Technology Needs Assessment Report

Ministry of Environment, Rural Modernization and Kalinago Upliftment
Commonwealth of Dominica

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FOREWORD

Climate Change threatens the world with devastating consequences that affect all human activities. As a Small Island Developing State, Dominica is severely impacted by the slow and sudden onset of climate change induced by global dependence on unsustainable fossil fuels. Moreover, changing weather patterns impacting food security, and catastrophic cyclones reversing years of development progress while threatening fiscal stability are major climate-induced adversities which Dominica faces. These adversities tremendously impact sustainable livelihoods, security and well-being and contribute to an increased incidence of poverty and undue pressure on social services. This situation is compounded by limited resources for responding to those adverse effects of Climate Change.

COP decision 4/CP. 4 requires Non-Annex 1 Parties to undertake Technology Needs Assessments (TNA). Further, Article 4.5 of the UNFCCC urges developing countries like Dominica to identify technologies and incorporate practices and reforms in various sectors of the economy to reduce greenhouse gas emissions, build resilience and pursue national development goals. The TNA process in Dominica identified vulnerable sectors with options and measures to adapt and mitigate the impacts of climate change. In response to its treaty obligations to the UNFCCC, Dominica sought and obtained assistance from the Global Environment Facility (GEF) and United Nations Environment Programme (UNEP) to undertake its TNA. The sectors chosen for Adaptation technologies are Agriculture and Water, while for Mitigation technologies, Electricity and Transport were selected.

The report presents the results of the TNA process that took place in Dominica with the technologies for Adaptation and Mitigation to be pursued in the development of the country. The conduct of the TNA was also significantly impacted by the onset of the global pandemic COVID -19, and so this report have benefited from the creativity and novelty developed to navigate this most trying period. Despite the setbacks experienced, we are pleased to be in a position to present this report.

I take this opportunity to thank the Global Environment Facility and the UN Environment for the financial support provided as well as the UNEP/DTU Partnership and University of the West Indies for their technical and financial support which included facilitation of National and Regional Workshops. Highly commendable are the efforts of the Dominica TNA Team as well as Lead Consultant Mr. Bernard Nation and Mitigation Consultant Mr. Adenauer Douglas, the local stakeholders, experts and scientists.

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Acronyms

BAEF - Barrier Analysis and Enabling Framework
BGA – Bureau of Gender Affairs
CC - Climate Change
CDEMA – Caribbean Disaster Emergency Management Agency
CIF - Climate Investment Funds
CPACC - Caribbean Planning for Adaptation to Climate Change
CREAD - Climate Resilience Executing Agency for Dominica
CSO - Central Statistics Office
CARIMAN – Caribbean Male Action Network
DNCW - Dominica National Council of Women
DOMLEC - Dominica Electricity Company
DOWASCO –Dominica Water and Sewerage Company
DTU - Technical University of Denmark
DVRP - Dominica Vulnerability Reduction Programme (DVRP)
ECU - Environmental Coordinating Unit
FA0 – Food and Agriculture Organization
GCF NDA- Green Climate Fund National Designated Authority
GDP - Gross Domestic Product
GHG - Greenhouse Gas
GSP - GEF Small Grants Programme IDA -
International Development Association
IICA - Inter- America Institute for Cooperation on Agriculture
INDC - Intended Nationally Determined Contribution
ISMN –Integrated Soil Nutrient Management
LCCRDS -Low Carbon Climate Resilient Development Strategy
LED – Light-emitting Diode
MCA - Multi-criteria analysis
MACC - Mainstreaming Adaptation to Climate Change
MW - Megawatts
NDC - Nationally Determined Contribution
NSAP - Non-State Actor Panel
OECS – Organization of Eastern Caribbean States
PCDL - Petro Caribe Dominica Limited
PPCR - Pilot Programme for Climate Resilience
SIDS - Small Island Developing State
SLM - Sustainable Land Management
SPACC - Special Programme on Adaptation to Climate Change
SPCR - Strategic Programme for Climate Resilience
TAP - Technology Action Plan
TNA - Technical Needs Assessment
TOAS – Technology Opportunities Analysis System
TWG - Technical Working Groups
UN - United Nations
UNDP - United Nations Development Programme
UNFCCC- United Nations Framework Convention on Climate Change
WB - World Bank

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Executive Summary

In order to meet the objectives of the Paris Agreement to mitigate and adapt to the impact of climate change (CC), developing countries that are party to the UNFCCC, are required to undertake a process to identify the country's development priorities and the technologies that will achieve lower emissions and stronger climate resilience. For this reason, a partnership agreement between UNEP and UDT is being implemented to assist states like Dominica to develop its Technical Needs Assessment (TNA) project.

The TNA process is executed following guidebook recommended steps, namely: (a) Identification and prioritization of technologies for mitigation and adaptation, (b) Barrier analysis and enabling framework (BAEF) identification, and (c) Technology action plan (TAP).

In Dominica, two sub-sectors were designated as appropriate for implementing this process; the Agriculture and Water sectors as one, where adaptive measures to combat the impact of CC can be undertaken and, the Energy and Transportation sectors selected to investigate technologies for implementation to mitigate climate change.

The TNA process involved the activation of the already established Climate Advisory Group to perform the functions of Project Steering Committee, and the formation of sectoral technical working groups (TWG) to provide technical support. A series of workshops with key sectoral experts were also convened to allow participatory decision making regarding key project outputs and the validation of results. Workshops on adaptive measures – Water and Agriculture sector, were convened separately from that of mitigation technologies- Energy and Transport sectors.

The Technical Working Group (TWG) for Water and Agriculture convened and conducted a pre-screening of the long list of identified technologies to determine which should be carried forward for further analysis. This activity involved in-depth discussions that were moderated and guided by the specific industry expert on the working group supported by the Consultant. The technologies were shortlisted by the TWG members using the approach advocated in the TNA handbook following the preparation of technical factsheets. The technologies selected and their levels of implementation within the country were reviewed, and the results for the final ranking of the technologies assessed and presented in a matrix. This process involved the summation of the weighted normalized scores utilizing the weights determined by the sector working group.

Selected water technologies for possible implementation were ranked in this order of priority: Rainwater Harvesting (95%), Efficient fixtures & appliances (77%), Water resource mapping & assessment (39%), Leakage detection and management (38%). For selected agricultural technologies, final rankings were listed as follow; Soil nutrition management (83.75%), Soil conservation (81.255%), Drip irrigation (69.95%), Indoor farming (22.5%), Aquaponics and hydroponics (9.95%).

Both Water and Agriculture sectors and, Energy and Transportation sectors underwent similar review and analysis processes. However, the report of the latter sectors' TWG was separated into three sub-sections namely, energy generation, energy efficiency and transport.

The TWG identified the development of Renewable Energy options (targeting geothermal, run-of-the river hydro, wind, and solar) for electricity and the improvement of energy efficiency in generation, distribution, and consumption of electricity as imperative for mitigation of greenhouse emissions in the energy generation subsectors.

The final assessment results and ranking of the selected Mitigation Technologies indicate preference for Run-of-the-River Hydro (83%) followed closely by geothermal (80%). Wind (32%) and solar (20%).

While the assessments were conducted based on average countrywide distribution and conditions, actual technology selection also considered the location of technology use, as certain regions may have a localized competitive advantage for a particular technology.

For selected Energy Efficiency Technologies, the TWG in its deliberations put high priority on reduction of urban heat island effect, which is partly a derivative of hurricane impacts on physical structures influenced by designs and OEM capacity specifications of appliances and materials used. Ranking were in this order; Efficient Appliances (85%), Lighting Fixtures (73%), Windows (72%), Urban Heat Island Effect (minimize) (63%), Ground Source Heat Pumps (41%), Green Roofs (25%).

The Transportation of goods and people in Dominica is currently fuelled by gasoline or diesel and the TWG highlighted that the focus should be on public transportation and school buses. The TWG favoured bypassing introduction of hybrid vehicles and moving straight into electric vehicles with solar or wind charging stations at bus terminals and dedicated charging stations, powered by run-of-the-river hydro for end of day charging.

It was also the TWG's consensus that concurrent to the migration to electric vehicles, should be a corresponding transition to 100% renewable on the grid to charging stations or alternatively, off-grid charging stations powered by renewable energy.

Selected Transportation Technologies rankings were listed as; Walking and Cycling (95%), Car Pooling (65%),Electric vehicles (buses, cars)(52%), Public Transportation (scheduling, routes, reliability) – EV (51%), Fuel Cell vehicles (47%), Cableway in agriculture (44%), Public Transportation (scheduling, routes, reliability)(37%), Hybrid vehicles (37%), Efficient Road Design, Storage – avoidable traffic congestion & traffic regulation (36%), Sea Transport (island ferries, fishing boats)(28%).

At the time of reporting, there was only one (1) electric vehicle registered in Dominica. Most of the other operating vehicles are energized by fossil fuel. There are also two (2) hybrid vehicles. Public transportation is relatively well developed to and from population centres. But outside of the capital city off hours public transportation can be problematic.

Chapter 1 INTRODUCTION

1.1 Country Background

Dominica measures approximately 750.6 square kilometres (290 square miles) and occupies the largest land mass of the grouping of the Windward Islands within the Eastern Caribbean. Located at 15 degrees North (midway between the Horse latitudes i.e. subtropical ridge between 30-35 degrees North and South characterized by high pressure which guides tropical cyclones) and 61 degrees West, it occupies centralized position within the Eastern Caribbean. Given its high vulnerability to natural disasters namely storms and hurricanes, it forms part of a grouping of forty-seven (47) countries and territories that have been classified by the United Nations (UN) as Small Island Developing States (SIDS) that face a specific set of challenges and are especially highly vulnerable to the effects and impacts of climate change.

The island is volcanic in origin and is characterized by very rugged, steep and undulating terrain. A chain of mountains extends from the island's centre to the south and the topography is characterized by a number of ridges and steep river valleys with gently sloping lands being restricted to narrow coastal strips, particularly in the centre and northeast of the island. Dominica has rich volcanic soil and boast of 365 streams and rivers. Approximately sixty-seven percent (64% or 45,000 Ha) of Dominica's land mass (approx. 75,000 Ha) is still forested. Dominica's rich biodiversity accounts for a significant percentage of local food supply which comes in the form of fish (from the rivers and sea), wild meat, fruits, root crops and the wide range of domestic agriculture products.

Population estimates for 2011 indicate that Dominica had a population of approximately 71,293 persons (a decline from 74,750 in 1994), including two thousand Kalinago, the remaining survivors of the first inhabitants of the island. The total population comprises 36,411 males and 34,882 females the total population also represented a net decrease of 434 or a slight 0.6 percent decline over the 2001 head count and a fall below the 2010 mid -year population estimate of 72,720. After the devastation caused by Hurricane Maria in September 2017, the Caribbean Disaster Emergency Management Agency (CDEMA) gave an informal exodus estimate of between 15,000 - 20,000 (Hansen & Ayuso, in The New Humanitarian, October 2017).

The World Bank estimates GDP in 2019 to be US$596 million. The Dominican economy reflects many of the characteristic features of a small open economy inter alia, high dependence on external trade as a proportion of GDP, dependence on single sector export products (in this case agriculture and tourism revenue, high levels of underemployment and unemployment, and dependence on foreign capital (both public and private sector) for investment into productive sectors and for infrastructural development.

Economic growth in Dominica recovered from a -9.5%decline in 2017 after the passage of Hurricane Maria to 9.6% in 2019. As a result of the impact of Covid19 pandemic, economic growth is forecasted to decline to -4%. (https://data.worldbank.org/country/dominica)

Poverty remains a pervasive development issue in Dominica despite the fact that the 2014 United Nations Development Program Human Development Index ranked Dominica as 93 of 187 countries. According to the latest Country Poverty Assessment (2008-2009), 28.8 percent of the population lives below the locally defined poverty line (falling from 39 percent in 2003), approximately 3.1 percent of the population was deemed to be indigent (declining from 10 percent in 2003) and 11.5 percent was deemed vulnerable.

Dominica has no petroleum resources, and currently imports petroleum fuel to meet almost 100% of energy needs. Annual import costs for energy continue to rise and are currently EC$116.65 million (US$43.39 million) representing 11.92% of GDP (2014 – World Bank estimates). Electricity constitutes the primary source of commercial energy for industrial and other uses in Dominica. The country presently (2017) has an installed capacity of 26.74 megawatts (MW) consisting of 6.64MW (28.5%) of hydropower and 20.1 MW of diesel-powered units. High electricity costs (the highest in the Caribbean) constitute a real obstacle for numerous sectors, with the direct and indirect consequence of curtailing growth and parallel activities linked to the country's sustainable development. (INDC, 2015)

The amount of solar and wind energy utilized in Dominica is minimal. Solar energy for water heating constitutes the largest proportion of renewable energy currently used. This application is mainly for residential applications. A few commercial operations and residential buildings also utilize solar for power generation. There is also currently one commercial wind energy and one hybrid (solar + wind) generator in operation. Dominica's *Low Carbon Climate Resilient Development Strategy*, *National Energy Policy* (draft) (2014), *Sustainable Energy Plan* (draft) (2014), and *Intended Nationally Determined Contributions* (INDC) (September 2015) establish indicative targets for renewable energy in Dominica.

The vulnerability profile for Dominica is medium to high for a number natural hazards arising from meteorological events (high wind, excess rainfall and hurricanes) and geophysical events (earthquake, volcano and tsunami). Recurrent meteorological events have significantly impacted the growth and development of the country.

As a signatory to the UN's convention on climate change (UNCCC), Dominica has directed significant efforts at meeting its obligations under the convention. These efforts have yielded the preparation of numerous policy documents to provide developmental guidelines for various sectors in the country. Many of these policy documents that are concerned with climate change have also been approved by the cabinet of ministers and so are mainstreamed into annual national plans and programs. Some of the policy documents prepared include *inter alia*:

- Dominica National Climate Change Adaptation Policy (2002)
- Dominica's Initial National Communication on Climate Change (2001)
- Dominica's Second national Communication on Climate Change (2012)
- Dominica's Third National communication on Climate Change (noted by Cabinet and submitted to UNCCC in May 2020)
- Dominica's Nationally Determined Contribution on Climate Change (2015)
- Dominica's Low Carbon Climate Resilient Development Strategy (2012)
- Draft National Climate Change Policy and Action Plan, (awaiting approval)

1.2 About the TNA Project

The United Nations Framework Convention on Climate Change (UNFCCC) was adopted at the United Nations Headquarters on 9thMay 1992. It was opened for signaturesfrom4thJune 1992to 19th June 1993. By that date, the Convention had received signatures from 166 Parties. The UNFCC convention came into force on 21st March 1994. Currently, there are 197 Parties (196 States and 1 regional economic integration organization) to the United Nations Framework Convention on Climate Change.

The Commonwealth of Dominica signalled its acceptance of the UNFCCC on 21st June 1993. As a party to this Convention, the island is able to access resources to enable its compliance with the articles of the Convention. Among the many resources available, the TNA process provides an opportunity for the critical examination of key technologies that can significantly impact the Country's adaptive capacity and also mitigate the impacts of climate change.

1.3 Existing National Policies Related to Technological Innovation, Climate Change and Development Priorities

A listing of national policies related to technological innovation in climate change adaptation and mitigation are listed in table 1. These documents address actions across numerous sectors and are not limited to the selected priority sectors of agriculture, water, energy and transportation.

Table 1: National Policies Related to Climate Change and National Development

Year	Policy Document
2012	Growth and Social Protection Strategy
2010	Montreal Protocol (Substances that Deplete the Ozone Layer) Regulations, 2010
2010	National Strategy for Health
2010	Sector Strategy, Natural Resources and Energy Sector Plan
2010	Tourism 2010 Policy
2010	Draft Environmental & Planning Regulations for Renewable Energy
2010	Draft Geothermal Development Bill
2010	National Energy Policy (Draft)
2010	National Integration Water Resources Management Policy (Draft)
2009	Dominica Forestry Policy
2009	Disaster Management Plan
2009	National Emergency Management Policy
2009	National Shelter Policy
2007	National Policy for the Agriculture – Environment (Agri – Eco) System, 2007 – 2025, Submitted for Cabinet's approval
2006	Growth and Social Protection Strategy
2006	*St. George's Declaration*
2005	National Bio-safety Framework
2005	Draft National Implementation Plan on Persistent Organic Pollutants
2004	National Environment Policy/National Environment Management Strategy
2002	Dominica's Policy on Planning for Adaptation to Climate Change
2002	National Biodiversity Strategy and Action Plan
2002	Physical Planning Act
1998	Plan to reduce the vulnerability of school buildings to Natural Disasters

1.4 Country Vulnerability Assessments

Dominica's susceptibility to natural disasters coupled with its ecological and economic fragility makes it highly vulnerable to the impacts of climate change. Vulnerability to climate change in Dominica, like many developing countries, is aggravated by external pressures affecting its resilience and adaptive capacity. For example, terms of trade, impacts of globalization (both positive and negative), financial crises, international conflicts, external debt, and internal local conditions such as limited population growth, poverty, political immaturity, unemployment, reduced social cohesion, and a widening gap between poor and rich, together with the interactions between them. It is widely acknowledged that climate change can exacerbate natural disasters with enormous human and economic costs, (Climate Resilience in Dominica, 2015).

Cognizant of the threats posed by climate change, especially within the productive, health and wellness sectors, a number of initiatives have been undertaken to adapt and mitigate the negative impacts experienced. A *National Climate Change Adaptation Policy* was formulated with support under the Caribbean Planning for Adaptation to Climate Change (CPACC) Project. This policy was adopted by the Cabinet in 2002. Further, Phase II Enabling Activity, under the UNFCCC was completed in January 2005, which involved capacity building for climate change. The country has undertaken a number of adaptation projects, including:

- the Special Program on Adaptation to Climate Change (SPACC);
- the Sustainable Land Management (SLM);
- the Mainstreaming Adaptation to Climate Change (MACC);
- Strategic Program for Climate Resilience (SPCR) under which Dominica's *Low-Carbon Climate Resilient Development Strategy* was developed in 2011-2012 through an extensive consultative process that was supported under the Pilot Program for Climate Resilience (PPCR) funded under the Climate Investment Funds (CIF).

Source: Climate Resilience in Dominica. - PPCR Results Report, 2015

Through the climate-change risk assessment undertaken by experts and a wide cross section of national stakeholders during the development of *Dominica's Low-Carbon Climate Resilient Strategy*, the following risks from climate change have been identified as priority:

Table 2: Summary of Climate Change Risks

Event Risks and *Outcome Risks*	**Ranking of Risks (10 highest)**
Increase in extreme events and climate variability (Cumulative Risks) - ***Physical damage to crops and agricultural access roads, impact on agricultural and fisheries productivity, increase of pests/disease, impact on livelihoods and food security***	**10**
Increase in extreme events - ***More frequent economic setbacks, prolonged recovery periods, stress on economy (including increase in loss of life, impact on tourism arrivals, impact on agricultural production, food security, forest cover), and less attractive environment for foreign investment due to cumulative destruction of critical infrastructure for tourism, manufacturing, agriculture, trade***	**10**

Event Risks and *Outcome Risks*	Ranking of Risks (10 highest)
Increase in extreme events (increased intensity of hurricanes, flooding, landslides) – ***Increased damage to houses, human settlements, critical infrastructure, business and other properties***	**10**
Sea level rise – combined with increased incidents of storm surges - ***Damage to coastal infrastructure (roads, ports, jetties, storage, processing, packing, landing sites) used for agricultural trade and access to markets***	**9**
Increased frequency of extreme events - ***Water shortages due to increased drought and storms*** (Note: includes loss to crops)	**9**
Sea level rise – combined with increased incidents of storm surges - ***Damage to coastal tourism facilities (beaches, hotels, airports, cruise ship terminals)*** (NOTE: Includes impacts on Carib Territory and lost income to farmers)	**8**
Sea level rise and storm surge - ***Loss of coral reefs – loss of protection to coastal areas and impact of marine ecosystem and associated effect on livelihoods and food security***	**8**
Climate variability - ***Loss and impact on marine and terrestrial biodiversity which is key pillar for tourism***	**8**
Changes in rainfall intensity -***Increased coastal marine habitat degradation and damage to fisheries infrastructure***	**8**
Increased climate variability - ***Changes in fish and marine mammal migration patterns affecting food security and tourism***	**8**
Changes in rainfall patterns - ***Increased incidents of landslides affecting houses, human settlements and infrastructure, in addition to costs for insurance and building loans***	**8**
Increase in extreme events – ***Damage to coastal property and infrastructure due to storms surges***	**7**
Increase in extreme events - ***Reduced availability of international donor funding due to increased demand for emergency assistance from vulnerable countries***	**7**
Changes in national and local temperatures regimes - ***Increased damage to buildings and water cisterns from extreme dry conditions***	**7**
Sea level rise – combined with increased incidents of storm surges - ***Increased costs for insurance, re-insurance and costs to banks providing loans for coastal infrastructure***	**6**
Increased climate variability - ***Increased land degradation*** (variation in temperature) (Note: impact on food production, water quality, health and nutrition)	**6**
Changes in rainfall patterns - ***Impact on water quality/supply and costs of water treatment/delivery and damage to water/communication infrastructure*** (NOTE: hotels and restaurants at tipping point and loss of income due to lack of water could put them out of business)	**6**
Increased climate variability - ***Decline in tourism visitor arrivals due to more mild conditions affecting winter tourism market***	**6**

Event Risks and *Outcome Risks*	**Ranking of Risks (10 highest)**
Sea level rise and storm surge - ***Damage to coastal infrastructure from sea level rise and higher storm surges and associated impact on tourism (hotels, dive industry, yachting)*** (Note: Significant cultural loss in Carib Territory and loss of beaches for recreation)	**6**
Increase in extreme events - ***Increase cost of coastal resources management***	**6**
Increase in extreme events - ***Damage to water infrastructure and impact on costs for water supply***	**6**

Source: Dominica Low Carbon Climate Resilient Development Strategy 2012 - 2020

Dominica's Strategic Programme for Climate Resilience (SPCR) is being implemented under the US$35 million Disaster Vulnerability Reduction Project (DVRP), which was officially launched in September 2014. The DVRP is funded by the World Bank, International Development Association (IDA), Pilot Programme for Climate Resilience (PPCR), Strategic Climate Fund (SCF) and the Government of the Commonwealth of Dominica. The total approved financing is US$39.5 million, (http://dvrp.gov.dm/about-us).

1.5 Sector Selection

The selection of the priority subsectors, namely the Agriculture, Water, Energy and Transportation subsectors, was completed at the onset of the TNA project in consultation with the TNA Coordinator. The selection process was guided by the Low Carbon Climate Resilient Development Strategy (LCCRDS) of 2013 and the national priorities articulated in the Nationally Determined Contributions (NDCs) of 2012.

The SPCR and INDC planning processes identified several important sectors and issues that requires attention in addressing climate change risks in Dominica. A priority listing was also identified by national stakeholders during the SPCR planning processes, some that have not yet been funded or implemented under the DVRP, but also possess significant potential to contribute to the successful transformation of the country to a climate resilient, low carbon development path (Strategic Program for Climate Resilience 2012-2017).

These include:

a) Addressing climate change ***mitigation measures*** on the basis that savings in energy costs will allow Dominica to invest more in priority and much needed ***adaptation measures***,
b) Establishing ***community off-grid mini-grid or micro-grid renewable energy electrical supply systems*** (backed up by emergency alternative energy systems such bio-diesel generators should local conditions allow for the operation to be efficiently established) in vulnerable communities on the east and south east coasts that are periodically without electricity as a consequence of storm and hurricane events;
c) Establishing ***early warning systems, multi-use disaster shelters (powered by renewable energy and back up bio-diesel generators) and emergency preparedness training programs*** in vulnerable communities,
d) Facilitating ***capacity building*** through education, awareness and training programs on climate change risk management and resiliency measures in order to strengthen capacity at the

community and sectoral level, within municipalities and local authorities, and the private sector,

e) ***Promotion of Food Security through Climate Resilient Agricultural/Fisheries Development*** to build climate resilient communities by strengthening capacity to address climate change risks to food security associated with changing precipitation patterns,

f) Establishing the ***enabling legal/institutional framework to facilitate coordination/implementation*** of priority climate change measures and the mainstreaming of climate change activities into national, sectorial and community planning/development, ***Creating the supportive enabling framework whereby communities and vulnerable segments of society (women, youth, elderly, people with disabilities) can manage their own climate change risks,*** thereby addressing climate change impacts on vulnerable sectors (particularly agriculture, fisheries and water resources) and threats to food security, human health, poverty alleviation, sustainable livelihoods and economic growth; (Strategic Programme for Climate Resilience 2012-2017).

Chapter 2 INSTITUTIONAL ARRANGEMENT FOR THE TNA AND STAKEHOLDER INVOLVEMENT

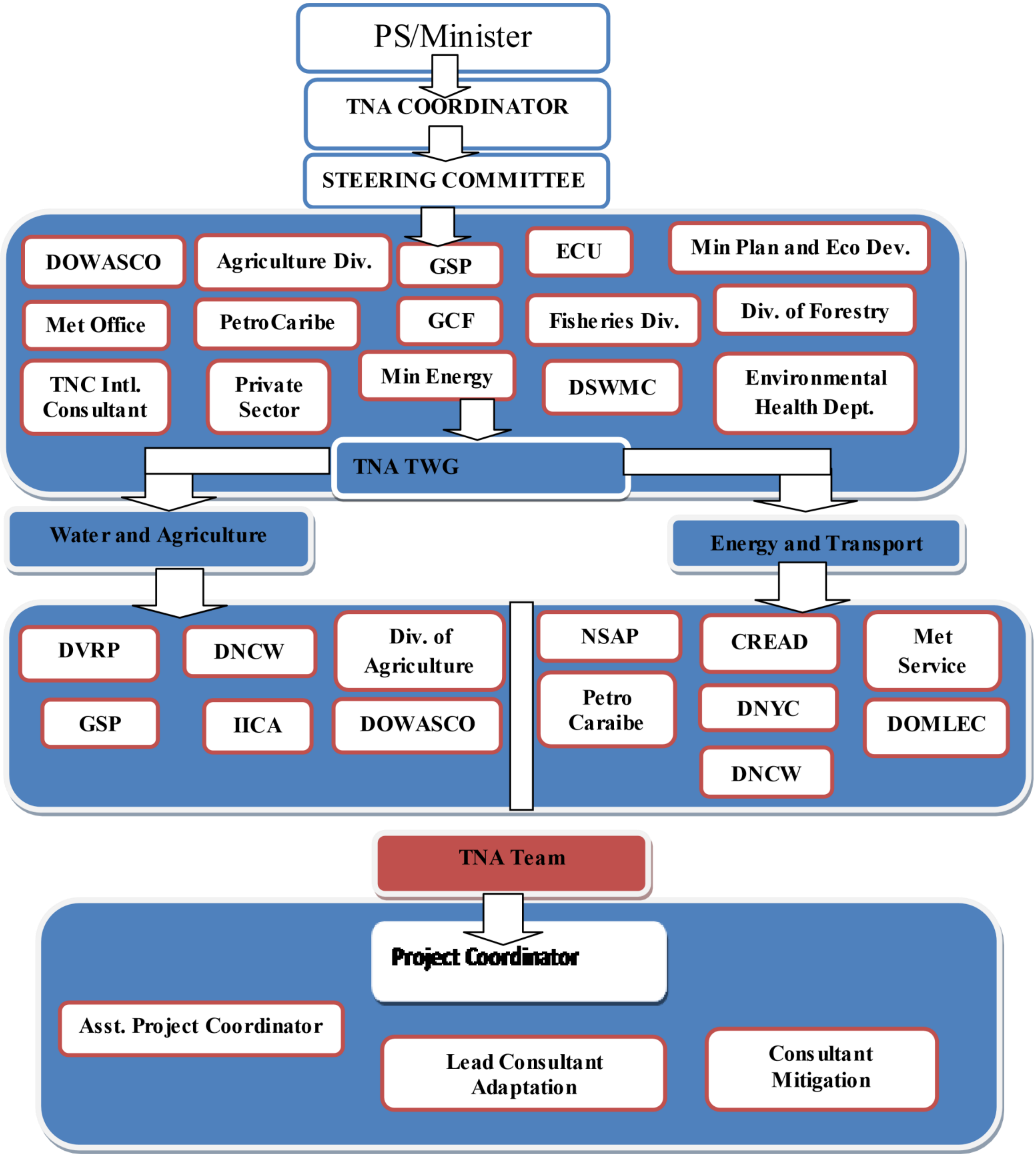
The Ministry for the Environment, Rural Modernization and Kalinago Affairs currently coordinates all activities related to Dominica's implementation of the Articles of the UNFCCC. The most prevalent mode of intervention is through projects employing varied technical teams and resources to make recommendations to reduce the impact of climate change. The Minister with responsibility for this Ministry is also part of the National Cabinet of Ministers, and so, directly influences policy decisions impacting climate change.

2.1 National TNA Team

The institutional arrangement established for the management of the TNA process locally is represented in fig 1. The position of the Minister within this framework is understood to be representative of the Cabinet of Ministers or the Executive decision-making body within the country.

In keeping with the encouraged practice of utilizing existing mechanisms, the previously existing Climate Advisory Group (CAG) was activated to perform the role of the Project Steering Committee (PSC) within the context of the TNA. Committee members had been previously selected for their level of expertise and availability to consult and provide directions and validation of work done within the climate change domain. Further, their engagement in decision-making positions in key public sector and stakeholder institutions was also considered selection criteria. The reality of limited resource in country to constitute such decision-making entities also encourages the utilization of already existing structures.

Figure 1: Institutional Management Framework for TNA Process


PS/Minister
TNA COORDINATOR
STEERING COMMITTEE
DOWASCO
Agriculture Div.
GSP
ECU
Min Plan and Eco Dev.
Met Office
PetroCaribe
GCF
Fisheries Div.
Div. of Forestry
TNC Intl. Consultant
Private Sector
Min Energy
DSWMC
Environmental Health Dept.
TNA TWG
Water and Agriculture
Energy and Transport
DVRP
DNCW
Div. of Agriculture
NSAP
CREAD
Met Service
GSP
IICA
DOWASCO
Petro Caraibe
DNYC
DOMLEC
DNCW
TNA Team
Project Coordinator
Asst. Project Coordinator
Lead Consultant Adaptation
Consultant Mitigation

2.2 Stakeholder Engagement Process Followed in the TNA – Overall Assessment

The identification and engagement of stakeholders within the TNA process in Dominica essentially followed the guidelines provided within the publication by Zevallos, Pía, 2015: *'Identification and Engagement of Stakeholders in the TNA process: A guide for national TNA teams'*. Late engagement of the local project team necessitated some compromise in the length of the consultative process with stakeholders. Unforeseen events such as the convening of national general elections, reshuffling of government ministries and the onset of the Coronavirus pandemic also significantly affected the organising of stakeholder consultation sessions during these processes. Consequently, there was a heavy dependence on electronic communication for the generation of adaptive and mitigation technologies and most importantly the validation of selected approaches and outputs.

2.3 Consideration of Gender Aspects in the TNA Process

Gender sensitivity has become an accepted and practiced norm in the planning and execution of climate change transformational initiatives in Dominica. This sensitivity has also been recognized on a national level with the establishment and maintenance of a governmental Ministry of Gender Affairs over the past two decades. The work of this government ministry is articulated through a department, Bureau of Gender Affairs (BGA). The work of the BGA is ably supported with civil society entities such as the renowned Dominica National Council of Women (DNCW) and more recently CARIMAN; who both advocate on issues related to gender.

Representatives of the DNCW sit on both the Steering Committee (SC) and the technical working groups (TWG) and are actively encouraged to provide feedback and comments. Further, members of the TWG were required to consider and discuss specific gender related impacts of all selected technologies, with final validation by the National Council of Women representative. The established protocol within the TNA process makes provision for any dissenting position from such organisations to be noted and subjected to sensitivity analysis during the technology selection and analysis process. The same approach was adopted with representatives of people with disabilities and youth at risk.

Chapter 3 TECHNOLOGY PRIORITISATION FOR ADAPTATIO N

3.1 Greenhouse Gas (GHG) Emissions for Selected Sectors

The Third National Communication (TNC) on Climate Change for Dominica is currently awaiting Cabinet approval. The inventory of greenhouse gas emissions compiled in the TNC, was completed using the 2006 *Intergovernmental Panel on Climate Change (IPCC) guidelines for National Greenhouse Gas Inventories*. The gases included in the current inventories are the direct GHGs found in Dominica namely, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and partially fluorinated hydrocarbons (HFCs) and the indirect GHGs – non-methane volatile organic compounds (NMVOC), and sulphur dioxide (SO_2).

Dominica's Second National Communication on Climate Change reported greenhouse gas emissions up to 2005. The TNC reported for the period 2007 – 2017, notwithstanding that, spatial data utilized in the analysis of land mass was obtained from 2014. Estimates of the GHG inventories for 2005 and 2006 to 2017 are summarized in Table3 (for some of the GHGs) and Table 4 (for CO_2 only). Estimates associated with the water sector are considered under the Commercial / Institutional component in Table 4.

Table 3: Comparisons of GHG Emissions (Gg) for 2000, 2005 to 2017

Year/Emissions	CO_2	CH_4	N_2O	NMVOC	SO_2	HFCs
2005	119.00	1.56	0.097	2.30	0.218	0.003
2006	122.01	1.32	0.0054	0.172	0.250	0.042
2007	128.46	1.32	0.0054	0.074	0.274	0.056
2008	122.46	1.37	0.0055	0.142	0.248	0.060
2009	133.78	1.33	0.0054	1.110	0.282	0.049
2010	141.56	1.33	0.0054	0.043	0.299	0.046
2011	149.80	1.35	0.0054	0.850	0.316	0.045
2012	158.91	1.37	0.0054	0.583	0.335	0.053
2013	161.02	1.37	0.0054	0.358	0.339	0.046
2014	167.23	1.38	0.0053	0.645	0.355	0.051
2015	170.14	1.38	0.0053	0.524	0.362	0.049
2016	169.83	1.38	0.0053	0.481	0.356	0.049
2017	156.20	1.55	0.0048	0.455	0.305	0.046

Table4: Comparisons of CO_2 Emissions (Gg) for 2005 to 2017

Sectorial Categories	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1.Energy	119.00	122.01	128.46	122.46	133.78	141.56	149.80	158.91	161.02	167.23	170.14	169.83	156.20
Fuel Combustion (sectoral Approach)	119.00	121.01	123.46	120.46	130.78	141.56	145.80	154.91	160.02	164.23	170.14	162.83	153.20

Sectorial Categories	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1A.1.EnergyIndustry (electricity)	41.80	42.70	44.96	42.86	46.82	49.55	55.43	63.56	53.14	50.17	56.15	54.35	46.86
1A.2. Manufacturing Industries& Construction	11.00	11.10	11.69	11.14	11.37	12.03	12.73	13.51	13.69	14.21	9.24	6.01	4.08
1A.3.Transport (road transportation)	46.8	51.24	53.95	51.43	54.85	56.62	59.92	60.38	64.41	70.24	69.76	71.33	67.17
1A.4.Other Sectors	19.5	16.96	17.86	17.02	20.74	23.36	21.73	21.46	29.78	32.61	35.00	38.15	38.09
a. Commercial/ Institutional	15.4	10.25	10.80	9.67	12.71	14.86	12.74	11.92	20.12	22.58	24.79	27.96	28.71
b. Residential (LPG)	3.29	5.49	5.78	5.51	6.02	6.37	6.74	7.15	7.25	7.53	7.66	7.64	7.03
c. Agriculture/ Forestry/ (mainly Fishing)	0.76	1.22	1.28	1.84	2.01	2.12	2.25	2.38	2.42	2.51	2.55	2.55	2.34

The trend of increasing annual emissions is evident throughout all sectors considered. Observed anomalies for 2017 were as a result of the passage of Hurricane Maria, where important sectors such as electricity generation, transportation and manufacturing were all significantly impacted.

3.2 Overview of Adaptation Technologies

The identification of technologies for further consideration and analysis within each of the selected sectors followed the problem tree – solution approach where multiple possible technologies to address each key vulnerability previously articulated in the LCCRDS were identified. This information is presented in tables 5 and 6 for the Water and Agricultural sectors, respectively.

Table 5: Water Sub-sector Technology Identification

Constraints	Key Vulnerabilities	Current Management Practice	Proposed Management Technology
Low flows during dry season and other low rainfall period	Unreliability of potable water supply to users	Water supply scheduling. Supply to a location is not constant	- Institute home water storage: (P.E Tanks suitable secured by cable ties or concrete) - Invest in larger offsite storage - Explore subsurface / underground water sources - Install rainwater harvesting system to include underground cistern storage tank. Storage for portable water and rainwater must be independent to avoid contamination.
Water intakes located in areas that are vulnerable to erosion, flooding and other	Water quality is affected	- Shutdown of supply during inclement weather event	- Develop localized traditional community springs - Explore subsurface water sources

Constraints	Key Vulnerabilities	Current Management Practice	Proposed Management Technology
types of contamination		- Improve treatment capacity	- Install water treatment facilities – Clarifiers and flocculators - Integrated watershed management initiative
22 Electrical pumping stations - costing 1520 K/station/month	High energy cost for maintaining supply to users. High cost discourages wider application of pumping for water supply.	Pursue gravity options for water supply.	- Alternate renewable energy source assessment
Intake structure and transmission lines are installed within high-risk areas - re flooding, erosion, and rock fall.	Significant repair and replacement cost after inclement weather impact	- Bury transmission mains if practical - Careful intake site selection	- Design modification of intake structure - selection of transmission pipe material and selected placement along water courses

Table 6: Agricultural Sector Technology Identification

Constraints	Key Vulnerabilities	Current Management Practice	Proposed Management Technology
Decline in crop productivity - food security	Reduce return on investment for farmers and impacts food security-availability, access, use and utilization, food stability	- Pesticides, herbicides, mechanization, improved agronomic practices - Selected varieties and germplasm - Improved livestock - Irrigation - Synthetic fertilizers	- Disease or pest resistant crops - Improved agronomic practices - Tissue culture and micropropagation - Low cost diagnostic toolkit for extension workers (plants & animals) - High nutritive, low cost animal fodder - Artificial insemination - Water storage technologies, microirrigation - Water lifting - Rainwater harvesting, - Planting technology for increase water efficiency - Potable sensor for ground water detection - Wastewater reuse - Conservation agriculture - Organic & synthetic fertilizers - Biogas digesters - Conservation tillage - Natural nitrogen fixation - Soil micro-organisms - Farm management software - Drones - Indoor farming/low cost greenhouse - Aquaponics/hydroponics - Tractors/robotics - Post-harvest- fruit preservation, packaging, cool stores, low cost dryers and refrigerated vehicles - High nutritive crops - Weather forecasting tech. - Index based insurance

Soil loss	Soil conservation and management	Surface drainage and intercropping. Very limited grass barrier application.	- Crop cover - Contour drainage - Green and dry soil barriers - Wind breaks - Intercropping - Composting, manures

3.3 Climate Change Vulnerabilities within the Adaptation Sector and Establishment of Context

The selected technologies within the water sub-sector is intended to address key vulnerabilities in the unreliability of potable water supply to consumers that are exacerbated by the impacts of climate change specifically more intense adverse effects relating to droughts and floods.

The water network infrastructure locally is predominantly setup to be powered by gravity. The high energy cost of pumping is among the primary reasons that this option is favoured though it often involved the establishment of supply networks within areas that are generally difficult to access and also high risk to flooding. High-energy cost of pumping discourages wider application of pumping for water supply within closer proximity of users. The utilization of renewable energy to supply energy needs for pump stations is also being considered.

Technology consideration within the agricultural subsector is intended to address the issue of food and nutrition security and soil loss, issues that are significantly impacted by climate change. Food availability, quality and access are also all significantly impacted by climate change.

3.4 Key Benefits of Identified Adaptation Technology Options

Under the laws of the Commonwealth of Dominica Water and Sewerage Act Chapter 43: 40, (Act of Parliament No. 17 of 1989), Dominica Water and Sewerage Company (DOWASCO) was granted an exclusive license for the development and control of water supply and sewerage facilities in Dominica. While the Departments of Forestry and National Parks also participate in the management of this important resource, DOWASCO's interest takes priority. DOWASCO is also solely responsible for the commercialization of the resource and so are primarily responsible and interested in activities related to water resource management to include mapping and assessment, and leakage detection and management along the potable water system network.

3.4.1 Water Resource Mapping and Assessment

Cadastral surveys have been undertaken to map all surface water source as far back as the early late 1950's to early 1960's, when the mapping of the entire island was undertaken (*personal communication with M. Williams, Chief Engineer DOWASCO*). Assessment of surface water sources were undertaken from the mid-1960s for all sources that were being tapped for the provision of potable water. Assessment data collected included water quality – physical and limited biological *(E. coli*) and river flow data especially dry season flow, which was critical for determination of the sufficiency of the source to provide water needs. Currently, with the advent of increase in the intensity of precipitation with resultant flooding due to climate change, data on both flood levels and dry season flows are collected together with water quality, biological and physical on sources utilized for potable water.

Over ninety percent (90%) of the population of Dominica resides along the coastline. The interior of the island is largely uninhabited contributing to approximately sixty-seven percent 67% forest cover over the island (Dominica Agricultural National Census, 1995). The conservation effort within the island has significantly benefitted from the designation of three (3) national parks, namely the Morne Trois Piton, Cabrits and Morne Diablotin National Parks and two (2) forest reserve namely the Northern and Central Reserve. Collectively, a total acreage of 51,256.86 acres comprising 36,714.77 acres in National parks and 14,542.09 acres in forest reserve is protected. (http://forestry.gov.dm/units/national-parks-section). Detailed description and location of terrestrial protected areas in Dominica are presented in Table 7 and Fig 2.

Historical meteorological data indicates that average rainfall within the interior of the island averages approximately three hundred (300 in) inches annually. This area is therefore the genesis of many of the rivers / streams that generate the surface flows that is tapped, treated and utilized in the potable water network. The relative inaccessibility of the highlands due to its rugged topography coupled with the significant aforementioned efforts at protection, legislates and limits human activities within the watersheds, resulting in relatively high-quality surface flows. The increase incidence of extreme climatic events as experienced during the recent passage of tropical storm Erika in August of 2015, and hurricane Maria in September of 2017, caused significant forest cover damage and generated substantial soil loss within the watershed, increasing the susceptibility of the potable water network to the influx of poor water quality, increasing treatment cost to levels that are not sustainable. This situation therefore necessitates the investigation of water sources that are less susceptible to these types of impacts and thus warrants a comprehensive mapping and assessment of both surface and subsurface water sources on island.

Table 7: Terrestrial Protected Areas in Dominica

Area	Name	Description	Site Status
Morne Diablotin National Park	National Park	• Size: 33.35 km^2, Established in 2000 • Location of Dominica's tallest Mountain, Morne Diablotin • The area was established for the Endangered Imperial Amazon (*Amazona Imperialis*) and the Vulnerable Red-necked Amazon (*A. arausiaca*) as well as the Forest Thrush (Cichlherminia lherminieri) • Inhabited by Iguana (*Iguana delacatissima*), the endemic Dominica Anole (*Anolis oculatus*) and the regionally endemic Vincent's Least Gecko (*Sphaerodactylus vincenti*)	National park

Area	Name	Description	Site Status
Central Forest Reserve	Central Forest Reserve	• Size: 4.1 km^2, Established in 1951 • Inhabited by an abundance of Gommier tree (*Pachylobus excelsa*), which grows to heights of almost 36.57m	Forest reserve
Northern Forest Reserve	Northern Forest Reserve	• Size: 54.75 km^2 • Established in 1977	Forest reserve
MorneTrois Pitons National Park	National Park	• Size: 64.85 km^2, Established in 1975 • Declared a UNESCO World Heritage Site in 1998 □ Features: The Valley of Desolation, The Boiling Lake, The Fresh Water Lake and the Emerald Pool • Important Bird Area for Endangered Imperial Amazon (*Amazona imperialis*) and the Vulnerable Red-necked (Amazon A. arausiaca) □ Supports: The Endangered endemic Dominican tink frog *Eleutherodactylus amplinympha*), the endemic Dominica Anolis (Anolisoculatus) and endemic subspecies of agouti *Dasyprocta leporina* and opossum (*Didelphys marsupialis insularis*)	National park
Cabrits National Park	National Park/ Marine Reserve	• Size: 53.88 km^2 • Size of Marine area: 3.5 km^2 • Established in 1986 • Avifauna species include Scaly-naped Pigeon (Columba squamosa), Smooth-billed Ani (*Crotophaga ani*), little blue Heron *(Egretta caerulea*), Green Heron (*Butorides striatus*), Teals (Anas sp.), Dowitchers (*Limnodromus* sp.), Sand pipers (Calidris sp.) • Mangal Species: white mangrove (Laguncularia racemosa)	National Park/ Marine Reserve

Source: http://forestry.gov.dm/units/national-parks-section

Source: http://www.natureisland.com

Figure 2: Location of Terrestrial Protected Areas in Dominica

3.4.2 Leakage Detection and Management System

Leakage detection and associated management is essentially under the remit of DOWASCO, since they manage the island's water network system. The implementation of effective programmes to address leakage on the water networks is becoming increasing critical given the increase impacts of climate change on the water catchment areas resulting in reduction in quality and quantity of harvested flow. Increase land movement / slippage resulting from over saturation of soil profile during extreme rainfall events also impact the integrity of the pipe network increasing the incidence of leakage along the supply and distribution network. These in turn often trigger larger more destructive erosion events that impact not only the pipe network but also other infrastructure such as roads and other utilities.

A water audit was commissioned by DOWASCO in 2016to assess the volume of non-revenue water (NRV) loss in the face increasing cost of provision of potable water. The results of this exercise conducted by Fichtner Water and Transportation GmbH, estimated losses at 58.5 % percent of system input volume or 6, 906,418 cubic meters annually, with a potential revenue loss of at least XCD 15,374,297.00(*Third Water Supply Project "WA-1 Network Upgrade" Consulting Service – Water Audit, 2016)*. The report further estimates that the normal NRV value for a small country such as Dominica is 30% of system input and so recommended the implementation of an NRV management programme to effect the necessary changes to reduce losses.

The issues of procurement or availability of appropriate equipment and the engagement of dedicated staff were identified as the main reasons for the non-implementation of the recommended management programme to date.

3.4.3 Rainwater Harvesting from Roof-tops

Empirical evidence suggests that this technology has achieved extensive social acceptance and penetration island-wide, with varying level of effectiveness and complexity. The revised OECS building code which is currently being discussed and implemented in regional countries, advocates for the collection of runoffs from the roofs of buildings and the secure storage in sealed containers for use in non-potable and other applications. The occurrence of rain barrels and storage tanks is evident around the majority of homes throughout Dominica. These are gradually being modified to allow for greater stability during severe storms events, thus guaranteeing water availability in case of disruption in mains supply. Rainwater collected is often stored for use during periods of non-provision of potable water and also for provision of water to livestock and other agricultural purposes.

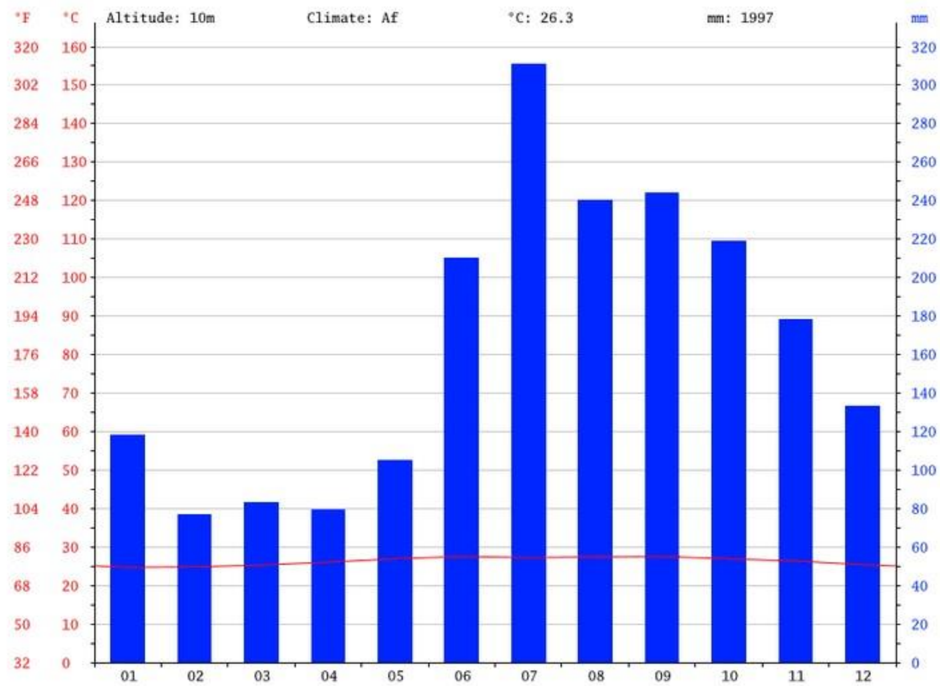
The issue of fitness for purpose of stored water as it relates to physical and biological quality and the associated treatment process to be undertaken to achieve fitness are issues that are increasingly being highlighted as requiring attention. Increasingly, stored rainwater is being viewed not only to provide for domestic use, but also as an alternative to continue cottage industry operation during periods of water shortages. The issue of appropriate low cost/ easily managed effective treatment methods, which can be applied in a decentralized manner throughout the country, thus becomes increasingly necessary and important. The most common form of treatment currently being practised involves the use of filtration and the application of chlorine for improving physical and biological quality respectively.

Proper water storage process and structure to discourage water-based vector borne diseases are also critical issues requiring consideration in the further development of this technology. Recent outbreaks of diseases associated with the mosquito vector – Dengue, Zika and Chikungunya increased the critical nature of this issue.

3.4.4 Drip Irrigation

There are two climatic production seasons in Dominica. The dry season traditionally runs from late December to the end of May and the rainy season which commences from June to November. The precipitation temperature chart displayed in fig 3 shows that precipitation occurs even during the dry season though at significantly reduced depths, thus allowing some level of agricultural production to continue. Rainfall distribution over the island is also highly variable due to the topography with higher depths experienced at the higher altitudes; up to 300 inches annually at the interior of the island and 50 inches annually at the coast, see Fig 4. This variation has a significant impact on plant cover and distribution over the island.

Figure 3: Average Precipitation and Temperature Chart for Dominica

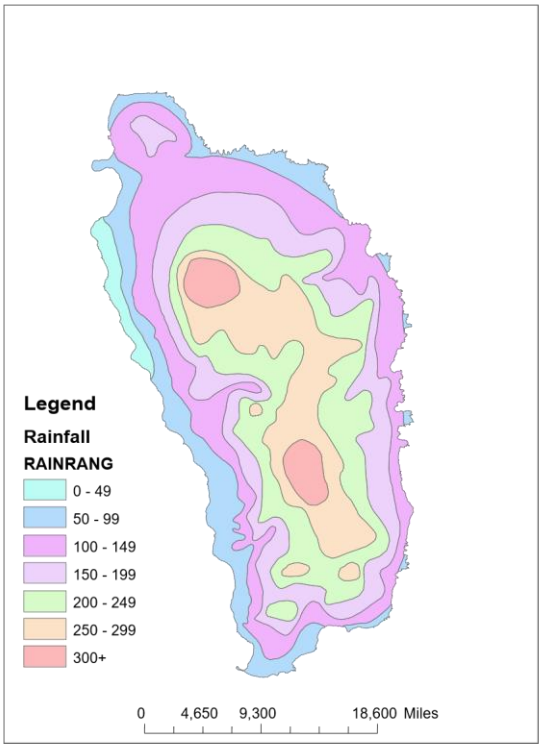


Temperature Month Rainfall depth

Rain-fed agriculture accounts for over 70% of agricultural production in Dominica. Commercial irrigation systems consisted mainly of surface / canal irrigation and were introduced in the 1970's for high value crops growing on the large estates located along the coast.

Drip irrigation was introduced into Dominica in the mid-90s for use within the protected agriculture (vegetable greenhouse) production system along the west coast of the country. The economic success of this technology and the observed water saving characteristic encouraged its transition into open field production in the vegetable sector and later into the banana sector as a means of increasing productivity. The collapse of the Banana Industry as a result of the loss of preferential market arrangement with the European Union, which occurred shortly after the transitioning of the drip irrigation technology into the banana production system significantly affected the continued wide spread transfer of this technology. Its benefits of water use efficiency and reduction in labour cost as a result of fertigation and chemigation, continues to be achieved within the vegetable production sector.

Figure 4: Rainfall Map of Dominica - Depth in inches



Source: https://en.climate-data.org/north-america/dominica

3.4.5 Slow Forming Terraces/Contour Farming – Soil Conservation

The technology of contour farming has been an integral part of the soil conservation effort nationally. The adoption of the technology has however been very limited and has not been mainstreamed in various crop production systems notwithstanding anecdotal evidence of the existence of basic knowledge of the benefits to be accrued by its implementation.

Within the period 1960- 78, soil conservation within open field production system in Dominica was prioritized with the establishment of a Soil Conservation Unit within the Department of Agriculture. This was however discontinued in the 1980's with serious deterioration in gains previously realized, evidenced by the notable record of the incidence of land slippage / erosion within agricultural production area. This issue was also evidenced by the inclusion of a national soil conservation component into a farm productivity enhancement project implemented by the Dominica Banana Market Corporation (DBMC) in 1995. The DBMC was the technical management entity tasked with the overall management of the local Banana industry, which generated more than XCD $16 million (US$5.9 M) dollars in 2001. (CSO)

3.4.6 Integrated Soil Nutrient Management

This technology is well aligned with the desire to implement the low carbon technology initiative into the agricultural sector as articulated by the *Low Carbon Climate Resilient Development Strategy 2012 - 2020*. This has resulted in the Division of Agriculture initiating an organic agriculture desk with a view of encouraging more sustainable agricultural production. Critical decisions have also been taken regarding the application of key classes of organic pesticides and other organic production inputs. A resurvey and reclassification of the island's soils to accord with international classification standards as defined by FAO have been initiated with a view of encouraging improved management strategies for the various soil types occurring across the Island. The accompanying crop feasibility exercise that is expected to follow is intended to critically inform the production process to encourage a significant reduction in input requirement for optimal crop production. The availability of ready to use soil ameliorants and conditioners continues to be an issue requiring attention.

3.4.7 Aquaponics and Hydroponics – Soilless Production Systems

This technology is relatively new and unfamiliar to local entrepreneurs. The potential for adoption has however been recognized in addressing food security especially in view of severe weather events such as hurricanes. The production centres can be located within more secure facilities and can be more easily protected and re-established after the passage of a storm. The advantage of utilizing relatively high density production techniques and a controlled production area also increases the appeal of this technology.

3.5 Shortlisted Adaptation Technology Options

The decision to utilize the same working group for both selected adaption subsectors was agreed at the second stakeholder workshop where members of the TWG were selected. Stakeholders in attendance were requested to submit nominations of organizations that would best represent their interest within the TWG. It was also decided that the TWG would be keep to a maximum of 7-9 representative institutions, with the selected institutions provided with the option to select 1-2 individual representative/s on the TWG.

The adaption sector working group for Water and Agriculture was constituted with representation from the following institutions:

- Dominica Water and Sewerage Company Ltd
- Dominica National Council of Women
- UNDP GEF Small Grants
- Division of Agriculture
- IICA
- CREAD
- National Youth Council
- Civil Societies Non-State Actors

The TWG convened and conducted a pre-screening of the long list of identified technologies to determine which should be carried forward for further analysis. This activity involved in-depth discussions that were moderated and guided by the specific industry expert on the working group supported by the Consultant. During the process of short listing the technologies, the TWG members were first introduced to the approach advocated in the TNA handbook and encouraged to give consideration to:

- Contribution of the technology to improve climate resilience,
- Technical potential of the technology,
- How the technology accords with other articulated national development policies,
- Cost of the technology and
- Relative level of diffusion of the technology within the country or other similar locales.

The working group consultation and discussions recommended a listing of eight (8) technologies from the long list be retained for the MCA. These were:

1. Water resource mapping and assessment – surface and ground water,
2. Leakage management and detection system,
3. Efficient fixtures and appliances,
4. Rain water harvesting from rooftops for the water sector and
5. Drip Irrigation,
6. Slow forming terraces/Contour farming – soil conservation,
7. Integrated soil nutrient management,
8. Aquaponics& Hydroponics for the agricultural sector.

Technical factsheets summarizing the technical characteristics of the technologies, impacts, cost, and level of diffusion were then prepared by the consultant in consultation with relevant industry experts, and circulated to members of the TWG for review and comments. By necessity, the review period was kept relatively short (7 days) due to the delays experienced with overall project implementation. All relevant comments received were considered during the finalization of the factsheets. Factsheets were finalized for the following technologies listed below. The information presented in the factsheets served as the basis for the assessment of the technology.

Finalized Fact Sheets included:

1. Water resource mapping and assessment – surface and ground water,
2. Leakage management and detection system,
3. Efficient fixtures and appliances,
4. Rain water harvesting from rooftops for the water sector and
5. Drip Irrigation,
6. Slow forming terraces/Contour farming – soil conservation,
7. Integrated soil nutrient management,

3.6 Criteria and Process of Technology Prioritisation for Adaptation Sector

Criteria selection was completed utilizing the guidelines established by the DTU for evaluating and prioritizing technologies for adaptation to climate change. This was prepared from undertaking desk review of TNAs conducted in other similar locales, the input of local experts to ensure that selected criteria were applicable and could be locally validated. Independence from other selected criteria, ease of assessment and measurability were all considered in determining the final list of criteria selected. This listing was presented at the meeting of the working group for consideration, together with a description of each criterion (Table 8) to ensure that all members of the working group had a clear understanding prior to scoring the shortlisted technologies against the MCA criteria.

Chapter 4 RANKING OF ADAPTATION TECHNOLOGIES

Information related to the actual investment cost of the selected technology within Dominica or even similar locale was largely unavailable, and so cost was determined by the relative comparison of the disaggregated actions and or materials required to implement the various technologies being considered. A scoringsystemof1–5 with '1' being the least cost and '5' the highest cost involved in implementing the technology, was then applied.

Each adaptation technology was scored after extensive discussions against the various criteria on a scale of 0–5, with '0' being the least benefit and '5' the highest possible benefit derived from the technology against the considered criterion. Though there were no cases where consensus could not be achieved, it was agreed beforehand that such cases will be solved by adopting the majority view. Strong deferring views would however be noted and recorded for use in the sensitivity analysis at a later stage.

Technical working group members insisted on utilizing the scaling regime of 0-5 instead of 0-100 because of the perceived lack of sensitivity associated with the larger scale. Significant discussion ensued on the issues of the perceived difference between e.g. a technology scored at e.g. 20 compared to one scored at 22. It was felt that utilizing 0-5 allowed for more distinctive comparison. Table 9 also presents a descriptive ranking of the agreed scale.

Table 8: Description of Assessment Criteria of Technologies

Assessment Criteria	Brief Description of Assessment Criteria
1. Investment Cost (as estimated by the Working group)	Investment cost for implementation and operation of technology. This must consider both direct and indirect cost. The actual investment costs of most of the technologies were not precisely known. The working group therefore discussed the estimated costs on the basis of their knowledge and experience with the facilitation of the experts and consultants.
2. Socio-Economic benefit	Potential of technology to contribute positively to the economy of the country / addressing issues of poverty reduction especially among vulnerable groups such as women, children, disabled people by improving incomes, nutrition and health security.
3. Environmental benefit	Potential to support ecosystems and enhance environmental integrity
4. Climate measure	Potential to reduce vulnerability to climate change impacts
5. National development priority / Political	Extent to which technology has been included in the National Development Agenda, e.g. Agricultural policy and Low Carbon Development Strategy
6. Stakeholder acceptability	Extent to which technology is culturally and socially acceptable considerations of indigenous knowledge and practices, ease of implementation
7. Endorsement by experts	Extent to which experts recommend the technology, e.g. as feasible, desirable, implementable, manageable

Table 9: Description of Scoring Scale Utilized To Rank Relationship between Technology and Assessment Criteria

0	Information on technology do not apply to criteria
0.1 – 1.0	Extremely weak performance / Strongly unfavourable
1.1 – 2.0	Poor performance, major improvement needed
2.1 – 3.0	Acceptable level or just above
3.1 – 4.0	Favourable performance but still in need of improvement
4.1 – 5.0	Outstanding performance which is way above the norm

The options were presented for each technical working group member to complete scores independently followed by the determination of an average score per technology, or for the entire TWG to determine the scores for every technology via consensus. It was accepted that scoring would be via consensus. The consultant and sector experts led the discussions followed by the vote for each technology assessed against each criterion. TWG members were reminded of the provision of sensitivity assessment for strongly dissenting views or special interest of any member during the assessment process. Members were thus encouraged throughout the process to indicate any such view that should be considered.

Scores were then entered in the matrix below and summed. Cost related criteria were also assessed on a scale from 1-5, with '1' being the most beneficial or least expensive and '5' being the least beneficial or most costly. This ranking must be considered particularly during the scoring and normalization process to ensure consistency with expressed rankings. It was necessary to constantly remind working group members of this during the scoring process to avoid confusion. Consideration was also given to reversing the scales to reflect increase as the scales moved from 1-5 so as to align with the ratings for the other criteria.

Table 10: Performance Matrix for Water Resource Technologies

Technology	Capital Cost/Unit Yield	Socio-Economic Value	Environmental Benefit	Contribution to Reduce Vulnerability to Climate Change	National Development Priority	Stakeholder Acceptance	Endorsed by Experts
WRM&A	4.5	3	4	5	5	4	5
LM&D	5	3	4	5	5	4	5
EF&A	3	3	5	5	5	5	5
RWH	2	4	5	5	3.5	5	5

Table 11: Water Resource Technology (Normalized)

Technology	Capital Cost/Unit Yield	Socio-Economic Value	Environmental Benefit	Contribution to Reduce Vulnerability to Climate Change	National Development Priority	Stakeholder Acceptance	Endorsed by Experts
WRM&A	0	0	0	100	100	0	100
LM&D	20	0	0	100	100	0	100
EF&A	60	0	100	100	100	100	100
RWH	100	100	100	100	0	100	100

WRM&A – Water resource mapping and assessment M&D – Leakage management and detection EF&A – Efficient fixture and appliances RWH – Rainwater harvesting from rooftops

Table 12: Performance Matrix for Agricultural Technology

Technology	Capital Cost/Unit Yield	Socio-Economic Value	Environmental Benefit	Contribution to Reduce Vulnerability to Climate Change	National Development Priority	Stakeholder Acceptance	Endorsed by Experts
D.I	3	4	5	4	4	4	5
S.C	3.5	4.5	5	5	3	3.5	5
A.H	5	4	4	4	3	2	4
S.N.M	3	5	5	4.5	3.5	3.5	5
I.F	3.5	3.5	4	4	3	3	3

Table 13: Agriculture Technology (Normalized)

Technology	Capital Cost/Unit Yield	Socio-Economic Value	Environmental Benefit	Contribution to Reduce Vulnerability to Climate Change	National Development Priority	Stakeholder Acceptance	Endorsed by Experts
D.I	100	33	100	0	100	100	100
S.C	75	66.7	100	100	0	75	100
A.H	0	33	0	0	0	0	50
S.N.M	100	100	100	50	50	75	100
I.F	75	0	0	0	0	50	0

D.I – Drip Irrigation
S.C – Soil conservation: slow forming terraces
A. H – Aquaponics and hydroponics
S.N.M – Soil nutrient management
I.F – Indoor farming – Low cost greenhouse

4.1 Assigned Weight to Selection Criteria

This section generated significant discussion with TWG members holding differing views regarding the criteria that should be assigned preferential status- weighting. This situation was settled with the Consultant and project Coordinator providing the necessary guidance relating to the main objective of the project, and also referencing the targeted strategies contained in Cabinet approved Low Carbon Climate Resilience Development Strategy. The weighting contained in table 14 was agreed via consensus.

Table 14: Weighting of Assessment Criteria

1. Investment Cost (as estimated by the Working group)	Investment cost for implementation and operation of technology. This must consider both direct and indirect cost. The actual investment costs of most of the technologies were not precisely known. The working group therefore discussed the estimated costs on the basis of their knowledge and experience with the facilitation of the experts and consultants.	**20**
2. Socio-Economic benefit	Potential of technology to contribute positively to the economy of the country / addressing issues of poverty reduction especially among vulnerable groups such as women, children, disabled by improving incomes, nutrition and health security.	**15**
3. Environmental benefit	Potential to support ecosystems and enhance environmental integrity.	**15**
4. Climate measure	Potential to reduce vulnerability to climate change impacts.	**20**
5. National development priority / Political	Extent to which the technology has been included in the National Development Agenda, e.g. Agricultural policy and low-carbon development strategy.	**5**
6. Stakeholder acceptability	Extent to which technology is culturally and socially acceptable - considerations of indigenous knowledge and practices, ease of implementation.	**15**
7. Endorsement by experts	Extent to which experts recommend the technology, e.g. as feasible, desirable, implementable, manageable**.**	**10**

4.2 Results of Technology Prioritisation for Adaptation Sector

The results for the final ranking of the technologies assessed are presented in the matrix below. This process involved the summation of the weighted normalized scores utilizing the weights determined by the TWG.

The listing of the technologies in order of priority and the scores attained are listed in Tables 17&18 for water and agricultural technologies respectively. It was decided that the technologies with the highest ranking will be taken forward to the Barrier analysis. The prioritized listing for the water technology was particularly surprising to the stakeholders, who opined that the leakage detection and management or water resource assessment and mapping was the preferred technology for adoption. All however recognized the scientific approach adopted and as such agreed with the final results.

Table 15: Assessment Scoring – Water Technologies

Technology	Capital Cost/Unit Yield	Socio-Economic Value	Environmental Benefit	Contribution to Reduce Vulnerability to Climate Change	National Development Priority	Stakeholder Acceptance	Endorsed by Experts	TOTAL
	20%	**15%**	**15%**	**20%**	**5%**	**15%**	**10%**	
WRM&A	20	0	0	100	100	0	100	39
LM&D	0	0	20	100	100	0	100	38
EF&A	60	0	100	100	100	100	100	77
RWH	100	100	100	100	0	100	100	95

Table 16: Assessment Scoring – Agricultural Technologies

Technology	Capital Cost/Unit Yield	Socio-Economic Value	Environmental Benefit	Contribution to Reduce Vulnerability to Climate Change	National Development Priority	Stakeholder Acceptance	Endorsed by Experts	TOTAL
	20%	**15%**	**15%**	**20%**	**5%**	**15%**	**10%**	
D.I	100	33	100	0	100	100	100	70
S.C	75	66.7	100	100	0	75	100	81
A.H	0	33	0	0	0	0	50	10
S.N.M	100	100	100	50	50	75	100	84
I.F	75	0	0	0	0	50	0	23

Table 17: Final Ranking of Selected Water Technologies

Ranking	Technology	Total
1	Rainwater Harvesting	95
2	Efficient fixtures & appliances	77
3	Water resource mapping & assessment	39
4	Leakage detection and management	38

Table 18: Final Ranking of Selected Agricultural Technologies

Ranking	Technology	Total
1	Soil nutrition management	84
2	Soil conservation	81
3	Drip irrigation	70
4	Indoor farming	23
5	Aquaponics and hydroponics	10

Chapter 5 TECHNOLOGY PRIORITISATION FOR MITIGATION

5.1 Overview of Mitigation Technologies

Technologies were considered within the selected subsectors including Energy: renewable energy, energy efficiency; and Transportation. After in-depth discussion and consideration by the technical working group, the following renewable energy options were selected: geothermal energy, run-of-the river hydro, wind, and photovoltaic solar.

Energy efficiency options selected were LED lighting, Ground Source Heat Pumps (GSHP) air conditioning, windows, green roofs, energy efficient appliances and urban heat island effect. For the Transportation subsector, electric vehicles, hybrid vehicles, fuel cell vehicles, public transportation, ride sharing and carpooling, walking and cycling, cableways, traffic control, and sea ferries were all considered.

Table 19: Energy Sector Technology Identification

Options	Key Vulnerabilities	Current Management Practice	Proposed Management Technology
Geothermal Energy			
	Minor tremors if EGS is used without due care and attention	7.5MW binary plant under construction	Monitor system flows and emissions
Hydro Energy			
	Reduce production: Low flows during dry season and other low rainfall period	Increase use of fossil fuel	Increase supply from other baseload RE sources like geothermal
	Damage to intake: Flooding or debris laden water due to heavy rainfall	Install filters and barriers to prevent logs and other debris entering the system	Improve intake construction
Wind Energy			
	Unpredictable Fluctuating output		Supplement with baseload supply like geothermal which is capable of ramping up quickly to maintain output
	High wind could damage system		Feasibility of lower turbine or those with appropriate inbuilt technology e.g. go into stall mode
Photovoltaic Solar Energy			
	Fluctuating output: Output dependent on sun's energy reaching panels	Battery, Hydrogen Storage, and/or grid backup	Baseload supply like geothermal which is capable of ramping up quickly to maintain output
Transmission & Distribution			
	No supply to end user: Broken lines	Use of standby generators by those who have them	• Reduce occurrence of broken lines by burying transmission and distribution cables • Introduce and/or enhance mini and micro grids

Table 20: Energy Efficiency Technology Identification

Options	Key Vulnerabilities	Current Management Practice	Proposed Management Technology
LED Lights		Change to LEDs when the non-LEDs useful life is over	Replace less efficient incandescent and compact fluorescent bulbs with lower wattage LEDs
Automatic Light Controls: Photocells, Light Level Sensors, Motion Detectors, Occupancy Sensors			None required
Air-Conditioning: Ground Source Heat Pumps	Difficult to install in existing buildings with limited space		No specific requirements except to include as part of new designs
Windows	Ventilation and light restrictions	Less than 50% ventilation allowed	Utilize more efficient ventilation and light windows
Green Roofs	Building structure must be able to support the additional weight		Design modifications to enable building structure to support saturated green roof weight.
Energy Efficient Appliances	Technologies are usually imported and so are not always well suited to environment	Importation of maintenance protocol	Greater effort to adaptation technology
Minimizing Urban Heat Island Effect		None	Put an effective system in place that enhances factors that minimizes heat island effect while simultaneously reducing or eliminating factors that maximizes heat island effect

Table 21: Transportation Sector Technology Identification

Options	Key Vulnerabilities	Current Management Practice	Proposed Management Technology
Electric vehicles (buses, cars)	Not yet introduced		Build main and top-up charging stations to accommodate EV fleet
Public Transportation (scheduling, routes, reliability)	No set schedules. Transport media are privately owned. After hour rides are uncertain	Loose	Augment with some set departure times especially in off-peak hours
Car Pooling	Not widespread	By happenstance	Encourage business, trade, and employment institutions to promote use

Cableway in Agriculture	Maintenance of metal cable and system in salty environment Installation could be	This system is not deployed	No particular management practice required.
Options	**Key Vulnerabilities**	**Current Management Practice**	**Proposed Management Technology**
	challenging, as many farms are located in steep terrain.		
Efficient Road Design, Storage – avoidable traffic congestion & traffic regulation		Respond to existing design	Provide due consideration and incorporate appropriate measures during initial design to reduce negative impacts later
Sea Transport (island ferries, fishing boats)	• Insufficient wharfs in community ports to load and discharge cargo/passengers • Inclement sea and weather conditions from time to time	System used infrequently	Repair or build new wharfs in areas where this service would be beneficial

5.2 Key Features of Identified Mitigation Technology Options

5.2.1 Energy Options and Selection

Various mitigation technologies were identified for the Energy and Transportation sub-sectors. The options for mitigation of greenhouse gas emissions in the energy sector are the development of renewable energy options for electricity and the improvement of energy efficiency in generation, distribution, and consumption of electricity. The emerging consensus targets geothermal, run-of-the river hydro, wind, and photovoltaic and thermal solar. Of these, there is further sentiment that the population is fairly acquainted with thermal solar (water heating) and the migration towards this technology is expected to continue without much external prodding.

Biofuels technology diffusion is a desirable goal, but the available volumes on island are relatively small with limited information regarding potential uptake. There is currently an ongoing investigation and project to investigate the utilization of waste to energy at the central landfill that will provide more information upon completion. This report will therefore forgo any further analysis on biofuels.

After the review of available information, it was the general consensus that while desirable, an interconnected smart micro grid has to be a work in progress, since the prohibitive cost to install in the mountainous terrain suggests a more incremental implementation agenda.

5.2.1.1 Geothermal Energy

Dominica has many geothermal manifestations, and these holds great promise for the island. Studies and development are most advanced in the Roseau Valley in the geothermal field associated with the Morne Micotrin cauldron. About 10 square kilometres in the Roseau Valley has a minimum sustainable capacity of 300MW, (INDC 2012). Soufriere, Picard, and Morneaux Diables western valley, close to Penville, also have exploitable geothermal possibilities. Dominica's geothermal resources are well beyond what the island can consume. If the resource is developed, Dominica could export clean energy to the neighbouring French islands of Guadeloupe and Martinique.

5.2.1.2 Hydro Energy

Hydropower can be one of the most available and consistent forms of renewable energy on the island. Touted to possess 365 rivers / streams, the potential for developing hydropower of varying capacity is fair. Run-of-the-River hydro energy provided about 30% of Dominica's electricity requirements prior to 2016, (TNC, 2016) i.e. prior to the passage of T.S Ericka in 2015 which damaged the infrastructure housing the turbine and H. Maria in 2017 which caused further catastrophic damage. Post H. Maria in 2017, all of the power generated by the power utility company on island is from fossil fuels.

Prior to 2017, The electric utility company operated three hydroelectric power stations (Laudat, Trafalgar and Padu).The plants are all located in the Roseau Valley and were powered with water from the Roseau River. Since there are several other similar capacity rivers in Dominica, there are good possibilities for the development of run-of-the-river hydro power plants on some of these rivers.

5.2.1.3 Wind Energy

Dominica's commercial wind potential lies mainly on the east coast with possibilities for small and domestic installations in other areas of the island. The intermittent nature of wind energy would best be coupled with hydro wherever possible. There is one independent power producer with a 225-kW wind turbine at Rosalie Bay on the east coast.

5.2.1.4 Photovoltaic Solar

Solar is a good option and is normally available about seven hours on cloudless days. Dominica has a solar resource of 5.6 kWh per square meter per day (TNC, 2016).Since Dominica is known to be among the islands to experience the most rainfall within the Caribbean island chain, over 300 inches annually within the interior highland forest, there will be days when cloud cover renders the solar panels impotent.

5.2.2 Status of Energy Efficiency Options in Dominica: Lighting, Air Conditioning, Windows

Energy efficiency can usher a major cost-effective reduction in energy consumption. Energy efficiency measures for buildings, appliances and equipment can reduce the need for investment in energy infrastructure, cut energy bills, increase competitiveness, and improve consumer welfare. The various suggested schemes are things the population has the capacity to implement. As these actions are widely implemented, they will usher significant reduction in greenhouse gas emissions.

Buildings and workspaces are design with little consideration for natural ventilation and shading of walls to reduce heating from the sun. Even work and official attire is not tropics-friendly and, by nature, require artificial cooling.

The main energy efficiency options that will have a significant energy reduction usage and are relatively easy to implement are LED lights, automatic lights controls, Ground Source Heat Pump air conditioning, windows (type and configuration), green roofs, energy efficient appliances, and minimizing Urban Heat Island Effect.

5.2.2.1 LED Lights

LED lights are taking over the light bulb market. LED bulbs have surpassed compact fluorescents whose availability has dwindled. So too has the availability of incandescent light bulbs. The energy savings range from 30% to 70% of non-LEDs lights. LEDs tubes have replaced fluorescents in new installations and are gradually replacing fluorescent in existing installations. Street and floodlights have largely moved to LEDs.

5.2.2.2 Automatic Light Controls: Photocells, Light Level Sensors, Motion Detectors, Occupancy Sensors

Photocells, light level sensors, motion detectors, and occupancy sensors are very effective energy efficiency gargets. Ubiquitous use of photocells, light level sensors, motion detectors, and occupancy sensors should be commonplace. Similarly, motion detectors and occupancy sensors will automatically turn off lights when a space is not occupied. Light level sensors will control working area light level as per pre-set functions. Light level within confined spaces may vary due to the effects of shading and sun positioning. Properly set sensors can automatically turn on / off lights to predetermined desired levels.

5.2.2.3 Air-Conditioning: Ground Source Heat Pumps

Air-conditioning, especially in hotels and office settings, are major energy guzzlers. Natural ventilation schemes are hardly ever deployed, and most are oblivious to their existence and possibilities. Again, there are no regulations on minimum efficiency of air conditioners. Recently, more efficient inverter type air conditioners have been promoted as the wiser option as, over time, their combined purchasing price and running cost is lower than the other motorized units.

Ground source heat pumps (also known as geo-exchange, earth-coupled systems, earth energy systems, geothermal ground source heat pumps) are very low-energy cooling systems which should be incorporated in all new standalone buildings which have the space requirement. The only energy they need is to operate their pump. This system is over 50% more efficient than other air conditioners. Operating models of this technologies is provided in the technical fact sheet

5.2.2.4 Windows

Windows have taken several steps backwards from the last generation. Most existing and newly installed windows are at best less than 50% effective both in terms of ventilation and natural lighting. Various measures including building codes, customs tariffs, population enlightenment etc. can reverse that trend.

In colonial days 50+ years ago, most windows were wooden casement windows on the outside, and sometimes augmented with wooden shutter louvers on the inside. This was superseded with glass louvres mounted horizontally. In the last thirty years, sliding windows have been the standard with probably 90+% of the market. This type of window cuts off over 50% of ventilation in good weather, and has to be totally closed if it’s raining towards its direction. This situation equates to a significant retrogressive step with regards to energy efficiency.

Casement windows or awning windows are much better options. They guarantee at least 100% ventilation. Awning windows are preferable for the rain facing side, as they can remain open without water intrusion. Casement windows can allow over 100% breeze, as they can open wider than the window cavity. These are both excellent ventilation options. See fact sheet for illustrations of different windows.

5.2.2.5 Green Roofs

Due to their durability in hurricanes, most new houses are built with concrete roofs, but the roof’s concrete is exposed to the sun thus the heat on the top floor is unbearable up to the wee hours of the morning and can only be overcome with air conditioning. Green roofs can solve this problem.

A green roof, or rooftop garden, is a vegetative layer grown on a rooftop. Green roofs provide shade and remove heat from the air through evapotranspiration. It reduces temperatures of the roof surface and the surrounding air. Green roofs absorb heat and act as insulators for the floor immediately below the roof, thus reducing the energy demand for cooling, improving indoor comfort, and lowering heat stress associated with heat waves.

Green roofs insulate the concrete with three to six inches of dirt plus vegetation. It also reduces flooding by retaining some water in the soil. The vegetation on the roof also sequestrates carbon dioxide. Although there are many concrete roof buildings and the occupants of their top floor are quite familiar with the unbearable heat, green roofs are yet to be introduced in the country. A typical cross section of a green roof can be viewed within the fact sheet.

5.2.2.6 Energy Efficient Appliances

Although there is an environmental levy on imported goods, the concept has not been advanced further into ensuring that appliances are energy efficient and are rated by a reputable agency like the EPA's ENERGY STAR. Used vehicles beyond a certain age are subjected to additional taxes but these measures have not been applied to appliances.

More efficient appliances will also reduce energy requirements. Stricter energy efficient standards must be introduced and enforced.

5.2.2.7 Minimizing Urban Heat Island Effect (UHIE)

Urban Heat Island Effect refers to the increased heat effect associated to locales with a predominance of concrete and other heat reflective structures. The existing layout and nature of the capital city provides little potential to accommodate trees on the sidewalks and backyards which can act as overall sinks and thus assist in the overall reduction in temperature. So too, streets are already aligned. Minimizing Urban Heat Island Effect has to come mainly from the greening of buildings, which can be encouraged in new construction and also buildings under repair. Further, more climate sensitive buildings combined with efficient traffic and green spaces can ease the hot island effect in the capital city.

5.3 Transportation Options and Selection

Currently, Dominica imports in the range of 900 - 1,000 barrels of oil daily for energy generation and other applications. Power generation represents the main use of imported fossil fuels (50%), followed by transportation (33%) (TNC, 2016).Most imported cars and SUVs are pre-owned gasoline or diesel Japanese vehicles, most of which exceed or are about to exceed the exporting country's emissions standards. Accordingly, GHG emissions increased from 46.8Gg in 2005 to 71Gg in 2014, (TNC, 2016).Dominica's import duties and related port charges on motor vehicles is approximately 140% of Cost, Insurance and Freight (CIF).An environmental levy of 1% of the CIF is added to the import duties on vehicles less than 5 years old. The levy rises to EC$3000 for vehicles over 5 years.

Most passenger vehicles in Dominica run for less than 150 miles per day, so for electric vehicles a single daily charge would suffice for most passenger vehicles. With the abundance of rivers island-wide, and with good wind resources on the east coast and solar radiation everywhere, a few rapid charging stations can be setup around the island powered by hydro or wind to provide the daily charging requirement with solar PV reserved for top-up at bus stops and parking garages. The transition can begin with passenger and school buses, which would have the added benefit of lowering fares. Currently electric vehicles are cheaper to own and operate over four years than fossil-fuelled vehicles (https://www.sciencedirect.com/science/article/abs/pii).

Diesel vehicles in Dominica are especially polluting. Most older diesel vehicles' mufflers invariably can be seen emitting exhaust soot. Particulate matter pollution from diesel vehicles has been linked to incidences of juvenile asthma.

Dominica does not own or operate any airline and has little influence on the fuel used by airplanes. However, Dominica Air and Sea Port Authority (DASPA) has embarked on a programme to augment their airport and seaport facilities with solar PV and possibly hydro off-grid electricity. Over the next three year the Douglas Charles Airport, the Roseau Ferry Terminal, Woodridge Bay Port, Longhouse

Port, and the Cabrits Cruise Ship Berth will all be fitted with solar PV systems. Fishing boats, cargo trawlers, and cargo vessels all use fossil fuel.

Daily traffic rush-hour delays, roadway bottlenecks, indiscriminate parking, and the lack of storage on most roadways, extend trips by several minutes with the corresponding avoidable emissions.

Comparatively inexpensive roadway design could reduce trip time by thirty percent (30%) or more.

The motorization rate in Dominica is one car for every 3 inhabitants with 24,600 vehicles registered in 2014 for 71,000 people. On average, each car covers 18,500 km/year, ((TNC, 2016). This phenomenon is driven to a large extent by inadequate public transportation. With an improvement in public transportation, a corresponding decline in motorization rate, and concurrent reduction in GHG emissions, should result.

Many Dominicans in the urban areas drive when walking would save time, enhance health, and avoid emissions. A combination of improved public transportation, enhanced pedestrian walkways, routes and sidewalks, and public awareness on the cross benefit of exercise could reverse that trend.

Over the years, cycling has given way to motorized transportation, with a significant reduction in adult bicycle riders. This situation is in part due to safety concerns on the roads with motorized traffic and the nonexistence of dedicated bike lanes to provide safety to riders. A newly formed cycling association could help reverse this situation, but so far, its focus has been on competitions and not more public use of cycling.

The general consensus is that the country should migrate straight to electric vehicles. Concurrent to that migration should be a corresponding transition to 100% renewables on the grid to energize charging stations or alternatively, off-grid charging stations powered by renewable energy. The consensus is hybrid vehicles are an unnecessary intermediate step in the country's circumstance, and fuel cell vehicles are still a step or two behind electric vehicles mass marketwise.

The initial foray into electric vehicles should be focused on public transportation and school buses with solar or wind charging stations at bus terminals and dedicated charging stations, powered by run-of the-river hydro for end of day charging. More targeted and responsive scheduling combined with cheaper energy should lead to reduced costs, which should lead to rapid public gravitation to that mode of transportation. There was also discussion that point-to-point sea ferries might be a more efficient form of public transportation on sections of the west coast.

Cableways and donkeys could also be a preferred option in certain areas in agriculture.
Car-pooling, park and ride, efficient road design with storage, dedicated parking lots, and improved traffic regulations will also improve transportation efficiency. Walking and cycling are highly desirable options and should be encouraged.

Chapter 6 RANKING OF MITIGATION TECHNOLOGIES

6.1 Status of Renewable Energy in Dominica

The price of electricity (tariff structure) in Dominica is approximately US$ 0.38 kWh for residential consumers and between US$ 0.38 and US$ 0.41 kWh for businesses. At the time of reporting, 100% of grid energy is generated from diesel generators. The main options for renewable energy are geothermal, hydro, wind, and photovoltaic solar.

6.1.1 Geothermal

The island's estimated exploitable geothermal energy potential ranges from 300MW to 1390MW (TNC, 2016).Site assessments and feasibility studies have been carried out which indicate that the energy capacity in the Roseau Valley Geothermal Resource area is at least 300 MW (INDC, 2015).A 7.5MW geothermal production unit is being developed in the Roseau Valley.

6.1.2 Run-of-the-River Hydro

The three Run-of-the-River Hydro plants on the island with 6.64 MW installed capacity are operating on water from the Roseau River. In 2018, the recovery year after the devastating Hurricane Maria, they produced 24.18MWh, which was 37% of grid electricity in 2018 (TNC, 2016).There are several other rivers scattered over the country of similar capacity with good Run-of-the-River Hydro potential, which have not been exploited.

6.1.3 Wind Energy

The grid wind energy potential lies mainly on the east coast of the island; estimated at approximately 30 MW of wind power, (TNC, 2016).After reviewing nine wind studies, DOMLEC concluded that Crompton Point, located in Saint Andrew, has a potential of 10 MW of wind power and that an additional 20 MW of wind potential is available elsewhere in the country, (NREL, 2015).Currently there are no wind generators supplying the electricity grid. There is an independent power producer with a 225-kW wind turbine supplying power to Rosalie Bay Hotel.

6.1.4 Photovoltaic Solar

Dominica has a good solar resource of 5.6 kWh per square metre per day (TNC, 2016).Prior to Hurricane Maria, 0.25% of Dominica's electricity power generation came from solar. Hurricane Maria familiarized the population to photovoltaic solar, which was ubiquitous all over the island pending the restoration of grid electricity. Some of that familiarity to photovoltaic solar has been retained by many households, manifested in many homes, which have either converted or intending to convert, fully or partially, to photovoltaic solar. Also are the numerous standby rechargeable solar light packs in most dwellings.

6.2 Criteria and Process of Technology Prioritisation for Mitigation Sector

Guided by the Consultant and industry experts the Technical Working Group considered the various energy options presented in table 22. Through the process of discussion and review of available GHG emission data, inter alia, a short list of four technologies was selected for further assessment.

Geothermal, hydro, wind, and photovoltaic solar were selected for further consideration and assessed in tables 23 & 24 utilizing the MCA approach. Solar thermal, biofuels, waste to energy, and interconnected smart grids were not selected for further consideration at this time due to the novelty and absence of relevant information and experience with the technologies within the jurisdiction. Further, the non-inclusion of these technologies in previous mitigation consultation proceedings reviewed also factored in the decision.

6.2.1 Criteria Selection for Assessment of Technologies for Mitigation to Climate Change

The long list of various energy technology options was listed within the matrix in Table 22 and assessed utilizing the criteria listed below. A shortlist of technology options was then selected for further assessment utilizing the MCA in Tables 23 and 24.

A brief description of the criteria utilized for assessment is also provided below.

Assessment Criteria	Description
Installation cost	Cost to install a kilowatt of power for the specified generation scheme.
Levelized Cost	Present value of the produced electrical energy, considering the economic life of the plant and the costs incurred in the construction, operation and maintenance. It allows for the comparison of different technologies of unequal life spans, project size, different capital cost, risk, return, and capacities.
Base Load Acceptability	Daily minimum electrical power needed by consumers – The electrical grid power requirement never falls below this minimum. Variable supply generators like wind turbines and solar panel are not suitable as base load generators
Availability	Percentage of the year the generator will be producing power. Down time attributed to shut down for maintenance, and the nonproduction variability of the supply, like the non-sunshine hours in the case of solar power, or absence of wind in the case of wind turbines, are considered as periods when production is not available
Resource Potential	Potential of the supply over an extended number of years – like whether the resource will be around for a few hundred years or forever.
Socio-Economic benefit	Potential of technology to contribute positively to the economy of the country / addressing issues of poverty reduction especially among vulnerable groups such as women, children, disabled people, by improving incomes, nutrition and health security.

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Table 22: Selection Matrix - Energy

Options	**Installation Cost/kW**	**Levelized Cost (operating cost)**	**Availability**	**Base Load acceptability**	**GHG Emission**	**Resource Potential** Very	**SocioEconomic benefit**
Geothermal	US$2500/k W	<US$0.06/kWh	94%	Good	3.8 to 5.2 g CO_2e/k Wh	Good	Very good
Run-of-the-River Hydro	US$1,300/k W to US$8,000/kW	<US$0.10/kWh	90+%	Good	0	Very Good	Very Good
Wind	US$2000 to US$3000/ kW	<US$0.20/kWh (Location dependent)	Varies	Not good	0	Good on east coast	Good
Solar Photovoltaic	Grid tied units US$2600/k W Standalone US$5200/k W	<US$0.22/kWh	on cloudless days 8 hours	Not good	0	Good	Good
Solar Thermal	US$2500/k W	<US$0.17/kWh	on cloudless days 8 hours	Not good	0	Good	Good
Biofuels	$3,000 to $5,000 per kW	$0.08 to $0.15 per kWh	Depending on supply	Good	Neutral	Moderate	Good
Interconnected Smart Micro Grids	Not applicable	Not applicable	Always	Not applicable	0	Good	Good
Waste to Energy	Multiple schemes with varying costs	$0.10 to $0.17 per kWh	90%	Good	Low	Moderate	Good

6.2.2 Assessment of technologies for mitigation – Energy

The shortlisted technologies were then assessed utilizing the pre-selected criteria approved by the TWG. The process pursued the attainment of consensus from all parties with regards to the ranking of the scores. The availability of key cost and emission data together with recent renewable energy studies data (recorded in table 23) greatly facilitated the process.

Table 23: Performance Matrix Energy

Options	Installation Cost/kW	Levelized Cost	Availability	Base Load	GHG Emission	Resource Potential	Socio-Economic benefit
Geothermal	US$2500/kW	<US$0.06/kWh	94%	Good (5)	3.8 to 5.2 (4.5) gCO2e/kWh	Very Good (4)	Very good (5)
Run-of-theRiver Hydro	US$1,300/kW to US$8,000/kW	<US$0.10/kWh	90+%	Good (5)	0	Very Good (4)	Very Good (5)
Wind	US$2000 to US$3000/ kW	<US$0.20/kWh (Location dependent)	Varies (40%)	Not good (1)	0	Good on east coast (2.5)	Good (3)
PV Solar	US$5200/kW	<US$0.22/kWh	33%	Not good	0	Good (2.5)	Good (3)

The values in the performance matrix were normalized using formula(a) if the preferred value is higher, and(b) if the preferred value is lower:

Preferred value is higher $Y_i = ((X_i – X_{min}) / (X_{max} – X_{min})) * 100$ ………………….(a)
Preferred value is lower $Y_i = ((X_{max} – X_i) / (X_{max} – X_{min})) * 100$………………….(b)

Yi – score of option i;
Xi – performance of option i;
X_{max}, X_{min} – the highest and the lowest performance among all the options.

Process repeated for each criterion.

Table 24: Normalized Energy Performance Matrix

Options	Installation Cost/kW	Levelized Cost	Availability	Base Load	GHG Emission	Resource Potential	Socio-Economic
Geothermal	100	100	100	100	0	100	100
Run-of-the River Hydro	50	60	100	100	100	100	100
Wind	100	0	17	0	100	0	0
PV Solar	0	0	0	0	100	0	0

6.3 Assessment of Technologies for Mitigation – Energy Efficiency

The focus on mitigation within Dominica has not included energy efficiency to a deserving extent. Apart from LED light bulbs, which got a boost in 2009 with the island-wide incandescent to LEDs light bulbs exchange, other energy efficiency schemes have hardly featured in previous national communication reports and INDCs. There is however a growing recognition that energy consumption avoided is energy production eluded, and so due consideration needs to be directed to efficiency.

Six energy efficiency technologies were selected. Due to the prominent absence of efficiency features in previous climate-change mitigation reports, the TWG decided to allow all six of the technologies identified to go through the MCA process.

Table 25: Performance Matrix - Energy Efficiency

Options	Capital Cost/Unit Yield	Operating Cost	GHG Emission	Potential Technology Diffusion	Socio – Economic
Lighting Fixtures (schemes and controls)	2.5	1.5	4.5	5	3.5
Ground Source Heat Pumps (Geo exchange)	3.5	2.5	4	2	3.5
Green Roofs	5	3	4	3.5	2
Windows	3	0	3.5	4	3
Efficient Appliances	3.5	2.5	3	5	4
Urban Heat Island Effect (minimize)	1.5	2.5	5	5	3.5

Table 26: Normalized Performance Matrix - Energy Efficiency

Options	Capital Cost/Unit Yield	Operating Cost	GHG Emission	Potential Technology Diffusion	Socio - Economic
Lighting Fixtures (schemes and control)	71	75	25	100	75
Ground Source Heat Pumps (Geo exchange)	43	25	50	0	75
Green Roofs	0	0	50	50	0
Windows	57	100	75	67	50
Efficient Appliances	43	25	100	100	100
Urban Heat Island Effect (minimize)	100	25	0	100	75

6.4 Assessment of Technologies for Mitigation –Transportation

The transportation options in Dominica is a mixed bag. All but one (1) registered vehicles on Island, are energized by fossil fuel. The lone electrically powered car is owned by the sole power utility company providing grid power by burning fossil fuel. Public transportation is pretty well developed to and from population centres, but outside of the capital, off hours public transportation can be problematic as it quickly degrades into a luck and chance situation.

A lot of more walking and cycling could be done, but for various reasons ranging from comfort and safety, many people would rather drive when walking is just as fast. Further, drivers' allowance and due care and attention for cyclists and pedestrians must improve to increase confidence that these can be accomplished safely. The opportunity also exists to replan the urban centres to provide for no drive or regulated access sectors to allow pedestrians to traverse in greater safety. The relatively narrow roads throughout the island suggest a heighten level of coexistence. Future designs and upgrades should consider bike lanes and better pedestrian accessways. There must also be incentives by the traffic department and local government to encourage carpooling and ride sharing.

Not enough attention is paid to the mitigation aspect of proper road design. Too often, parking consideration, one-way traffic, storage, and road width are not sufficiently taken into account in the design phase, only to become the causation of traffic delays, extended routes, and inefficient flow.

There are no cableways on the island. Farm transportation efficiency on the many undulating farm roads could be improved immensely with the installation of cableways and the use of beast of burden such as donkeys.

Table 27: Performance Matrix Transportation (Efficiencies and Practices)

Options	**Capital Cost /Unit Yield**	**Operating Cost**	**GHG Emission**	**Potential Technology Diffusion**	**Socio – Economic**
Electric vehicles (buses, cars)	4.0	1.5	4.5	5	4.5
Hybrid vehicles	4.5	3	3	3.5	3.5
Fuel Cell vehicles	5	1.5	4.5	5	4.5
Sea Transport (island ferries, fishing boats)	3.8	4	2	2.0	2.5
Public Transportation (scheduling, routes, reliability)	4.5	3.8	2	3	3.5
Public Transportation (scheduling, routes, reliability) – EV	5	1.0	4	5	4
Car Pooling	1	1.2	3.2	3.5	3.5
Efficient Road Design, Storage – avoidable traffic congestion & traffic regulation	5	1.0	4	4.5	2
Cableway in agriculture	3.8	3	4	4.5	4.5
Walking and Cycling	2	1	0.5	5	5

Table 28: Normalized Performance Matrix Transportation (Efficiencies and Practices)

Options	**Capital Cost/Unit Yield**	**Operating Cost**	**GHG Emission**	**Potential**	**Socio – Economic**

Electric vehicles (buses, cars)	25	83	0	100	100
Hybrid vehicles	13	33	38	50	60
Fuel Cell vehicles	0	83	0	100	100
Sea Transport (island ferries, fishing boats)	30	0	63	0	20
Public Transportation (scheduling, routes, reliability)	13	7	63	33	60
Public Transportation (scheduling, routes, reliability) – EV	0	100	13	100	80
Car Pooling	100	93	33	50	60
Efficient Road Design, Storage – avoidable traffic congestion & traffic regulation	0	100	13	83	0
Cableway in agriculture	30	33	13	83	100
Walking and Cycling	75	100	100	100	100

6.5 Ranking of Mitigation Technology – Energy, Energy Efficiency & Transportation

Ranking of the technologies assessed in the energy, energy efficiency and transportation subsectors follows as per the methodology articulated in the MCA process. The weighting of the assessment criteria for all subsectors were discussed at length with due consideration being given to the views of gender representatives. Finalized weightings were then applied to the assessed scores to determine the technologies overall scores and final rating.

6.5.1 Energy Technologies

Table 29: Weighting of Energy Assessment Criteria

Category	Weight	Criteria	Weight
Cost	40%	Cost to design and install	10%
		Levelized Cost (Energy affordability)	30%

Economic	25%	Availability and Sustainability	10%
		Base Load	15%
Environment	25%	GHG Emission reduction	20%
		Impact on local environment	5%
Social	10%	Employment	10%

Table 30: Assessment Scoring – Energy Options

Energy	Cost to Design and Install	Levelized Cost	Availability and Sustainability	Base Load	GHG Emission Reduction	Impact on Local Environment	Social	TOTAL
	10%	30%	10%	15%	20%	5%	10%	
Geothermal	100	100	100	100	0	100	100	80
Hydro	50	60	100	100	100	100	100	83
Wind	100	0	17	0	100	0	0	32
PV Solar	0	0	0	0	100	0	0	20

Table 31: Ranking of Selected Energy Technologies

Ranking	Technology	Total
1	Run-of-River Hydro	83
2	Geothermal	80
3	Wind	32
4	PV Solar	20

6.5.1.1 Results

The energy technologies ranking indicate preference for Run-of-the-River Hydro followed closely by geothermal. Wind and solar, which is unable to provide continuous on demand supply without development of storage potential ranked third and fourth. While the ranking is countrywide, the actual technology selection would be location based since certain areas may provide greater advantages to particular technologies.

6.5.2 Energy Efficiency Technology

Table 32: Energy Efficiency Criteria Category and Criteria Weights

Category	Weight	Criteria	Weight
Capital Cost	25%	Cost to design and install	15%
		Operation and Maintenance costs	10%
Environmental	25%	GHG Emissions	25%
Potential for Technology diffusion	25%	Every household can implement	13%
		Widespread familiarity with technology	12%
Socio-Economic	25%	Employment / Ease of implementation	25%

Table 33: Assessment Scoring – Energy Efficiency Options

Energy Efficiency	Cost to design and install	Operation and Maintenance costs	GHG Emissions	Potential Technology Diffusion	Socio – Economic	TOTAL
	15%	**15%**	**25%**	**25%**	**25%**	
Lighting Fixtures	71	75	25	100	75	71.9
Ground Source Heat Pumps	43	25	50	0	75	41.45
Green Roofs	0	0	50	50	0	25
Windows	57	100	75	67	50	71.55
Efficient Appliances	43	25	100	100	100	85.2
Urban Heat Island Effect (minimize)	100	25	0	100	75	62.5

Table 34: Ranking of Selected Energy Efficiency Technologies

Ranking	Technology	Total
1	Efficient Appliances	85
2	Lighting Fixtures	73
3	Windows	72
4	Urban Heat Island Effect (minimize)	63
5	Ground Source Heat Pumps	41
6	Green Roofs	25

6.5.2.1 Results

The first four items in the energy efficiency technologies ranking are relatively low hanging fruits which can be implemented at the initial purchase or installation, or at the time of renovation or replacement at minimal additional cost. Geothermal, Ground Source Heat Pumps and Green Roofs can only be implemented if they are taken into consideration at the time of design. Existing buildings can only be retrofitted if there is sufficient space for installing the pipes in the case of the ground source heat pumps, or whether the building structure can carry the additional weight of a green roof.

6.5.3 Transportation Technology

Table 35: Transportation Criteria Category and Criteria Weights

Category	Weight	Criteria	Weight
Cost	40%	Cost to design and install	20%
		Operation and Maintenance costs	20%
Environmental	30%	GHG Emissions	30%
Potential for Technology diffusion	15%	Relatively seamless to implement	15%
Socio-Economic	15%	Employment / Ease of implementation	15%

Table 36: Assessment Scoring – Transportation Options

Energy Efficiency	Cost to design and install	Operation and Maintenance costs	GHG Emissions	Potential Technology Diffusion	Socio - Economic	TOTAL
	20%	20%	30%	15%	15%	
Electric vehicles (buses, cars)	25	83	0	100	100	52
Hybrid vehicles	13	33	38	50	60	37
Fuel Cell vehicles	0	83	0	100	100	47
Sea Transport (island ferries, fishing boats)	30	0	63	0	20	28
Public Transportation (scheduling, routes, reliability)	13	7	63	33	60	37
Public Transportation (scheduling, routes, reliability) - EV	0	100	13	100	80	51
Car Pooling	100	93	33	50	60	65
Efficient Road Design, Storage – avoidable traffic congestion & traffic regulation	0	100	13	83	0	36
Cableway in agriculture	30	33	13	83	100	44
Walking and Cycling	75	100	100	100	100	95

Table 37: Ranking of Selected Transportation Technologies

Ranking	Technology	Total
1	Walking and Cycling	95
2	Car Pooling	65
3	Electric vehicles (buses, cars)	52
4	Public Transportation (scheduling, routes, reliability) – EV	51
5	Fuel Cell vehicles	47
6	Cableway in agriculture	44

7	Public Transportation (scheduling, routes, reliability)	37
Ranking	**Technology**	**Total**
8	Hybrid vehicles	37
9	Efficient Road Design, Storage – avoidable traffic congestion & traffic regulation	36
10	Sea Transport (island ferries, fishing boats)	28

6.5.3.1 Results

Walking and cycling, obtained the highest ranking. The other rankings were mostly as expected except for #9: Efficient Road Design, Storage – avoidable traffic congestion & traffic regulation, which scored particularly low.

Chapter 7 VALIDATION AND CONCLUSIONS

The validation workshop for TNA report was held on 4th February, 2020. Participants from the corresponding sectors were invited. The Lead Consultant presented the report and thereafter participants were divided into two groups, one for adaptation and other for mitigation. In the groups, participants deliberated upon the technologies prioritized reverting to the details of the technologies presented in the fact sheets. After the discussions, the groups presented their conclusions in a plenary setting.

Adaptation Technologies

- Given the abundance of water, appropriate weather conditions and fertile soils in Dominica in contrast with the prevalence of cancer-related illnesses and death in our society, it was suggested that a bigger effort should be made to pursue a sustainable approach to agricultural production, in particular vegetables, root crops and tree crops, by preventing the importation and use of agrochemicals like Glyphosate (roundup).
- More efforts should be made to introduce hydroponics and aquaponics.
- Discussions also centred around food and nutrition security and import substitution and the required support that are required to lessen our food import bill in the context of Climate Change. Reference was made to experiences in the aftermath of Hurricane Maria when emergency food supplies were sent to Dominica but lots of those foods lacked the appropriate nutrition and wholesomeness. Much plastic bottled water was also sent to us which had serious health implications.
- Technologies for soil conservation, particularly on slopes.
- Commercial production of seasonings, spices and condiments as well as production of small ruminants
- Soil conservation on slopes, with reference to terracing and contours to maximize use of the island's topography, was discussed.

For the Water Sector:

- Augmenting water resources by exploring aquifers and ground water recharge, waste water treatment and recycling, as well as rainwater harvesting.
- Efficient irrigation methods, data collection on river and stream flows, as well as weather forecasting island-wide.
- It was felt that improved water quality would contribute to an improved health and wellness sector.

Mitigation Technologies

Energy

Various mitigation technologies were identified for energy and transportation TNA. The options for mitigation of greenhouse emissions in the energy sector are the development of renewable energy options for electricity and the improvement of energy efficiency in generation, distribution, and consumption of electricity. The emerging consensus targets geothermal, run-of-the-river hydro, wind, and solar. Of these, there is further sentiment that the population is fairly acquainted with solar (photovoltaic and thermal) and the migration towards these technologies is expected to continue without much external prodding. Biofuels technology diffusion is a desirable goal, but the quantities are relatively small therefore its dissemination will be by other means. Since there is an on going investigation and project to utilize waste to energy at the central landfill, this report will forgo further analysis. The consensus is that while desirable, an interconnected smart micro grid has to be a work in progress, since the prohibitive cost to install in the mountainous terrain suggests a more piecewise implementation agenda.

Energy Efficiency

Energy efficiency can usher a major cost-effective reduction in energy consumption. Energy efficiency measures for buildings, appliances and equipment can reduce the need for investment in energy infrastructure, cut energy bills, increase competitiveness and improve consumer welfare. The various suggested schemes are things the population has the capacity to implement. As these actions are widely implemented, they will usher significant reduction in greenhouse gas emissions.

LED lights are taking over the light bulb market. LED bulbs have surpassed compact fluorescents as their availability has dwindled. So too have the availability of incandescent light bulbs. Their energy savings range from 30% to 70% of non-LEDs. LEDs tubes have replaced fluorescents in new installations and are gradually replacing fluorescent in existing installations. Street and floodlights have largely moved to LEDs. Ubiquitous use of photocells and occupancy sensors should be commonplace. Too often, and especially on weekends and holidays, manual switched lights stay on long pass needed.

Air-conditioning, especially in office settings and hotels, are a major energy guzzler. Natural ventilation schemes are hardly ever deployed and most are oblivious to their existents and possibilities. Geothermal Ground Source Heat Pumps (Geo-exchange) are not offered, though inverter type air conditioners are increasing market share.

Windows in constructed buildings have taken several steps backwards from the last generation. Most existing and newly installed windows are at best less than 50% effective, both in terms of ventilation and natural lighting. Various measures including building codes, customs tariffs, population enlightenment etc. can reverse that trend.

Due to its durability in hurricanes, most new houses are built with concrete roofs, but the roofs' concrete is exposed to the sun thus the heat on the top floor is unbearable in the wee hours of the morning and can only be overcome with air conditioning. Green roofs can solve this problem. So too, more climate sensitive buildings combined with efficient traffic and green spaces, can ease the hot island effect in the capital city.

More efficient appliances will also reduce energy requirements. Stricter energy efficient standards must be enforced.

Transport

Currently, transportation is energized with gasoline and diesel. The general consensus is that the country should migrate straight to electric vehicles. Concurrent to that migration should be a corresponding transition to 100% renewables on the grid to charging stations or alternatively, off grid charging stations powered by renewable energy. The consensus is hybrid vehicles are an unnecessary intermediate step in the country's circumstance, and fuel cell vehicles are still a step or two behind electric vehicles mass marketwise.

The initial foray into electric vehicles should be focused on public transportation and school buses with solar or wind charging stations at bus terminals and dedicated charging stations, powered by run-of-the-river hydro for end of day charging. More targeted and responsive scheduling combined with cheaper energy should lead to reduced costs, which should lead to rapid public gravitation to this mode of transportation. There was also discussion that point-to-point sea ferries might be a cheaper form of public transportation on sections of the west coast.

Cableways and donkeys could also be a preferred option in certain areas in agriculture. Improved traffic regulations will also improve transportation efficiency. Walking and cycling are also desirable options and should be encouraged.

Technology selection for BAEF

Participants commended the consultants and Technical Working Groups on the work that was done on the Factsheets. The detailed explanations were well received. The prioritization process went as follows:

For Adaptation Technologies in the Water subsector, technology rankings were as follows: Rainwater harvesting (95%), efficient fixtures & appliances (77%), water resource mapping & assessment (39%) and leakage detection and management (38%).

For the Adaptation technologies in the Agriculture sector, technologies rankings were as follow: Soil nutrition management (83.75%), Soil conservation (81.255%), Drip irrigation (69.95%), Indoor farming (22.5%), Aquaponics and hydroponics (9.95%).

For the Water sector, technologies rankings were as follow; Rainwater Harvesting (95%), Efficient fixtures & appliances (77%), Water resource mapping & assessment (39%), Leakage detection and management (38%).

For Mitigation technologies in the Energy subsector there was a preference for Run-of-the-River Hydro (83%) followed closely by geothermal (80%).Wind (32%) and solar (20%) rank third and fourth, respectively.

Energy efficiency:
Efficient appliances (85%), Lighting fixtures (73%), Windows (72%), Urban heat effect (minimize) (63%), Ground source heat pumps (41%), Green roofs (25%).

For Mitigation technologies in the Transportation subsector, the rankings were listed as:
Walking and Cycling (95%), Car Pooling (65%), Electric vehicles –buses, cars(52%), Public (scheduling, routes, reliability) – EV (51%), Fuel Cell vehicles (47%), Cableway in agriculture (44%), Public Transportation (scheduling, routes, reliability) (37%), Hybrid vehicles (37%), Efficient Road Design, Storage – avoidable traffic congestion & traffic regulation (36%), Sea Transport –island ferries, fishing boats (28%).

The technologies selected to move forward to the BAEF stage are as follows:

Agriculture sector
1. Soil nutrition management
2. Soil conservation

Water sector
1. Rainwater harvesting
2. Water resource mapping & assessment

Energy sector
1. Run-of-the-River Hydro
2. Geothermal
3. Wind

Energy efficiency sector
1. Green roofs
2. Geothermal heat pumps

Transportation sector
1. Electric vehicles
2. Walking and Cycling (Sidewalks, cycling lanes and no drive zones)

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Annex I: TECHNOLOGY FACTSHEETS FOR SELECTED ADAPTATION TECHNOLOGIES

Fact Sheet: Rainwater Harvesting (RWH) from Rooftops

Definition

Collection of rainwater from rooftop catchment and storing it in a tank or barrel is well established practice in Dominica. This effort is focused on making this mandatory for all new construction and introducing new features to improve safety of storage and water quality and volume.

Rainwater harvesting is utilized to collect water for household and agricultural uses nationally. After the passage of Hurricane Maria, RWH for irrigated agriculture was promoted under a food security programme by the Division of Agriculture, with the distribution of several P.E water storage tanks. A recent UNDP / Japan Caribbean Climate change Partnership project also distributed forty (40) 800-gallon water storage tanks to farmers in the vegetable farming community of Morne Prosper.

Continued demand on DOWASCO to provide portable water to households even after the impacts of catastrophic events which often compromise the water infrastructure, has resulted in the idea that onsite storage for a minimum period of two days should be provisioned within every household. The introduction of technology such as the first rain flush to allow a volume of water equivalent to that which is required to cleanse the receiving surface to bypass the storage tank, should be considered and made available. Additionally, the promotion of technology to reduce the susceptibility of the storage tank to wind and other environmental hazards during a tropical cyclone.

How the Technology/ Practice Contributes to Climate Change Adaptation?

RWH contributes to climate change adaptation at the household level primarily through two mechanisms:

(1) Provision of an alternate water supply to household especially in areas where the provision of portable water is achieved by pumping; and

(2) Increased resilience to water quality issues especially during and after flood events. It can also reduce the pressure on surface water by decreasing household demand.

Costs and Financial Requirements

RWH can often provide household water at lower expense than other available options. If a household already has a suitable hard roof for use as a catchment surface, storage containers are the major expense. The cost of storage containers typically depends on construction quality, tank size, and other factors. A large, high quality storage container can be a major investment for poor households. In the context of climate change, increased precipitation extremes could necessitate greater storage volume, thus enabling the capture of maximum volume during intense periods and providing for household water needs during extended dry periods.

Status of the Technology in Dominica

RWH is becoming increasingly important especially in areas where surface water sources are non-existent. The cost of providing water service to some of the locales where there is limited development is often unsustainable and so the practice of RWH is invaluable. RWH is also widely practiced in the agricultural sector.

Fact Sheet: Water Efficient Fixtures and Appliances

Definition

Water efficient appliances use less water while yielding comparable performance to other non-efficient appliances and fixtures, (e.g. low-flow showerheads). These include dish and clothes washers, popular fixtures including toilets, showerheads and faucets.

Strategies used to increase the use of water efficient technologies include:

- Public education
- Mandates – mandating water efficiency standards for new construction and replacement of old fixtures and appliances; mandating use of water efficient products in government facilities.
- Labeling – certification systems for water efficient products, adding the estimated cost of use, also called the "second price tag," to labels.
- Tax incentives – for purchasing and installing efficient products, retrofitting and replacing older fixtures.

How the Technology/ Practice Contributes to Climate Change Adaptation

Residential conservation efforts can make a strong positive contribution to reducing pressure on water resources.

Reducing water use in municipal systems also contributes to climate change mitigation by decreasing energy consumption and greenhouse gas emissions. Water conservation can lead to large savings in the energy used to transport, treat and distribute piped water.

Costs and Financial Requirements

Establishing a functioning certification process may be costly depending on existing capacity. However, the costs for individual households are generally small and may be fully recovered by water savings over the lifetime of the product.

Status of the Technology in Dominica

Water efficient washing machines are sold locally, but they are more expensive and are therefore not widely used. The low flow faucets and shower heads are sold but they tend to be more expensive and therefore not widely used. Many of the toilets imported today are 1.5 gallons.

Fact Sheet: Leakage Management and Detection System

Definition

Leakage in distribution systems is a major problem for water utilities throughout the developing world. While there has been a concerted effort locally to renew and upgrade the supply mains and some distribution networks, many water distribution networks are still dated and contribute to a significant percentage of non-metered water loss. Leakage rate in Dominica is estimated to be in excess of fifty (50) percent.

Management, detection and repair of small leaks in a distribution system are critical functions of system operation and maintenance, yet they often go undetected or neglected for prolong periods. These sometimes contribute to secondary infrastructural failure (roads) and soil erosion. Leak management methods can prevent or reduce leakage volume and leak detection technology can improve the ability of water utilities to respond quickly and repair leaks.

How the Technology/ Practice Contributes to Climate Change Adaptation

Growing population and further development continue to exert significant demand on this resource, often resulting in water scarcity and rationing during the dry season. Conversely, the additional inflows received during the rainy period overwhelm already saturated soils, increasing the risk of erosion and loss of this valuable resource. Detection and repair of leaks in water systems is an important part of comprehensive strategies to reduce pressure on existing water resources.

Costs and Financial Requirements

The costs of leak management, detection and repair include staff training, management, labor, and equipment. However, leak management, detection and repair programs generally pay for themselves by enabling early repair of leaks and reducing water waste. As already indicated, leaks from damage pipes often escalates into more significant failure of infrastructure to include roads and pipe support. Additional benefit of early detection therefore includes reduced maintenance costs and lower risk of catastrophic failures.

Status of the Technology in Dominica

DOWASCO do not currently possess equipment to detect water leaks in the distribution network.

Fact Sheet: Drip irrigation

Definition

Drip irrigation is a method of crop micro irrigation that involves a controlled delivery of water to plants through a system of pipes, valves, tubing and emitters. The water is delivered from a source directly to the root zone of individual plants or to the surface of the soil under particular volume and pressure specifications. The system can maintain adequate levels of soil moisture in the rooting zone, thereby significantly reducing water wastage and promoting efficient use. The system can also be utilized to apply nutrients and chemical directly to the root zone of the plant.

Description

A drip irrigation system typically consists of:

Pumps or pressurized water system

- Filtration system
- Systems control -pressure control valve (pressure control regulator), pressure gauges
- Distribution system -pipes (including main pipe line and drip tubes with emitters)
- Control valves and safety valves
- Poly fittings and accessories (to make connections)

How the Technology Contributes to Climate Change Adaptation

Drip irrigation technology can support farmers to adapt to climate change by making more efficient use of their water supply. This reduction in water volume mitigates additional pumping cost, reduce erosion risk and reduce weed growth. Water use efficiency of a drip irrigation system can be as high as 90%.

Drip irrigation delivers water directly to the root zone of the plant thus reducing evaporative losses and minimizing the impact of wind.

Advantages

- High water application efficiency
- Limits water loss via run-off, deep percolation or evaporation is almost zero.
- Adaptable to most terrains and soil types.
- Adaptable to a wide variety of crops
- It is particularly efficient in sand areas with crops such as vegetables.
- Drip irrigation systems are the best type of irrigation for windy conditions.
- Can support the application of nutrients and other pesticides
- Can be used to irrigate crops with water that contain contaminants that should not be applied directly to the plant

Disadvantages

- Filtration is essential to prevent clogging and so requires higher quality water (physical) leading to generally higher capital cost.
- Emitters are easily clogged by flooding or rain splash.
- Drip lines and equipment are easily damaged by animals and rodents.
- It can be difficult to combine drip irrigation with mechanized production such as tractors, which can damage pipes, tubes and emitters.

- Drip irrigation requires regular maintenance and thus capacity building is required to effect and manage maintenance requirements

Costs and Financial Requirements

The technology is widely variable; however, the cost of a drip irrigation system ranges from US$ 2,000 – US$ 3,500 per acre, based on the specific type of technology.

Status of the Technology in Dominica

There is no unit within the Division of Agriculture directly responsible for the provision or support of irrigation services. Drip irrigation is however widely utilized, mainly in protective agriculture / greenhouse production and limited open field application. It is utilized primarily in vegetable production.

The basic components of the system can be procured locally or readily imported.

Fact Sheet: Slow-forming Terraces / Contour farming -Soil conservation

Definition

A terrace is a levelled surface used in farming to cultivate sloping, hilly or mountainous terrain. They can be used on relatively flat land in cases where soil and climate conditions are conducive to erosion. Some of the functions of Terraces include:

- Decrease the rate of soil erosion;
- Improve the natural conditions for cultural practices and other production functions - Decrease run-off and increase water percolation into soil - Generate positive ecological benefits.

Description

Slow-forming terraces, so called because they take between three and five years (possibly even ten years), to fully develop, are constructed from a combination of infiltration ditches, hedgerows and earth or stone walls. This technology decreases water run-off, increasing water infiltration and intercepting the soil sediment (UNESCO-ROSTLAC, 1997).

Slow-forming terraces can be built where the land is marginally to steeply inclined, and where the soil is sufficiently deep to create a drag effect. This leads to the formation of steps as sediment accumulates due to rainfall and natural gravity. Level ditches are traced and excavated along the contour line of a slope and then an embankment of earth, stones or plants is constructed at given intervals based on the steepness of the slope; the steeper the slope, the closer the intervals. Eroded soil accumulates in these buffer strips every year and terraces slowly form.

Where plants (lower cost option) are utilized to form the terrace, they should be resistant to local conditions, and grow well and fast. Where possible, plants should be used that can provide some alternate benefit such as being feed for livestock or leguminous as so contribute to soil nitrogen content.

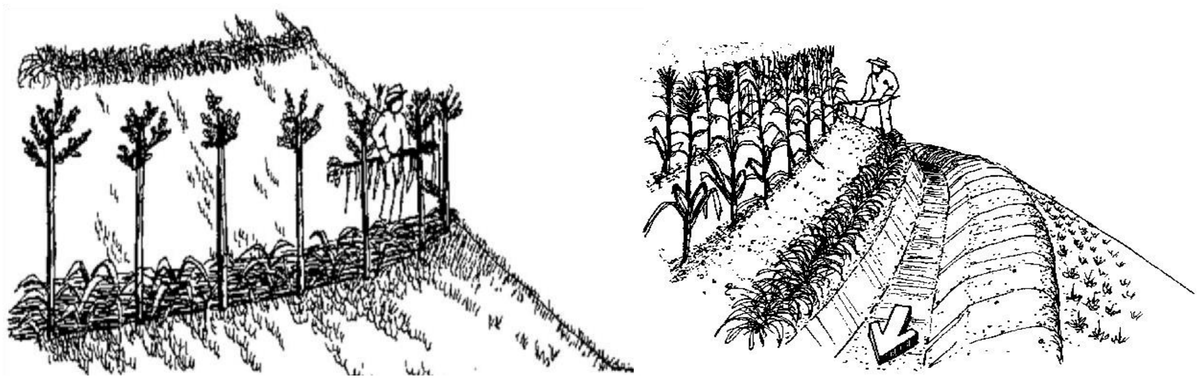


Figure 1: Structure of slow-forming terraces and contour ditches

Lower cost options have been developed that are also effective in trapping sediment and forming terraces but do not require the building of physical structures. One option is the use of contour planted hedgerows (Young 1997), this system has been used on 10,000 hectares of land in the Philippines, Rwanda and Haiti. Double hedges of Leucaena, Gliricidia or similar shrubs are planted 4 to 8 meters apart along the contour. The shrubs are pruned two or three times per year and the leaf and branch material applied to the soil or against the stems of the shrubs, to trap the moving sediment. This leads to the formation of terraces up to 50 cm high in the first two to three years. Another alternative is to use deep rooting grass species such as Vetiver or Panicum bunch grass often used for cut and carry fodder. An even simpler method is to leave natural vegetative strips to when preparing the soil for planting, which gradually form the stabilized edges of terraces (ICRAF, 1996). These different live barrier methods of terracing reduce erosion from half to just 2 percent of the level without the live barriers, and rainfall infiltration is significantly improved.

How the Technology Contributes to Climate Change Adaptation

This technology facilitates adaptation to climate change by optimizing water use. This is particularly relevant in areas that depend on seasonal rainfall for production and where there is uncertainty about future rainfall patterns. Climate variability also affects the soil, since heavy rainfall coupled with poor soil management, give rise to landslides and mudslides. In this respect, slow-formation terraces reduce soil erosion and, consequently, the danger of large landslides occurring.

Advantages of the Technology

- Allow for the development of larger areas of arable land in rugged terrain
- Facilitate modern cropping techniques such as mechanization, irrigation and transportation on sloping land.
- Higher water percolation leading to increasing soil moisture content
- Intercept and capture run-off, which can be diverted through lined channels at a controlled speed to prevent soil erosion.
- Increase soil exposure to the sun
- Replenish the soil and maintain its fertility as the sediments are deposited in each level - Increase organic matter content and preserve biodiversity.
- Increase crop productivity
- Live barriers used in terraces can be pruned and used as fodder for livestock or leguminous species can be minced and re-applied to the soil

Disadvantages of the Technology

- Impact is over a prolong period
- Requires regular maintenance
- Reduction in available land area for cultivation due to the space taken by the ditch and banks, or vegetation strips
- Live barrier terraces can compete with associated crops if not sufficiently maintained

Costs and Financial Requirements

The costliest component of terrace construction is labour which will depend on average local daily wages. The time required to construct a slow-forming terrace will depend on available manpower, the type of soil and the time of year. The basic tools required (such as picks and shovels) usually belong to the farmer and can be used at no extra cost. Once built, annual maintenance costs are minimal (Treacey, 1989). Research indicates that two people can build 7m² of wall in one day. Assuming a common size terrace wall of dimensions 1.8m high and 50m long, two people could restore an entire terrace in two weeks, or build an entirely new one in a slightly longer period of time (Valdivia, 2002).Clements R et al 2011 quoted Yanggen et al, 2003as requiring an initial investment of $350/h was required with $86/h per annum for maintenance for a project in northern Peru.

Institutional and Organizational Requirements

Slow-forming terraces can be implemented at farm-level without specific institutional and organizational arrangements. In terms of social organization, advantage should be taken of communal work ethics and other mutual cooperation systems for faster construction and more efficient maintenance.

Knowledge of terrace design, construction and maintenance, including contouring or levelling techniques as well as knowledge of crops suited to slow-terrace irrigation is required.

Factsheet: Integrated Soil Nutrient Management (ISNM)

Introduction

Also referred TOAS integrated soil fertility management, this technology is intended to promote the efficient use of both synthetic and natural plant nutrient sources to enhance soil fertility towards improving and preserving soil productivity. The success of ISNM relies on the appropriate application and conservation of nutrients and transfer of knowledge to farmers. The technology enables the adaptation of plant nutrient and soil fertility management with in a farming system to site specific characteristics; an important ingredient for climate change adaptation.

Integrated soil fertility management in Dominica, has been widely promoted. There is availability of capacity for effective transfer of the technology to farmers. However, the use of the technology is low compared to use of synthetic nutrient sources.

Description and Institutional requirements

The technology has been endorsed as appropriate for effective management of soil resources for increased and sustainable productivity; necessity for climate change adaptation. It depends largely on locally sourced inputs as raw materials and depends on decomposition, fermentation and distillation process to extract beneficial elements to improve soil fertility.

The technology requires a well-resourced research and extension organization for its effective promotion and use. In addition, there is the need for appropriate extension approaches and methodologies that provides opportunity for farmer experimentation and adoption of technology.

The technology can be promoted using existing research, extension and farmer linkages for technology dissemination. This however needs to be supported by effective capacity building at various levels to support operations at the farmer level

How the Technology Contributes to Climate Change Adaptation

Integrated Soil Nutrient Management is relevant and has provided excellent results in addressing current climate change effects at the field /farmer level, to include moisture deficiency, pest and disease management, etc. Its effectiveness will however be significantly enhanced in combination with other related technologies – soil conservation, improved cultural practices etc. The technology has the potential of increasing the number of farmers and scope of improved yields obtained from their farms.

Disadvantage

A major disadvantage of the technology is the inadequacy of available organic nutrients sources and other critical raw materials required to effect significant change on a commercial scale. Large staging or operation areas are also often required for processing.

Advantages

- Contributes to reduction of vulnerability to climate change through improvements in soil resources and increases in productivity.
- The technology can contribute to generation of employment at the community level sales of transformed organic sources e.g. compost
- Requires low investment in tools and equipment, and training of farmers for transforming organic sources into easily usable forms.
- Reduce public and private expenditures in terms of expenditure on the use of inorganic soil nutrients.

- Could provide a source of extra income for individuals and groups from sales of transformed organic materials into organic soil nutrients e.g. compost.
- Creates opportunity for increased group and individual learning at group and community level.

The technology could provide opportunity for reducing health risks within communities from improved sanitation achieved from processing of waste.

Integrated Soil Nutrient Management will contribute to reduction in the use of inorganic fertilizers hence reduced angers of water pollution from poor handling and overuse of chemical fertilizer.

Cost

The technology will contribute to cost associated with use of soil nutrients on farmers' field. It will however require some level of investment for harvesting, collection, processing, testing and packaging of finish products. Awareness creation, training of technicians and farmers; and product demonstrations will need to be done to ensure ownership. The technology could create a market for organic soil nutrients.

Status of Technology in Dominica

The technology has been developed on a very limited scale. The continued utilization of partially decomposed poultry manure by farmers is an indication of the existing demand for this technology.

FactSheet: Hydroponics and Soilless Crop Production

Introduction

The development of new techniques to improve protected agriculture, particularly the adoption of hydroponics/soilless culture, can contribute to the preservation of the water resource and thus to food security.

Soilless cultivation is intensively used in protected agriculture to improve control over the growing environment and to avoid uncertainties in the water and nutrient status of the soil. It also overcomes the problem of salinity and the accumulation of pests and diseases. This technique offers good yields and quality of products yet, it requires high technical levels and investment costs. To increase its cost effectiveness and its efficiency to cope with climate change, it can be topped up by other adaptation technologies namely Integrated Production and Protection in greenhouses. The technology contributes to climate change adaptation primarily through:

- Addressing food security by improving crop productivity, quality and availability.
- Improving efficiency of water use for food production; saving water.

Description

Soilless culture has two (2) categories, namely:

1. Water culture or liquid non-aggregate hydroponics stems where the nutrient film technique (NFT) is the most common type.
2. The substrate culture or aggregate hydroponic systems (open and closed systems)

Different kinds of inert substrates are used in soilless culture: perlite, sandgravel, vermiculite, rockwool, pozzolana. Organic substrates (peat, peat-based mixtures and sawdust) though used in other locales are not encouraged because they tend to decay quickly within a tropical environment due to microbiological action, and also react chemically with the nutrient solution affecting the frequency with which the Electrical conductivity (EC)[1] and pH[2] of the nutrient solution has to be adjusted.

Components of a hydroponics system include:

Hydroponic soilless system:

- Monitoring equipment: It is a computerized system, which has the duty of controlling, monitoring and distributing the nutrient solution. It is also able to regulate pH and EC according to the required values.
- Fertigation unit: coupled with a pump that allow to carry water from reservoir to tanks (usually made from plastic material) and equipped with screen filters and valves for the micro and macronutrient solutions.
- Injection pumps: controlled by the computer, supplying the proper amount of stock nutrient solution to a mixing tank.
- Nutrient solution mixing tank: where the settled amounts from stock nutrient solution are mixed to get the required value of EC and pH. Then, the irrigation nutrient solution can be distributed to the irrigation system.
- Irrigation unit: Nutritive solution is carried to plants through an irrigation system.
- Benches and troughs: The benches serve as support for the growing media containers or Trough.

[1] Measure of nutrient concentration in solution

[2] Measure of acidity and alkalinity

The operation and maintenance of hydroponics requires specialized knowledge and skills and so specialized training and equipment is required. This form of production predominantly occurs within a protected structure such as greenhouse and is currently being adapted as an indoor response to food security after the passage of cyclones and natural disasters.

Disadvantages

Some of the disadvantages of this technology include:

1. Steep learning curve and so require operators at a given technical skilled level.
2. Substrate cultures do not have buffering capacity similar to that of soil, so any error in fertilization application will most likely be fatal to plants.
3. Higher consumption of energy to maintain the production system.
4. High capital cost.

Advantages

1. Higher productivity and crop quality.
2. Greater efficiency in use of nutrients and water.
3. Well adapted to indoor production thus limits the impacts of external climatic and pest issues allowing better response to market requirements.

How the Technology Contributes to Climate Change Adaptation

This technology promotes greater efficiency in the utilization of production inputs such as water and nutrients, while having the potential to increase productivity per unit area, thus addressing the main pillar of food and nutrition security and resource conservation. The technology also addresses the issue of soil degradation given production occurs in a soilless medium.

Status of Technology in Dominica

This technology is now being introduced at a lower technological input to encourage acceptance. The approach currently being advocated is to allow for human interaction in the monitoring and adjustment of nutrients and pH, and so production systems are relatively small scale.

Annex 2: TECHNOLOGY FACTSHEETS FOR SELECTED MITIGATION TECHNOLOGIES

Fact Sheet: Geothermal Energy

Introduction

Geothermal energy is basically sourcing heat from the earth's core. Water trapped in underground fissures at high temperatures and pressures is extracted via wells and piping where the steam is used to drive turbines to generate electricity. There are many schemes to extract the energy from the fluid, and reinject the water back into the ground to sustain the process. Due to its consistency, stability, and 90%+ availability, geothermal energy is a good base load source.

There are geothermal manifestations all over Dominica. Studies are most advanced in the geothermal field associated with the Morne Micotrin calderon. About 10 square kilometres in the Roseau Valley has a minimum sustainable capacity of 100MW.

How this Technology Contributes to Climate Change Mitigation and Adaptation

Geothermal energy will reduce emissions significantly from fossil fuel generation. Since the extracted steam in the Roseau Valley field is very acidic with hydrogen sulphide, systems can be installed to scrub these pollutants.

Much of the geothermal system consists of subterranean pipes which can be corrosion proof specified. The surface facilities can be made hurricane resilient so the entire production facilities can be adapted to climate change.

What are the Costs and Financial Requirements?

With the exploitable geothermal fields 300km to 500km below the surface with good permeability, the resource can be exploited (or exploration can be done) at a relatively low cost. The low ph of the fluid will require noncorrosive piping.

In the USA where the geothermal fields are over 1000km below the surface, the cost to install a kilowatt of geothermal energy is around US$2500/kilowatt. The levelized cost of a kilowatt-hour of geothermal energy is about US$0.044 cents per kilowatt-hour, the lowest among energy sources. Additionally, the cost of geothermal energy is not influenced by fluctuations in the market like fossil fuels.

The upfront cost to develop geothermal energy is generally very high, but the levelized cost could see geothermal energy being produced at less than US$0.10 per kilowatt-hour, far less than the other options.

Status of the Technology in Dominica

While there are many geothermal manifestations in Dominica, comprehensive studies have only been done in the Morne Micotrin geothermal field in the Roseau Valley. The first plant (7.5MW) is in the works.

Fact Sheet: Hydro Energy

Introduction

Hydropower can be one of the most available and consistent forms of renewable energy on the island. In the land of 365 rivers, water is flowing almost everywhere. Many communities, small businesses, or farmers are within mini, micro, or pico hydropower possibilities. Most of the micro and pico hydropower systems need a turbine, pump, or waterwheel to transform the energy of flowing water into rotational energy, which is converted into electricity through the turbine generator set. The relevant hydro energy systems for Dominica are: the damp type, Run-of-the-River, and kinetic energy systems. Inefficient water wheel systems used in old sugar mills are more historical artifact than for power. The following classifications of hydropower can be applied in the Dominican setting.

Classification of Hydropower

Power	Class
> 10 MW	Large
< 10 MW	Small
< 1 MW	Mini
< 100 kW	Micro
< 5 Kw	Pico

Dam Small Hydro

The electric utility generates about a third of its electricity from small hydropower electricity.There are limited possibilities for other small hydro systems.

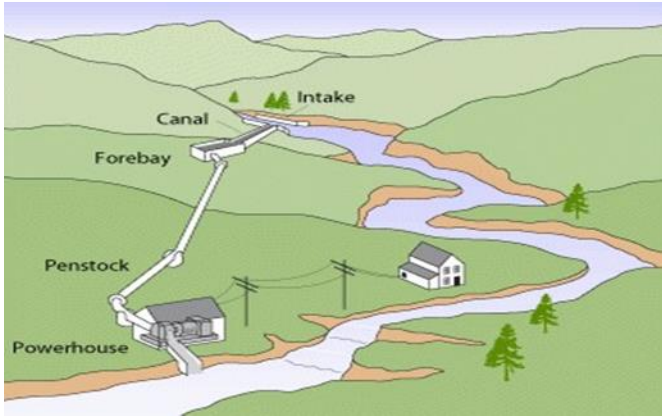
Run of the River Hydro

Run-of-the-river mini and micro-hydropower systems consist of these basic components:

- Water conveyance -- channel, pipeline, or pressurized pipeline (penstock) that delivers the water
- Turbine, pump, or waterwheel -- transforms the energy of flowing water into rotational energy
- Alternator or generator -- transforms the rotational energy into electricity
- Regulator -- controls the generator
- Wiring -- delivers the electricity.
-

There are many locations that are conducive to run-of-the-river mini and micro-hydropower systems. Developing this potential would be consistent to transitioning to a resilient smart distributed grid system.

Fact Sheet: Impulse Turbines



Impulse turbines are most commonly used for high-head micro-hydro systems. They rely on the velocity of water to move the turbine wheel (runner). The most common types of impulse turbines are the Pelton wheel and the Turgo wheel.

- Pelton wheel -- uses the concept of jet force to create energy. Water is funnelled into a pressurized pipeline with a narrow nozzle at one end. The water sprays out of the nozzle in a jet, striking the double-cupped buckets attached to the wheel. The impact of the jet spray on the curved buckets creates a force that rotates the wheel at high efficiency rates of 70–90%. Pelton wheel turbines operate best under low-flow and high-head conditions.
- Turgo impulse wheel – is an upgraded version of the Pelton, which uses the same jet spray concept, but the Turgo jet, is half the size of the Pelton and is angled so that the spray hits three buckets at once, which doubles the speed of rotation.

How this Technology Contributes to Climate Change Mitigation and Adaptation

Beyond the construction phase, hydro energy is essentially t: a zero emissions technology. Water is everywhere. What is required is to determining which hydro system is the most appropriate for a particular location.

What are the Costs and Financial Requirements?

The International Renewable Energy Agency (IRENA) reports that the average investment cost of developing small hydropower plants are US$1,300/kW to US$8,000/kW depending on the location. Even at the higher cost, this translates in a levelized cost of less than a third of current grid electric rates.

Status of the Technology in Dominica

Hydropower has a long history on the island dating back to waterwheels in the sugar colonial days. In recent times, hydropower has provided about a third of the grid electricity on island and a high of over seventy percent 50 years ago. However, mini and micro systems have not been deployed and need to be considered in the way forward.

Fact Sheet: Wind Energy

Introduction

Energy from wind can be harvested using horizontal or vertical axis wind turbines. Wind can also generate propulsion energy via sails on vessels. The use of sails has been around for years and have somewhat disappeared in recent times, replaced by fossil fuel motors. Because of the possibility of hurricane force winds, turbines in the area should either have mechanisms so they can be lowered when high winds are eminent, or be massive enough to withstand hurricane force winds.

Wind energy proportional is to the wind, therefore storage or other means is necessary if energy is needed in periods when the wind is below the minimum threshold. Since wind energy varies with the wind it cannot be used as baseload. Therefore, it must be coupled with a base load system like hydro or geothermal.

How this Technology Contributes to Climate Change Mitigation and Adaptation

Beyond the manufacture and installation of the wind turbines, the operation of the turbine produces zero emissions. Noise, visual, and bird kill are issues with wind turbines. New commercial turbines are reasonable quiet and their slow blade rotation is a relatively low hazard to birds and bats. Visual pollution depends on location and the viewer. Domestic turbines rotate much faster and are generally louder, and may need some wildlife protection.

What are the Costs and Financial Requirements?

The cost to install a kilowatt of commercial wind energy is varies but US$2000 to US$3000 per kilowatt is the expected ballpark; smaller home systems are higher. Turbines need to be serviced periodically.

Status of the Technology in Dominica

Wind turbines are not very prevalent in Dominica. A 200kW unit was installed at Rosalie Bay Resort on the east coast. Also, a small Bergeys unit was installed on a farm in Delices over 15 years ago. A commercial wind study was completed on the east coast in 2004, but the process never graduated to commercial production.

Fact Sheet: Solar Energy

Introduction

Solar energy is energy from the sun. Sun light is transformed either to electricity in photovoltaic (PV) cells, or to heat water in solar thermal units. Solar thermal heats water directly. The water is then stored in insulated tanks to be used as needed.

Electricity can also be generated by "concentrating solar thermal" (CST) generation. This system uses several tilted mirrors to reflect the sun's rays to a collector in a power tower producing water temperatures as high as 1000 °C. The steam is then used to drive turbine generators to produce electricity.

Direct current electricity from photovoltaic cells is stored in batteries and can either be used as direct current electricity or inverted to alternating current electricity. The electricity generated can be used directly at the generating facility, or can be grid tied in an exchange scheme with the grid or other offsite electricity supplier.

Solar energy is limited to useful daylight hours therefore storage or other means are necessary if energy is needed in periods when the sun energy is not available. Because solar electricity varies with transformable sunlight, it cannot be used as baseload; therefore, it must be coupled with a baseload system like hydro or geothermal.

Solar electric systems require a lot of space. Roof space can be used for homes and businesses, but utility solar generation would require large preferably flat or gently undulating fields to install panels or mirrors.

How this Technology Contributes to Climate Change Mitigation and Adaptation

Installed solar systems emit zero greenhouse gases.

What are the Costs and Financial Requirements?

Grid tied units cost about $7/W, while standalone units cost about $14/W installed. ($7000/kW grid tied, and $14,000/kW standalone).
Solar pv useful life is about 20 years if they survive hurricanes.

Status of the Technology in Dominica

Solar water heaters have been around for over 40 years. At one point, most new houses got their hot water from rooftop solar thermal systems. Recently showerhead water heaters have become very prevalent mainly because of the ease of installation. However if consumers were enlightened on the energy guzzling nature of these systems and their impact on their electric bills, many may migrate to solar thermal systems.

Fact Sheet: Optimizing Energy Efficiency from Windows

Introduction

There are various window schemes that improve lighting, air circulation, cross flow and comfort in buildings. Windows placement and design are important elements to optimize ventilation and lighting. Without proper ventilation or natural lighting, occupants revert to sourcing them through artificial means thus consuming avoidable energy. Most older buildings were properly ventilated, but with the advent of "modernity" many discarded the tried and proven for artificially lit and cooled enclosed spaces with grossly inefficient windows.

Basically, there are two types of windows: the hinged type which includes casement windows, awning windows, and hoper windows; and sliding type which includes slider windows and single and double hung windows.

Casement Windows

Casement windows are hinged at the sides and open outward providing significantly better ventilation than sliders of equal size. They are used singly or in pairs within a common frame. Because the sash protrudes from the plane of the wall, it can be controlled to catch passing breezes. Virtually the entire casement window area can be opened and depending on the angle of the sash, blowing breeze can be redirected into the window cavity. Windows hinged at the top are referred to as awning windows, and ones hinged at the bottom are called hoppers. Casement windows are sometimes louvered.

Casement Awning Hopper

Sliding Windows / Slider Windows

Slider windows sash slides up and down or side to side. Both sashes slide horizontally in a double-sliding window. Only one sash slides in a single-sliding window. Both sashes slide horizontally in a double sliding window. Only one sash slides in a single-sliding window. Ventilation area can vary from a small crack to an opening of one-half the total window area. Sliding windows inhibit at least 50% of the ventilation area therefore should not be the preferred option where natural ventilation is desired. Additionally, if air conditioning is anticipated, horizontally sliding windows generally have higher air leakage rates than projecting or hinged windows.

Single and Double Hung Slider

Dormer and Gable Windows can be used in Gable and A frame roofs.

How this Technology Contributes to Climate Change Mitigation and Adaptation

The use of tropical region appropriate windows significantly reduces the need for artificial cooling and the use of artificial lighting in daylight hours.

What are the Costs and Financial Requirements?

The population should be encouraged to install energy efficient windows in their new buildings. The cost to install energy efficient windows in buildings under construction is the same as inefficient alternatives, and savings will accrue as soon as the building is occupied.

In existing buildings, owners can either replace windows when replacement is due, or make the upgrades if energy savings would result in payoff within an acceptable time.

Status of the Technology in Dominica

No new training is necessary; these windows have been around for centuries. All that is necessary is that the population recognize the error in their ways and revert to tradition with the new hinges and installation schemes/systems that have since become commonplace.

Fact Sheet: Green Roofs

Introduction

A green roof is a vegetated roof that stores rainwater in a soil medium that provides a layer of insulation which reduces solar heating. The basic roof is shielded from ultraviolet light and thermal stress. Green roofs reduce peak discharge rates by retaining runoff and creating longer flow paths thus reducing storm water runoff.

How this Technology Contributes to Climate Change Mitigation and Adaptation

Green roofs (vegetation, soil, and protective membranes) shield roofs from the sun's rays and the associated elevated temperature. This in turn reduces the need for artificial cooling and its associated energy requirements within the floor directly beneath the roof. Hence, the dispensation of energy to cancel this heat is avoided whilst the space immediately below the roof is kept tolerable.

A generous deployment of green roofs within built-up areas also reduces urban "*heat island*" effect. This in turn reduces the need for artificial cooling in buildings and urban traffic.

What are the Costs and Financial Requirements?

The cost of installing a green roof is around EC$30 to EC$50 per square foot depending on the site's specifications. There is also a maintenance cost especially for large businesses and commercial premises.

Some roofs and/or buildings may require some structural engineering strengthening to accommodate the added weight especially when the soil is saturated with water.

Status of the Technology in Dominica

Green roofs are not part of the Dominican landscape. In fact, many concrete buildings can be seen with exposed concrete roof absorbing sunlight and transforming the space immediately below them into infernos sometimes persisting well past midnight. These unbearable spaces must be cooled be artificial means thus expending avoidable energy.

Fact Sheet: Ground Source Heat Pumps (Geo-Exchange™)

Introduction

Ground Source Heat Pumps, also referred to as Geo Exchange, earth-coupled, geothermal, or water source heat pumps, are basically space heating or cooling systems which use heat exchangers to import or export heat from the space to or from the earth or nearby pond.

In Dominica's tropical location, Ground Source Heat Pumps would extract heat from buildings and reject the heat to the ground through heat exchanger(s).The operating principle is based on the earth's temperature of about 65 degrees Fahrenheit (18 degrees Centigrade or Celsius) 6 feet below the ground. This can be accomplished by burying pipes with coolant liquid about 6 feet horizontally, 150 to 450 feet vertically, or immersing the pipes in an adjacent/nearby body of water. Minimal power is needed to circulate the coolant through the pipes and heat exchanger. This power can be sourced from the household power supply or from a dedicated renewable energy source.

How this Technology Contributes to Climate Change Mitigation

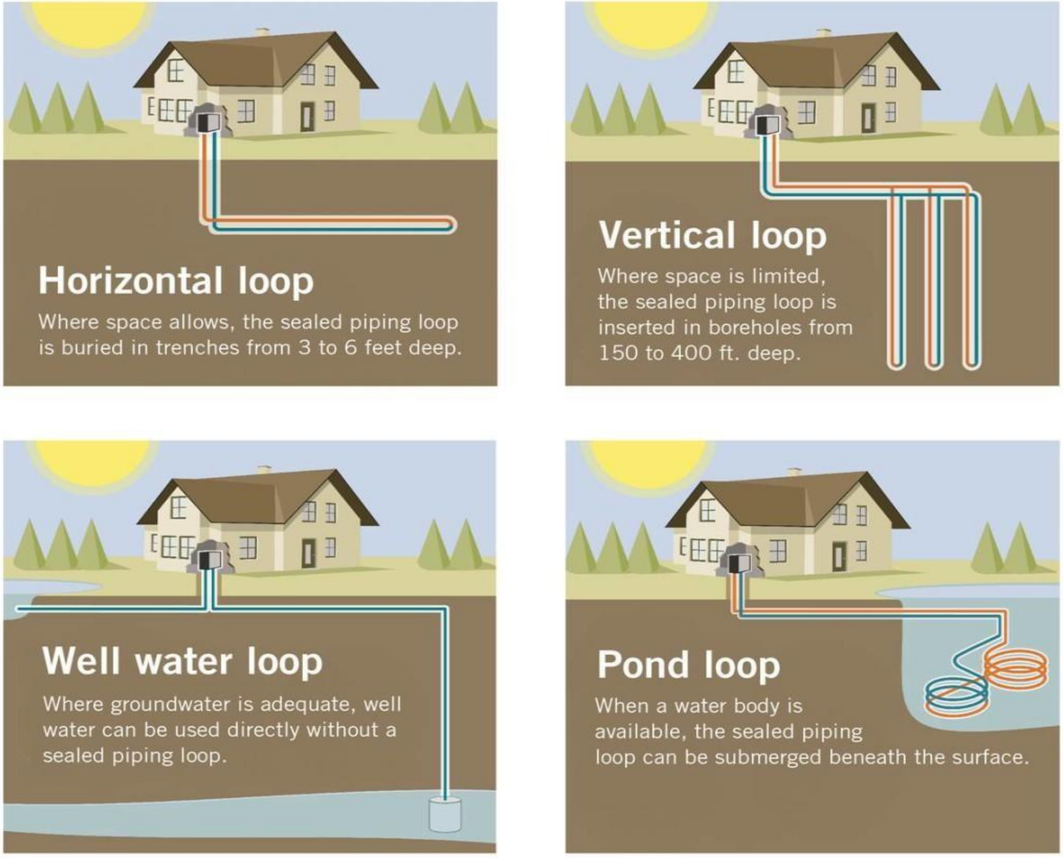
The use of geothermal heat pumps will reduce the need for traditional air condition systems and the associated power consumption. Any reduction in the need for power would reduce the need for fossil fuel energy or installation of renewable energy systems, both of which have associated carbon footprint.

What are the Costs and Financial Requirements?

The cost of installation is about EC$6,750 per ton (US$2,500 per ton).A 3-bedroom house would need 2 tons (24,000 BTU) to 4 tons (48,000 BTU) depending on the comfort tolerance of its occupants.

Status of the technology in Dominica

The technology has never been installed in Dominica but all the elements of the technology are already available on the island. With some training, this technology can easily be implemented in new or existing buildings with sufficient adjoining space.


Horizontal loop
Where space allows, the sealed piping loop
is buried in trenches from 3 to 6 feet deep.
Vertical loop
Where space is limited,
the sealed piping loop is
inserted in boreholes from
150 to 400 ft. deep.
Well water loop
Where groundwater is adequate, well
water can be used directly without a
sealed piping loop.
Pond loop
When a water body is
available, the sealed piping
loop can be submerged beneath the surface.

Fact Sheet: Urban Heat Island Effect

Introduction

Urban heat island effect is the phenomenon where, due to human activities, an urban area is discernibly warmer than its surrounding countryside. The elevate temperature often impairs comfort thus requiring artificial cooling to achieve an acceptable comfort level.

Causes of Urban Heat Island

Urban heat islands are caused by paved and impermeable surfaces, thermal mass, and dark surfaces exposed to the sun rays. Waste heat from vehicles engines and exhaust, air conditioners, and commercial and industrial operations adds to the elevated temperature. This is further exasperated by the lack of vegetation which provides shade and helps cool the area through evapotranspiration and evaporation. Additionally, tall buildings and narrow streets nested without due consideration to air flow hinder the circulation of air, reduce wind speed, and thus reduce natural cooling.

Strategies and Technologies to Reducing Urban Heat Island

Urban Heat Islands can be abated by:

- Installing green and cool roofs on buildings;
- Painting buildings and other structures in light reflective colours;
- Using coatings or materials on streets, sidewalks, and parking lots which remain cooler than conventional pavements;
- Increase trees and vegetation cover;
- Maintain efficient traffic flow which emphasizes energy efficiency;
- Maintain wind corridors and avoid construction which will hinder free flow of air;
- Smart growth which considers the environment, climate change adaptation, and quality of life in every action taken in the urban area.

How this Technology Contributes to Climate Change Mitigation and Adaptation

Abating urban heat island effect essentially combines a number of mitigation and adaptation technologies. It fosters a wholesome approach to many mitigation technologies in urban areas and suggests a combination of adaptation measures to combat them.

What are the Costs and Financial Requirements?

The cost to implement mitigation and adaptation measures is essential zero if it is incorporated at the design stage. For existing structures, the upfront cost depends on the particular measure, but over time these measures are cost effective.

Status of the Technology in Dominica

Urban heat island effect is a new concept in Dominica and needs to be incorporated in the various design codes.

Fact Sheet: Fuel Cell Vehicles

Introduction

Hydrogen fuel cell vehicles (FCV) are vehicles whose power comes from hydrogen fuel cells. The Hydrogen fuel cell powers an electric motor which propels the vehicle. This vehicle does not use the traditional fossil fuel combustion engine. The fuel cells, driven by a battery, convert chemical energy directly into electrical energy. Hydrogen fuel cells vehicles exhaust water.

Fuel cell vehicles are very low GHG emitters. However the amount of GHGs they emit is a function of the source from which the hydrogen is produced. If their hydrogen is produced by a non-renewable energy source then their GHG emission is relatively high compared to if their hydrogen is produced from a renewable energy source.

Because fuel cell vehicles still constitute a small percentage of the vehicles' market, their full production economies of scale have not yet been realized.

Because of the additional components in fuel cell vehicles relative to electric vehicles, some industry analysts believe fuels cell vehicles may be better suited for long-distance heavy-duty vehicles like 18-wheeler trucks, trains, ships, and planes.

How this Technology Contributes to Climate Change Mitigation

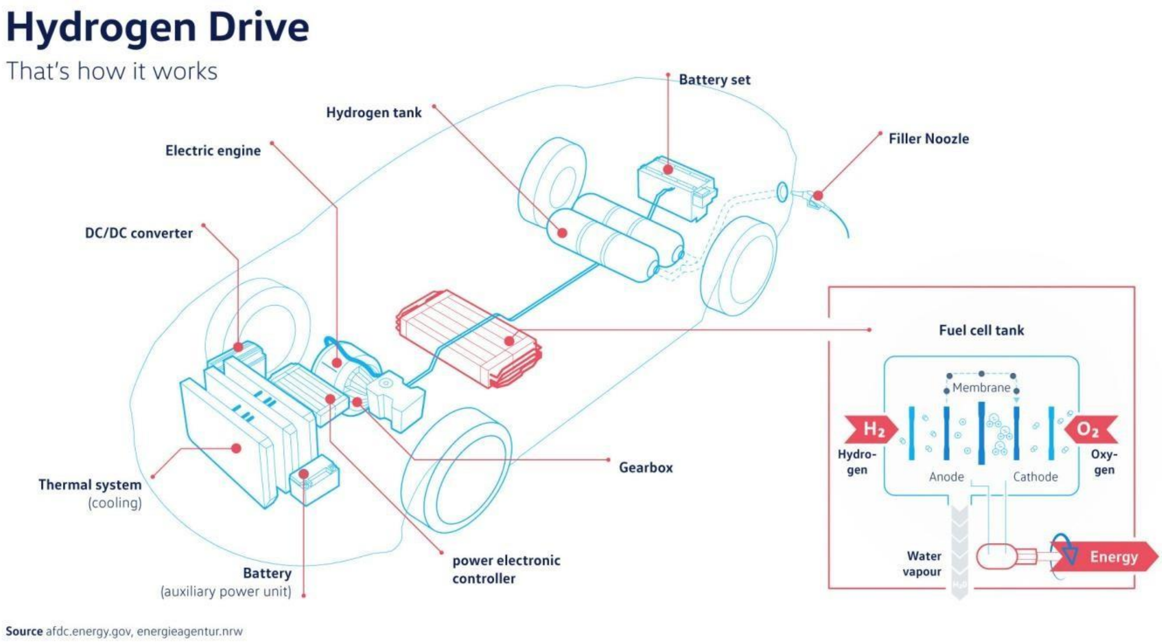
A fuel cells vehicle, whose hydrogen is derived from a renewable energy source, operational emission is essential the emission of the hydrogen production source and the overall emission incurred during the vehicle's production. This is significantly lower emissions than combustion engine vehicles.

What are the Costs and Financial Requirements

The prices of new fuel cells vehicles are relatively higher than equivalent fossil fuel combustion engine vehicles. They are also higher than battery electric vehicles because fuel cell vehicles carry two additional components relative to battery electric vehicles; hydrogen storage tanks, and the fuel cells. Also the production economies of scale of fuel cells vehicles are still relatively low. The higher cost can be alleviated a bit if the importation taxes on fuel cells vehicles were adjusted downwards to counter the initial higher purchasing price.

Status of the technology in Dominica

Fuel cells vehicles are not part of the transportation mix in Dominica. Most people have never seen a fuel-cell vehicle or understand its virtues.


Hydrogen Drive
That's how it works
Battery set
Hydrogen tank
Filler Noozle
Electric engine
DC/DC converter
Fuel cell tank
Membrane
H2
Hydro-
gen
Anode
Cathode
O2
Oxy-
gen
Gearbox
Thermal system
(cooling)
Battery
(auxiliary power unit)
power electronic
controller
Water
vapour
Energy
Source afdc.energy.gov, energieagentur.nrw

Fact Sheet: Electric Vehicles

Introduction

Battery electric vehicles (BEV) are vehicles whose power comes from an electric source like a battery, and the prime mover is an electric motor. This vehicle does not use the traditional fossil fuel combustion engine.

Electric vehicles themselves are very low GHG emitters. Their GHG emissions come mainly from the vehicle's manufacture and from the periodic replacement of the battery, whose current life is in the five years range. However the amount of operational GHGs they emitter is a function of the source from which the battery is charged. If the charging station is powered by a non-renewable energy source then the GHG emission is relatively high compared to if the battery is charged from a renewable energy source.

The power per pound of battery, a battery's energy density, is a critical element influencing the higher cost of electric vehicles. As batteries' energy density increases, there will be a corresponding drop in the price of electric vehicles. A battery with high energy density is inherently cheaper because it requires fewer raw materials and less weight to deliver the same range. The projected tipping point for price parity between electric vehicles and combustion engine vehicles ranges from 2023 to 2025.Actually, price parity is already here for high-end vehicles.

Because electric vehicles still constitute a small percentage of the vehicles' market, their full production economies of scale have not yet been realized, yet according to James Tate and colleagues who conducted the research published in the journal Applied Energy at the University of Leeds, UK, a comparable sized electric vehicle powered by moderately priced electricity is cheaper to own and operate over a four year period than a comparable combustion engine vehicle.

How this Technology Contributes to Climate Change Mitigation

An electric vehicle charged from a renewable energy source operational emission is essential the emission of the charging source, and the overall emission incurred during the vehicle's and battery's production. This is significantly lower emissions than combustion engine vehicles.

What are the Costs and Financial Requirements

The prices of new electric vehicles are relatively higher than equivalent fossil fuel combustion engine vehicles. This is a function of the price of the battery and the production economies of scale of the two types of vehicles as electric vehicles sales are still relatively low and still ramping up on the production lines. Lithium batteries are also still relatively expensive. The higher new vehicle cost can be alleviated a bit if the importation taxes on electric vehicles were adjusted downwards to counter the initial higher purchasing price. As electricity is cheaper per mile than gasoline, running cost of electric vehicles are lower.

Status of the technology in Dominica

Electric vehicles are not part of the transportation mix in Dominica. The electric utility imported an electric vehicle years ago, but most people have never seen an electric vehicle or understand its virtues. Because most vehicles daily mileage is way less than 150 miles, electric vehicles can ply Dominica roads on a single full charge. For the few buses and vehicles with longer daily mileages, rapid charging stations can be installed at designated areas and bus stops.

<u>Fact Sheet: Walking and Cycling</u> (Sidewalks, Cycling Lanes and no drive areas)

Introduction

Walking and cycling is a means of getting from point A to point B if the points are passable and relatively close. For some reason or another, these ancient means of getting around seems to have given way to motorize transportation for those with motorized means. To facilitate walking and cycling, dedicated sidewalks should be provided for pedestrians and joggers, while dedicate bike lanes provided for bikers.

How this Technology Contributes to Climate Change Mitigation

Walking and cycling contributes to the significant reduction and sometimes the complete avoidance of emissions that impact climate change. It can be argued that individuals involved in cycling will have higher respiration rates and as such will release more Carbon dioxide, than those who sit and ride.

The increase need for improved sidewalks and dedicated bike lanes to encourage these activities will lead to an increase in emissions in the initial stages of implementation as the sidewalks are improved and the bike lanes are constructed. There is expected to be a net overall decrease in emissions with time.

The opportunity also exists for the creation of no drive or restricted access areas within the urban centres to encourage greater use of these technologies through increase safety.

What are the Costs and Financial Requirements

The cost of walking is zero, and it helps maintain a healthy mind and body. Adequate sidewalks and no drive areas are needed to facilitate unimpeded walking.

Cycling requires bicycles and wherever possible dedicated bike lanes.

Status of the technology in Dominica

Walking and cycling is often pushed to the fringes of mobility by many who belongs to the relatively well to do. Often walking or cycling is much faster than motorized transportation, but for some, walking has become an indicator of lessor means.

The relatively narrow roads throughout the island suggest a heighten level of coexistence. Future roads upgrade and new roads construction should consider bike lanes and better pedestrian access ways. The planning upgrade within the city centres should also consider the creation of no drive zones.

A lot of more walking and cycling could be done, but for various reasons many people would rather drive when walking is just as fast. Further, drivers' allowance and due care and attention for cyclists and pedestrians must improve to increase confidence that these can be accomplished safely. The relatively narrow roads throughout the island suggest a heighten level of coexistence. Future designs and upgrades should consider bike lanes and better pedestrian access ways. There must also be incentives by the traffic department and local government to encourage carpooling and ride sharing.