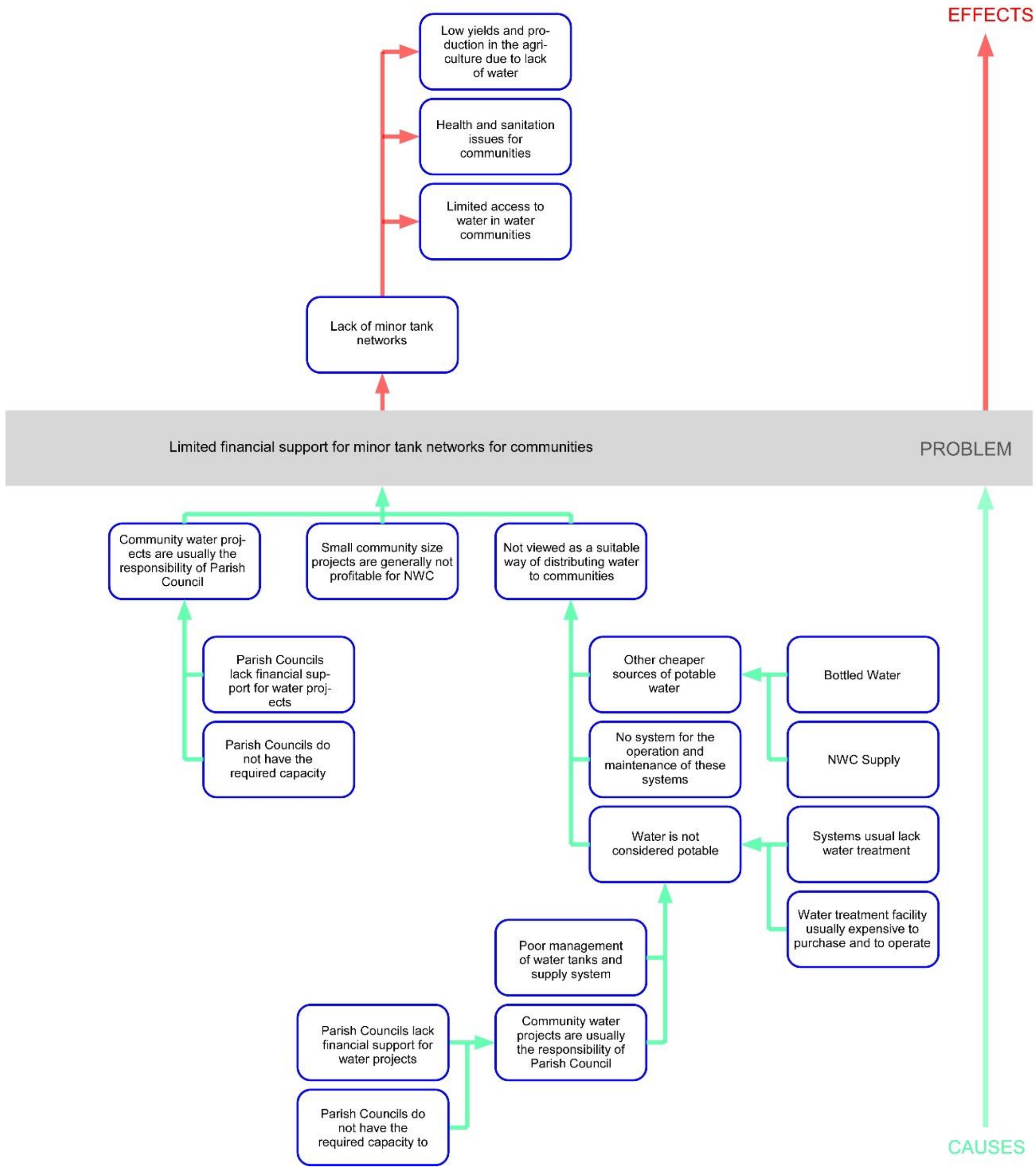

Figure 4-3: Problem tree analysis for the major economic and financial barriers for community scale water harvesting and minor water tank networks for non-utility supplied rural communities in Jamaica

Security

In the past, many community systems have been vandalized and much of the equipment stolen. These sentiments have been echoed across many water user groups, especially in rural communities. There is therefore some reluctance to set up these systems without additional measures for security. The Water Sector Policy and Implementation Plan, 2019, has also identified that one of the threats to water supply in rural and urban areas is that many of these assets are at risk due to inadequate physical security (GoJ, 2019).

Regulatory

Rainwater harvesting has generally been done on an ad hoc basis with limited consideration for rainfall dynamics, water quality and water use. Agencies such as the Rural Water Supply Limited and the Jamaica Social Investment Fund (JSIF) have been implementing projects across Jamaica, specifically for schools. Historically, water supply in Jamaica has usually focused on ground and surface water. Therefore, agencies such as WRA, NWC and Municipal Co-operations have not focused on rainwater harvesting systems as a primary source of water supply. Additionally, communities supplied by harvested rainwater are sometimes viewed as 'under-developed' or 'poor' and therefore, there has been a push from community and local representatives to develop more 'modern' piped water supply systems as a sign of 'progress' in the community. These initiatives are sometimes politically motivated or influenced.

4.5 Identified Measures

Table 4-6 outlines the proposed measures for overcoming the most significant barriers for the two prioritized technologies for water resources in Jamaica.

Table 4-6: Proposed measures for water resources

Major Barriers	Proposed Measures
Limited financial support for community-scale rainwater supply and minor tank network systems for non-utility supplied communities	• Local government budget should be realistic for community water supply. Budgets should include capital cost for the construction of rainwater harvesting and minor tank network systems. Additionally, the budgets should include finances for operation and maintenance. • Creating a practice of payment for water may provide some cash flow for agencies to construct and maintain rainwater harvesting and minor tank network systems. • Ensure development plans, loans and grants for rainwater harvesting systems or minor tank networks has a component for operation, maintenance, and repairs. It should include some sort of financing mechanics to ensure the continuity and sustainability of the system. • Community organizations can be responsible for the rainwater harvesting and minor storage tanks, however, they will need financial support from local agencies on the management of the water supply.
High levels of theft and vandalism preventing	• Increased patrols for public security services (Police) and private security entities for the security of water collection, storage, treatment, and supply systems.

Major Barriers	Proposed Measures
additional investment into the technology	
Lack of unified approach to the promotion and use of technology	• Development of national standards and guidelines for rainwater harvesting. This should be done with the required agencies responsible for water management and the environment. Therefore, it should include WRA, NWC, MOHW, NEPA and Rural Water Limited. • Government to create a department in an existing agency with related portfolio (NWC, WRA) with the sole responsibility of rainwater harvest research and development. This should include conducting research into rainfall and watershed analysis, catchment dynamics and rainwater quality. • Community organizations can be responsible for the rainwater harvesting and minor storage tanks, however, they will need technical support from local agencies on the management of the water supply.

4.5.1 Cost-Benefit of proposed Measures for Water Resources

A simple cost-benefit analysis was conducted for the implementation of the identified measures (Table 4-7). The cost-benefit analysis was completed with the best available information. While the prioritized technologies identified for water resources in Jamaica are not new, there is limited research and data to effectively quantify the benefits of these technologies. Such analysis is required to effectively develop a full quantitative financial model for the expected benefits these systems are expected to have on water resources in Jamaica.

Table 4-7: Simple cost-benefit for the proposed measures for water resources

Major Barriers	Proposed Measures	Expected Costs	Expected Benefits
Limited financial support for community scale rainwater supply and minor tank network systems for non-utility supplied communities	Local government budget should be realistic for community water supply. Budgets should include capital costs for the construction of rainwater harvesting and minor tank network systems. Additionally, the budgets should include finances for operation and maintenance.	• **Rainwater Harvesting System with a 24,000-gallon water storage and water treatment system.** Estimated capital cost: US$50,000 per system. Operational and maintenance: US$1,000 per year (average) per system • **Minor Tank Networks system with a 24,000-gallon water storage capacity** Estimated capital cost: US$50,000 to US$200,000. Operational and maintenance costs: US$1,000 per year (average) per system	• Increased water supply to non-utility serviced rural communities. This will increase access to water for women, children, differently abled and vulnerable groups. • Rainwater harvesting system can add another primary source of water for non-utility services communities. This can decrease costs associated with obtaining other sources of water by an estimated 50%. • Improves rural communities' adaptive capacity and resilience to the effects of climate change. • Rainwater harvesting decreases the dependency on other water supply options, such as trucked water, well water and surface water.

Major Barriers	Proposed Measures	Expected Costs	Expected Benefits
	Creating a practice of payment for water may provide some cash flow for agencies to construct and maintain rainwater harvesting and minor tank network systems.	• **Public/community consultations to promote awareness of water billing.** Estimated cost: US$2,000 per consultation. • **Training and capacity building for water management agencies in billing systems, etc.** Estimated Cost: US$3,000 per community • **Implementation of metering and billing system** Estimated cost: Unknown.	• Creates a source of revenue which will go towards the expansion, operation, and maintenance of the water supply systems. • Promotes efficient water use as there is a cost associated with the use of the resource. • Creates a financial benefit for investment into the supply of rural water. This may encourage additional investment from public and private entities, therefore increasing water supply options/opportunities.
	Ensure development plans, loans and grants for rainwater harvesting systems or minor tank networks have a component for operation, maintenance, and repairs. It should include some sort of financing mechanics to ensure the continuity and sustainability of the system.		• Increased water supply options in the long term because of increased operational and maintenance measures • Increased long term water supply resilience

Major Barriers	Proposed Measures	Expected Costs	Expected Benefits
	Community organizations can be responsible for the rainwater harvesting and minor storage tanks, however, they will need financial support from local agencies on the management of the water supply.	• **Training and capacity building for community organizations** Estimated Cost: US$3,000 per community • **Provision of professional services for inspection and audits of community rainwater harvesting and minor tank network systems.** Estimated Cost: US$4,000 per visit/assessment.	• Improved management of water supply systems in non-utility supplied rural communities. • Increased water supply options for non-utility supplied rural communities. • Increased water supply resilience in rural communities in the medium to long term
High levels of theft and vandalism preventing additional investment into the technology	Increased patrols for public security services (Police) and private security entities for the security of water collection, storage, treatment, and supply systems		• Increased security for water supply and distribution systems • Ensure reliability and resilience in water supply to communities. • Reduced repair and replacement cost of property and equipment
Lack of unified approach to the promotion and	Development of national standards and guidelines for rainwater harvesting. This should be done with the required agencies responsible for water management and the	• **Consultant fees for development of national standards and guidelines** Estimated lump sum cost: US$35,000.	• Improved water quality from rainwater harvesting systems.

Major Barriers	Proposed Measures	Expected Costs	Expected Benefits
Use of technology	environment. Therefore, it should include WRA, NWC, MOHW, NEPA and Rural Water Limited.		• Increased use of harvested rainwater due to improved quality of harvested rainwater
	Government to create a department in an existing agency with related portfolio (NWC, WRA) with the sole responsibility of rainwater harvesting research and development. This should include conducting research into rainfall and watershed analysis, catchment dynamics and rainwater quality.		• A unified approach to the development of rainwater harvesting systems across Jamaica. • Increased research and development in rainwater harvesting systems across Jamaica. • Increased promotion of rainwater harvesting use in Jamaica.

4.6 Enabling Framework for Overcoming the Barriers

Community-scale integrated water management will play a key role in ensuring water is efficiently captured, stored, treated, and distributed across the island, especially in rural communities currently with limited access to water. Prioritized technologies for water resources in Jamaica focus on creating community-scale rainwater capture and storage systems, which will be especially useful for rural communities and other water-stressed communities across Jamaica.

The provision of safe and reliable water for rural communities must be considered as a priority for community health and safety. The effects of climate change on these rural communities with limited access to water will increase their vulnerability. Therefore, Municipal Corporations and by extension the GoJ should provide capital funding and operation funding for the construction, rehabilitation and operation of community-scale water harvesting and management systems.

The Water Sector Policy should be amended to allow for the creation of an agency with the sole focus of developing targets, systems, supply and demand, legislation, regulations and standards to specify the safe collection and distribution of rainwater, especially as a public service for rural communities. Additionally, the water policy should include the creation of a special water licencing scheme which will allow for private entities to set up rainwater harvesting, storage, and distribution networks for communities. This approach will need cooperation between the private sector and various public agencies such as the WRA, NWC, MOHW, Office of Utilities Regulation (OUR) and NEPA.

Government, municipal corporations, local police, communities, and the private sector should create partnerships to allow for great security and safety of the community water capture, storage, and distribution systems. Community organizations will have to play a critical role, especially in rural locations. The use of surveillance technologies to enhance security measures will be critical, especially in rural communities.

5 Coastal Resources

Jamaica’s coastal resources, like those of other small island states, are of major environmental, social, and economic significance. These include natural ecosystems as well as anthropogenic constructs, all of which are exposed to the diverse impacts of climate change: sea level rise; changes in the frequency and intensity of storms and storm surges; increases in precipitation and surface runoff; and ocean warming and acidification.

Jamaica has been experiencing coastal erosion due to sea level rise; reduced fish production due to increases in sea surface temperatures and overfishing; reduction of reefs and calcareous species due to ocean acidification and storm damage; fish kills and coral bleaching related to increases in sea surface temperatures; and the destruction of coastal ecosystems, marine habitats and spawning grounds by hurricanes and tropical storms (CSGM, 2016).

Over the past several decades, coastal ecosystems in many areas around Jamaica have been undergoing stress from anthropogenic activities like coastal development, land use changes, pollution, and over-harvesting of commercially valuable species. The removal of mangroves, seagrass beds, and coral reefs occasioned by this multi-purpose use of the coastal zone has increased Jamaica's vulnerability to hurricanes and storm surges and has been posing a major threat to coastal ecosystems and marine life.

Of further significance is the settlement pattern and economic lifelines associated with the coastal zone. An estimated 75% of economic assets, including air and seaport facilities, urban centres, industrial production, energy generation and tourism infrastructure, are concentrated in coastal areas and are responsible for generating approximately 90% of the island's gross domestic product (GDP) (Met Office, 2010). The demand for coastal space in Jamaica has also intensified with the increase in population in coastal towns, where approximately 70% of the population resides along coastal plains (SDC, 2011).

There has been resultant coastal erosion, landward migration of coastal habitats and reduced effectiveness of reefs in dissipating wave energy. The impacts of climate change on an already deteriorating ecosystem are likely to become more severe and worsen problems that coastal areas experience. Confronting existing challenges that affect coastal infrastructure and coastal ecosystems is already a concern in Jamaica and is an imperative for attention.

In recognizing this, the restoration and protection of mangrove, seagrass and coral reef ecosystems have been identified as key outputs for climate change adaptation, as the ecosystem services they provide can help to minimize coastal erosion as well as reduce the risk of damage and loss to industries, communities, key infrastructure, and economic lifelines.

The technologies which have been selected for prioritization are therefore related to:

i. Wetland (mangrove) and Seagrass restoration and protection
ii. Coral reef restoration and protection.

5.1 Preliminary Targets for Technology Transfer and Diffusion

Preliminary targets for the transfer and diffusion of the prioritized technologies were identified and discussed during stakeholder consultations. The targets for the technologies are given in Table 5-1.

Table 5-1: Preliminary targets for the prioritized technologies for coastal resources

Prioritized Technology	Preliminary Target
Wetland Restoration	Over a five-year period, 2021–2026, complete the enhancement and/or replacement of 20% of critical wetland areas across Jamaica, based on a list of critical areas identified in consultation with NEPA
Coral Reef Restoration	Over a five-year period, 2021–2026, complete coral reef restoration at two sites. Site selection, method, implementation, and monitoring should be done in consultation with NEPA.

5.2 Barrier Analysis for Wetland (Mangrove and Seagrass) Restoration

5.2.1 General Description of Wetland (Mangrove and Seagrass) Restoration and Protection

Wetland habitats are important because they perform essential functions in terms of coastal flood reduction, erosion management, and provision of species habitats. They induce wave and tidal energy dissipation (Brampton, 1992) and acts as a sediment trap for materials, thus helping to build land seawards. The dense root mats of wetland plants also help to stabilize shore sediments, thus reducing erosion (USACE, 1989).

Nature-based solutions to coastal protection and disaster risk management have been receiving increased attention in recent years, and a recently published World Bank funded study (World Bank, 2019) examines the considerable flood risk reduction services that mangroves provide to Jamaica, together with benefits related to fisheries production, and carbon sequestration.

Wetland restoration re-establishes the advantageous functions, and techniques have been developed to reintroduce coastal wetlands to areas where they previously existed and to areas where they did not, if conditions allow. The diversity of wetland types means there are numerous methods for restoring wetlands, and the respective 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.

The most successfully restored wetland ecosystems for coastal protection are salt marshes and mangroves. Seagrasses may also be employed as a coastal defence, to dampen waves, but on their own are seldom considered an adequate shore protection alternative.

5.2.2 Identification of Barriers

Wetland (mangrove and seagrass) restoration has been categorized as 'Publicly Provided Good' based on the definition for publicly provided goods (Nygaard & Hansen, 2015). There have been several wetland (mangrove and seagrass) restoration projects in Jamaica, and in 2019, a mangrove seedling bank for restoration projects was established. The Palisadoes Mangrove Replanting Project was funded by the National Works Agency (NWA), in partnership with the UWI, to restore mangrove cover along the stabilized Palisadoes shoreline. The project included the reintroduction of young mangrove plants that were removed from the site in 2012 and the planting of over 5,000 other mangrove saplings that had been raised, nurtured, and hardened in a unique mangrove nursery at The UWI Port Royal Marine Laboratory. The efforts resulted in a 70% survival rate of both planted and fallen seedlings, however, a pause in funding from the NWA caused a lack of maintenance and monitoring of the area, leading to reoccurrence of solid waste build-up that caused damage to barrier nets and reduced the survival rate of saplings to 40%.

A seagrass restoration project was carried out as part of a €4.3 million (£3.34 million) Climate Change Adaptation and Disaster Risk Reduction initiative by the US marine environmental firm, CSA International (formerly Canadian Standards Association), for the National Environment and Planning Agency (NEPA). It was aimed at improving coastal ecosystems and reducing natural hazard risks from the island by transplanting 692 planting units consisting of two types of seagrass, shoal grass and manatee grass, over 1,000 square metres.

Other notable wetland restoration projects include: -

- The Jamaica Awareness of Mangroves in Nature (JAMIN) project was a year-long mangrove restoration project in Jamaica launched in 2014 through a joint venture between Khaled bin Sultan Living Oceans Foundation and The University of the West Indies-Discovery Bay Marine Laboratory. Refuge Cay Mangrove Rehabilitation project in 2018/19 sought to remove solid waste which restricted tidal flow causing mangrove loss in the central areas of the Cay. Regrowth was possible through these efforts and a net was placed around the cay to trap solid waste.
- Mangrove restoration pilot project was funded by the Environmental Foundation of Jamaica (EFJ) in East Boggy Pond in southern Clarendon in 2009. A U-Drain culvert was installed, and excavation works carried out to allow tidal flushing between the isolated and the main mangrove hydrological systems. The intervention led to regrowth of lost mangrove habitat and ecosystem just 2 months after.
- The Blue Carbon Restoration Project in southern Clarendon, Jamaica is the largest mangrove restoration project to be undertaken in the island. It seeks to restore over 1,000 hectares of degraded mangrove forest and boost ecosystem-based livelihood opportunities. These efforts are possible through the US$2.45 million grant provided by the UK Blue Carbon Fund, which was established in the IDB in 2019, and funded by the United Kingdom's Department for Environment, Food and Rural Affairs (DEFRA). The project began in June 2020 and is expected to be completed by 2026 resulting in a mangrove system that is viable, healthy, and optimally functioning.

Other seagrass restoration projects across the island include Fort Augusta Causeway seagrass restoration and biological survey; Dolphin Cove seagrass mitigation in Hanover in 2007; and Dolphin Island seagrass survey and restoration plan.

5.2.2.1 Economic and financial barriers

Economic and financial barriers were identified from stakeholder consultation and scored to determine which barriers were most significant. The barriers and scores are given in Table 5-2.**Error! Reference source not found.**

Table 5-2: Preliminary targets for the prioritized technologies for coastal resources

Identified economic and financial barriers		Total/10
Indirect		
2	Generally, restoration activities for wetlands (seagrass and mangroves) offer little guarantee of success and return on investment. Therefore, developers and investors might see little financial benefit for conducting and preserving these kinds of activities.	9

Identified economic and financial barriers		Total/10
3	Mangrove restoration occurs over a long period and requires continued financial input into managing site. Therefore, it is usually seen as an ongoing expense.	9

5.2.2.2 Non-financial barriers

Non-Financial barriers were identified by stakeholders and were scored to determine relative significance. The barriers and scores are given in Table 5-3.

Table 5-3: Identified non-financial barriers for water resources

Identified non-financial barriers		Total/10
Knowledge		
1	There exists a knowledge gap between the marine ecologists who are practising restoration activities across Jamaica and the general agencies and authorities who have responsibility for approving and monitoring these activities. Therefore, there is usually a misalignment of the process and way forward for restoration activities.	5
Environmental		
2	Wetland restoration and coral reef restoration projects are long term and susceptible to storm events. Therefore, there is a relatively high probability that the project could be destroyed by one storm event over the growth phase of the project.	8
3	The marine environment is constantly changing especially with the rate with which climate change has been progressing. The technologies for coral reef restoration may not be progressing fast enough within the region and locally to keep pace with this changing environment.	8
Technical		
4	Mangrove and seagrass restoration can be challenging due to low success rates associated with some species.	7
5	Seagrass is seen as a hindrance and is largely removed from beaches as it forms a bad experience for beach users and tourists.	5
6	There are limited areas for seagrass restoration across Jamaica.	6
7	Mangrove and seagrass restoration has no proof of concept unlike hard (grey) protection structures. In each site, the restoration would be unique and therefore there is never any proof that the restoration activities will work.	7
8	There are limited areas across Jamaica where restoration projects can occur. Many of the most suitable areas have been developed.	6
Regulatory		
9	The coastal zone is governed by environmental laws but monitoring and enforcement to guard against degradation is inadequate. Modification of the natural ecosystems requires permits and licenses from NEPA. However, Development Orders of the planning regime allow for tourism, recreational and structural development which often militate against protection of the natural systems.	7

Identified non-financial barriers		Total/10
10	Areas which have been restored require monitoring for protection against future destruction.	6
11	Generally, areas with the best conditions for wetland restoration are the same areas which compete with development such as tourism, ports, and coastal developments.	8
Political		
12	Political decision-making often directs creation of development zones. The process is sometimes inimical to either the preservation or restoration of coastal ecosystems.	7
Social		
13	There is a negative view of mangroves as it is not considered aesthetically pleasing. Additionally, mangroves are perceived as areas which promote the proliferation of vectors, such as mosquitoes and sandflies.	4
14	There has generally been the mindset of investors and technocrats to prefer recommendations for coastal protection from engineers over recommendations from ecologists. Therefore, coastal protection projects have been generally focused towards 'grey' structures rather than 'green' structures or a mix of 'grey-green' protection projects.	5
15	Wetland restoration projects in Jamaica and across the Caribbean have suffered from poor marketing and promotion. Therefore, there has been little exposure of what has been done and where.	4
16	The importance on mangroves is generally not understood by the public and it is not seen as important.	4
17	Non-governmental groups which serve as advocates for the protection of mangroves and important ecosystems are limited in resources, influence, and geographical spread around the island.	4
18	Increase in wetland areas across Jamaica will require an increase in the Government of Jamaica's capacity to monitor these locations.	4

5.3 Barrier Analysis for Coral Reef Restoration and Protection

5.3.1 General Description of Coral Reef Restoration and Protection

This technology consists of manmade underwater structures built to simulate the function of natural coral reefs in reducing wave energy entering the coastal zone to 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 many areas and has been successful. The artificial reefs will be constructed on land and transported and set into place in the marine environment.

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 “out planting”. Once the stock and capacity of the nursery have increased, coral colonies are transported and out planted on to natural reefs to grow and become reproductive, spawning members of the population.

5.3.2 Identification of Barriers

Coral reef restoration has been categorized as a ‘Publicly Provided Good’ based on the definition for publicly provided goods (Nygaard & Hansen, 2015).

There are several coral reef restoration projects active in Jamaica. Underwater nurseries are in the White River Fish Sanctuary and the Oracabessa Fish Sanctuary. Fishermen from the area are trained as coral gardeners who cultivate coral pieces and out-plant them on to the reefs when they grow into larger corals. Similar efforts were carried out at the Discovery Bay Marine Laboratory in St. Ann. These initiatives are supported by small grants from foundations, local businesses such as hotels and scuba clinics, and the Jamaican government. Issues with coral bleaching and hurricanes have caused delays in restoration efforts, but overall, the establishment of fish sanctuaries, coupled with coral replanting, has resulted in a resurgence of marine fauna in these areas.

Additionally, in 2015, the Inter-American Development Bank (IDB) and the Centre for Marine Sciences (CMS) at The University of the West Indies launched a US$350,000-project aimed at restoring the island's coral reefs and ultimately providing applicable information and techniques to other countries in the region experiencing similar challenges. The Coral Reef Restoration Project was an 18-month endeavour inclusive of research activities and mitigating coral depletion by identifying and cultivating coral species that are resistant to the ravages of the impact of climate change.

Seascape Caribbean established in 2008 by Andrew Ross focuses on the development of financially sustainable coral restoration sites and programmes through fisheries enhancement by way of habitat restoration, replacement, and harvest management; the development of live-in coral snorkelling parks and coral gardens for tourists; and coastal protection and beach restoration, focusing on the restoration of live corals and artificial reefs, mangroves and seagrass. Initial coral restoration efforts were supported by a local beach club and hoteliers in Montego Bay.

Most recent efforts in coral restoration were in September 2020 by the National Environment and Planning Agency (NEPA). The team planted some 150 pieces of corals on to the reef at the Orange Bay Fish Sanctuary, as part of efforts to restore the reef systems in Negril, Westmoreland, and surrounding areas. The out-planting exercise was conducted in partnership with the Negril Area Environmental Protection Trust (NEPT) and forms part of the Integrating Water, Land and Ecosystems Management in

Caribbean Small Island Developing States (IWEco) Project which is being funded by the Global Environment Facility (GEF) and the United Nations Environment Programme (UNEP). The nursery from which the corals are out planted was established in 2019 with the support of the Environment Foundation of Jamaica (EFJ) and is one of the largest efforts in western Jamaica in relation to coral restoration.

5.3.2.1 Economic and financial barriers

Financial barriers were identified from stakeholder consultation and scored to determine which barriers were most significant. The barriers and scores are given in Table 5-4.

Table 5-4: Identified financial barriers for coral reef restoration

Identified economic and financial barriers		Total/10
Direct		
1	Capital and operational cost for coral reef restoration is particularly high. This is because there is a relatively high cost associated with the initial research and development and a high cost for operating and maintaining a coral nursery.	9
Indirect		
2	Generally, restoration activities, such as that of coral reefs, offer little guarantee of success and direct return on investment. Therefore, developers and investors see little financial benefit for conducting and preserving these kinds of activities.	9
3	Coral reef restoration occurs over a long period and requires continued financial input into managing sites. Therefore, it is usually seen as an ongoing expense.	9

5.3.2.2 Non-financial barriers

Non-financial barriers were identified by stakeholders and were scored to determine relative significance. The barriers and scores are given in Table 5-5.

Table 5-5: Identified non-financial barriers for coastal resources

Identified non-financial barriers		Total/10
Knowledge		
1	Knowledge gap was noted between the knowledge professionals who are practising restoration activities across Jamaica and the general agencies and authorities who are responsible for approving and monitoring these activities. Therefore, there is usually a misalignment of the process and way forward for restoration activities.	5
Environmental		
2	Coral reef restoration projects are long term and susceptible to storm events. Therefore, there is a relatively high probability that the project could be destroyed by one storm event over the growth phase of the project.	8
3	The marine environment is constantly changing especially given the rate at which climate change has been progressing. The technologies for wetland and coral reef restoration may not be progressing fast enough, within the region and locally, to keep pace with this changing environment.	8

Identified non-financial barriers		Total/10
Technical		
4	Coral reef restoration is generally still a novel technology in Jamaica and there is limited capacity. Additionally, there are few success stories in the Jamaica or the Caribbean of coral reef restoration projects which can be used as a showcase example.	6
5	Coral reef restoration is difficult as it depends on water quality factors which are usually not a localized issue. The issues along the coastal zone are largely affected by factors within the watershed, such as pollution and development, and therefore an integrated approach is needed for sustainable restoration.	7
6	Coral reef restoration has no proof of concept unlike hard (grey) protection structures. In each site, the restoration would be unique and therefore, there is never any proof that the restoration activities will work.	7
7	There are limited areas across Jamaica where coral reef restoration projects can occur. Many of the most suitable areas have already been developed.	6
Regulatory		
8	The coastal zone is governed by environmental laws but monitoring and enforcement to guard against degradation are inadequate. Modification of the natural ecosystems requires permits and licences from NEPA. However, Development Orders of the planning regime allow for tourism, recreational and structural development which often militate against protection of the natural systems.	7
9	Areas which have been restored require monitoring for protection against future destruction.	6
10	Generally, areas with the best conditions for coral reef restoration are the same areas which compete with development options such as tourism projects, ports, and coastal developments.	8
Institutional		
11	There is limited institutional attention to or know-how about coral reef restoration technologies.	4
Political		
12	Political decision-making often directs creation of development zones. The process is sometimes inimical to either the preservation or restoration of coastal ecosystems.	7
Social		
13	Younger fishermen do not understand the importance of coral reefs as part of the fisheries industry. Many have not seen active coral reefs and therefore do not understand the benefits of preserving these ecosystems.	4
14	There has generally been the mindset of investors and technocrats to prefer recommendations for coastal protection from engineers over recommendations from ecologists. Therefore, coastal protection projects have been generally focused	5

	Identified non-financial barriers	Total/10
	towards 'grey' structures rather than 'green' structures or a mix of 'grey-green' protection projects.	
15	Coral reef restoration projects in Jamaica and across the Caribbean have suffered from poor marketing and promotion. Therefore, there has been little exposure of what has been done and where.	4
16	Increase in wetland areas across Jamaica will require an increase in the Government of Jamaica's capacity to monitor these locations.	4

5.4 Linkages of the Barriers Identified

Jamaica has lost more than 770 hectares of mangroves in the period 1996 to 2016 (World Bank, 2019). Mangroves in Jamaica are continuously threatened by continued removal for timber, farming, coastal development, pollution and changes in land use and climate change (World Bank, 2019). The GoJ has recognized the importance of mangroves in Jamaica for coastal protection and the preservation of biodiversity. It has been estimated that damage to residential and industrial property would increase by nearly 24%, or by more than US$32.6 Million annually, if more mangroves were removed (World Bank, 2019). About 70% of the lost mangrove have the potential to be restored, therefore adding additional coastal protection from coastal flood hazards.

Similarly, coral reefs in the coastal zone of Jamaica offer various benefits, including the estimated annual revenue of over US$32.7 million from tourism-based activities; they also provide over US$33.1 million in revenue annually from reef-related fisheries and acts as a buffering zone, protecting many other resources and coastal infrastructure (WRI, n.d.). At current rates of beach erosion associated with reef degradation, it is expected that Jamaica will experience additional losses within the next decade. The GoJ has been moving to improve the management of marine protected areas and expand these protected area networks and fish sanctuaries.

While the GoJ seeks to improve protection for both mangroves and coral reefs across the island, restoration of degraded mangroves sites and coral reefs will be important to increase coastal zone protection and promote biodiversity. Restoration of mangroves and coral reefs therefore will play an important role to increasing the country's resilience to climate change. Jamaica in the past has benefited from several mangrove restoration projects and to a lesser extent, coral reef restoration. However, several challenges exist which prevent the inclusion of additional restoration projects across the island.

The barrier analysis has identified the major barriers which prevent widespread mangrove and coral reef restoration activities across the coastal resources in Jamaica. The barriers identified are also similar for both technologies. This section seeks to link these barriers under common themes. This allows for identifying broad measures across the sector to reduce/illuminate the effects of these barriers.

<u>Economic and Financial</u>

Capital and operational costs for coastal wetland restoration across Jamaica represent a major environmental investment, particularly coral reef restoration. This has led to a general lack of funding for restoration projects, particularly for the longer-term management and operation of the restoration activities. A problem tree root cause analysis (Figure 5-1) indicated the following:

1. There is a high cost associated with the initial setup of the restoration project, including extensive research and site monitoring. Additionally, restoration requires setup of a managed coral or mangrove nursery.
2. These activities also require long-term financial support to manage the operations as restoration projects can extend from 5 to 25 years, and sometimes longer. Wetland restoration projects also offer little guarantee of success and there is almost no immediate return on investment, therefore, developers, investors see little, short-medium term economic or financial benefit in the preserving, protecting, and restoring coastal wetlands.
3. Coastal wetlands are widely affected by factors outside of the coastal zone. In particular, pollution and runoff from the watershed have major impacts on coastal wetlands.

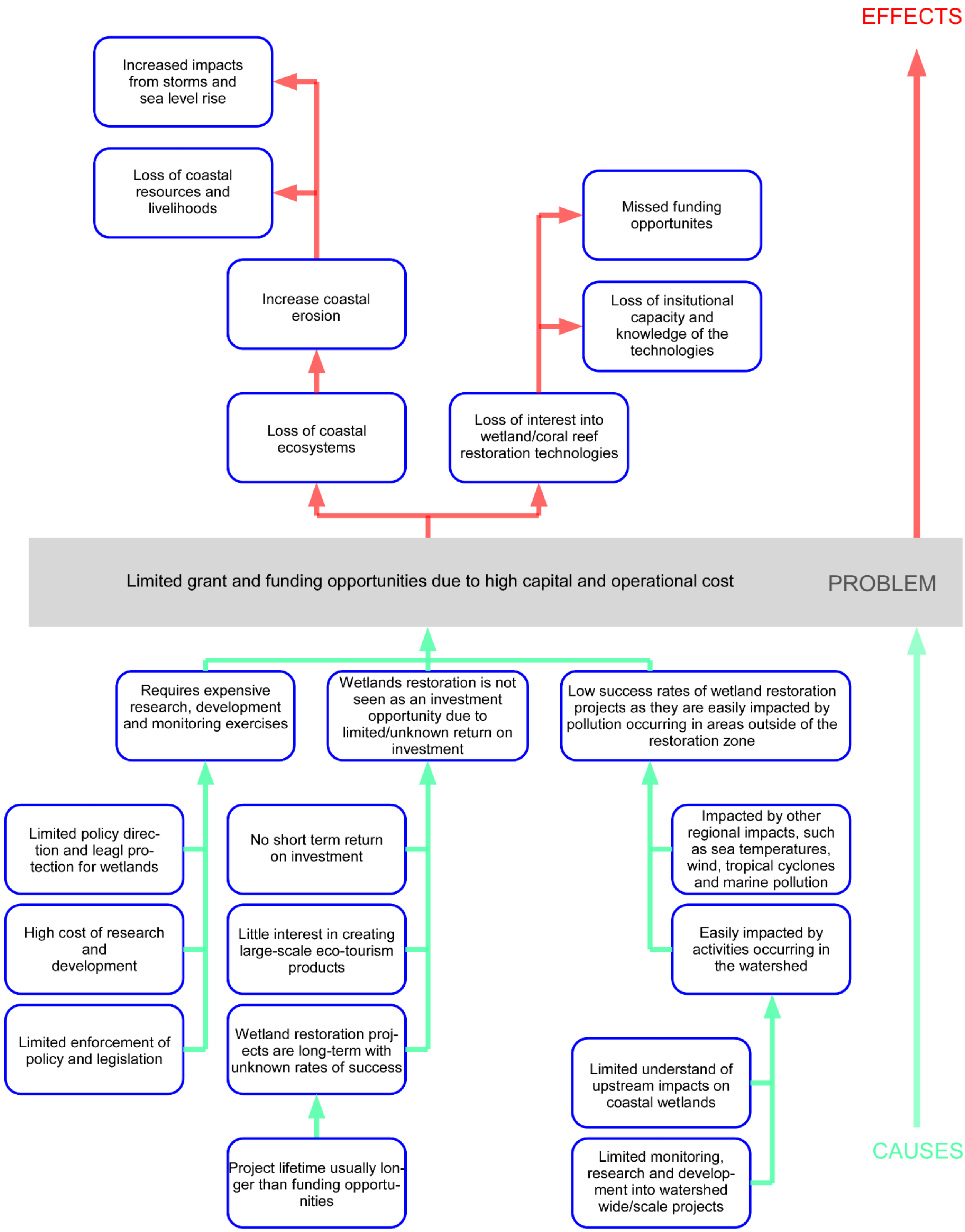

Figure 5-1: Problem tree analysis for the major economic and financial barrier for mangrove and coral reef restoration in Jamaica

5.5 Identified Measures

Table 5-6 outlines the proposed measures for overcoming the most significant barriers for the two prioritized technologies for the water sector in Jamaica.

Table 5-6: Proposed measures for coastal resources

Overarching barriers	Proposed Measures
Lack of financial investment due to high development costs of the technology **Limited financial return on investment in the traditional business model** **Requires long-term financial commitment.**	• Create incentives at all levels for the restoration of mangroves. This may include making coastal land space available for restoration and providing financial and legislative support. • Restoration projects should be valued and have insurance coverage to allow for finances to be recovered for the project in the event of a storm or hurricane. • Funding needs to also be placed largely into research and development of these technologies and not only into the restoration project itself. The technologies require research, modelling, and simulation to understand how the environments can adapt to future climate conditions.
Susceptible to changes in the environment which can cause high failure rate of the technology	• There is a need for a more holistic approach to the technologies that allow for not only rehabilitation, but to address other factors within the watershed that affect mangroves and coral reef systems.
Weak regulation and protection for areas which are best suited for the development of the technology	• NEPA is very open to new ideas, technologies and methodologies when it relates to ecological restoration projects, however, further capacity building is required.
	• There needs to be stronger regulation and stakeholder support for the incorporation of mangroves into the design of coastal developments. For example, hotels can integrate mangroves into their design as part of the growing trend to green tourism and to pay attention to the blue economy. These areas can serve as eco-tourism attractions for the hotels. • The guideline which allows for mangrove restoration on a 1:1 ratio should be adjusted to a high ratio.

5.5.1 Cost-Benefit of proposed Measures for Coastal Resources

A simple cost-benefit analysis was conducted for the implementation of the identified measures (Table 5-7). The cost benefit analysis was completed with the best available information. While the prioritized technologies identified for coastal protection are not new, there is limited research and data to effectively quantify the benefits of these technologies. The World Bank study (World Bank, 2019) was instructive in terms of the analysis of mangrove restoration in selected areas of Jamaica. It was stated that one hectare of mangroves in Jamaica provides on average more than US$2,500 per year of direct flood reduction benefits from tropical cyclones. If considered over a 30-year period, the average benefits per hectare for a mangrove conservation or restoration project would exceed US$43,000 in coastal protection benefits alone.

Further, the role in carbon sequestration was noted. Using global averages, 3.7 million tons of carbon are sequestered annually by Jamaica's mangroves. Mangroves contribute between US$5,218 (at Salt Marsh) and US$54,145 (at Portland Cottage) in mixed fisheries per hectare per year. Other currently untapped benefits include potential for high-end recreational fishing, low-impact mariculture, and ecotourism. Research is continuing in one of three study areas of Jamaica and it is expected that data generation will contribute to the cost-benefit database for coastal resource management (World Bank, 2019).

Table 5-7: Simple cost-benefit for the proposed measures for coastal resources

Major Barriers	Proposed Measures	Expected Cost	Expected Benefits
Lack of financial investment due to high development cost of the technology	Create incentives at all levels for the restoration of mangroves. This may include making coastal land space available for restoration and providing financial and legislative support.		• Increased investment into coastal restoration projects in Jamaica by private entities • Increased grant funding for non-profit coastal restoration activities in Jamaica • Increased number of coastal wetland restoration projects across Jamaica
	Restoration projects should be valued and have insurance coverage to allow for finances to be recovered for the project in the event of a storm or hurricane.	• **Consultant fees for the economic valuation of mangroves and coral reefs across Jamaica** Estimated lump sum cost: US$150,000.	• Improved understanding of the economic value of mangrove and coral reefs sites across Jamaica • Increased opportunities for long-term funding and insurance coverage for wetland restoration activities
	Funding needs to be also placed largely into research and development of these technologies and not only into the restoration project itself. The technologies require research, modelling, and simulation to understand how the environments can adapt to future climate conditions.	25% to 50% increase in funding for wetland restoration activities to cover required pre-modelling and simulation studies	Increased success rate of wetland restoration activities across Jamaica

Major Barriers	Proposed Measures	Expected Cost	Expected Benefits
Susceptible to changes in the environment which can cause high failure rate of the technology	There is a need for a more holistic approach to the technologies that allow for not only rehabilitation, but to address other factors within the watershed that affect mangroves and coral reef systems.		
	NEPA is very open to new ideas, technologies and methodologies when it relates to ecological restoration projects, however, further capacity building is required.	• **Training and capacity building for NEPA in new concepts, technologies, and methodologies for wetland restoration. This may take the form of workshops, conferences, and research activities.** Estimated Cost: US$20,000 per annum	Introduction of new methods and technologies in wetland restoration Increased knowledge transfer of new technologies and methods for wetland restoration across Jamaica Increase in the number and area of wetland restoration activities across Jamaica
	There needs to be stronger regulation and stakeholder support for the incorporation of mangroves into the design of coastal developments. For example, hotels can integrate mangroves into their design as part of the growing trend to green tourism and to pay attention to the blue economy. These areas can serve as eco-tourism attractions for the hotels.		Increased protection and preservation of mangroves Increased eco-tourism activities
	The guideline which allows for mangrove restoration on a 1:1 ratio should be adjusted to a high ratio.		Increased the area of mangrove replanting and restoration activities across Jamaica

5.6 Enabling Framework for Overcoming the Barriers

It is important to consider the synergistic value of reducing the coastal energy to allow wetlands to be established, by supporting reef restoration. By removing barriers to coral reef and wetland restoration, it is possible to enhance the success of beach and wetland restoration projects across Jamaica. This will allow the communities, developments and users of the coastal zones to become more resilient to the effects of climate change.

Government should create a tax or bond that businesses which receive a permit or licence to operate along the coast must pay on a yearly basis. The purpose of these taxes/bonds will be for the management of coastal resources, including restoration and coastal monitoring activities. The established fund can be managed in such a way that resources are allocated to accessing the best available technology/data to improve decision-making on where to focus ecosystem-based interventions.

Incentives and fiscal support should be provided to coastal developers who endeavour to avoid disturbance/destruction of the natural coastal, wetlands and the marine environment. Such support should consider favourable terms for import of equipment or materials which are proven to support healthy natural resources; tax benefits or fees reduction to compensate for designs which avoid disturbance/destruction of the natural environment; and more selective approvals for smaller customized developments versus large developments which employ wide-scale land clearance.

Increase funding initiatives for organizations that promote the sustainable use of coastal resources through the implementation and management of various projects and programmes. This additional funding should improve the capacity of these organizations to not only effectively manage and monitor coastal areas, but it will also allow them to extend these activities to other vulnerable coastlines across Jamaica.

Capacity building is required for the regulatory agencies. There is a need to improve the knowledge and experience of staff through training, research, and development. These should cover the areas for new methods in wetland and coral reef restoration and improve technologies in monitoring of coastal zones and coastal zone management.

Regional tertiary academic institutions could support scholarships for professional programmes which deliberately incorporate coastal environmental protection and alternative building designs into development type activities.

Part II Technologies for Mitigation

6 Agriculture Sector

The impacts of climate change on the agriculture sector are well known. However, several techniques and inefficient management strategies used by persons within the sector have, ironically, contributed to increases in the emissions of greenhouse gases that contribute to climate change. This is because most, if not all, stages of both the production and post-harvest processes involved in cultivating and providing food to consumers release greenhouse gases into the atmosphere. Methane (CH_4) and Nitrous oxide (N_2O) are two prominent gases released by farming processes. Methane is produced by livestock during digestion due to fermentation and can escape from stored manure. Nitrous oxide emissions are an indirect product of organic and mineral nitrogen fertilizers used widely by farmers in Jamaica. Carbon dioxide (CO_2) is also emitted directly from the use of farm equipment (e.g., diesel or gasoline pumps), heavy machinery (e.g., tractors) and general light or heavy transportation. Indirectly, there is CO_2 contribution from the 24-hour use of electricity for pumping, motors, lighting, and heavy-duty fans (e.g., wind tunnel methods for poultry rearing).

Specific to the Jamaican agriculture sector, the average Greenhouse Gas (GHG) emissions from agriculture between 2006 – 2014 was 3,765 Gg CO_2 equivalent (Josling, et al., 2017) Of the various contributions, N_2O from manure management accounted for 43% of total crop and livestock emissions. Other major contributions came from N_2O emissions from organic fertilizer and soil leaching. Poultry was found to contribute approximately 1,505.4 Gg CO_2 equivalent (39.3%) while sugar, the second highest contributor, released approximately 762.9 Gg CO_2 equivalent (19.9%) (Josling, et al., 2017). As such, a reduction in the use of fossil fuels to power machinery with the incorporation of renewables for energy, innovative techniques into food production, engaging in practices which encourage better manure/waste management and more efficient application of fertilizers have been target areas for reduction of emissions by stakeholders involved in the sector.

The technologies prioritized to aid mitigating against climate change within the agriculture sector are:

i. Concentrated solar power.
ii. Composting.

6.1 Preliminary Targets for Technology Transfer and Diffusion

Preliminary targets for the transfer and diffusion of the prioritized technologies for climate change mitigation for the agriculture sector in Jamaica were discussed and identified during stakeholder consultations. The targets for the technologies are given in Table 6-1.

Table 6-1: Preliminary targets for prioritized technologies for climate change mitigation in the agriculture sector

Prioritized Technology	Preliminary Target
Concentrated Solar Power (CSP)	To reduce GHG emissions from the multi-dimensional agricultural sector through implementation of Concentrated Solar Power where there is demand for electricity. CSP systems up to 5 MW may be applicable for large commercial farms with large power demands for water pumping, electrical equipment (e.g., cold storage), conveyors, external security lighting and offices, etc. Due to the cost for the CSP technology focus will be placed on 3 opportunities: • A 100kW CSP Stirling engine system (4 x 25 kWe) at one (1) of the 9 Agro Parks[5]. Agro Parks operate under a cooperative structure with multiple users so power demand within the Park boundary will be continuous throughout various crop cycles therefore improving commercial viability of the investment. • 100kW CSP Stirling engine system each at 2 private sector farms.
Aerobic Biological Treatment of Agricultural/Organic Waste (Composting)	To allow for an effective system for handling agricultural waste while contributing to the reduction of greenhouse gases from decomposition of the organic matter Small farmers are already composting in small containers, used barrels and wooden troughs at a subsistence level. It is recommended that at least a 1-acre commercial composting operation be established in each of the 3 counties of Jamaica (Cornwall, Middlesex, and Surrey, i.e., 3 in total) to demonstrate the feasibility of commercial composting and give easier access to visits and observation for interested parties across the island. Agro Parks, with their mixed cropping, could be ideally used as various crops mature at different times, hence the possibility of year-round organic material based on crop cycles. Also, the compost can be utilized at the same location by the farmers or the excess sold.

[5] *An Agro Park is an area of intensive, contiguous, parcel of land for agricultural production which seeks to integrate all facets of the agricultural value chain from pre-production to production, post harvesting and marketing.*

6.2 Barrier Analysis and Possible Enabling Measures for Concentrating Solar Power

6.2.1 General Description of Concentrating Solar Power

Concentrated Solar Power (CSP) uses concentrated 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.

CSP technologies use mirrors to reflect and concentrate sunlight on to receivers which then convert the energy to electrical or heat energy. There are four basic designs for CSP, all using curved mirrors to concentrate solar energy on to a thermal receptor vessel (gas or liquid filled) to power a steam turbine.

I. **A solar powered Stirling engine** is a heat engine powered by a temperature gradient generated by the sun. An engine which is driven by working gases – the Stirling cycle engine is at the focal point at the centre of a solar dish, and when heated by the focused rays of the sun, it produces electricity directly by causing the heat transfer from the hot source to a cold sink, to move pistons in and out. This motion of the pistons in the Stirling cycle then drives a generator to create electric power. Dish Stirling engines lack the energy storage capabilities of other CSP designs. This may be the most likely technology for adoption in the Jamaican environment due to unit size, cost of energy from the grid and flexible placement on uneven terrain. These systems range in size from 1 to 25 kWe (but can be as much as 950 kWe) for commercial onsite power generation. Stirling engines are efficient and can convert as much as 35 – 40% of the solar energy received to electricity to the grid, versus flat-plate solar photovoltaics which may deliver 15 –18% to the grid.

II. **Simple parabolic dish** focuses the sun's energy on to a thermal receiver mounted at the focal point of the dish. Temperatures greater than 1000°C can be reached. Due to the dish's limited size, the output from one dish is about 25 kW at maximum.

III. **Central receiver or solar tower** uses thousands of mirrors to track the sun's movement and focus the light rays on a tall central tower to produce temperatures in the range of 300–1000°C to heat transfer fluids (e.g., a molten salt, air, water/steam, liquid sodium). If molten salts or sodium are used, the heated fluids further transfer heat to a secondary carrier, water, in order 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). The land requirements are high, possibly challenging this technology application.

IV. **Parabolic troughs** have mirrors up to 100m long and may be used to track the sun to focus the sun's 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.

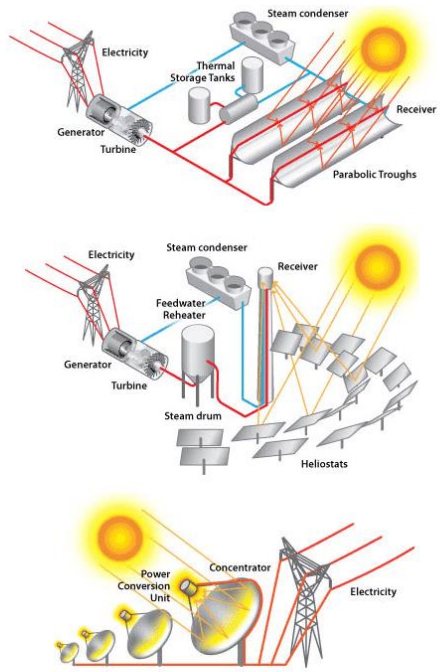

Figure 6-1: Concentrated Solar Power (U.S. Department of Energy, 2001)

These CSP designs, especially the Stirling Dish and parabolic troughs, can be readily integrated into agricultural activities. The Stirling dish is suitable for generating electricity needs for a farm for pumping, motors, security lights and other electricity demands. Because the system is relatively small (like individual satellite dishes) it can be placed on plots which may be less fertile and productive to avoid competing with fertile land for agriculture. The parabolic troughs can minimize or replace fossil fuel sources for process heat used to sterilize or pre-cook foods in agro-processing plants. As for the Stirling dish, both systems are modular, allowing the investor to install units as needed and in various locations on a farm. Unlike the other CSP technologies, the Stirling Engines will not require contiguous parcels of flat land as individual 25 kWe units can be placed conveniently at various levels and locations. The main constraint would be the length of power cables to deliver electricity to the points of demand, however, advantageously each Stirling Engine can be placed in close proximity to the point of demand (e.g., water pump, office, processing house).

Concentrated Solar Power plants require access to water resources (except for Stirling Engines) 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, rainfall sediments negatively impacting reflection of the sun’s energy and plant efficiency. Some CSP plants, however, can utilize wet, dry, and hybrid cooling techniques to maximize efficiency in electricity generation and water conservation.

6.2.2 Identification of Barriers

Concentrated solar power has been categorized as a ‘Capital Good’ as it will only be feasible for large agro-processing facilities (e.g., agro-parks and large commercial farms). There is a limited number of these locations across Jamaica, however, many of them are energy-intensive, therefore making CSP suitable.

However, there is very little interest or investment into this technology in Jamaica. A barrier analysis was conducted to determine the major barriers preventing the dissemination and use of this technology across Jamaica.

6.2.2.1 Economic and financial barriers

Economic and financial barriers were identified from stakeholder consultation and scored to determine which barriers were most significant. The barriers and scores are given in Table 6-2.

Table 6-2: Financial barriers and scores for concentrated solar power technology

Identified economic and financial barriers		Total/10
Direct		
1	CSP requires high capital and operating costs.	9
Indirect		
2	CSP: There is high permitting cost for users to produce electricity and have it sold back to the grid.	8
3	Fluctuating and lower cost of fossil fuels causes uncertainties for return on investment. (When fossil fuel cost is low, investments decision for electricity production is made in favour of fossil fuel power plants over more expensive renewable energy options).	4

6.2.2.2 Non-financial barriers

Non-financial barriers were identified from stakeholder consultation and scored to determine which barriers were most significant. The barriers and scores are given in Table 6-3.

Table 6-3: Non-financial barriers and scores for concentrated solar power technology

Identified non-economic barriers		Total/10
Technical		
1	There have not been any known local feasibility studies to understand if CSP can be used in Jamaica and the efficiency of the technology in this climate.	6

6.3 Barrier Analysis and Possible Enabling Measures for Aerobic Biological Treatment (composting)

6.3.1 General Description of Aerobic Biological Treatment (Composting)

This technology entails biological degradation of agricultural/organic waste under controlled aerobic conditions where the waste is decomposed into carbon dioxide, water, and solids (soil ameliorants or mulch) and added to the soil. Carbon storage also occurs in the residual compost and further CO_2 sequestration occurs as the compost is used for crops.

Composting requires several steps which include, waste collection, sorting, piling, turning, sprinkling, and curing.

Waste composting can result in economic, social, and environmental benefits for Jamaica. It can reduce the overall volume of waste for collection in rural areas, thus reducing costs to the authorities. Sorting and reuse of biodegradable 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. Commercial scale composting will require some calculation for estimating operational spaces:

- Windrow Volume and Dimensions
- Number of active Windrows
- Active Pad Footprints
- Curing and Storage Area
- Feedstock Storage
- Receiving and Blending Area
- Total Site Footprint.

Smaller less scientific farms may consider commercial composting daunting for by the technical nature of the endeavour.

Commercial composting also requires extended time for completion, being an active composting phase of possibly 8 months, a curing composting phase of approximately 2 months and a need to store compost before use. Composting therefore requires adequate non-agricultural space which will be challenging for small operators.

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

In Jamaica, composting can be easily implemented especially in rural areas where the practice can be done away from residential or farm buildings. Waste material from farms would feed the compost pile thereby minimizing the need for general disposal. The mulch from the compost would be used in farming as a soil ameliorant with some nutrients, thus reducing the need for chemical fertilizers. Composting is not practised widely across Jamaica; however, there is the potential for this to be adopted across the island by farmers who general have compostable waste material.

6.3.2 Identification of Barriers

Aerobic biological treatment (composting) has been categorized as ‘Consumer Good’ based on the definition for consumer goods (Nygaard & Hansen, 2015).

6.3.2.1 Economic and financial measures

Financial barriers were identified from stakeholder consultation and scored to determine which barriers were most significant. The barriers and scores are given in Table 6-4.

Table 6-4: Financial barriers and scores for aerobic biological treatment

Identified economic and financial barriers		Total/10
Indirect		
1	Composting is seen as an additional task to be completed at additional cost to the operations on the farm with little perceived immediate tangible benefits/monetary return for the farmer.	5
2	The process to complete composting is seen as labour-intensive to the farmer and since there is no immediate return, the farmer will prefer to do other tasks which may have some immediate financial and material benefit.	6
3	There is limited ability to scale up from a small compost to larger compost for use on a farm. That is because composting requires inputs and land area which are not readily available to small and medium farmers. Commercial viability may require scaling up.	5

6.3.2.2 Non-financial measures

Non-financial barriers were identified from stakeholder consultation and scored to determine which barriers were most significant. The barriers and scores are given in Table 6-5.

Table 6-5: Non-financial barriers and scores aerobic biological treatment

Identified non-financial barriers		Total/10
Knowledge		
1	The long-term benefits of composting as a technology for soil management is not well known and understood by farmers.	4
Cultural		
2	Some farmers have a general resistance to change and adoption of new technologies.	4

6.4 Linkages of the Identified Barriers

No linkages in the barriers have been identified between the two technologies for mitigating against the effects of climate change in the agriculture sector for Jamaica.

The major barriers identified for CSP are economic and financial. The capital cost for this technology is particularly high. Additionally, since such technology has not yet been used in Jamaica, there is no supply chain and limited local capacity for the development of this technology. Therefore, there is an increased cost associated with this technology as many of the required professional skills will also have to be imported or locals will be required to undergo extensive training and capacity building.

The barrier analysis did not identify any major barriers for aerobic biological treatment (composting). Composting is practised in Jamaica on a very small scale, particularly in small back-yard gardens, but also on a small scale by the municipal waste management agency and one of two large agro-producers. However, the consultation process highlighted that the major barrier to the diffusion and use of composting in Jamaica is a general lack of understanding of the technology. A problem tree analysis (Figure 6-2) determined that this was due to: -

- A general lack of suitable farm-sized composting projects/site to show how the technology can be conducted on a large scale successfully.
- General ad hoc and poor communication of the benefits of the technology.
- The limited information that farmers have about soil and soil testing is rarely carried out on small and medium-sized farms across Jamaica.

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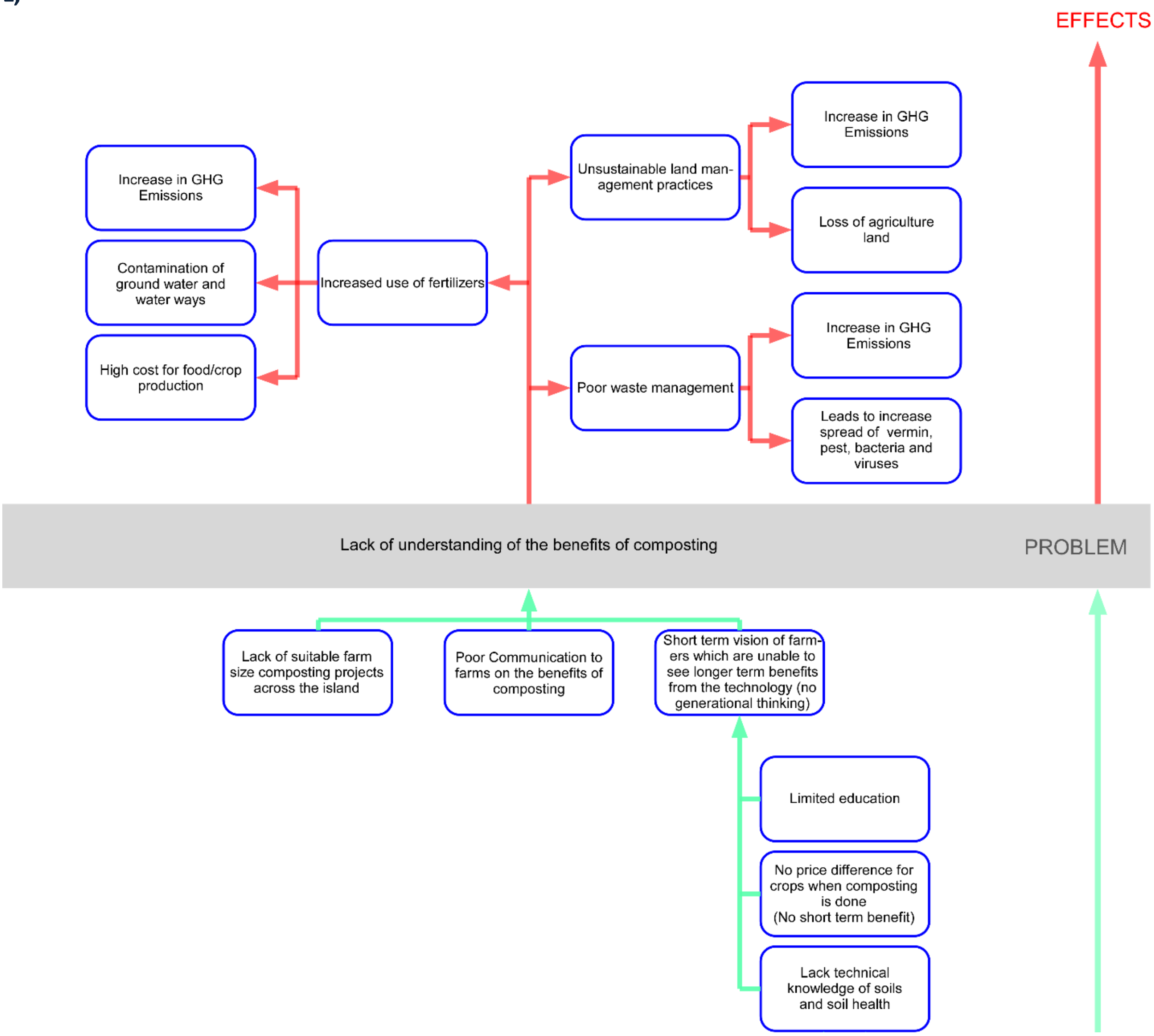

Figure 6-2: Problem tree for composting in the agriculture sector in Jamaica

6.5 Identified Measures

Table 6-6 outlines the proposed measures for overcoming the most significant barrier to the use of concentrating solar power in the agriculture sector in Jamaica. Table 6-7 outlines the proposed measures for overcoming barriers identified to the use of aerobic biological treatment (composting) in the agriculture sector in Jamaica.

Table 6-6: Proposed measures for overcoming barriers for concentrating solar power technology

Barrier	Proposed Measures
CSP (Stirling Engines) requires high capital and operating costs.	The Ministry of Industry Commercial, Agriculture and Fisheries (MICAF), being the administrator of Agro Parks, should consider the values of reducing operational costs for lease holders in the Parks, supporting small enterprise and local food security through budgetary support of this technology. Also, this technology is an opportunity for MICAF to support the renewable energy target of Jamaica and introduce a more energy-efficient solar technology to the grid. State budgets should include capital costs for the installation and connectivity of the Stirling Engines, however, costs for delivery of power, operation and maintenance should be allocated to the Agro Park. The State should also permit the supply of energy as a special intervention to overcome the barrier of the Electricity Act, 2015, which approves the utility as the only distributor of electricity; or form a public-private joint venture to enable same. For large commercial private farms, Stirling Engine systems should be approved for the exemption of GCT on the energy efficient and renewable energy products and technologies tariffs and CARICOM External Tariffs as listed by the Jamaica Customs Agency (Appendix II - Approved Energy Efficient items for CET Suspension). Private farms should utilize the Net Billing Regulations for commercial entities (up to 100kW) to facilitate grid interconnection.
	Utilize stakeholder consultations and capacity development to promote CSP for the agriculture sector. The stakeholders should include, but not limited to: - • Jamaica Public Service Company • Office of Utilities Regulation • Jamaica Renewable Energy Association • MICAF

Barrier	Proposed Measures
	• Ministry of Science Energy and Technology (MSET) • RADA • Jamaica Agriculture Society • Jamaica Institute of Engineers • Universities and training institutions (academia)
	Secure green financing for loans and grants to reduce initial capital costs. Utilize special low-interest rates from the Development Bank of Jamaica to finance project.
There is high permitting cost for users to produce electricity and have it sold back to the grid.	Waiver or reduction of Government fees and utility costs for Net Billing application and interconnection.
Fluctuating and lower cost of fossil fuels causes uncertainties for return on investments (low fossil fuel costs favour fossil technologies).	No controls over imported fossil costs, however, green financing, and financing from the Development Bank of Jamaica will make technology more viable in the face of fossil fuel prices.
No known local feasibility studies of CSP in Jamaica and the efficiency of the technology in this climate	Obtain green funding to do feasibility location specific study.

Table 6-7: Proposed measures for overcoming barriers for aerobic biological treatment technology

Barrier	Proposed Measures
Labour intensive technology with low tangible returns on investment.	• Composting should be promoted by the Ministry of Agriculture and Fisheries, and Ministry of Industry, Investment and Commerce (and their respective agencies) for sustainable land management and waste management for the agriculture sector. • Bureau of Standards should establish standards for composted materials to enable incremental pricing for products of the technology and for access to export markets. • The Government of Jamaica needs to have a large initiative to focus on composting. This should be done in conjunction with farmers' boards and farming associations. • There needs to be greater public awareness through demonstration examples of successful composting projects on a scale suitable for farmer's needs. Most examples used today are very small-scale composting projects.

Barrier	Proposed Measures
	• There needs to be some policy and guidelines directed towards composting. This should focus on the reduced use of chemical fertilization, reduce importation of organic fertilizers and to increase soil health. • Composting and feedstock materials may not be viable on a small scale, therefore, there need to be commercial scale facilities across the country which collect waste products from small farmers for composting initially supported by Ministry of Agriculture and Fisheries, and Ministry of Industry, Investment and Commerce, and the Ministry of Economic Growth and Job Creation (and their respective agencies). Farmers can then get compost from these facilities.
Composting is seen as an additional task to be completed at additional cost to the operations on the farm with little perceived immediate tangible benefits/monetary return for the farmer.	Utilize stakeholder consultations and capacity development to train farmers/composters and promote aerobic biological treatment for the agriculture sector. Stakeholders should include: - • MICAF • RADA • Jamaica Agriculture Society • Food and Agriculture Organization • Caribbean Agricultural Research and Development Institute (CARDI) • Jamaica Environment Trust (JET) • College of Agriculture Science and Educations (CASE), other Universities and training institutions (academia) • United Nations Environment Programme • National Solid Waste Management Authority (NSWMA) • Bureau of Standards.
	Secure green financing for loans and grants to reduce initial capital costs. Utilize special low interest rates from the Development Bank of Jamaica to finance project.
The process to complete composting is seen as labour intensive to the farmer and since there is no immediate return, the farmer will prefer to do other task which may have some immediate financial and material benefit.	Utilize stakeholder consultations and capacity development to train farmers/composters and promote aerobic biological treatment for the agriculture sector.
There is limited ability to scale up from a small compost to larger	Utilization of Agro Parks will scale up the resources for composting and provide year-round feedstock.

Barrier	Proposed Measures
compost for use on a farm. That is because composting requires inputs and land area which are not readily available to small and medium sized farmers. Commercial viability may require scaling up.	
The long-term benefits of composting as a technology for soil management is not well known and understood by farmers.	• Utilize stakeholder consultations and capacity development to train farmers/composters and promote aerobic biological treatment for the agriculture sector. • One hectare model composting site developed by the Government in a public private partnership model, part funded by international agencies.
Some farmers have a general resistance to change and adoption of new technologies	Farmer education, capacity development and stakeholder consultations. (see solutions above).

6.5.1 Cost-Benefit of Proposed Measures for the Agriculture Sector

A simple cost-benefit analysis was conducted for the implementation of the identified measures. These are given in Table 6-8 for CSP and Table 6-9 for Aerobic Biological Treatment. The cost-benefit analysis was completed with information available at the time of analysis. While this prioritized technology identified for the agriculture sector in Jamaica is not new, there is limited data to effectively quantify the benefits of these technologies. An analysis is required to effectively develop a full quantitative financial model for the expected benefits these systems will have on the agricultural sector in Jamaica.

Table 6-8: Simple cost-benefit for the proposed measures for CSP for the agriculture sector

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
CSP (Stirling Engines) requires high capital and operating costs.	The Ministry of Industry Commercial, Agriculture and Fisheries (MICAF) being the administrator of Agro Parks, should consider the values of reducing operational costs for lease holders in the Parks, supporting small enterprise and local food security through budgetary support of this technology. Also, this technology is an opportunity for MICAF to support the renewable energy target of Jamaica and introduce a more energy-efficiency solar technology to the grid. State budgets should include capital cost for the installation and connectivity of the Stirling Engines, however, costs for delivery of power, operation and maintenance should be allocated to the Agro Park. The State should also permit the supply of energy as a special intervention to overcome the barrier of the Electricity Act, 2015, which approves the utility as the only distributor of electricity; or	The capital cost of CSP is about USD 2,500/kW (but could decrease to USD 1,000/kW in the near future with economies of scale) for options without storage equipment. Construction and planning with generation costs of approximately USD 0.11/kWh without storage. Most developers estimate operation and maintenance cost of the CSP plant of USD 0.5-1¢/kWh over a useful product lifetime of 5,000–10,000 hours.	• Currently Stirling Engine generation costs are projected to be lower than local commercial electricity costs from the grid ranging USD 0.25 – 0.30/kWh. Small agro-producers could experience an increase in profitability. • Positive generation experiences could provide distributed generation alternatives in places where solar PV is disadvantageous (e.g., ground mounted systems requiring large tracks of land). Proliferation could accelerate renewable energy targets during IRP timelines (2022; 2024; 2026-27; and 2032 – 37). • Reductions of GHG emissions (e.g., for every doubling of installed photovoltaic capacity, energy use decreases by 13 and 12% and greenhouse gas footprints by 17 and 24%, for poly-crystalline and monocrystalline based photovoltaic systems,

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
	form a public-private joint-venture to enable same. For large commercial private farms, Stirling Engine systems should be approved for the exemption of GCT on the energy-efficient and renewable energy products and technologies tariffs and CARICOM External Tariffs as listed by the Jamaica Customs Agency (Appendix II - Approved Energy Efficient items for CET Suspension). Private farms should utilize the Net Billing Regulations for commercial entities (up to 100kW) to facilitate grid interconnection.		respectively). Stirling engines would present similar GHG reduction benefits.
	Utilize stakeholder consultations and capacity development to promote CSP for the agriculture sector. The stakeholders should include, but not be limited to: - • Jamaica Public Service Company • Office of Utilities Regulation • Jamaica Renewable Energy Association • MICAF	• **Public/community consultations to promote awareness of CSP.** Estimated cost: US$20,000 per consultation x 2. • **Training and capacity development for technology application and maintenance** Estimated Cost: US$50,000 x 2.	• Encourages the near-term and future adoption of the technology. • Provides additional feedback to enable application of the technology. • Provides local competency for early application of the technology. • Employment opportunity

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
	• Ministry of Science Energy and Technology (MSET) • RADA • Jamaica Agriculture Society • Jamaica Institute of Engineers • Universities and training institutions (academia)		
	Secure green financing for loans and grants to reduce initial capital costs. Utilize special low-interest rates from the Development Bank of Jamaica to finance project.	Capital cost of approximately US$950,000 for 3 x 100kW CSP systems.	• Improved financial feasibility to introduce the technology
There is high permitting cost for users to produce electricity and have it sold back to the grid.	Waiver or reduction of Government fees and utility costs for Net Billing application and interconnection	US$30,000	• Improved financial feasibility to introduce the technology
Fluctuating and lower cost of fossil fuels causes uncertainties for return on investments (low fossil fuel costs favour fossil technologies)	No controls over imported fossil costs, however, green financing, and financing from the Development Bank of Jamaica will make technology more viable in the face of fossil fuel prices.		Improved financial feasibility to introduce the technology
No known local feasibility studies of CSP in Jamaica and the efficiency of the	Obtain green funding to do feasibility location specific study.	US$30,000	• Location specific data for implementation of technology

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
technology in this climate			• Encourage private and public sector to utilize the technology without increasing project costs.

Table 6-9: Simple cost-benefit for the proposed measures for aerobic biological treatment for the agriculture sector

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
Labour intensive technology with low tangible returns on investment.	• Composting should be promoted by the Ministry of Agriculture and Fisheries, and Ministry of Industry, Investment and Commerce (and their respective agencies) for sustainable land management and waste management for the agriculture sector. • Bureau of Standards should establish standards for composted materials to enable incremental pricing for products of the technology	• **National campaign to demonstrate, promote and encourage composting within the agricultural sector.** Estimated cost: US$100,000. • **Setup of large-scale composting demonstration sites across Jamaica**	• Greater understanding of the benefits of composting • Increase use of composting in the agriculture sector and other sectors across Jamaica. • Improved long-term soil health, particularly in agriculture areas. This may lead to increased production in the long-term.

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
	and for access to export markets. • The Government of Jamaica needs to have a large initiative to focus on composting. This should be done in conjunction with farmers' boards and farming associations. • There needs to be greater public awareness through demonstration examples of successful composting projects on a scale suitable for farmer's needs. Most examples used today are very small-scale composting projects. • There needs to be some policy and guidelines directed towards composting. This should focus on the reduced use of chemical fertilization, reduced importation of organic fertilizers and the increase in soil health. • Composting and feedstock materials may not be viable on a small scale, therefore, there needs to be commercial		• Decrease in the overall use of fertilizers in the long-term • Overall decrease in greenhouse gases from the agriculture sector

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
	scale facilities across the country which collect waste products from small farmers for composting initially supported by the Ministry of Agriculture and Fisheries, and the Ministry of Industry, Investment and Commerce, and the Ministry of Economic Growth and Job Creation (and their respective agencies). Farmers can then get compost from these facilities.		
Composting is seen as an additional task to be completed at additional cost to the operations on the farm with little perceived immediate tangible benefits/monetary return for the farmer.	Utilize stakeholder consultations and capacity development to train farmers/composters and promote aerobic biological treatment for the agriculture sector. Stakeholders should include: - • MICAF • RADA • Jamaica Agriculture Society • Food and Agriculture Organization • Caribbean Agricultural Research and Development Institute (CARDI) • Jamaica Environment Trust (JET)	• **Farmer, public/community consultations to promote awareness of aerobic biological treatment.** Estimated cost: US$15,000 per consultation for two consultants. • **Training and capacity development for aerobic biological treatment application maintenance.** Estimated Cost: US$20,000 each for two consultants.	• Encourages the near-term and future adoption of the technology. • Provides additional feedback to enable application of the technology. • Provides local competency for early application of the technology. Employment opportunity

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
	• College of Agriculture Science and Educations (CASE), other Universities and training institutions (academia) • United Nations Environment Programme • National Solid Waste Management Authority (NSWMA) • Bureau of Standards		
	Secure green financing for loans and grants to reduce initial capital costs. Utilize special low interest rates from the Development Bank of Jamaica to finance project.	Capital cost of approximately US$950,000 for 3 x 100-kW CSP systems	• Improved financial feasibility to introduce the technology
The process to complete composting is seen as labour intensive to the farmer and since there is no immediate return, the farmer will prefer to do other tasks which may have some immediate financial and material benefit.	Utilize stakeholder consultations and capacity development to train farmers/composters and promote aerobic biological treatment for the agriculture sector.	• **Farmer, public/community consultations to promote awareness of aerobic biological treatment.** Estimated cost: US$15,000 per consultation for two consultants. • **Training and capacity development for aerobic biological treatment application maintenance** Estimated Cost: US$20,000 each for two consultants	• Encourages the near-term and future adoption of the technology. • Provides additional feedback to enable application of the technology. • Provides local competency for early application of the technology. Employment opportunity.

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
There is limited ability to scale up from a small compost to larger compost for use on a farm. That is because composting requires inputs and land area which are not readily available to small and medium farmers. Commercial viability may require scaling up.	Utilization of agro-parks to scale up the resources for composting and provide year-round feedstock. Utilize Agro Parks for composting sites. One hectare model composting site developed by the Government in a public private partnership model, part funded by international agencies.	• US$254,358 per ha for site preparation and construction. • US$850,000 to 1.5 M per ha for mechanization/equipment.	Equipment, material and labour costs for composting can be shared thus making the technology more viable, and product of higher demand on the farm and for sale.
The long-term benefits of composting as a technology for soil management is not well known and understood by farmers.	• Utilize stakeholder consultations and capacity development to train farmers/composters and promote aerobic biological treatment for the agriculture sector.	• Farmer training and capacity development and promotion of the technology US$ 20,000	• Equipment, material and labour costs for composting can be shared, thus making the technology more viable, and product of higher demand on the farm and for sale. • Farmers can develop familiarity and comfort with the technology, products, and potential markets.

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
			• Risk management strategy to encourage farmers to invest
Some farmers have a general resistance to change and adoption of new technologies.	Farmer education, capacity development and stakeholder consultations. (See solutions above).		• Equipment, material and labour costs for composting can be shared thus making the technology more viable, and product of higher demand on the farm and for sale. • Farmers can develop familiarity and comfort with the technology, products, and potential markets. • Risk management strategy to encourage farmers to invest.

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. Dedicated commercial composting can, however, be an expensive operation and therefore, the need for a viable, standardized, and competitive marketplace. Such a marketplace has not yet been established in Jamaica. Sample costs for a 1-acre farm in USA area as follows:

Composting Site Construction/Preparation Cost	**US$**
Material	$ 168,333
Labour	$ 51,399
Equipment	$ 34,626
	$ 254,358

Compositing Processing Equipment Costs	**Low (US$)**	**High (US$)**
Loaders	$ 150,000	$ 600,000
Grinders	$ 300,000	$ 750,000
Turners (pull-behind)	$ 30,000	$ 75,000
Turners (straddle)	$ 250,000	$ 950,000
Mixers	$ 250,000	$ 400,000
De-packers	$ 300,000	$ 450,000
Blowers/piping (per pile)	$ 2,000	$ 10,000
Screens	$ 50,000	$ 650,000
Contaminant Removal	$ 200,000	$ 600,000
Baggers	$ 50,000	$ 900,000
	$ 1,582,000	**$ 5,385,000**

Processing Equipment Costs		
Thermometer probe - 36" dial-face or wireless with SCADA computer interface	$ 150	$ 2,000
iPad/Tablet	$ 750	$ 1,000
Weather station	$ 700	$ 2,000
	$ 1,600	**$ 5,000**

Source: -Biocycle.net

6.6 Enabling Framework to Overcome the Barriers

The Government of Jamaica will have to provide fiscal and legislative support for the adoption of CSP Stirling engines in Jamaica. This will have to be a concerted effort to encourage the uptake of this technology within the agriculture sector and must be driven by strong policy.

Fiscal options may include:

- Inclusion of CSP on duty free and zero rated scheduled for proven renewable and energy efficiency technologies.
- Corporate Tax reductions/rebates for introduction for the technology.

Legislative options could include:

- Application of Power Wheeling legislation.
- Allow under the Electricity Act, special approvals for joint ventures with non-utility investors.

As it relates to composting, state agencies, should take a more holistic approach to the promotion, teaching and the development of composting technology across Jamaica. The benefits of promoting should be marketed from several standpoints, including integrated waste management and soil health. This should be done through agencies such as Rural Agricultural Development Agency (RADA). The Bureau of Standards should establish standard for composted materials to enable incremental pricing for products of the technology and for access to export markets.

Academia should consider highlighting these technologies in their respective sectors. For example, an institution such as the College of Agriculture, Science and Education or The UWI St Augustine could provide training for composting. Other regional or international entities such as Caribbean Research and Development Institute (CARDI) and the Inter-American Institute for Cooperation on Agriculture (IICA) could support research and development, funding, and capacity building.

Public-Private partnerships could be used to setup farm scale composting sites across Jamaica to be used as examples for teaching purposes. Produced compost could also be sold to produce revenue for the PPP to conduct its day-to-day operations. Technical aspects such as soil nutrient testing and best practices can be conducted and managed by academic/technical institutions such as The UWI and CASE.

7 Energy Sector

In 2013, Jamaica's GHG emissions were dominated by the energy sector (72.8%), with manufacturing and construction, electricity, and heat generation contributing 71% of sector emissions (USAID). Between 1990 and 2013, the energy sector emissions increased by 0.18 $MtCO_2e$, with transportation, electricity and heat production driving this increase, although energy emissions from manufacturing and construction decreased 29% during this period (WRI, 2017). As of 2019, 45% of electricity was generated by fuel oil, 37% by natural gas, solar (5%), hydro-electric power (3%), and wind (10%) (GoJ, 2015).

In 2009, Jamaica developed its 2009 – 2030 National Energy Policy (NEP) to achieve a modern, efficient, diversified, and environmentally sustainable energy sector by 2030. As part of the main goals of the policy, Jamaica plans to provide incentives for improving energy efficiency in power generation and bauxite/alumina production, and promote energy efficiency and conservation in transportation, and building design and construction. Jamaica's Energy Policy also plans to have a modernized energy infrastructure including energy efficient power plants and distribution systems as well as to increase the use of renewables including solar, hydro, wind, and biofuels in the energy mix to 20% by 2030.

The prioritized technologies for the energy sector are not only in alignment with the GoJ's strategy outlined in the NEP, but they also address issues with waste management in Jamaica. The prioritized technologies are:

i. Refuse Derived Fuels (Waste-to-Energy)
ii. Large scale use of biogas (anaerobic biodigesters).

7.1 Preliminary Targets for Technology Transfer and Diffusion

Preliminary targets for the transfer and diffusion of the prioritized technologies for climate change mitigation in the energy sector as presented in Table 7.1 were identified and discussed during stakeholder consultations.

Table 7-1: Preliminary targets for the prioritized technologies for climate change mitigation for the energy sector

Prioritized Technology	Preliminary Target
Refuse Derived Fuels	One (1) power 10 MW plant at a waste facility is proposed for this mitigation technology, producing lower GHG emissions than a typical fossil fuel plant. Pre-sorting and critical temperature pyrolysis for energy production will reduce the solid waste burden at all national disposal sites, reduce spontaneous combustion and inadvertent release of GHG (by removing combustibles), while contributing useful power within the national IRP projected demand. The draft National Energy-from-Waste Policy (October 2010) estimates that for each tonne of municipal solid waste (MSW) combusted rather than landfilled, the overall carbon dioxide reduction can be as high as 1.3 tonnes of CO_2 per tonne of MSW when both the avoided landfill emissions and the avoided use of fossil fuel are considered. Also, it estimates that thermal treatment of MSW results in the generation of 500-600 kWh of electricity per tonne of MSW combusted. A feasibility analysis in 1995/1996 for waste at the Riverton City waste site reported an average calorific value of the waste disposed at the site as 8.87 MJ per kg per day and an estimated annual energy output of 67,500 MWh with about 9 MW available for export to the national grid (thermal efficiency of about 25%). In 2009, the Petroleum Corporation of Jamaica (PCJ) entered into an agreement with a private sector company to establish two waste-to-energy co-fired plants using new technologies, with capacities of 45 MW at the Riverton facility (358 GWh/yr) and one 20 MW facility at the

Prioritized Technology	Preliminary Target
	Retirement facility (141 GWh). If methane energy content recovered from the Riverton facility of 222,424,440 x 105kJ per year was considered, it could potentially serve[6] over 3,000 homes. Additionally, from the sugar companies the EFW Policy indicates cogeneration potential from bagasse for the period 2008 to 2030 is estimated to range between 20 and 63 MW. RDF as a result will reduce competition for land as per modus operandi for solid waste management, reduce vermin hosting, and offer continued employment for healthier and productive basic livelihoods of persons currently using the disposal sites for an income (improved OHS conditions). Pre-sorting of solid waste will also improve feed stock quality to the scrap market for specific by-products, for example, scrap metals or new feedstock such as ash for cinder blocks. RDF/WTE will be included in the next generation Request for Proposals (RFP) based on the 2019 Integrated Resource Plan.
Biogas (large-scale)	At least one (1) medium commercial scale biodigester facility is being targeted as a catalyst for development at other sewerage sites island wide. A system this scale could be tested at any of the nearly 100 sewerage (wastewater) treatment plants operated by the National Water Commission island wide. The largest single sewerage treatment plant is in Greater Portmore (18,180 m^3/day). The proposed system should receive approximately 100,000 – 200,000 m^3 of wastewater/annum, with potential to generate enough biogas for approximately 4,000 MWh_e/annum[7]. A system such as this has the potential to save 2,500t CO_{2e}/annum. A continuous digester may be best suited for sewage operations, where the organic material can be constantly or regularly fed into the enclosed digester. Of special interest for immediate intervention would be the Soapberry Wastewater Treatment Plant (SWTP) and associated sewerage infrastructure (i.e., Pumping Stations and Transmission mains), for which

[6] According to JPSCo, the average requirement per household is 1,869 kWh per year. Therefore, based on the estimated conversion of 3.6 x 106J = 1kWh, the energy produced can serve over 3,300 homes (Model: Emcon Associates-Henry 1989 study, Model: Zsuzsa- Hungarian – biogas)

[7] Bio-engineering Installations - HoSt Holding B.V. 2020. https://www.host.nl/en/biogas-plants/sludge-biogas-plants/?gclid=CjwKCAiArIH_BRB2EiwALfbH1NadycAC4sewP7buB0XA3_lgfd4Wqh4vjYGlSEaTx5cc3E8KN8bZixoCe5EQAvD_BwE

Prioritized Technology	Preliminary Target
	NWC has an 85% shareholding, and is now required to expand its current treatment capacity from 75,000 m^3/day to 150,000 m^3/day, in order to meet the medium-term requirement for treatment of wastewater collected by NWC in the Kingston Metropolitan Area (KMA). In the expansion, it is envisaged that the output from SWTP be reused for agricultural purposes to offset the current use of potable water sourced from the Rio Cobre. It is mandated that in privatization, the SWTP should have the climate change mitigation and adaptation designs via new technologies and renewable energy solutions. For this purpose, an invitation for consultancy to provide advisory services for the "Expansion and Privatization of the Soapberry Wastewater Treatment Plant in Jamaica was posted 18 November 2020[8]. Part of this consultancy is to give attention to the potential value of treated effluent and/or any other by-products and/or derivate from the plant that could provide financial (via complementary revenue streams) and economic benefits i.e., recycling, renewables. These objectives align well with an anaerobic biodigester coupled to a renewable biogas combined cycle power plant.

7.2 Barrier Analysis and Possible Enabling Measures for Refuse Derived Fuel

7.2.1 General Description of Refuse Derived Fuel

Jamaica waste production exceeds 900,000 tonnes of municipal solid waste (MSW) annually, with high moisture and organic contents especially from garden cuttings, furniture, textiles, and paper derived packaging. A Characterization of Waste Study undertaken by NSWMA in 2006 reported that 69% of the solid waste generated in Jamaica is organic, representing a good source of input into an energy-from-waste sector[9]. Many attempts have been made to convert MSW into energy, however, this has not materialized as it has been considered that the combustible volumes are small (relative to developed and industrial nations), onsite livelihoods may be affected, tipping fees would not be granted to the developers for financing recurrent costs, and the government ministries which would be the lead/beneficiary agency for such systems have not been determined.

In the proposed technology, MSW may be sorted and combusted using a gasification technology to reduce the volume of permanent solid waste, reduce emissions and the space required for the far future, to generate electricity and maintain livelihoods.

[8] Summary Terms of Reference Assignment Title: Engagement of Transaction Advisory Services for the Expansion and Privatisation of the Soapberry Wastewater Treatment Plant

[9] Draft Energy from Waste (sub) Policy 2010–2030.

There are many technology options for utilizing solid waste to create energy. These include: -

1. **Incineration** - involving low-cost simple technology of combustion with some GHG emissions.
2. **Anaerobic Digestion (composting)** – a clean simple technology producing biodegradable organic soil ameliorants with lowered GHG especially methane.
3. **Landfill Gas to Energy** – relatively simple technology extracting naturally produced methane in a capital-intensive engineered landfill with system of extraction of clean burning methane. Methane emissions reduced, but CO_2 produced from burning.
4. **Refuse Derived Fuels** – clean moderately advanced and capital-intensive technology producing various fuel types for further combustion using pyrolysis (absence of air) or gasification (production of combustible gases) for energy.
5. **Gasification** – advanced capital-intensive technology with the production of a clean combustible gas from solid wastes. CO_2 emissions produced, but lower relative to open landfills.
6. **Plasma Arc** – advanced and capital-intensive technology with extreme heating temperatures and high destruction rates for wastes, while producing energy with very low GHG production.
7. **Plastic Waste into Fuels** – advanced expensive chemical processing which derives clean liquid fuels. GHG produced from resulting use in combustion engines.

In Jamaica's scenario, landfill gas extraction, and very high temperature gasification/pyrolisis technologies are options which would satisfy MSW disposal volume constraints; access to technology; sustaibnable livelihoods; and desired environemntal outcomes (emissions). Dual fuel co-firing technologies can be included to facilitate supplimental alternative fossil sources such as natural gas.

The production of combustible gaseous fuels from waste for combustion in MSW would involve:

1. Manual and mechanized sorting - preliminary, manual sorting and recovery of recyclable, reusable, and non-combustible items such as glass bottles and metals for recycling.
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.

Jamaica is currently experiencing a solid waste crisis where continued deposal of MSW intrudes into community living spaces, pollutes ground water sources, accumulates toxic materials, and produces vermin, and other public health hazards. Additionally, annual fires from combustible materials cause hospitalization of citizens in neighbouring communities and slows traffic.

The electricity supply will also be expanded, and the state has a 50% renewable energy goal for 2030. RDF or waste-to-energy has been included as a potential technology for new base load generation (yr-2023 – 74 MW of Hydro, Waste-to-Energy, or Biomass).

7.2.2 Identification of Barriers

Refuse derived fuels has been categorized as a 'Capital Good' based on the definition for capital goods in the guidebook "Overcoming barriers to the Transfer and Diffusion of Climate Technologies" (Nygaard & Hansen, 2015).

7.2.2.1 Economic and financial barriers

Economic and financial barriers were identified from stakeholder consultation and scored to determine the relative significance of the barriers. The barriers and scores are given in Table 7-2**Error! Reference source not found.**.

Table 7-2: Identified barriers and scores for refuse derived fuels/waste-to-energy

Identified economic and financial measures		Total/10
Direct		
1	Refuse Derived Fuels/Waste-to-Energy requires large capital investment and infrastructure upgrades to be integrated into the current waste disposal system in Jamaica.	9
Indirect		
2	Funding from lending agencies usually has a cap which is much lower than the capital investment required for large-scale energy projects. Therefore, these projects are generally driven by private investors who may not be willing to take the high risk associated with the introduction of unproven technologies.	7
3	The economics and return on investment for these technologies are lower than other technologies such as solar PV and wind energy. It may also require additional inputs such as the tipping fees for viability.	7

7.2.2.2 Non-financial barriers

Non-financial barriers were evaluated, and the relative significance is presented in Table 7-3.

Table 7-3: Identified non-financial barriers and scores for refuse derived fuels

Identified non-financial measures		Total/10
Regulatory		
1	Government policy and possible incentives will be required to foster the development of these technologies in Jamaica. This could be a lengthy process if these polices are not part of the National Energy Policy.	5
2	Waste-to-energy may be competing with recycling for the same waste resources.	7
Technical		
3	Though the technology presents a major solution to solid waste issues, and sanitation risks and also contributes to fossil fuel and GHG reduction, energy efficiencies would have to be taken into consideration in the diversification to these sources of energy. If this is not considered, then the energy demand will be too high and unsustainable.	3

Identified non-financial measures		Total/10
4	There are no examples of RDF technologies in Jamaica which can be used as a gage to understand the technologies and how it will work in the Jamaican market.	3
5	RDF requires more information and feasibility studies to aid in the decision-making process for the government agencies and private entities.	6
6	There is high competition from other more proven and efficient renewable energy technologies such as Solar PV and wind.	8
7	RFD may require dual fuel to maintain commercial baseload levels to the grid. In most cases, it considers the use of fossil fuels as this is usually cheaper, however, this causes emissions of GHG.	4
8	Previous studies for considering special feed-in tariffs (FIT) favourable for similar RE projects was done by GoJ. FIT was rejected so it will be a barrier for incorporation of the selected technologies.	6
Institutional Capacity		
9	Jamaica lacks the required professionals that fully understand the technology and the required tools and supply chain to sustainably operate and maintain these technology options.	4

7.3 Barrier Analysis and Possible Enabling Measures for Biogas

7.3.1 General Description of Biogas

This involves the decomposition of biodegradable material like agricultural waste, manure, municipal waste, plant material, sewage, green waste, or food waste by micro-organisms in the absence of oxygen. The process of anaerobic digestion produces three principal outputs: biogas, consisting mainly of CH_4 (up to >60%) and CO_2, which can be used for energy production; a nutrient-rich solid digestate which can be used as a soil ameliorant; and a liquor that can be used as a fertilizer.

The biogas is a renewable energy source which may be used for heating, electricity, and cooking (Figure 7-2).

A biogas (anaerobic biodigesters) facility with an anaerobic digester has four main components:

1. A waste collection system.
2. An anaerobic digester to produce the biogas consisting of methane and CO_2. There are two basic types of digesters – batch and continuous:
    a. Batch-type digesters load organic materials into an air-tight chamber in the digester, allowing it to digest (breakdown) while producing biogas. The retention time depends on temperature and other factors. Once the digestion is complete, the solids and effluents are removed, and the process is repeated.
    b. The continuous digester is constantly or regularly fed organic material, and this goes into the enclosed 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 solids and effluents. 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.

3. Biogas Handling System is a device that puts the biogas to use such as a combined heat and power plant.

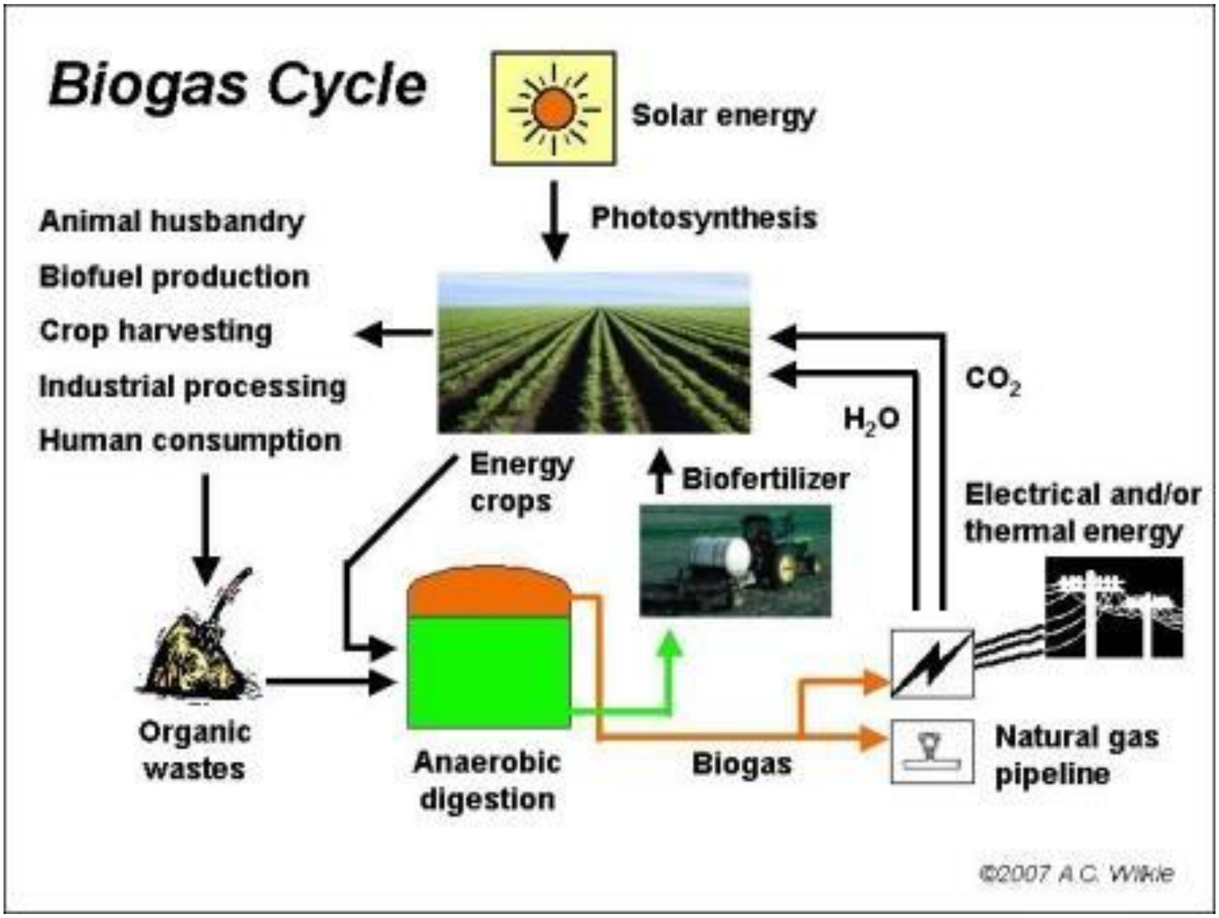

Figure 7-2: The bio digestion process (Wilkie, Smith, & Bordeaux, 2004)

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

1. Covered lagoon (least desired for Jamaica).
2. Completely enclosed mixed reactor (metal or concrete).
3. Plug flow anaerobic digester.
4. Induced blanket reactor.

The recovery of biogas through anaerobic digestion systems is a proven technology worldwide and Jamaica has an abundance of feedstock at the sites such as farms or sewage plants, where electricity is needed. 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 in the agriculture sector (predominantly rural), which is significant in the Jamaican economy. As farms increase in number and complexity, their waste flow and energy requirements will also increase making biodigesters a valuable waste and energy solution. Large amounts of animal waste and methane emissions can create serious environmental concerns. When animal manure enters rivers, streams or groundwater supplies, eutrophication occurs, and social uses are diminished; emissions to the atmosphere contribute to global warming. The technology avoids the emission of methane as the fuel is combusted for heat or electricity.

7.3.2 Identification of Barriers

Biogas has been categorized as a 'Capital Good' based on the definition for capital goods in the guidebook "Overcoming barriers to the Transfer and Diffusion of Climate Technologies" (Nygaard & Hansen, 2015).

7.3.2.1 Economic and financial measures

Economic and financial barriers were identified from stakeholder consultations and scored to determine the relative significance of the barriers. The barriers and scores are given in Table 7-4.

Table 7-4: Identified barriers and scores for biogas

Identified economic and financial barriers		Total/10
Direct		
1	Biogas requires capital investment and infrastructure upgrades for the capture, storage and use of the gas.	9
Indirect		
2	The economics and return on investment for biogas are generally lower compared to other traditional fossil fuels.	7
3	The Scientific Research Council (SRC) retains patents for biogas technology designs and therefore, this adds additional financial layers for the use of this technology in Jamaica.	4

7.3.2.2 Non-financial measures

Non-financial barriers were evaluated, and the relative significance is presented in Table 7-5**Error! Reference source not found.**.

Table 7-5: Identified non-financial barriers and scores for biogas

Identified economic and financial barriers		Total/10
Regulatory		
1	It is likely that government incentives will be required to foster the development of biogas in Jamaica. This could therefore be a lengthy process.	5
Technical		
2	Jamaica has very few examples of biogas technologies which could be used as a gage to understand the technologies and determine the possible market response in this country.	3

Identified economic and financial barriers		Total/10
3	There is high competition for other more proven and efficient technologies such as Solar PV and wind versus biogas.	8
4	Biogas is difficult to handle as it produces gasses such as H_2S which burn the eyes, produce a foul odour, and corrode equipment very easily.	4
5	There are limited options available for biogas stoves/appliances and the repair and maintenance of these stoves/appliances in Jamaica.	4
Culture		
6	There have generally been significant cultural blocks regarding the use of biogas. This is because there is reluctance to handle the waste material.	3

7.4 Linkages of the Identified Barriers

The prioritized technologies for the energy sector in Jamaica are closely related. These technologies have similar barriers in the areas of economics, financial and technical.

Economic and Financial

Refuse derived fuels and biogas are currently not utilized in Jamaica on a large scale. Therefore, the introduction of these technologies will demand a major capital investment as existing infrastructure for the collection, storage and processing of waste will have to be modified and upgraded. Additionally, there are either none or limited supply chains locally which supply the hardware for these technologies.

Technical

The two technologies, refuse derived fuels and biogas, recycle waste material to produce energy, thus, reducing the amount of greenhouse gases from landfills and waste disposal sites. However, as it relates to the production of energy (electricity), there is high competition from other more proven and efficient renewable energy technologies such as solar PV and wind. These technologies are well known across Jamaica and the cost to the consumer is considerably cheaper than the cost of using refuse derived fuels and biogas.

7.5 Identified Measures

Table 7-6**Error! Reference source not found.** outlines the proposed measures for overcoming the most significant barriers for Refuse Derived Fuels (Waste-to-Energy) for the energy sector in Jamaica. Table 7-7 outlines the proposed measures for overcoming barriers identified for Biogas.

Table 7-6: Proposed measures for the Refuse derived fuels (Waste-to-Energy)

Major Barriers	Proposed Measures
Waste to energy (gasification) requires large	The Ministry of Science Energy and Technology should prepare bid invitations specifically identifying the WTE technology under the REN

Major Barriers	Proposed Measures
capital investment and infrastructure upgrades to be integrated into the current waste disposal system in Jamaica	category. Duty, tax, and other benefits for clean energy technology is to be made available for preferred bidders. Government waste disposal sites to offer concessional land lease for the life of technology (20 – 25 years) Due to the large capital expenditures needed to fund WTE projects and the specific expertise needed to design, construct, and operate these facilities, the majority of WTE projects are pursued as public-private partnerships (PPPs)[10]. This is supportive of the objectives of meeting the renewable energy target of Jamaica, namely, reducing the waste burden on land assets and lowering the barriers for investments.
	Secure green financing for loans and grants to reduce initial capital costs
Funding caps for lending agencies, lower than the capital investment required for large-scale energy projects. Private investors may not be willing to undertake the high risk of an unproven technology in Jamaica	Utilize mixed financing options including PPP, green financing, and reduce land lease costs. Government to deliver seminars on the technology to generate interest in the financial sector and private sector organizations (e.g., Jamaica Chamber of Commerce, and Private Sector Organization of Jamaica).
The economics and ROI are lower than other technologies (solar PV and wind energy) and may require additional inputs such as the tipping fees for viability.	Allow revenue to be collected from electricity tariffs charged to the utility; from tipping fees charged to waste haulers (both public and private); and sales of scrap metals or other recyclable materials sorted from feedstock. Reduce capital costs as above.
Government policy and possible incentives will be required to foster the	Ensure clear government policy directives are given to support WTE technology, consistent with the *Energy from Waste Draft* sub-Policy

[10] Capital Cost Comparison of Waste-to-Energy (WTE), Facilities in China and the U.S. Jane Siyuan Wu January 3, 2018. Department of Earth and Environmental Engineering Fu Foundation School of Engineering and Applied Science Columbia University.

Major Barriers	Proposed Measures
development of these technologies in Jamaica. This could be a lengthy process if these polices are not part of the National Energy Policy.	2010 – 2030 and IRP implementation scenario of REN technologies including WTE in 2023. Prepare clear procurement rules ahead of RFP inclusive of WTE options.
Waste-to-energy may be competing with recycling for the same waste resources.	Educate decision-makers of the multiple benefits of WTE for solid waste reduction and disposal especially for plastics, toxic and hazardous wastes; GHG reduction; electricity generation; upskilling community residents for new and continuing employment; economic by products (e.g., scrap metals, glass, etc.) versus recycling only which generated limited waste reduction; increases land requirements; and generates low value products. Current plastic waste recovery initiatives.
There are no examples of Waste-to-energy (gasification) technologies in Jamaica which can be used as a gage to understand the technologies and how it will work in the Jamaican market.	Seek support of international development partners to provide evidence or desktop analysis of WTE successes globally and with applications for the Jamaican context. Utilize local and regional universities at the postgraduate research level to develop feasible options for technology application.
Waste-to-energy (gasification) requires more information and feasibility studies to aid in the decision-making process for the government agencies and private entities.	Seek support of international development partners to provide evidence or desktop analysis of WTE successes globally and with applications for the Jamaican context. Utilize local and regional universities at the postgraduate research level to develop feasible options for technology application.
There is high competition from other more proven and efficient renewable	Provide clear distinctions regarding roles, inputs, benefits and limitations of wind and solar technologies versus WTE as each technology has different contributions for national development, the energy mix, sustainability, and resilience.

Major Barriers	Proposed Measures
energy technologies such as Solar PV and wind.	
Waste-to-energy (gasification) may require dual fuel to maintain commercial baseload levels to the grid. In most cases, it considers the use of fossil fuels as this is usually cheaper, however, this causes emissions of GHG.	Ensure procurement rules for 2018 – 2037 IRP implementation should mandate that any acceptable fossil fuel source should be only considered as a supplemental source and must be low carbon in nature.
Previous studies for considering special feed in tariffs (FIT) favourable for similar RE projects was done by GoJ. FIT was rejected so will be a barrier for incorporation of the selected technologies.	Review of the FIT to consider other critical non-energetic, economic and environmental benefits from WTE, namely. • *Solid waste reduction.* • *Increased incentive for collection of all wastes by waste collection services.* • *Reduced environmental pollution (ground and surface water sources, air pollution, solid waste pollution).* • *Maintenance of new higher paying skilled employment opportunities.* Seek funding (preferably grant) to conduct Environmental Accounting to incorporate principles of environmental management and conservation into financial reporting practices and cost/benefit analyses. This will permit the government to determine the real impact of ecologically sustainable practices in everything from supply chain to generation expansion plan or IRP, and for the government to take proactive decisions about processes that simultaneously meet environmental regulations while achieving energy and environmental policy goals.
Jamaica lacks the required professionals that fully understand the technology and the required tools and	• As part of request for technical consultancy support from development partners, a request for capacity building in the year of/or preceding a WTE procurement notice could be included.

Major Barriers	Proposed Measures
supply chain to sustainably operate and maintain these technology options.	• Local academic institutions under the Ministry of Education, Youth and Culture (e.g., The University of Technology); local training institutions (e.g., HEART-NCST); and private and Regional universities (e.g., The University of the West Indies), could be encouraged to prepare academic/courses inclusion for short-term professional or undergraduate and graduate capacity development in WTE dimensions. • Professional workshops and seminars on WTE hosted by private sector, government, and energy-related associations.

Table 7-7: Proposed measures for Biogas (anaerobic biodigesters)

Major Barriers	Proposed Measures
Biogas requires capital investment and infrastructure upgrades for the capture, storage and use of the gas.	Biogas technology is proposed for sewage waste treatment by NWC. Private farms should utilize the Net Billing Regulations for commercial entities (up to 100kW) to facilitate grid interconnection. The current operations of the state-owned NWC which is the main but not exclusive provider of potable water supply and the collection, treatment, and disposal of wastewater services in Jamaica, is not viable as it has a negative net worth of about JA$12.6 billion and bills customers for less than one-third of the 177 million imperial gallons of water it produces daily. Additionally, an Inter-American Development Bank (IDB) study found that the cost of water and the tariff charged were already too high, so increasing charges is not an option. Against this background the utility is to be privatized (or financed via a PPP instrument). The addition of biodigesters to treat sewage and produce electricity can therefore be a positive strategy to improve the income stream and viability of the entity. Anaerobic biodigesters should therefore be incorporated in the Engagement of Transaction Advisory Services for the Expansion and Privatization of the Soapberry Wastewater Treatment Plant (SWTP) Phase 1 of the consultancy, which is intended to *"Prepare a complete Business Case on the preferred option for the development and expansion of the Soapberry Wastewater Treatment Plant including providing a recommended transaction structure"* is the ideal timing

Major Barriers	Proposed Measures
	to analyse to capital requirements for investments and infrastructure upgrades for this technology at SWTP. If favourable, the consultancy should encourage this technology for the Government Procurement Plans to improve operations. Legal and regulatory reforms will be needed as well as the promulgation of a new Water Act to guide the new privatized entity.
The economics and return on investment for biogas are generally lower compared to other traditional fossil fuels.	Enable an accurate comparison of the economics of the technology by using Environmental Accounting to compare BAU unsustainable fossil fuel importation, pollution and attendant impacts of price volatility and energy security related to the commodity, versus exploitation of an indigenous renewable energy source. This will also enable stakeholders to take appropriate decisions about processes that simultaneously meet environmental regulations while adding to the bottom line.
Scientific Research Council (SRC) retains patents for Biogas technology designs and therefore this adds additional financial layers for the use of this technology in Jamaica.	Early legal intervention may be required from the Government to remove or reduce this barrier to achieve climate change and renewable energy goals with this technology. SRC should also be engaged as the agent of the government and PPP representative to facilitate the technology for national good.
Government possible incentives will be required to foster the development of biogas in Jamaica. This could be a lengthy process.	Government is eschewing direct sector or company subsidies or incentives where this can be avoided. A partial revenue balancing option could be considered by surrendering the tipping fee to the investor for cashflow, but also levying a lower fee/cess on the entity for the opportunity. As a renewable energy technology, imported equipment could be added to the list of renewable energy and energy efficient equipment.
Very few examples of biogas technologies are available in Jamaica which can be used as a gage to understand the technologies and how it will	Leverage and scale up the experiences of the existing examples from (SRC) and others including the small 100 m^3 biodigester and 18-kW generator at the St. John Bosco Boys Home to determine the lessons learnt.

Major Barriers	Proposed Measures
work in the Jamaican market	Access development grants and engage local universities to do research/desktop studies equivalent to the applicable scale for the technology in Jamaica.
There is high competition for biogas when compared to other more proven and efficient technologies such as Solar PV and wind.	Provide clear distinctions regarding roles, inputs, benefits, and limitations of biogas as a fuel versus wind and solar technologies as each technology has different contributions for national development, the energy mix, sustainability and resilience.
Biogas is difficult to handle as it produces gases such as H_2S which burns the eyes, has a bad odour, and corrodes equipment very easily.	Operational interruption for the biogas-fuelled engine-generator sets may be experienced due to damage from hydrogen sulphide (H_2S) in biogas, resulting in high maintenance costs and/or lost revenues. H_2S scrubbers (e.g., in-vessel oxidation using air injection, iron-oxide sponge scrubber systems or chemical scrubbers) can be added to the infrastructure facilitating power generation. H_2S is significantly responsible for the challenges faced, however modern industrial scale biogas anaerobic digester systems are sealed from generation to combustion so present less challenges.
There has generally been a great cultural block towards the use of biogas. This is because there is resistance to handling the waste material.	No specific actions as NWC which treats sewage in its operations, is proposed to be the beneficiary. There will be no additional odour or hygiene concerns.

7.5.1 Cost-Benefit of Proposed Measures for the Energy Sector

A simple cost benefit analysis was conducted for the implementation of the identified measures. These are given in Table 7-8 for Refuse Derived Fuels (Waste-to-Energy) and Table 7-9 for Biogas. The cost benefit analysis was completed with the best available information. While the technologies are not new to Jamaica, they only occur on a very small scale and the success of these small initiatives have not yet been proven. Therefore, is limited research and data to effectively quantify the benefits of these technologies. Such analysis is required to effectively develop a full quantitative financial model for the expected benefits these systems will have on the energy sector in Jamaica.

Table 7-8: Simple cost benefit for the proposed measures for Refuse derived fuel (waste-to-energy)

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
Waste to energy (gasification) requires large capital investment and infrastructure upgrades to be integrated into the current waste disposal system in Jamaica.	The Ministry of Science Energy and Technology to prepare bid invitations specifically identifying the WTE technology under the REN category. Duty, tax, and other benefits for clean energy technology to be available for preferred bidders. Government waste disposal sites to offer concessional land lease for life of technology (20 – 25 years). Due to the large capital expenditures needed to fund WTE projects and the specific expertise needed to design, construct, and operate these facilities, the majority of WTE projects are pursued as public-private partnerships (PPPs)[11]. This is supportive of the objectives of meeting the renewable energy target of Jamaica, reducing the waste burden on land assets and lowering the hurdle for investments.	The average initial capital cost of 21 U.S. facilities was US$840 per annual ton capacity (range of US$386 - 1,811) (Survey of Waste-to-Energy Facilities, 2017). The largest waste facility at Riverton receiving 390,585 tons per annum could cost approximately US$242.2 Million capex or US$615 per annum ton.[12] Based on the power plant, WTE capital cost is about US$ 1,900/kW.	• Contribution to renewable energy target. • Reduction of methane production and global warming. • Reduction of solid waste and land demand. • Proliferation could accelerate renewable energy targets during IRP timelines (2023).

[11] Capital Cost Comparison of Waste-to-Energy (WTE), Facilities in China and the U.S. Jane Siyuan Wu January 3, 2018. Department of Earth and Environmental Engineering Fu Foundation School of Engineering and Applied Science Columbia University.

[12] Calculator-https://wteinternational.com/cost-of-incineration-plant/#:~:text=where%20I%20is%20the%20investment,per%20ton%20of%20annual%20capacity.

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
	Secure green financing for loans and grants to reduce initial capital costs.	The average initial capital cost of 21 U.S. facilities was US$840 per annual ton capacity (range of $386 - $1,811) (Survey of Waste-to-Energy Facilities, 2017). The largest waste facility at Riverton receiving 390,585 tons per annum could cost approximately US$242.2 Million capex or US$615 per annum ton.[13] Based on the power plant, WTE capital cost is about US$ 1,900/kW.	• Improved financial feasibility to introduce the technology.
Funding caps for lending agencies, lower than the capital investment required for large scale energy projects. Private investors may not be willing to	Utilize mixed financing options including PPP, green financing, and reduced land lease costs. Government to deliver seminars on the technology to develop interest to financial sector and private sector organizations (e.g.,	The average initial capital cost of 21 U.S. facilities was US$840 per annual ton capacity (range of US$386 - 1,811) (Survey of Waste-to-Energy Facilities, 2017). The largest waste facility at Riverton receiving 390,585	• Improved financial feasibility to introduce the technology.

[13] Calculator-https://wteinternational.com/cost-of-incineration-plant/#:~:text=where%20I%20is%20the%20investment,per%20ton%20of%20annual%20capacity.

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
undertake the high risk of an unproven technology in Jamaica.	Jamaica Chamber of Commerce, and Private Sector Organisation of Jamaica).	tons per annum could cost approximately US$242.2 Million capex or US$615 per annum ton.[14] Based on the power plant, WTE capital cost is about US$ 1,900/kW. 2 seminars at US$3,500 each	
The economics and ROI are lower than other technologies (solar PV and wind energy and may require additional inputs such as the tipping fees for viability.	Allow revenue to be collected from electricity tariffs charged to the utility; from tipping fees charged to waste haulers (both public and private); and sales of scrap metals or other recyclable materials sorted from feedstock. Reduce capital costs as above.	In the USA, tipping fees may average US$52 per ton (Environmental Research & Education Foundation, 2017), however, in comparison, WTE facility tipping fees are generally higher at US$60 - 110. Maintenance cost is approximately 5 - 10% from CAPEX annually.	Improved financial feasibility to introduce the technology.
Government policy and possible	Ensure clear government policy directives are given to support WTE technology,	Undetermined.	Achievement of policy and IRP generation targets.

[14] Calculator-https://wteinternational.com/cost-of-incineration-plant/#:~:text=where%20I%20is%20the%20investment,per%20ton%20of%20annual%20capacity.

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
incentives will be required to foster the development of these technologies in Jamaica. This could be a lengthy process if these polices are not part of the National Energy Policy.	consistent with the *Energy from Waste Draft* sub-Policy 2010 – 2030 and IRP implementation scenario of REN technologies including WTE in 2023. Prepare clear procurement rules ahead of RFP inclusive of WTE options.		• Reduction of GHG emissions. • Employment and improvement of livelihoods in nearby communities, through higher paid jobs and skilled employment at WTE plant, relative to manual harvesting as the waste facilities.
Waste-to-energy may be competing with recycling for the same waste resources.	Educate decision-makers of the multiple benefits of WTE for solid waste reduction and disposal especially for plastics, toxic and hazardous wastes; GHG reduction; electricity generation; upskilling community residents for new and continuing employment; economic by-products (e.g., scrap metals, glass, etc.) versus recycling only which generated limited waste reduction; increases land requirements; and generates low value products. Current plastic waste recovery initiatives.	Education campaign = US$4,000.	• Potential increase in availability of some recycling feedstocks from pre-sorting process (e.g., scrap metals, glass, etc). • Solid waste reduction and disposal. • GHG reduction. • Electricity generation. • Upskilling community residents for new and continuing employment.

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
There are no examples of Waste-to-energy (gasification) technologies in Jamaica which can be used as a gage to understand the technologies and how it will work in the Jamaican market.	Seek support of international development partners to provide evidence or desktop analysis of WTE successes globally and with applications for the Jamaican context. Utilize local and regional universities at the postgraduate research level to develop feasible options for technology application.	US$10,000 – 15,000 (grant) for funded consultancy.	• Confidence in technology application or at least basis for consideration. • Information/data Input for 2023 procurement by government.
Waste-to-energy (gasification) requires more information and feasibility studies to aid in the decision-making process for the government agencies and private entities.	Seek support of international development partners to provide evidence or desktop analysis of WTE successes globally and with applications for the Jamaican context. Utilize local and regional universities at the postgraduate research level to develop feasible options for technology application.	US$10,000 – 15,000 (grant) for funded consultancy.	• Confidence in technology application or at least basis for consideration. • Information/data Input for 2023 procurement by government.
There is high competition from other more proven and efficient	Provide clear distinctions regarding roles, inputs, benefits and limitations of wind and solar technologies versus WTE as each technology has different contributions for	Undetermined	• Wind, solar and WTE will have the requisite priorities in the expansion of

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
renewable energy technologies such as Solar PV and wind.	national development, the energy mix, sustainability, and resilience.		REN technology in the energy mix, and not to be treated as mutually exclusive. • Energy resilience and diversity for a stable grid power supply.
Waste-to-energy (gasification) may require dual fuel to maintain commercial baseload levels to the grid. In most cases it considers the use of fossil fuels as this is usually cheaper, however, this cause emissions of GHG.	Ensure procurement rules for 2018 – 2037 IRP implementation should mandate that any acceptable fossil fuel source should be only considered as a supplemental source and must be low carbon in nature.	Cost for procurement preparations undetermined.	• WTE will achieve GHG emission reductions. • WTE technology will satisfy renewable energy criteria versus fossil generation plant criteria based on fuel source.
Previous studies for considering special feed in tariffs (FIT) favourable for similar RE projects was done by GoJ. FIT was rejected so	Review of the FIT to consider other critical non-energetic, economic and environmental benefits from WTE, namely. • *Solid waste reduction.* • *Increased incentive for collection of all wastes by waste collection services.*		• Enabling financial decision-making tool to enable government to embrace multiple benefits of WTE (as aforementioned).

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
will be a barrier for incorporation of the selected technologies.	• *Reduced environmental pollution (ground and surface water sources, air pollution, solid waste pollution).* • *Maintenance of new higher paying skilled employment opportunities.* Seek funding (preferably grant) to conduct Environmental Accounting to incorporate principles of environmental management and conservation into financial reporting practices and cost/benefit analyses. This will permit the government to determine the real impact of ecologically sustainable practices in everything from supply chain to generation expansion plan or IRP, and for the government to take proactive decisions about processes that simultaneously meet environmental regulations while achieving energy and environmental policy goals.	US$40,000	
Jamaica lacks the required professionals that fully understand the technology and the required tools	• As part of request for technical consultancy support from development partners, a request for capacity building in the year of/or preceding a WTE procurement notice could be included.	USD 10,000	• In-country competences for supporting WTE personnel and skills requirements.

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
and supply chain to sustainably operate and maintain these technology options.	• Local academic institutions under the Ministry of Education, Youth and Culture (e.g., The University of Technology); local training institutions (e.g., HEART-NCST); and private and Regional universities (e.g., The University of the West Indies), could be encouraged to prepare syllabus inclusion for short-term professional or undergraduate and graduate capacity development in WTE dimensions. • Professional workshops and seminars on WTE hosted by private sector, government, and energy related associations.	US$70,000	

Table 7-9: Simple cost benefit for the proposed measures for Biogas (anaerobic biodigesters)

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
Biogas requires capital investment and infrastructure upgrades for the	Biogas technology is proposed for sewage waste treatment by NWC. Private farms should utilize the Net Billing Regulations for commercial entities (up to 100kW) to facilitate grid interconnection.	Consultancy estimated at US$ $35,000.	Determination of the capital costs and feasibility of the technology and potential sources for funding.

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
capture, storage and use of the gas.	The current operations of the state-owned NWC which is the main but not exclusive provider of potable water supply and the collection, treatment, and disposal of wastewater services in Jamaica, is not viable as it has a negative net worth of about JA$12.6 billion and bills customers for less than one-third of the 177 million imperial gallons of water it produces daily. Additionally, an Inter-American Development Bank (IDB) study found that the cost of water and the tariff charged were already too high, so increasing charges is not an option. Against this background the utility is to be privatized (or financed via a PPP instrument). The addition of biodigesters to treat sewage and produce electricity can therefore be a positive strategy to improve the income stream and viability of the entity. Anaerobic biodigesters should therefore be incorporated in the Engagement of Transaction Advisory Services for the Expansion and Privatization of the Soapberry Wastewater Treatment Plant (SWTP). Phase 1 of the consultancy, which is intended to *"Prepare a complete Business Case on the preferred option for the development and expansion of the Soapberry Wastewater Treatment Plant including providing a recommended transaction structure"* is the ideal timing to analyse to capital requirements for investments and infrastructure upgrades for this technology at SWTP.		

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
	If favourable, the consultancy should encourage this technology for the Government Procurement Plans to improve operations. Legal and regulatory reforms will be needed as well as the promulgation of a new Water Act to guide the new privatized entity.		
The economics and return on investment for biogas are generally lower compared to other traditional fossil fuels.	Enable an accurate comparison of the economics of the technology by using Environmental Accounting to compare BAU unsustainable fossil fuel importation, pollution and attendant impacts of price volatility and energy security related to the commodity, versus exploitation of an indigenous renewable energy source. This will also enable stakeholders to take appropriate decisions about processes that simultaneously meet environmental regulations while adding to the bottom line.	Consultancy estimated at US$ 15,000	• Determination of the capital costs and feasibility of the technology and potential sources for funding.
Scientific Research Council (SRC) retains patents for Biogas technology designs and therefore this adds additional financial layers for the use of this	Early legal intervention may be required from the Government to remove or reduce this barrier to achieve climate change and renewable energy goals with this technology. SRC should also be engaged as the agent of the government and PPP representative to facilitate the technology for national good.	Need for and cost of legal intervention undetermined.	Removal of barrier to enable investment

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
technology in Jamaica.			
Government possible incentives will be required to foster the development of biogas in Jamaica. This could be a lengthy process.	Government is eschewing direct sector or company subsidies or incentives where this can be avoided. A partial revenue balancing option could be considered by surrendering the tipping fee to the investor for cash flow, but also levying a lower fee/cess on the entity for the opportunity. As a renewable energy technology, imported equipment could be added to the list of renewable energy and energy efficient equipment.	The revenue impact on the state budged cannot be determined at this time.	• Encourage private and public sector to utilize the technology without increasing project costs.
Very few examples of biogas technologies are available in Jamaica which can be used as a gage to understand the technologies and how it will work in the Jamaican market	Leverage and scale up the experiences of the existing examples from (SRC) and others including the small 100 m^3 biodigester and 18-kW generator at the St. John Bosco Boys Home to determine the lessons learnt. Access development grants and engage local universities to do research/desktop studies equivalent to the applicable scale for the technology in Jamaica.	US$15,000	• Critical data for application for the technology at scale.

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
There is high competition for biogas when compared to other more proven and efficient technologies such as Solar PV and wind.	Provide clear distinctions regarding roles, inputs, benefits and limitations of biogas as a fuel versus wind and solar technologies as each technology has different contributions for national development, the energy mix, sustainability and resilience.	Undetermined	• Wind, solar and biogas will have the requisite priorities in the expansion of REN technology in the energy mix, and not be treated as mutually exclusive. • Energy resilience and diversity for a stable grid power supply. • Additional revenue for a privatized NWC.
Biogas is difficult to handle as it produces gases such as H_2S which burns the eyes, has a bad odour, and corrodes equipment very easily.	Operational interruption for the biogas-fuelled engine-generator sets may be experienced due to damage from hydrogen sulphide (H_2S) in biogas, resulting in high maintenance costs and/or lost revenues. H_2S scrubbers (e.g., in-vessel oxidation using air injection, iron-oxide sponge scrubber systems or chemical scrubbers) can be added to the infrastructure facilitating power generation. H_2S is significantly responsible for the challenges faced, however modern industrial scale biogas anaerobic	Indicative costs from a study at 2 dairy farms in New York State[15], which had generator capacities of 1MW, and 502 kW indicate the following costs for H_2S trickle scrubbers: <u>Mean Averages:</u> • Scrubber system capital cost = US$355.3/kW	• Cleaner biogas for technology application and success. • Reduced odour and systems impact for greater viability.

[15] Quantifying and Demonstrating Scrubbing H_2S from Biogas Produced by Farm-Based Anaerobic Digestion Systems. Department of Biological and Environmental Engineering PRO-DAIRY Dairy Environmental Systems Program Cornell University. 2016 (https://cdn.sare.org/wp-content/uploads/20171204121718/Quantifying-and-Demonstrating-Scrubbing-H2S-from-Farm-12-2016.pdf).

Major Barriers	Proposed Measures	Expected Cost	Expected Benefit
	digester systems are sealed from generation to combustion so present less challenges.	• Scrubber annual labour cost = US$6.2/kW/yr. • Scrubber annual cleanout labour = US$3.7/kW/yr. • Scrubber - annual nutrient purchases = US$9.6/kW/yr. • Scrubber - annual trickle media replacement = US$4.2/kW/yr. Costs will vary with feedstock source, type, and characteristics; gas production technology; generator and other factors.	
There has generally been a great cultural block towards the use of biogas. This is because there is resistance to handling the waste material.	No specific actions as NWC which treats sewage in its operations, is proposed to be the beneficiary. There will be no additional odour or hygiene concerns.	Undetermined	

7.6 Enabling Framework to Overcome the Barriers

Both anaerobic digestion of wastes and more so RDF at commercial scales are new technologies for Jamaica. The risk appetite from commercial financiers for locally unproven technology is low, the competition from generation proven technologies place both proposed technologies at a disadvantage and the potential project proponents are limited due to the investment scale required for success. Otherwise, both technologies are proven and successful in other jurisdictions.

There are also legal and institutional barriers. Patents held by SRC (a state agency) has in the past deterred investors in anaerobic digestors. Unless investors can prove that their designs are significantly different from the technology principles of SRC, the agency requires involvement in the projects. For RDF the energy and waste management ministries are yet to develop an understanding for the authority under which RDF/WTE projects are to be implemented. Also, the value of the tipping fee is of significant value to the waste management ministry.

Other barriers such as technical capacity in the technologies, and loss of employment can be more easily overcome. As such some enabling actions for implementation would include:

1. Inter-governmental coordination of various agencies and Ministries with responsibility for waste, energy, and environment to determine a mechanism for overcoming challenges and advancing the technologies.

2. Cabinet or Parliamentary decision to permit anaerobic digestion technologies to proceed with favourable legal and financial agreements with SRC. Such legal arrangements should be developed by the Attorney General's Chambers, SRC, and the appropriate ministry involvement, in advance of RFP for the technology.

3. The Ministry of Finance and Public Services and the Ministry of Science, Energy and Technology should seek access to innovative financing for WTE and anaerobic bio-digestion projects, where PPP are being considered. Sensitization of the key financial institutions will also be valuable in preparation for upcoming renewable energy RFPs.

4. Strengthen research and commercialization capabilities of universities in the areas of RDF and anaerobic bio-digestion to build local competence and obtain data/information for future private sector interests.

8. Conclusion and Next Steps

The outputs of the Barrier Analysis and Enabling framework exercise as presented in the report reflect the enlightening contributions of the many and diverse stakeholders consulted in each of the four sectors assessed for technological needs in adaptation and mitigation and the ten technologies prioritized. In addition, the Consultants pulled on previous reports prepared for other jurisdictions under TNA projects as well as background material relevant to overall development needs of Jamaica under the conditions of climate change.

The findings identified several interrelated barriers among the ten technologies, and it is noteworthy that for all potential interventions, access to finance for capital and operating expenses was a common thread. Market categorization of the technologies was useful for relating potential cost and source of funding, and the categories were as follows: Consumer goods - 3; Capital goods- 3; and Publicly Provided Goods- 4. The need for incentives and fiscal support was a recurring theme.

Other barriers and associated enabling measures included: the perception of risk related to innovative technologies and willingness to engage, notwithstanding acceptance of the need for climate-smart interventions; Government policy framework; integrated approaches to the management of water capture and storage and water for irrigation; knowledge gaps, research and knowledge transfer mechanisms; technical capacity and the value of on-the-ground/field/practical approaches to introducing change ; regulatory and institutional environments; political decision-making and social factors.

Barriers were not considered insurmountable although the challenges of accessing /identifying funding and creating behavioural change would require targeted and innovative approaches. It is important to underscore that the technologies prioritized for each sector are linked to Goal 4 of Jamaica's National Development Plan - Vision 2030 - which stipulates **Jamaica has a Healthy Natural Environment**. The associated outcomes of this goal are Sustainable Management and Use of Environmental and Natural Resources, Hazard risk Reduction and Climate Change Adaptation, and Sustainable Urban and Rural Development. Goal 3 speaks to Energy security and Efficiency and Internationally Competitive Agriculture. Of further note is the Medium-Term Socioeconomic Policy Framework (MTF) which underpins implementation of long-term Vision 2030, and which identifies medium term priorities, strategies, and actions to achieve Agenda 2030. The 2018/19 – 2020-/2021 MTF has identified environmental sustainability and climate change response as one of the strategic priorities to be addressed. The MTF further aligns with the Sustainable Development Goals (SDGs) and the relevant targets for SDG 13 primarily - Climate action - and Goals 6 and 7 which address water and energy, respectively.

The ability to quantify costs and benefits of diffusing the technologies was stymied by readily available data. While many of the prioritized technologies are already used in Jamaica, there is a lack of research, auditing, and development on the true economic, environmental, and social benefit of these technologies. It is recommended that consideration be given to conducting audit and economic analysis, particularly to funded projects which utilized these prioritized technologies. This assessment will allow for a better understanding of the economic, social and environmental benefits of the proposed technologies.

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Appendix I – Stakeholders Consulted during the BAEF Exercise

	Name	Organization	Date	Meeting Type
Agriculture				
1	Dr. Gregory Robin	CARDI	4 March 2020	Group Meeting
2	Annabell Williams	Livestock Farmer Pig Farmers' Association	16 March 2020	Individual Meeting
3	Marianna Young	RADA	18 March 2020	Online Group Meeting
4	Everton Parks	Livestock Farmer Jamaica Dairy Development Board	18 March 2020	Online Group Meeting
5	Janet Lawrence	Consultant	18 March 2020	Online Individual Meeting
Water				
1	Monique Morris	NEPA	10 March 2020	Group Meeting
2	Desmond Wellington	WRA	10 March 2020	Group Meeting
3	Ian Gage	ESL	10 March 2020	Group Meeting
4	Natalia Reid	Rural Water Supply Ltd.	10 March 2020	Group Meeting
5	Leanne Spence	Instant Save Conservation Solutions	-	Individual Meeting
Coastal				
1	Danielle Nembhard		6 March 2020	Group Meeting
2	Gabrielle-Jae Watson	NEPA	6 March 2020	Group meeting
3	Pierre Diaz	Sea Control Oceanography	6 March 2020	Group Meeting
4	Dr. David Smith	Smith Warner International	6 March 2020	Group Meeting
5	Dr. Andrew Ross	Consultant	12 March 2020	Individual Meeting
6	Simone Lee	Environmental Consultant	17 March 2020	Online Individual Meeting
7	Yohan Rampair	TEF	17 March 2020	Online Individual Meeting
8	Camillo Trench	Discovery Bay Marine Laboratory	18 March 2020	Online Individual Meeting
Energy				

1	Michelle Chin Lenn	Wigton Wind Farm Ltd	17 March 2020	Online Group Meeting
2	Horace Buckley	Ministry of Science Energy and Technology	17 March 2020	Online Group Meeting
3	Kirk Abbott	Saddle Energy	17 March 2020	Online Group Meeting
4	Dionne Nugent	JPS	23 March 2020	Individual Online Meeting
Cross-Sector				
1	Allison Ramgolan	EFJ	19 March 2020	Online Group Meeting
2	Daniel Kitson	JSIF	19 March 2020	Online Group Meeting
3	Le-Anne Roper	CCD	19 March 2020	Online Group Meeting

Appendix II – Approved Energy Efficient Item for CET Suspension

In a letter dated August 15, 2013, the then Ministry of Finance and Planning advised the JCA that Cabinet approved the exemption of the GCT on the energy-efficient and renewable energy products and technologies listed in Appendix 1.

Appendix 1 – Approved Energy Efficient items for CET Suspension for the period June 01, 2018 to May 31, 2021

Tariff Codes	Description	ID	GCT	SCF	ENVL
8539.31	Compact Fluorescent Lamps	–	–	0.3%	0.5%
8415.82	Air conditioning chillers with rotary screw compressors	–	–	–	0.5%
8418.29 (electric)	Vapour absorption refrigeration systems	–	–	0.3%	0.5%
8418.29 (solar non-electric)	Vapour absorption refrigeration systems	–	–	0.3%	0.5%
8415.82	Thermal storage air condition systems	–	–	–	0.5%
8415.10	Ice thermal storage air conditioning systems	–	–	0.3%	0.5%
8415.20	Air conditioning chillers with Rotary Screw Compressor	–	–	0.3%	0.5%
8414.51	Solar electric Fans	–	–	0.3%	0.5%
8418.21	Solar electric refrigerators	–	–	0.3%	0.5%
3925.90(plastic)	Solar water heating mounting accessories	–	–	0.3%	0.5%
8506.80	Photovoltaic cycle batteries	–	–	–	0.5%
8507.80	Other (Electric) Accumulators	–	–	0.3%	0.5%
8539.39	Bulbs for solar powered systems	–	–	0.3%	0.5%
8418.29 (electric)	Absorption refrigeration	–	–	0.3%	0.5%

	equipment and materials utilizing solar energy				
8418.29(solar non-electric)	Absorption refrigeration equipment and materials utilizing solar energy	–	–	0.3%	0.5%

There is also Suspension of the Import Duty on 100,000 pieces of lithium ion batteries for the period May 13, 2019 to April 30, 2021

The item attracts GCT and other fees as follows:

ID – 0(suspended)

GCT – 15% (personal), 20% (registered commercial importer)

SCF – 0.3%

ENVL– 0.5%

All items attract a Customs Administrative Fee (CAF) determined by the size of the shipment and type of declaration used to clear the goods.