United Nations
Framework Convention on
Climate Change

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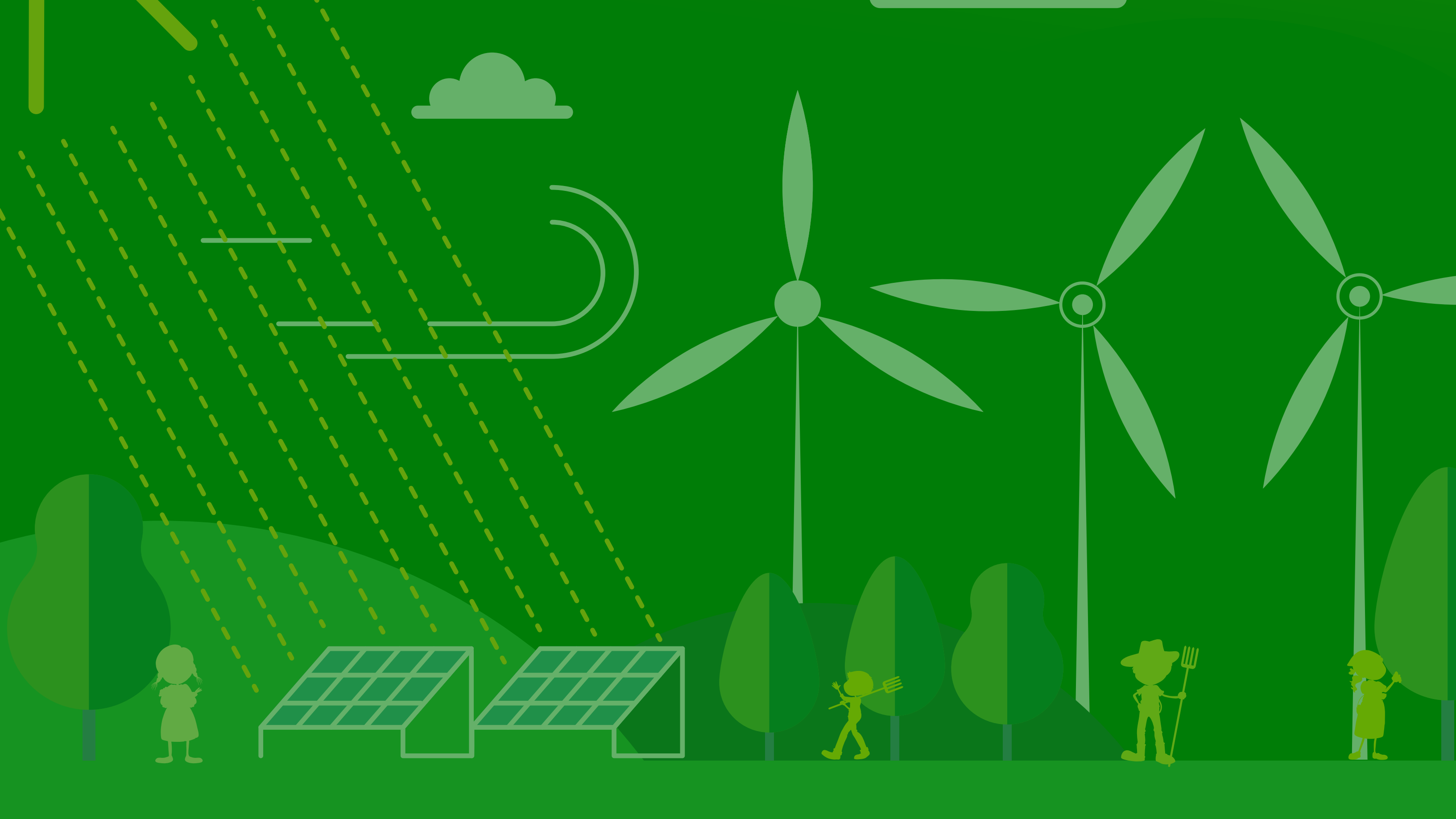
THIRD NATIONAL COMMUNICATION OF JAMAICA

to the

UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE



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prepared for the

Ministry of Economic Growth & Job Creation, Climate Change Division

MINISTRY OF ECONOMIC GROWTH AND JOB CREATION

FOREWORD

Climate change is recognized as a major threat that could affect Jamaica's strategy for growth and job creation. The impacts of climate change includes increased temperatures, changes in rainfall pattern with projections of less rainfall amounts, increases in the number of very intense hurricanes and more severe weather events such as drought and floods. This if not addressed, could severely impact the overall environment and also critical sectors such as water resources, human health, tourism, agriculture, coastal and marine resources and coastal communities.

The preparation of Jamaica's Third National Communication allows us to meet our reporting requirement as a Party to the United Nations Framework Convention on Climate Change and the Paris Agreement. It also allows us to communicate to the world on the actions that we have implemented so far as well as those that we intend to implement in the future as we respond to climate change by building greater resilience to minimise and cope with the projected impacts.

It reports on our emissions of Greenhouse Gases and those actions that are available to us to reduce those emissions even though our carbon footprint is considered as small within the global scale.

The Government of Jamaica expresses its gratitude to the Global Environment Facility and the United Nations Development Programme for their support in the preparation of this document.

Honourable Daryl Vaz,
Minister without Portfolio in the Ministry of Economic Growth and Job Creation

EXECUTIVE SUMMARY

1.0 Introduction & Background

Jamaica is a Small Island Developing State and highly dependent on natural resources. Its geographical location and biophysical landscape make it vulnerable to climate change impacts especially along coastal sectors and livelihood activities.

Jamaica has been a party to the United Nations Framework Convention on Climate Change (UNFCCC) since 1995. This requires the provision of timely updates on its actions to respond to climate change. This Third National Communication (TNC) provides an update on national circumstances contained in the Second National Communication and new information that has become available. It covers the time span of 2006 – 2012 and more recent information where possible.

Jamaica has experienced several storms and hurricanes in the past decade with severe flooding damage, loss of lives, and destruction of goods and services to the amount of $ 129 billion USD (State of the Climate 2012 Report). The impacts of increasing climatic events such as tropical hurricanes and associated peaks of strong winds have profound consequences on agricultural production, food security, and local livelihoods. It has been recognised that there is a strong interaction between climatic episodes such as increasing sea surface temperatures and hurricane intensities (Peterson et al. 2002), which has implications for natural resource sectors such as fisheries. For instance, El Niño events do influence hurricane activities and impacts both agriculture and fisheries sectors (Tataglione et al. 2003).

2.0 Third National Communication

The TNC also outlines Jamaica's inventory of its Greenhouse Gas (GHG) emissions for a similar period of 2006 – 2012. The "National System" is a term used to describe the overarching framework for the emissions inventory compilation. It includes not just the emission calculations, but also all other activities associated with, and supports, the emissions calculations.

For example the national system includes the assessment and planning of the following:

- Data provision/collection;
- Roles and responsibilities of all inventory team members,
- Quality assurance and quality control processes used throughout the inventory,
- Management of the different inventory processes and
- An inventory improvement programme.

The TNC also includes the results of five assessments for determining the island's vulnerability to the impacts of climate change. They were done for the priority sectors of coastal resources, tourism, agriculture, human health, and water.

The preparation of the TNC initially started under the Ministry of Water, Land, Environment and Climate Change (MWLECC) during the former administration. It was completed under the Ministry of Economic Growth and Job Creation (MEGJC) established by the current administration. The Climate Change Division is responsible for its preparation and submission to the United Nations Framework Convention on Climate Change after approval by the Cabinet of Jamaica.

3.0 National Circumstances

This Chapter gives an overview of Jamaica's National Circumstances and identifies some of updates in information since the Second National Communication. It assesses the sectors most vulnerable to climate impacts and makes recommendations for adapting to and mitigating climate change.

FOOD PRODUCTION - The agricultural sector currently contributes about 7% to the country' Gross Domestic Product (GDP) and employs close to 18% of the labour workforce (World Bank 2013).

Major export commodities include sugar, banana, coffee, and cocoa. Other local produce are important for the domestic food market, primarily vegetables, cassava, poultry, and livestock.

Similarly, the fisheries sector that also contributes to local seafood security, has been an important protein source, and is well integrated with tourism livelihoods in some regions. Fisheries also contribute tremendously to foreign earnings, for example, total seafood export was estimated at $11 million USD in 2013, up from US$8.93 million in 2012 (ref).

FISHERIES AND AGRICULTURE – They account for the majority of rural livelihoods. Compared to the 1940s when the agriculture sector contributed significantly to labor markets (about 45%) with GDP amounting to 28% in 1943, the 2000s have seen a gradual decrease in both employment and GDP, with GDP inputs amounting to only 7% in 2012 (Planning Institute if Jamaica, 2013: Government of Jamaica, 2013).

AGRICULTURE'S CONTRIBUTION TO GDP – This has fluctuated in the past few decades from 6.7% in 1991 to 5.8% in 2010 and reaching its nadir in 2008 (at 4.8%). However, recent production increase in the sector was observed through government's interventions in the agricultural industry from 2009 to 2011 but was cut short by extreme events and climate disasters.

LITERACY RATE - Jamaica has a relatively high literacy rate, which has improved from 86% in 2007 to 91% in 2012. This is a result of the premium investment that the Government has made in the education sector.

FERTILITY RATE - Data from the 2012 Economic and Social Survey showed that there has been no change in the birth rate from the last reporting period (2006). There are 17 births per 1000 population in the 15-49 age group. This is considered low in many quarters.

MORTALITY RATE - The 2012 Economic and Social Survey revealed Jamaica's death rate as 5.7 per 1000 population. This has not changed since 2006.

HEALTH – The latest data on health as provided by the Jamaica Survey of Living Conditions 2012 showed that 84.7% of Jamaicans were reported as having generally good or very good health although there was an increase in admissions and length of stay in hospitals. There was also a decline in the number of discharges. Climate change, however, is a threat to the population's health with increasing temperatures, humidity and dust being linked to an increase in hospital admissions for respiratory related illnesses like asthma and bronchitis[1].

POVERTY - A steady increase has been noted in all regions of Jamaica. In 2011, it was noted that 17.5 % of Jamaica's population were living below the poverty line, up from 9.9% in 2007. During 2012, the Kingston Metropolitan Area had its highest rate of poverty for the six year reporting period from 2006-2012. The 2012 Jamaica Survey of Living Conditions

1 *Bailey, W., Chen, A.A., and Taylor, M.A. , 2009, Review of Health Effects of Climate Variability and Climate Change in the Caribbean, Climate Studies Group, Mona, University of the West Indies, Mona in association with the Caribbean Environment and Health Institute for the Mainstreaming Adaptation to Climate Change Project of the Caribbean Community Climate Change Centre (CCCCC), 2nd Floor Lawrence Nicholas Building Bliss Parade, P.O. Box 536, Belmopan City, Belize, 85 p.*

identified the international economic recession as the main cause for this increase in poverty. Rural areas are consistently the poorest.

FEMALE HEADED HOUSEHOLDS - Poverty is especially acute among female headed households, which account for approximately half the households in Jamaica (Table 4.13). These are the most economically burdened with their households, having the most elderly people and young children. Data from the 2006 Socioeconomic study - Vulnerability to Dengue Fever showed that 66% of these households live in poverty.

LIFE EXPECTANCY - The Life Expectancy figure of 72.7 years generally remained the same for the Jamaican population, during the 2006-2012 reporting period (Jamaica's Survey of Living Conditions 2012)[2]. However, the Jamaican female life expectancy is reported at 78 versus 73 years, respectively (World Bank Statistics). Even though Jamaicans are living longer, much of the demographic of elderly people (60 years and older), who represent 10.6% of the population, currently lives in poverty[3].

ELECTRICITY - According to the 2012 Jamaica Survey of Living Conditions, 92% of Jamaican households are powered by the Jamaica Public Service Company. However, 4.3% of Jamaican households rely on kerosene oil as a lighting source. This is a significant improvement from 7.1% in 2006.

LOCAL ACCESS TO WATER - In 2011, about half of households in Jamaica had access to water that was piped into their dwellings (Table 1)[4]. Others relied on water harvesting (catchment), water piped in the yard or water accessible from standpipes. The rest had to 'carry water' from another source.

Table 1: Number of Households by source of water for domestic use (All of Jamaica: 881,089 households)

Source of water for domestic use	# of households
Piped into dwelling	438,014
Piped into yard	145,269
Access to standpipe	62,161
Catchment	19,348

Source: Jamaica's 2011 Census of Population and Housing

FORESTRY - One of the areas that it looks at is Jamaica's Forests. The Forestry Department has done several updates since the publication of the first and second national communications to the UNFCCC. One such updated assessment is the "Land Use Cover Assessment: A Comprehensive Assessment of Forest Change between 1998 and 2013" for Jamaica, which was carried out in 2012-2013 by the Forestry Department, supported by the European Union under the Climate Change Adaptation and Disaster Risk Reduction Project. It shows that there has been an increase in the land area classified as forest (from 30% to 40%). It also shows more defined estimates of forest composition and changes in forest classification systems.

Jamaica's forest cover is broken down into:

1. Limestone forests:
2. Shale forests:
3. Lowland dry forests:
4. Wetland forests (includes mangroves and other swamp forests).

WATERSHEDS - The Ecological importance of Jamaica's Watersheds are also noted. Watersheds arise mainly from the central ridge that runs across the island and include some of the island's best preserved forests, such as the Cockpit Country and Blue Mountains. Jamaica gets much of its freshwater supply from these areas through a system of above ground and underground rivers and streams, with Cockpit country being the source of approximately 40% of that supply.

Jamaica's watersheds are managed by 26 Watershed Management Units (WMUs) ranging in size from 46.6 Km^2 (South Negril–Orange River) to 1,638.8 Km^2 (Black River) that are located in 10 hydrological basins. There is a high density of endemic plants and animals within these forests, meaning these species are native to nowhere else in the world. The island is known to be home to 925 endemic species of vascular plants, seven endemic mammals, 31 endemic birds, 21 endemic frogs, 38 endemic reptiles, and many species of arthropods.

ENDEMIC SPECIES - A number of these species are, however, at risk of extinction. Currently, the endemic Jamaican species classified by the International Union for the Conservation of Nature (IUCN) Red List as vulnerable to critically endangered include 3 mammals, 21 birds, 2 reptiles, 2 amphibians and 3 plants. Among them are the Jamaican iguana (Cyclura collei) and the Jamaican coney (Geocapromys brownii), which both survive in mountainous, karst limestone forests.

THE CURRENT STATE OF JAMAICA'S FORESTS AND WATERSHEDS

Though there has been an increase in estimated forested area from 30% to 40% since previous assessments, it is due to improvements in satellite technology and not due to reforestation. There has been a slight gain in reforestation of 620 ha between 1998 and 2013. This is largely the result of an increase in secondary forest and has occurred despite a loss in forest quality. Secondary forest was recently introduced as a new, independent

2 *Jamaica Survey of Living Conditions,2012, A Joint Publication of the Planning Institute of Jamaica and the Statistical Institute of Jamaica, 16 Oxford Road, Kingston 5, and 7 Cecelio Avenue, Kingston 10, Jamaica, West Indies*

3 *Economic and Social Survey Jamaica, 2006, Published by the Statistical Institute of Jamaica, 16 Oxford Road, Kingston 5, Jamaica, West Indies*

4 *Statistical Institute of Jamaica, 2011, Jamaica's 2011 Census of Population and Housing Jamaica. Published by the Statistical Institute of Jamaica, 7 Cecelio Avenue, Kingston 10, Jamaica, West Indies*

classification, in which case more than 25% of total forest area has been disturbed.

Coastal zone boundary management should be a priority for Jamaica, since more than 70% of all major industries are located within the coastal zone and approximately 82% of the population live within 5 km of the coast[5]. The country is faced with the considerable challenge of reducing the island's vulnerability, while improving its low adaptive capacity to climate change.

Some of the issues identified can be address through Jamaica's development plans and orders to guide sustainable land use developments across the island. Several confirmed Development Orders were promulgated in the 2015/16 financial year and work will continue on the finalization of others.

CORAL REEFS - As of 2011, National Environment and Planning Authority (NEPA) has been monitoring 32 coral reef sites. According to the health assessment conducted by NEPA in 2011 and compiled in the report "Coral Reefs of Jamaica – An Evaluation of Ecosystem Health"[6] Jamaica's overall reef health is poor. Of the 23 sites assessed in nine coastal marine areas, six were found to be in critical condition and only one was considered to be in fair condition. As with forested areas, a major challenge to the health of coral reefs is the lack of efficient management systems to ensure sustainability and recovery[7].

At the end of its overall analysis, chapter one provides an assessment of measures to be put in place to address the issue identified.

A sample of the Assessments are:

1. Adequate policies and action plans have been put in place, but more has to be done in implementation. For this, more manpower is needed in the Climate Change Division, and greater cooperation and collaboration are needed among ministries and agencies.

2. Public Awareness - The CCD has learnt many lessons from its efforts. One startling lesson is the fact that, although 65% of the Jamaican population knows about climate change, not enough individuals know what to do about it.
   - The foremost awareness gap to be filled is lack of knowledge in the political directorate. There is a need to develop ways to engage the political directorate more in the climate change discussion. Personnel at every level must be sensitized to climate change, e.g. current programmes aimed at cabinet sensitisation to climate change, permanent secretaries, etc.

3. Jamaica needs to have in place Sector Strategies and Action Plans that will provide details on policies, initiatives and programmes to be put in place in each sector for climate resilience. [12 sectors are involved in this process and are currently working on such plans. Financial restrictions may force this exercise to spread over 2 to 3 years, which may also happen because of limited staff.

4. For renewable energy to supply 100% of Jamaica's energy needs, energy storage is necessary. To achieve this, some sort of Global Apollo Programme[8], which calls for a major global science and economics research programme to make carbon-free base-load electricity less costly than electricity from coal by the year 2025, is needed.

4.0 Greenhouse Gas Inventory

This chapter provides an update on Jamaica's Green House Gas inventory and its collection. The emissions inventory data was done for 2006-2012. However, data was also collected for the earlier years of 2000-2005 as far as resources allowed (as well as 2013), and emission estimates were calculated. This was done in an attempt to generate a longer time series to better illustrate emission trends. However, the data that was obtained for these earlier years were not of the same standard and so significantly restricts the uses of the data in these earlier years. So throughout this report, the years 2006-2012 are presented.

The limited data from years before 2006 also meant that it was not possible to undertake a detailed comparison with the GHG emissions inventory for Jamaica reported in the Second National Communication (2NC) covering the years 2000 – 2005 (Final Report Jamaica's Greenhouse Gas Emissions Inventory 2000 to 2005, Davis et al 2008). Comparing the different versions of the inventory provides a valuable quality check, highlighting and significant revisions to the emission estimates that arise either from improved input data or the use of more detailed emission estimation methodologies.

Possibly the most technical chapter in the TNC, it explores several ways of calculating GHG – including the 2006 IPCC guidelines as well as the Land Use, Land Use Change and Forestry (LULUCF). It gives details GHG emissions for several sectors including the Agriculture and Transportation sectors.

5 Government of Jamaica, 2015. Climate Change Policy Framework.
6 NEPA. 2011. Coral Reefs of Jamaica – An Evaluation of Ecosystem Health: 2011. National Environment and Planning Agency. Kingston, Jamaica.
7 NEPA. 2014. An Evaluation of Ecosystem Health: 2013- A Report Card for Reefs. National Environment and Planning Agency. Kingston, Jamaica.
8 http://cep.lse.ac.uk/pubs/download/special/Global_Apollo_Programme_Report.pdf

Table 2: Summary of Greenhouse Gas Emissions

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

The trend of the total emission is downwards and is dominated by reductions in CO2 emissions with time (see follow up figure in chapter two). Emissions N2O vary across the time series - this is a result of significant year-to-year variations in livestock numbers, with numbers being noticeably lower in 2006 and 2011.

Emission trends are considered in more detail, on a pollutant by pollutant basis, throughout the chapters and show that the reduced fuel consumption in the mining/bauxite industrial sector is the dominant component in determining the changes in emissions of CO2 across the time series, which, in turn, dominates the changes across the time series of total GHG emissions.

5.0 Adapting to Climate Change

This looks mainly at the measures that need to be taken to ensure that Jamaica adapts to climate change. It explores taking a holistic and integrated approach is necessary for dealing with multiple economic sectors and agencies based on the cross-cutting nature of climate change. During this chapter there is some focus on sectoral adaptation, which it says, calls for an assessment of the current state of knowledge on the risks and challenges posed by climate change as well as adaptive decision-making frameworks to cope and be resilient. Knowing that there are data availability and reliability concerns, in addition to temporal and spatial scale mismatches, various approaches have been suggested depending on specific contexts.

It highlights the shift from impact and vulnerability assessments to vulnerability and adaptation (V&A) assessment, in addition to vulnerability and capacity assessment especially in developing countries with limited scientific and technical competencies. This is the context under which various governments and NGOs have developed tools and bilateral cooperation under the Cancun Adaptation Framework to assist countries in need to develop and finalised their National Adaptation Plans and their National Communications.

This Chapter uses several case study methodologies to look at climate adaptation including:

5. **Blue Mountain Coffee Production in Cedar Valley in St Thomas and the impact of CC on its Coffee Production.**

   In summary it suggested that climate variability has ramifications on coffee production in Cedar Valley communities. These impacts will be pronounced in the future as temperature projections increase with a new norm of frequent storms and droughts. Thus, community engagement on adaptation planning and intervention is necessary and overdue in addressing these vulnerabilities. Livelihood security provides an entry point to understanding these interactions amongst climate and non-climatic factors as well as socioeconomic and policy overlays. A community-based adaptation approach that draws upon local farmer's knowledge and historical context can be instrumental in nurturing the building blocks for resiliency taking into account issues of power, class, gender and equitable access to resources.

6. **Southern St Elizabeth -** this Parish leads with the highest production of domestic crops (22% of Jamaica's total domestic food production (400,105 tonnes) in comparison to Trelawney.

   - Farmers in southern St. Elizabeth have demonstrated considerable fortitude in coping with a series of droughts in recent years. They have employed a number of damage-reducing coping strategies to lessen their exposure to drought hazard. Principal among these are: proactively introducing a variety of planting methods; proactively employing a range of moisture loss reduction techniques; varied responses to stress during the drought itself, including sacrificing a part of the growing crop in order to enhance survival of the remainder; and a variety of strategies to aid recovery, ranging from cutting back on the area farmed, seeking off-farm employment and a temporary exit from farming.

   - This case study showed that small farmers need help to adapt to changes in rainfall patterns brought on by climate change. They are doing their best to cope with the changes by utilising the rich body of local knowledge available to them. However, the implementation of future policies and programmes that complement these existing traditional coping mechanisms will be essential in alleviating stresses as well as preventing further degradation of the local knowledge base that supports the survival of these farming communities. Since most farm incomes are either stagnant or in decline, the impacts of droughts are presumed to be profound and far-reaching.

7. Wild Capture Fisheries Production – Alligator Pond:

Fishing is central to the economy of Alligator Pond and helps to support a population of 190,800 (Statistical Institute of Jamaica, 2013). Community members estimated that between 75 to 80 per cent of local businesses are dependent on fishing.

The 2008 Jamaica Economic and Social Survey indicated that 19 out of 34 beach sites monitored showed erosion and 15 showed signs of accretion (Myers, 2010).

So much of the fishing beach has been lost to erosion that fishers have resorted to ad hoc measures to secure their boats ashore, while fish vendors have been relegated to operating from the road side.

Some of the recommendations coming out of this study were:

- To promote climate-smart fishing practices: through more efficient gear, equipment and fishing methods, increased regulation for sustainable fisheries; tackle over-exploitation of species to meet quotas) that can have negative long term impacts.
- Improve cooperative management and effectiveness: Greater training on how to run cooperatives effectively and awareness of the role and value added that allowing women members into the group could enhance its operations. Increase awareness amongst non-members about the role and functions of the cooperative and criteria for membership. This type of support could strengthen structural arrangement of fisher's communities and improve livelihood conditions.
- Access and use of technology: Incorporate GPS training in local fisheries management strategies to increase awareness of its capabilities. This should be combined with improving the availability of GPS devices to locally. Promote the use of improved fish pots with biodegradable panels to prevent ghost fishing; greater involvement of fishers in the management of the new protected area; coral restoration program as a strategy to enhance fish stock
- Sector-specific approach to gender mainstreaming: female fishers own and manage a lot of the assets in the community and their losses to climate change impacts can often be underestimated. This could be partly achieved through greater involvement of female fishers in disaster risk management and community development planning at the community-level. Across the study sites, female fisherfolks are struggling with the dual burden of managing their business and domestic labour.

Policies, Plans, Programmes and Actions

This chapter highlighted the situation in Jamaica, which clearly indicates that various policies, plans, programmes and projects must be developed and implemented with great urgency in order to adapt and make the country resilient to climate change.

It emphasizes that communities have been adapting to global change since millennia. However, what is unique about current adaptation intervention is the severity and cost of inaction owing to the increasing level of climate hazards and natural disasters. Hence short-term coping strategies are not enough to meet such challenges but rather a continuous set of decision-making processes and outcomes that meet stakeholder needs (Campbell and Beckford, 2009).

Recommendations for Policy Decision Making

Several initiatives have already been undertaken and projects are at various stages of implementation in the water resources sector for example. The following are included among them and should be continued with the objective of informing policy decision making and integrating/mainstreaming outcomes into the national planning process:

1. A water sector strategy has been developed and is being further upgraded.
2. Watershed Management projects are being implemented. Among them are the Hope, Yallahs and Rio Minho watershed projects.
3. A major artificial aquifer recharge project is now under construction in St. Catherine
4. Discussions are underway concerning the damning of the Bog Walk Gorge, through which the Rio Cobre River flows. The objective is to provide more water for health care, residential, agricultural, industrial and commercial uses, while continuing to service eco-systems functions.
5. Water harvesting has been accepted as an alternative water conservation and adaptation strategy. This must be aggressively pursued.

6.0 Mitigating Climate Change

While Small Island Developing States like Jamaica have more to do re adapting to climate impacts, it nonetheless, looks to fulfil its international mitigation commitments as best as it can.

This chapter explored mitigation action using a dedicated scenario in the national Long-range Energy Alternative Planning System (LEAP) model of Jamaica's energy system and GHG emissions. These scenarios quantify the incremental cost and emissions impact of the actions compared to the baseline scenario selected for this analysis.

Planned activities are identified directly from national policy or planning documents, or they propose a basic representation of a measure which is specifically named in these sources. Potential activities are identified from academic studies, from reports produced by non-governmental organizations, from appropriate mitigation options selected from other countries' experiences, or through SEI's best judgement. Potential activities may also represent a more aggressive extrapolation of planned activities.
Thorough descriptions of each mitigation action, as well as necessary quantitative modelling assumptions, are included in Chapter 4.

Other Considerations:

The TNC takes into account the impacts of climate change on various vulnerable groups such as the elderly, persons with disabilities, youth and gender considerations. One key recommendation made is the establishment of a registry dealing with the collection of sex – disaggregated data. This will help to ensure that the gender dynamic can be supported with more data, to inform decision-making and policy-making mainly in responding to climate change impacts.

ACKNOWLEDGEMENTS

As a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and in accordance with Article 4.1(a) of the UNFCCC, all parties to the Convention are requested to update and report periodically on their inventory of anthropogenic emissions and removals of greenhouse gases (GHGs) not controlled by the Montreal Protocol.

The emission estimates presented have been compiled as part of the United Nations Development Programme supported project “Third National Communication (TNC) and Biennial Update Report (BUR) to the United Nations Framework Convention on Climate Change (UNFCCC)” IC/2015/1. The aim of the project was to compile an updated national GHG emissions inventory for Jamaica, and also draft contributions to the Biennial Update Report (BUR).

The project started under the Ministry of Water, Land, and Environment & Climate Change and was completed under the Ministry of Economic Growth and Job Creation.

The work was funded by the Global Environment Facility (GEF) and UNDP (IC/2015/1) and brought together international and local experts providing key inputs both in terms of technical knowledge and also ensuring effective data provision from a range of Government Departments as well as private companies.

Facilitation from the Ministry was provided by Chief Technical Director, Lt. Col. Oral Khan (ret.) and coordination from the Climate Change Division was provided by Principal Director, Ms. Una May Gordon, former Principal Director, Mr. Albert Daley, former Senior Director- Mitigation, Mr. Gerald Lindo, Senior Director, Adaptation, Dr. Orville Grey, Senior Director, Mitigation Mr. Omar Alcock, Project Administrator/Manager, Mr. Clifford Mahlung and Project Accountant, Mr. Winston Simon.

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GLOSSARY

AR4	Fourth Assessment Report of the Intergovernmental Panel on Climate Change
AR5	Fifth Assessment Report of the Intergovernmental Panel on Climate Change
ASO	August-September-October
BAU	Business –As-Usual
BUR	Biennial Update Report - a requirement of international GHG emissions inventory reporting
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CH4	Methane – a greenhouse gas
CMIP	Coupled Model Inter-comparison Project
CO2	Carbon dioxide – a greenhouse gas
COP	Conference of the Parties – an international co-ordination meeting
CO2eq	Carbon Dioxide equivalent
DQOs	Data Quality Objectives – specific objectives set for each emissions inventory.
DSA	Data Supply Agreement – a formal document relating to the supply of information/data.
DJF	December-January-February
EE	Energy Efficiency
ENSO	El Niño Southern Oscillation
FAO	Food and agriculture Organization
F-gases	HFC, PFC, SF6 – synthetic greenhouse gases often grouped together under this name.
GCF	Green Climate Fund
GCM	Global Climate Model
GEF	Global Environmental Facility
Gg	Giga grams
GHG	Greenhouse Gas
GWh	Giga Watts/Hour
GWP	Global Warming Potential
HFCs	Hydro fluorocarbons
ICAO	International Civil Aviation Organization
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change

JJA	June-July-August
LULUCF	Land use, land use change and forestry – a source sector of a greenhouse gas emissions inventory.
LDCs	Least Developed Countries
LNG	Liquefied Natural gas
LPG	Liquefied Petroleum Gas
MAM	March-April-May
MJJ	May-June-July
MoU	Memorandum of Understanding – a voluntary/informal document outlining data /information provision to the greenhouse gas emissions inventory.
MRV	Measurement, Reporting and Verification – a description of the requirements relating to transparency and general quality of a greenhouse gas emissions inventory.
MSD	Mid-Summer Drought
NAH	North Atlantic High Pressure System
NAMAs	Nationally Appropriate Mitigation Actions
NDJ	November-December-January
NGOs	Non-Governmental Organizations
N2O	Nitrous Oxide– a greenhouse gas
PPE	Perturbed Physics Experiment
PRECIS	Providing Regional Climates for Impact Studies
PV	Photovoltaic
QA/QC	Quality Assurance and Quality Control – a framework of activities for ensuring good quality in greenhouse gas emissions inventories.
ReCORD	Regional Climate Observed Records Database
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
SC	Steering Committee – part of the greenhouse gas emissions inventory management
SDSM	Statistical Downscaling Model
SIDS	Small Island Developing States – with specific status under the UNFCCC
SimCLIM	Climate Simulation Software
SLR	Sea Level Rise
SNE	Single National Entity - part of the greenhouse gas emissions inventory management
SON	September-October-November
SRES	Special Report on Emissions Scenarios
SST	Sea Surface Temperatures
TCCCA	Transparency, Completeness, Consistency, Comparability and Accuracy - IPCC terms used to define quality in GHG inventories.
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

WHO	World Health Organization
WMO	World Meteorological Organization

DEFINITIONS

Adaptation	Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm and exploits beneficial opportunities
Mitigation	In the context of climate change, a human intervention to reduce the sources or enhance the sinks of greenhouse gases.

CHAPTER 1
NATIONAL CIRCUMSTANCES, GAPS AND CONSTRAINTS

1.0 Introduction

Jamaica faces very serious threats from hotter temperatures, droughts and floods linked to climate change, and an existential threat due to sea level rise. There are several studies of the impacts of climate change that will affect us, and throughout the report instances of these are noted. Most of our agricultural crops and livestock will be affected by hotter temperatures and the existential threat is discussed in detail in the conclusion of the report.

Jamaica has just recovered from two years (2014-2015) of severe drought, which had devastating effects on agriculture and water resources. The passage of Hurricane Sandy (2012) that affected the eastern half of the island and Hurricane Matthew (2016) that was close to our shores should be of serious concern to us. The science of climate change is clear and tells us that we have to adapt to impacts caused by the amount of Carbon Dioxide (CO_2), that is already in the atmosphere, and that the situation will get progressively worse if we do not mitigate greenhouse gas emissions. However, the opportunity is provided for us to turn the adverse situation into one that leads to sustainable development.

This Chapter contains an update of the information contained in the Jamaica's Second National Communication, and new information that has since become available. The period covered is mainly 2006 to 2012, but more recent information is provided where possible.

1.2 Geographical and Environmental Information Related to Climate Change

Climate

The update is largely based on the "State of the Jamaican Climate (2012): Information for Resilience Building"[9] and recent projections made by the Climate Studies Group, Mona (CSGM) at the University of the West Indies. Observed climate variability and trends show:

a. A warming trend, with the most severe warming occurring in the months from June to August; and

b. An increase in the frequency of very hot days and nights with a concurrent decrease in cold days and nights.

Areas of increasing rainfall over the 1992-2010 period may be identified over the centre of the island and areas of decreasing rainfall over the eastern and western parishes, with the decreasing trends stronger than the increasing trends. Sea level measurements at Port Royal indicate an increasing rate of sea level rise.

Based on Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) results, Jamaica's mean annual surface temperature was projected by all climate change models to increase by 1.1 to 3.2° Celsius by the 2090s. More recent, the Fifth Assessment Report (AR5), results give a range of 0.82 to 3.09° Celsius for 2081-2100.

AR4 projections for rainfall changes, range from -44% to +18% by the 2050s and -55% to +18% by the 2080s, with the negative percentages indicating decreasing rainfall. The most severe models in AR5 project that Jamaica may be up to 21% drier by the end of the century.

The IPCC's AR4 report summarised a range of Sea Level Rise (SLR) projections under each of its standard scenarios, for which the combined range spanned 0.18 to 0.59 metre by 2100 relative to 1980-1999 levels, but other studies give projections up to 1.4 metre.

Projected SLR over all Representative Concentration Pathways (RCPs), of AR5 for Jamaica's north coast is 0.43 to 0.67 metre, by the end of the century with a maximum rise of 1.05 metre for the south coast.

CARIBSAVE Climate Change Risk Atlas – Jamaica (2011)[10] noted that intensity of hurricanes still increases despite decreases in frequency. More recently, CSGM reported a shift toward stronger storms by the end of the century as measured by maximum wind speed increases of +2 to +11%.

9 Produced for the Planning Institute of Jamaica (PIOJ), Kingston Jamaica by the Climate Studies Group, Mona (CSGM). 2012.

10 CARIBSAVE. 2011. The CARIBSAVE Climate Change Risk Atlas (CCCRA) Jamaica Final Draft Country Risk Profile. Funded by UK Department for International Development (DFID) and the Australian Agency for International Development (AusAID).

Table 2.1: Climate Trends and Projections for Jamaica at a Glance[11].

Historical Trend	Projection
Temperatures	
• Maximum, mean, and minimum temperatures show upward (linear) trend. • Minimum temperatures are increasing faster (~0.27 °C/decade) than maximum temperatures (~0.06 °C/decade). Mean temperatures increasing at a rate of 0.16 oC/decade. • Increases consistent with global rates. • Daily temperature range has decreased.	• Min, max and mean temperatures increase irrespective of scenario through the end of the century. • The mean temperature increase (in °C) from the GCMs will be 0.42-0.46 °C by the 2020s; 0.75-1.04 °C by the 2030s, 0.87-1.74 °C by the 2050s and 0.82-3.09 °C for 2081-2100 over all four RCPs. • RCMs suggest higher magnitude increases for the downscaled grid boxes – up to 4 °C by end of century. • Temperature increases across all seasons of the year. • Coastal regions show slightly smaller increases than interior regions. • Mean daily maximum temperature each month at the Norman Manley International Airport station is expected to increase by 0.8-1.3°C (1-2-2.0°C) across all RCPs by early (mid) century. • The annual frequency of warm days in any given month at the Norman Manley International Airport station may increase by 2-12 (4-19) days across all RCPs by early (mid) century.
Rainfall	
• Significant year-to-year variability due to the influence of phenomena like the El Niño Southern Oscillation (ENSO). • Insignificant upward trend • Strong decadal signal. With wet anomalies in the 1960s, early 1980s, late 1990s and mid to late 2000s. Dry anomalies in the late 1970s, mid and late 1980s and post 2010. • Four rainfall zones. • Interior (1), West (3) and Coasts (4) co-vary on decadal time scale. East least well correlated. • Intensity and occurrence of extreme rainfall events increasing between 2040-2100.	• GCMs suggest that mid 2020s will see 0 to 2 % less rainfall in the annual mean. The 2030s will be up to 4% drier, the 2050s up to 10% drier, while by the end of the century the country as a whole may be up to 21% drier for the most severe RCP scenario (RCP8.5). • The GCMs suggest that change in summer rainfall is the primary driver of the drying trend. • Dry season rainfall generally shows small increases or no change • RCM projections reflect the onset of a drying trend from the mid-2030s which continues through to the end of the century. • There is some spatial variation (across the country and even within Blocks) with the south and east showing greater decreases than the north and west. • The decreases are higher for the grid boxes in the RCM than for the GCM projections for the entire country.
Sea Levels	
• A regional rate of increase of 0.18 ± 0.01 mm/year between 1950 and 2010. • Higher rate of increase in later years: up to 3.2 mm/year between 1993 and 2010. • Caribbean Sea level changes are near the global mean. • SLR at Port Royal, Jamaica ~ 1.66 mm/year.	• For the Caribbean, the combined range for projected SLR spans 0.26-0.82 m by 2100 relative to 1986-2005 levels. The range is 0.17-0.38 for 2046 – 2065. Other recent studies suggest an upper limit for the Caribbean of up to 1.5 m under RCP8.5 • For Jamaica, projected SLR over all RCPs for the north coast is 0.43 - 0.67m by the end of the century. Maximum rise is 1.05 m. SLR rates are similar for the south coast.

11 *CSGM. 2016. Hand-out to participants at the TNC Workshop, UWI Mona.*

Historical Trend	Projection
Hurricanes	
• Dramatic increase in frequency and duration of Atlantic hurricanes since 1995. • Increase in category 4 and 5 hurricanes; rainfall intensity, associated peak wind intensities, mean rainfall for same period. • South more susceptible to hurricane influence.	• No change or slight decrease in frequency of hurricanes. • Shift toward stronger storms by the end of the century as measured by maximum wind speed increases of +2 to +11%. • +20% to +30% increase in rainfall rates for the model hurricane's inner core. Smaller increase (~10%) at radii of 200 km or larger. • An 80% increase in the frequency of Saffir-Simpson category 4 and 5 Atlantic hurricanes over the next 80 years using the A1B scenario.

PRECIS, the Regional Climate Model (RCM) run by CSGM, generally indicated much more rapid increases in temperature over Jamaica than any of the models in the AR4 Global Circulation Model (GCM), ensemble when similar scenarios are compared. The PRECIS projections of rainfall for Jamaica all gave a drying trend.

Table 2.1 above gives the latest analysis by CSGM of trends and projections. Significant year-to-year variability due to the influence of phenomena like the El Niño Southern Oscillation (ENSO) is to be expected. The positive phase of ENSO, the so called El Niño, has been associated with severe droughts in Jamaica. This finding indicates that we can experience more frequent droughts. At the same time, the intensity and occurrence of extreme rainfall events are projected to increase between 2040-2100.

1.3 Land

Jamaica's forests are key ecological areas that influence our watersheds, vegetation and livelihood. The Forestry Department has updated much of the existing information concerning the forests of Jamaica since the publication of the first and second national communications.

The updated information was obtained from NEPA, (2015)[12]. As a result of an assessment carried out between 2012 and 2013, with more defined estimates of forest composition and changes in forest classification systems, there has been an increase in the land area classified as forest from 30% to 40%. This increase is largely due to improvements in satellite technology and not due to reforestation. Observed reforestation has mainly been due to an increase in secondary forest and has occurred despite a loss in forest quality.

Climate change is of particular concern because it either exacerbates or is exacerbated by many of the factors that affect forests. Projected climate changes for the island include increased droughts and overall drying of the rainy seasons, warmer temperatures, and potentially more intense hurricanes and storm surges.

Forests are vulnerable to climate shifts and hazards, and the loss of forest area and quality could increase the negative effects of climate change on human settlements.

These effects are likely to include increased salination of coastal freshwater sources, decreased buffer zones against storms, and spread of diseases and loss of pollinators.

Forests are also more susceptible to fires during dry conditions, and Jamaica has had recent incidents of serious consequences in the hills of the parishes of St. Andrew (See Figure 2.1) and St. Thomas[13].

The fires may have been started by careless farmers practising 'slash and burn' farming, but the "drier than normal" conditions influenced by the "El Niño" phenomena would have certainly exacerbated the conditions.

Jamaica's watersheds are also key ecological areas. Much of the country's freshwater supply originate in these watersheds through a system of rivers and streams and underground water. The "Cockpit Country" in the western section of the island is the source of approximately 40% of that supply.

Jamaica's watersheds are managed through 26 Watershed Management Units (WMUs), ranging in size from 46.6 Km^2 (South Negril–Orange River) to 1,638.8 Km^2 (Black River), that are located in 10 hydrological basins, shown in Figure 2.2.

12 National Environment and Planning Agency (NEPA). 2015. State of the Environment Report 2013 – Jamaica, 2015 Draft Report, cited with permission and referred to as NEPA (2015) herein.

13 Jamaica Observer. "Bush fires have destroyed hundreds of acres of forests – Forestry Department boss," July 23, 2015. Retrieved from: http://www.jamaicaobserver.com/news/Bush-fires-have-destroyed-hundreds-of-acres-of-forests---Forestry-Department-boss

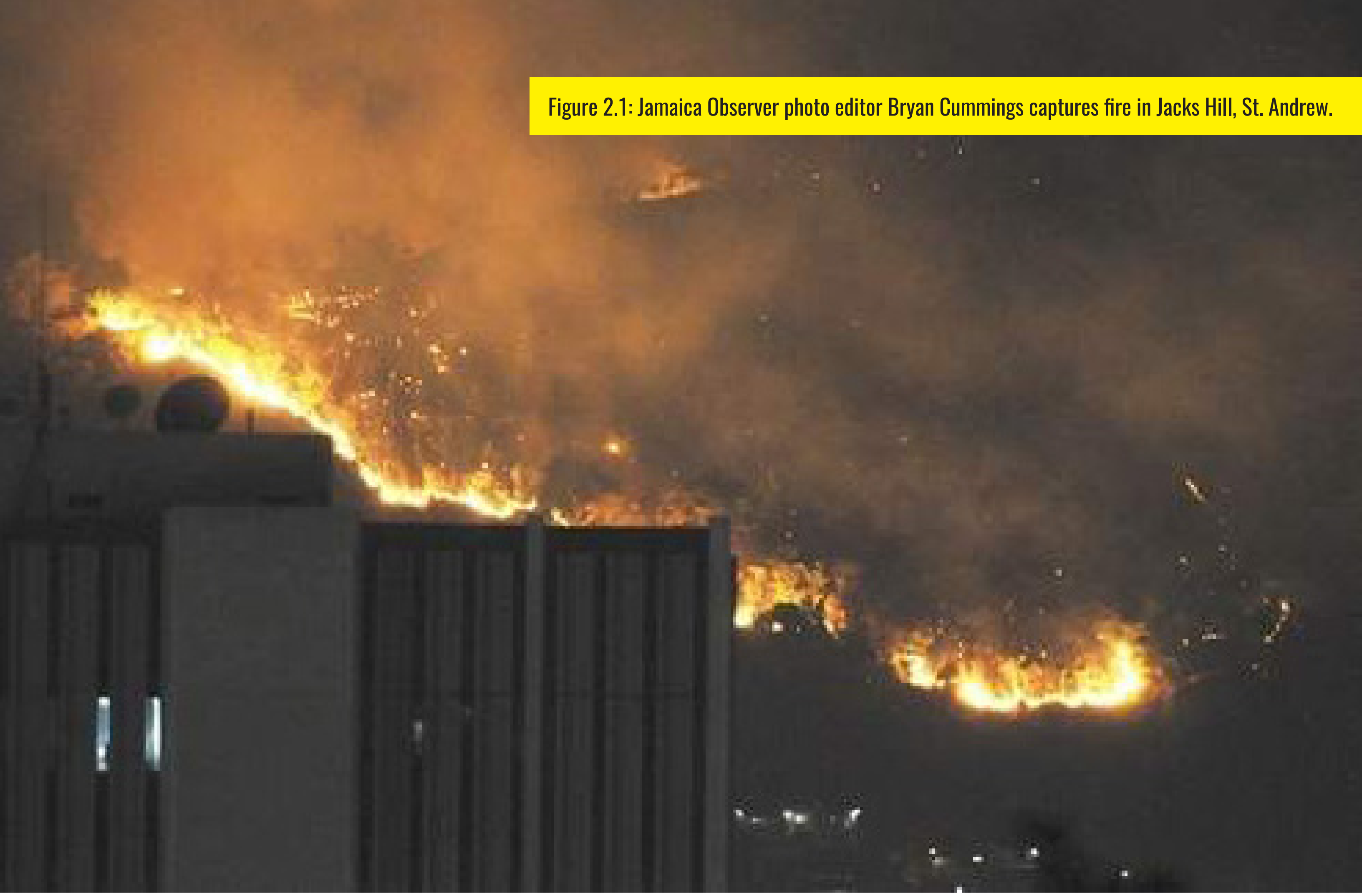


Figure 2.1: Jamaica Observer photo editor Bryan Cummings captures fire in Jacks Hill, St. Andrew.

In 2012-2013, 16 WMUs were specifically monitored as highest priority watersheds due to degradation, particularly from flooding, soil erosion and improper solid waste disposal.

NEPA (2015)[14] notes that the application of Land Use Policy is not effective and there is an urgent need to establish spatial plans in each watershed unit, in which development plans are clearly articulated in terms of present and future land use, and that decisions on land use are based on land capability and adaptation to climate change.

The effect of climate change on the water sector is summarised in section 3.8 below.

1.4 Endemic plants and animals within forests

There is a high density of endemic plants and animals within the forests. Currently, the endemic Jamaican species classified by the International Union for the Conservation of Nature (IUCN) Red List as vulnerable to critically endangered include 3 mammals, 21 birds, 2 reptiles, 2 amphibians and 3 plants. Among them are the Jamaican iguana (Cyclura collei) and the Jamaican coney (Geocapromys brownii), which both survive in mountainous, karst limestone forests. Climate change will bring additional stress to bear on these species[15].

Jamaica has committed itself to a number of conservation-based international agreements, implemented local policies and established protected areas. Some of these agreements and protection measures that have been put in place or modified since 2006 are:

- Convention on Biological Diversity (CBD),
- Draft Forest Policy, 2013,
- National Forest Management and Conservation Plan (NFMCP) of 2001 (currently undergoing revision to produce a new plan), and
- Strategic Forest Management Plan, 2010-2015.

Jamaica has designated many terrestrial areas of biological importance as protected areas. The Government of Jamaica prepared the latest draft of the Protected Areas System Master Plan in 2013. In 2009, environmental sustainability and conservation became a priority in the Vision 2030 plan for Jamaica, during which time the National Ecological Gap Assessment

14 *NEPA. 2015. Ibid.*
15 *See e.g., https://www.nwf.org/Wildlife/Threats-to-Wildlife/Global-Warming/Effects-on-Wildlife-and-Habitat.aspx; https://www.bgci.org/policy/climate-change-and-plants/*

Report (NEGAR) was also prepared. These documents identify the gaps in current protection strategies, and make recommendations for filling those gaps as well as for producing a national database to aid in monitoring the environment.

Though the number of protected forested areas has increased, the total area covered by these protected areas has decreased. Much of this loss has been due to the spread of invasive alien species (such as bamboo), human encroachment on forested land, and the lack of formal management plans and regulations for these sites.

1.5 Land Use and Land Use Change

Demand for forest products has been steadily increasing since 2010, placing stress particularly on closed broadleaf forests. The result has been a loss of 4.1% of closed broadleaf forest area and growth of disturbed broadleaf forests, with an estimated corresponding increase in land cover of bamboo of over 189% since 1998.

Greatest loss of forested area to infrastructure and other non-forest land use has occurred in open dry forests and swamp forests, but designated mangrove forest cover has been consistent. Major land use changes have been due to cultivations, herbaceous wetland, and buildings and other infrastructure. Table 2.2 details land use and land use changes in Jamaica from 1998 to 2013, and Figure 2.3 gives the latest estimate of land use in Jamaica. It was produced by the GIS Unit of the Forestry Department and shows that most of the building and infrastructure is located along the coast, and therefore in danger of storm surges.

Closed broadleaf forests, disturbed broadleaf forests, fields and secondary forests are located in the interior, and cultivation and plantations mainly in the southern parishes of St. Catherine, Clarendon, St. Elizabeth and Westmoreland in areas more prone to flooding (See Figure 5.6).

Figure 2.4 gives an example of land use change in the Rio Cobre Valley from 1988 to 2011. The map was provided by Mona Geoinformatics Institute with the courtesy of the Water-aCCSIS project led by CERMES and funded by Canadian International Development Research Centre (IDRC).

The increase in urban areas and secondary forest is noted, while at the same time mangrove forest, which protects against storm surges and coastal erosion, has decreased.

Figure 2.2: Hydrological river basins in Jamaica in 2013. Source: NEPA, 2015.

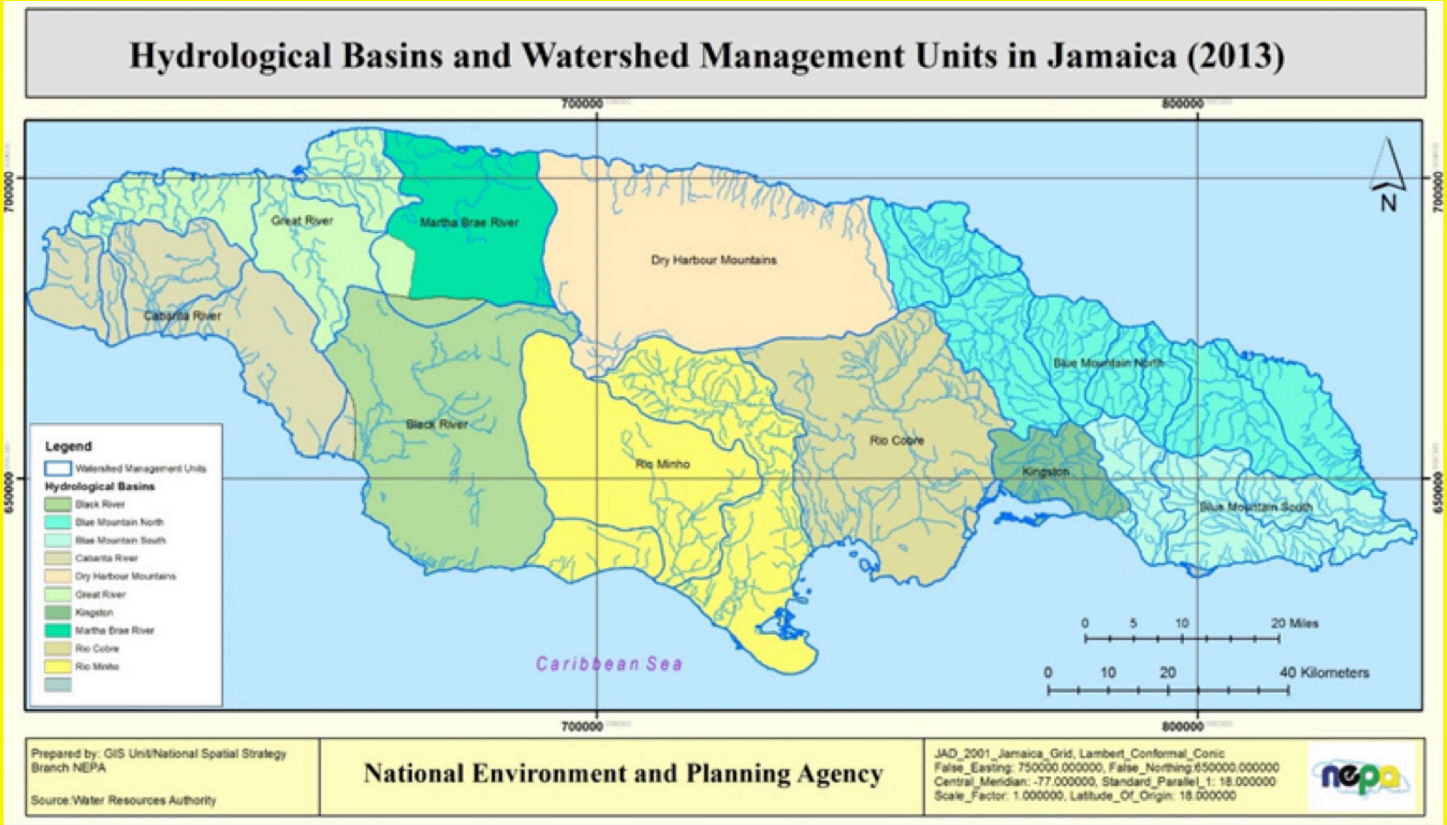


Table 2.2: Change in forest cover in Jamaica between 1998 and 2013 (in ' 000 hectares)

National Classes of Forest (2013)	1998	Land Use (%)	2013	Land Use (%)	Land Use change in 2013	% Loss/Gain
Closed Broadleaf	88.2	8.0	84.6	7.7	- 3.6	- 4.1
Disturbed Broadleaf	174.8	15.9	175.3	16.0	0.5	0.3
Short Open Dry	12.1	1.1	2.6	0.2	- 9.5	- 78.5
Tall Open Dry	42.0	3.8	37.6	3.4	- 4.4	- 10.5
Bamboo*	3.0	0.3	-	-	-	-
Mangrove forest	9.7	0.9	9.8	0.9	- 0.1	1.0
Swamp/Riparian forest	2.2	0.2	0.1	0.0	- 2.1	- 95.5
Forest Plantation**	8.2	0.7	8.3	0.8	0.1	1.2
Secondary Forest***	-	-	123.0	11.2	123.0	-
Total (change in forest cover)	**332.0**	**30.3**	**441.3**	**40.2**	**109.3**	**32.9**
Mixed Land Use						
Bamboo and Fields	29.0	2.6	-	-	- 29.0	-
Bamboo & Disturbed Broadleaf	12.7	1.2	36.8	3.4	- 24.1	189.8
Bauxite & Disturbed Broadleaf	2.9	0.3	-	-	- 2.9	-
Fields & Disturbed Broadleaf	118.0	10.8	166.4	15.2	48.4	41.0
Fields/Disturbed Broadleaf & Pine Plantation	8.2	0.7	-	-	- 8.2	-
Disturbed Broadleaf & Fields	166.0	15.1	-	-	- 166	-
Total (change in mixed use)	336.8	30.7	203.2	18.5	- 133.6	39.7
Non-Forest Land Use						
Non-Forest Land Use	411.6	37.5	447.6	40.8	36	8.7
Water	16.0	1.5	5.2	0.5	- 10.8	- 67.5
Total (change non-forest use)	**427.6**	**39.0**	**452.8**	**41.3**	**25.2**	**5.9**
GRAND TOTAL	**1,096.4**	**100**	**1,097.3**	**100**	**0.9**	**0.1**

** Bamboo included in Non-Forest Land-use;*
***Previously classified as Fields/Disbursed broadleaf and pine plantation;*
****New classification for 2013.*

Source: Forestry Department, 2013 via NEPA (2015)

The Town and Country Planning Authority (TCPA) currently guides and controls development in Jamaica by preparing development orders after consultation with local authorities. The importance of this role is reflected in the need for more land allocation for new industrial, commercial and residential development. Since 2009, spatial planning has been guided by the "Vision 2030 National Spatial Plan" and the "Regional Development Sector Plan for 2009-2030", which was launched by the Planning Institute of Jamaica (PIOJ) in 2011. These plans regulate resource allocation, urban planning and regional development, and contribute to the implementation of Vision 2030. As it relates to climate change building setbacks, coastal setbacks in particular should be clearly defined.

1.6 Marine Environment

Jamaica is surrounded by 1,240 km of varying coral reef species that support much of the island's biodiversity. According to a health assessment conducted by NEPA in 2011 and compiled in the report 'Coral Reefs of Jamaica – An Evaluation of Ecosystem Health'[16], Jamaica's overall reef health is poor. Of the 23 sites assessed in nine coastal marine areas, six were found to be in critical condition and only one was considered to be in fair condition. As with forested areas, a major challenge to the health of coral reefs is the lack of efficient management systems to ensure sustainability and recovery[17].

The marine environment is vulnerable and has declined due to clearing of corals, seagrass and forests for resorts and agriculture. In addition, the coastline is also vulnerable to climate and climate change related hazards, such as El Niño, hurricanes, storm surges and sea level rise.

An example of climate- and non-climate-induced hazards is the 2005 coral bleaching event (a weak El Niño year) due to extreme summer temperatures that affected a large portion of coral colonies around the Caribbean region. Despite up to 95% of corals being affected across the island, approximately 50% of affected corals recovered within six months. However, many were again affected by black and white plagues along the south coast by 2006.

Many organisms are at risk due to human activity. One example is the American Crocodile (Crocodylus acutus), which has lost its habitat to improper waste disposal and damaged mangroves and swamp ecosystems, and has increasingly been hunted for its tail meat. Since 2006, Jamaica has become party to a number of international conventions that cover both terrestrial and marine environment, including the Convention on Biological Diversity (CBD).

There are currently 14 Special Fisheries Conservation Areas (SFCAs) protecting 1,707 ha of coastline, adding to the overall 1,800 km^2 (15%) of Jamaica's archipelagic marine resources that are legally protected (meeting Aichi Target 11, which requires signatory countries to protect at least 10% of its coastal-marine area by 2020). These SFCAs are designed as Marine Protected Areas that protect fish stocks from being depleted through fisherfolks' involvement, through community education and involvement. The programme has resulted in an increase of 564% of fish biomass and 153% of coral cover. This gain can be wiped out by climate change-induced fish migration to cooler waters[18].

Jamaica's beaches are of both ecological and economic importance. Beach erosion has been monitored by the National Environment and Planning Agency since 2006, and there are currently 36 monitoring sites in eight locations. The data obtained indicated that coastal erosion has varied over time due to both human and environmental factors. Of the eight locations, five have experienced erosion while others have experienced accretion, indicating shifting materials among beaches. Examples of this are Jackson Bay and Long Bay in the western section of the island, each of which has one site losing beach area, while other sites gain beach area. Overall, however, sea level rise and increased storm surges should lead to a net loss.

Major coastal wetland cover amounted to approximately 11,674 hectares in 2011, NEPA estimates and 9,800 hectares in 2013. There has been a decline in wetland cover in recent years largely due to overharvesting, improper waste disposal and other detrimental human activities. This has major ecological and economic implications for Jamaica, as it leads to the depletion of both commercially and non-commercially important fish stocks as well as the services that mangroves provide, such as buffering storms and erosion, filtering water, and serving as carbon sinks.

The marine environment has been extensively studied by the Centre for Marine Sciences at the University of the West Indies via the Discovery Bay and Port Royal Marine Labs. The centre studies both the local and regional condition of coastal and marine resources in order to obtain a good spread of data and information for contribution to decision-making and understanding the local environment. They have active mangrove replanting and restoration projects around the island and conduct similar projects for corals, while closely monitoring the spread of invasive alien species.

1.7 Air Quality

At present, Jamaica does not monitor greenhouse gas emissions. Progress in developing a centralized database on GHG emissions has been slow due to limited capacity and resources, and the newly established Climate Change Division (CCD) has been charged with accelerating this.
Jamaica successfully phased out the use of chlorofluorocarbons in 2006, four years ahead of the Montreal Protocol´s 2010 phase out, and entered into an agreement with UNEP and UNDP in 2012 to implement the Phase-Out Management Plan for Hydro-chlorofluorocarbons (HCFCs), beginning with the official agreement of government to set import quotas of HCFCs in 2013 back down to 2009 levels.

16 NEPA. 2011. Coral Reefs of Jamaica – An Evaluation of Ecosystem Health: 2011. National Environment and Planning Agency. Kingston, Jamaica.
17 NEPA. 2014. An Evaluation of Ecosystem Health: 2013- A Report Card for Reefs. National Environment and Planning Agency. Kingston, Jamaica.
18 See e.g., http://news.nationalgeographic.com/news/2014/07/140725-climate-change-tropical-fish-animals-ocean-science/

1.8 Waste

Jamaica is party to a number of international agreements on the issue of waste, such as the Cartagena Convention and its Protocols including Oil Spills Protocol (1986), the International Convention on Oil Pollution, Preparedness, Response and Cooperation (1990) and other conventions dating back to 2004. Renewed focus on waste management came with the 2009 launch of Vision 2030. Since the launch of this national development plan, the effective management of waste based on the waste management hierarchy has been prioritised as a major prerequisite of achieving Goal 4: Jamaica has a healthy natural environment.

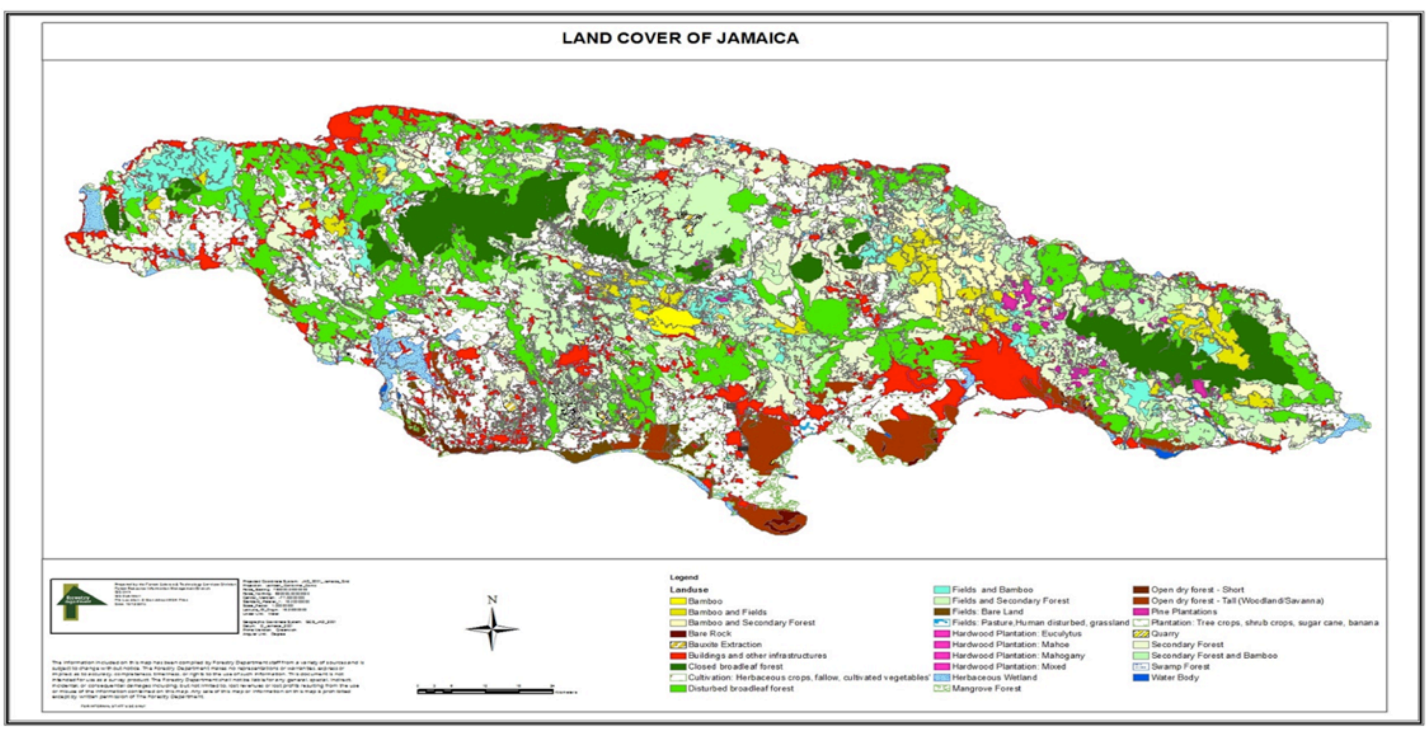
The National Solid Waste Management Agency (NSWMA) thus aspires to be recognised as a model waste management entity by 2030 that provides services comparable to developed countries. However, it has a long way to go. The NSWMA only services 70% of the island, which means waste generated in the remaining 30% of the island remains uncollected. The majority of the fleets of garbage trucks are privately contracted, while the rest are government owned. Currently, these trucks are inadequate to deal with waste management because, within the fleet of 109 trucks, most trucks are aging and have broken down or are out of commission for a time while replacement parts are being sourced.

At the moment, all solid waste disposal sites are either close to capacity and/or located in places that can trigger public health consequences. Riverton located in the capital city of Kingston, the main collecting site, exceeded its capacity in 2014.

Other challenges exist. Jamaica has no sanitary landfill, which means there is no systematic sorting of waste categories at any of these solid waste disposal sites for recycling, reuse or confined storage purposes. Also, no programme currently exists to produce energy from this waste. At the existing sites, there are limited resources to generate income from waste, such as making bags from organic material and wood chippings. None of the sites have the proper equipment to extend their own life, which means that the NSWMA does not possess compacting equipment to compress waste in the landfill, tyre and plastic shredders to reduce the volume of waste and enhance recycling opportunities, or waste oil receptors to accept oil that is not collected by operators licensed by NEPA.

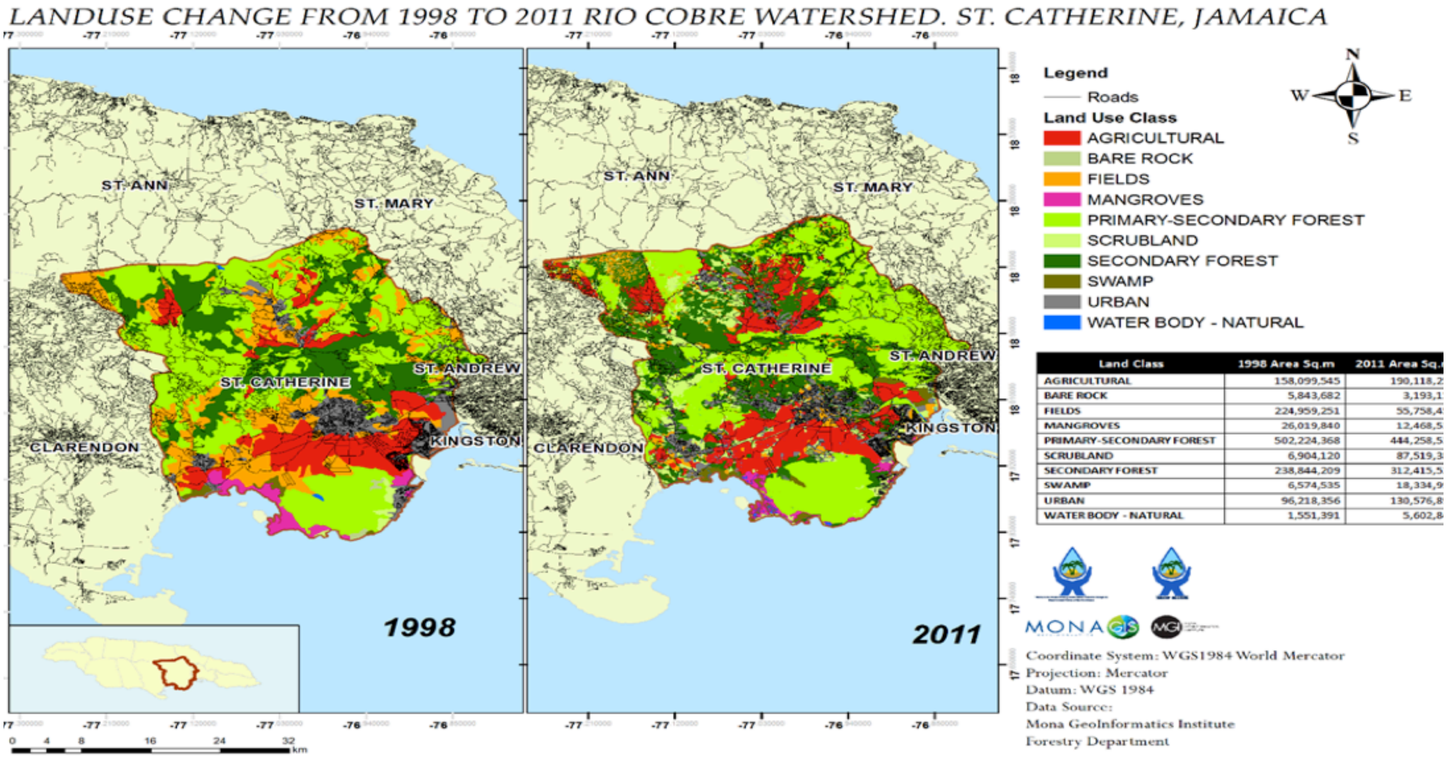
Hazardous waste poses potential threats to health and the environment. At the moment, Jamaica does not have an integrated policy that addresses hazardous waste management, leaving it to private entities or specific bodies to regulate individual industries. The Government of Jamaica is planning to address this lack of a comprehensive policy with the development of a Draft National Hazardous Substances and Hazardous Waste Management Policy. Many local commercial companies, therefore, do not dispose of their hazardous waste properly. Some illegally dump hazardous liquid and chemical waste into sewage and drainage systems, repackage hazardous waste as household waste, or illegally dump hazardous waste into the natural environment. In many cases, as reported by the Water Resources Authority, the groundwater has become so contaminated that it has forced the closure of some wells, and 25% of the island's groundwater sources are unsuitable for use due to the high presence of heavy metals from hazardous waste[19].

Figure 2.3: Most recent estimates of land use in Jamaica. Source: Forestry Department, 2016.



19 *NEPA. 2015. Ibid.*

Figure 2.4: Land use change from 1998 to 2011 in the Rio Cobre Watershed (Source: MGI with Permission from CERMES)



1.9 Wastewater

Since 2006, policies and action plans have been added to those that govern Jamaica's wastewater management. These include 'NRCA Wastewater and Sludge Regulations' (2013) and the 'Draft National Ambient Water Quality Standards' (2009). Jamaica currently has 307 sewage treatment plants monitored by NEPA, and only about 25% of these plants have met national standards of water quality[20]. Approximately 500,000 Jamaicans are connected to sewage systems. The remainder use "soak-away" pits, which lead to contamination of the underground water.

20 NEPA. 2015. Ibid.

2.0 Information relating to aspects of population, economic activities and relevant sectors

2.1 Population

The population of Jamaica grew from 2,657,760 in 2006 to 2,711,476 in 2012 at an annual growth rate ranging from 0.35 to 0.27%, with marginally more females from 2006 to 2008, and marginally more males thereafter (Table 3.1).

The population growth rate was steady from 2006 to 2010, but since 2011 the population growth rate has been declining. Migration continues to impact the size, growth and structure of the population, as well as other socio-economic factors. It is largely younger, more highly skilled persons who migrate to other countries, most of whom settle in the United States of America[21]. The net migration amounted to about 14,000 to 15,000 persons per year, except in 2010 when it was about 10,000.

Table 3.1: Population of Jamaica from 2006-2012.

	2006	2007	2008	2009	2010	2011	2012
Total Population	2,657,760	2,667,202	2,676,666	2,686,305	2,695,543	2,704,133	2,711,476
Growth Rate		0.35%	0.35%	0.36%	0.34%	0.32%	0.27%
Female	1,345,925	1,350,041	1,354,165	1,327,828	1,333,153	1,337,779	1,341,700
Male	1,311,835	1,317,161	1,322,501	1,358,277	1,362,390	1,366,354	1,369,776

Source: Statistical Institute of Jamaica

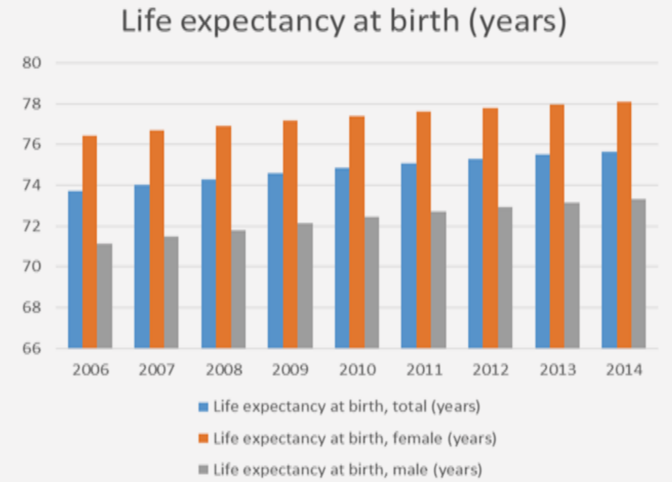
2.2 Life Expectancy

The death rate was between 6 and 8 per 1,000 in the population from 2006 to 2012. Besides diseases, homicides and traffic accidents, which are preventable causes of death, there have been other major external causeof death. Life expectancy at birth, derived from World Bank data, increased from just under 74 to just under 76 years from 2006 to 2014, with women living longer than men by over five years, as shown in Figure 3.1.

2.3 Living Conditions

Jamaica's "Survey of Living Conditions" (JSLC) 2012[22] revealed that the majority of households, some 60%, reported owning their dwelling house. This was followed by those who lived in their dwelling rent-free, about 21%, and approximately 17% who rented or leased. Some 38% of respondent households reported that they did not own, rent or lease the land on which their dwelling was situated, indicating a high degree of squatting. In many cases, these households are makeshift dwellings, usually located in floodplains, watersheds and coastal areas, making them prone to disaster during floods and heavy rains, including those induced by climate change. About 92% of Jamaican households are powered by the Jamaica Public Service Company (JPS), and about 4% of Jamaican households rely on kerosene oil as a lighting source. However, some of those powered by JPS are illegally connected and, in 2015, 709 persons were arrested for the illegal abstraction of electricity[23].

Figure 3.1: Annual Jamaican Life Expectancy at Birth 2006 - 2014.



(Source: World Bank. 2016. World Bank Country Data: Jamaica. Accessed from: http://data.worldbank.org/country/Jamaica)

21 *Planning Institute of Jamaica. 2012. Economic and Social Survey Jamaica. Published by the Planning Institute of Jamaica, 16 Ox ford Road Kingston 5, Jamaica W.I.*

22 *Jamaica Survey of Living Conditions. 2012. A Joint Publication of the Planning Institute of Jamaica and the Statistical Institute of Jamaica, 16 Oxford Road, Kingston 5, and 7 Cecelio Avenue, Kingston 10, Jamaica, West Indies.*

23 *Lobban, Brandon. "JPS Appeals to Non-Regularised Users in Light of Penalties Under Electricity Act 2015," JPS News, February 29, 2016. Retrieved from: http://www.myjpsco.com/news/jps-appeals-to-non-regularised-users-in-light-of-penalties-under-electricity-act-2015/*

2.4 Access to Water

In 2011, approximately half of households in Jamaica had access to water that was piped into their dwellings[24]. Others relied on water harvesting (catchment), water piped in the yard or water accessible from standpipes. The rest had to 'carry water' from another source. About 92% of households in the Kingston Metropolitan Area have flush toilets, while in other towns it is 60%. However, 42.4% of households that have flush toilets are not connected to sewerage systems[25]. This means sewage disposal in Jamaica is done, to a large extent, by soil absorption systems, septic tanks, tile fields and pit latrines. Soak away pits may lead to the contamination of groundwater as seepage reaches aquifers through the porous limestone base[26]. This has public health implications for all of Jamaica, because 84% of exploitable water comes from groundwater sources[27]. The level of contamination will increase with droughts caused by climate change.

2.5 Garbage Collection

About 68% of households used public or private garbage collection as of 2012. However, about 28% of the population disposed of their garbage by burning. Besides contributing to climate change, this activity has public health consequences because it releases harmful particulates and chemicals into the atmosphere, resulting in respiratory problems.

2.6 Economic Activity

The growth of Jamaica's Gross Domestic Product (GDP) slumped from 2005 to 2009, with subsequent recovery up to 2011, as shown in Figure 3.2. The Economic and Social Survey 2012[28] states that during 2012, economic growth remained flat, while there was a contraction by 0.3% in GDP relative to 2011.

Uncertainty surrounding the delay in the signing of an agreement with the International Monetary Fund (IMF) was given as one of the contributory factors. The successful conclusion of an agreement to establish a four-year arrangement under the Extended Fund Facility (EFF) with the International Monetary Fund (IMF) took place on May 1, 2013 and provided Jamaica with access to Special Drawing Rights (SDR) of 615.38 million (approximately US$932 million) in funds over the four-year period, 2013/14– 2016/17. The EFF also triggered resumption of budget support and loans from other International Development Partners[29] and the GDP has been growing since 2013, but slowly by under 1% annually. The recovery is not without hardship to the general population. A paper from the Washington DC-based Centre for Economic and Policy Research (CEPR) finds that Jamaica is running the most austere budget in the world, with a primary surplus of 7.5%, due to a four-year economic support programme with the International Monetary Fund (IMF)[30].

The main goal of the EFF is to reduce government debt/GDP to 96% ratio by 2020. The first year after the agreement was signed, the previously climbing GDP ratio decreased from 135.5% to 132.72%, as shown in Figure 3.3, and in March of 2016, the figure stood at 124.5%.

There has been a steady increase in the exchange rate relative to the US Dollar, while there has been a decreasing trend in the inflation rate from 25% in 2008 to less than 5% in 2016. According to the financial firm "Sagicor", "The ability to maintain single-digit inflation is partly attributable to the inability of firms to pass on to consumers the impact of the exchange rate depreciation. This resulted in improved efficiency in the agricultural sector"[31].

24 Statistical Institute of Jamaica. 2011. Jamaica's 2011 Census of Population and Housing Jamaica. Published by the Statistical Institute of Jamaica, 7 Cecelio Avenue, Kingston 10, Jamaica, West Indies.

25 National Environment and Planning Agency (NEPA). 2011. State of the Environment Report 2010. National Environmental Planning Agency. With support from UNDP.

26 Caribbean Regional Fund for Wastewater Management (CREW). Revised January 2015. Baseline Assessment Study on Wastewater Management. Retrieved from www.gefcrew.org.

27 Government of Jamaica. 2011. GOJ The Second National Communication of Jamaica to the United Nations Framework Convention Climate Change, National Meteorological Service Jamaica 65 ¾ Half Way Tree Road, Kingston 10, Jamaica, 409 p.

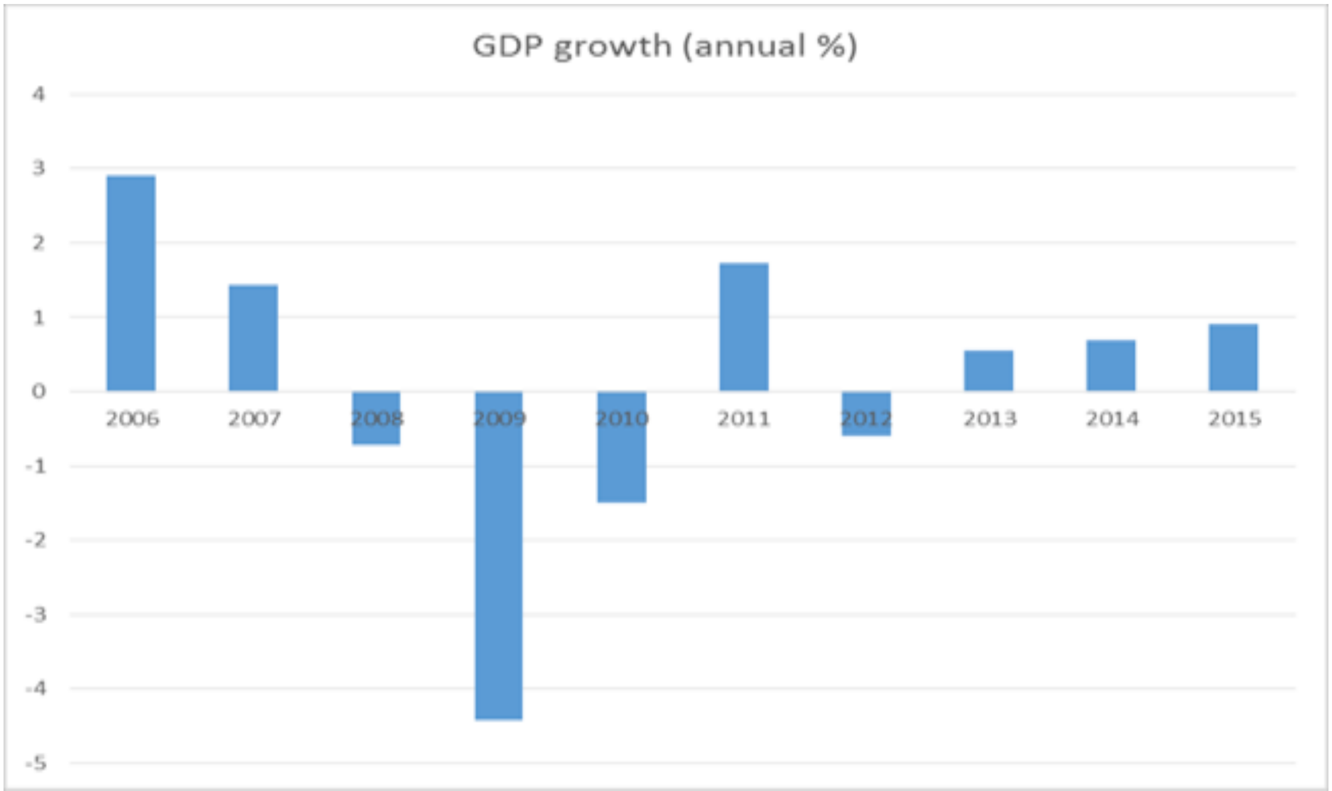
28 PIOJ. 2012. Ibid.

29 PIOJ. 2012. Ibid.

30 Jamaica Gleaner. "New Paper Finds Jamaica Suffering from Most Austere Budget," April 8, 2015. Retrieved from: http://jamaica-gleaner.com/article/business/20150408/new-paper-finds-jamaica-suffering-most-austere-budget

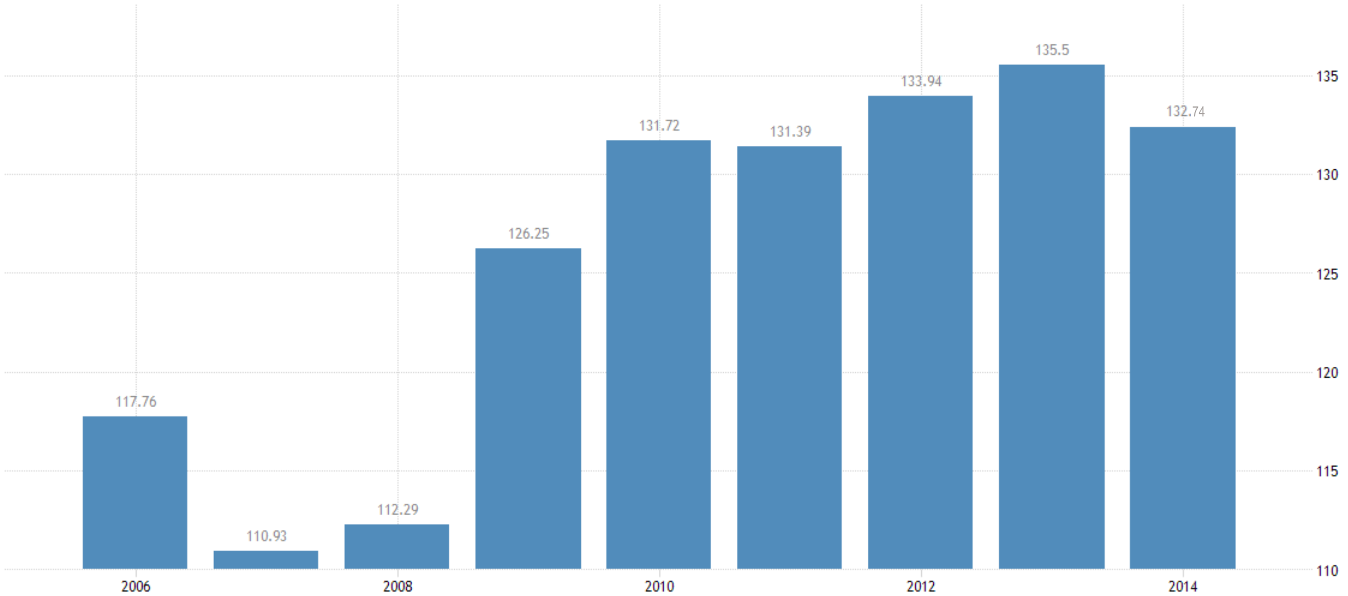
31 Avia Collinder. "Sagicor Bets On Low Interest Rates, Low Inflation and Slower Depreciation," Jamaica Gleaner, March 6, 2015. Retrieved from: http://jamaica-gleaner.com/article/business/20150306/sagicor-bets-low-interest-rates-low-inflation-and-slower-depreciation

Figure 3.2: Annual Percentage Jamaican Gross Domestic Product (GDP) Growth 2006-2015



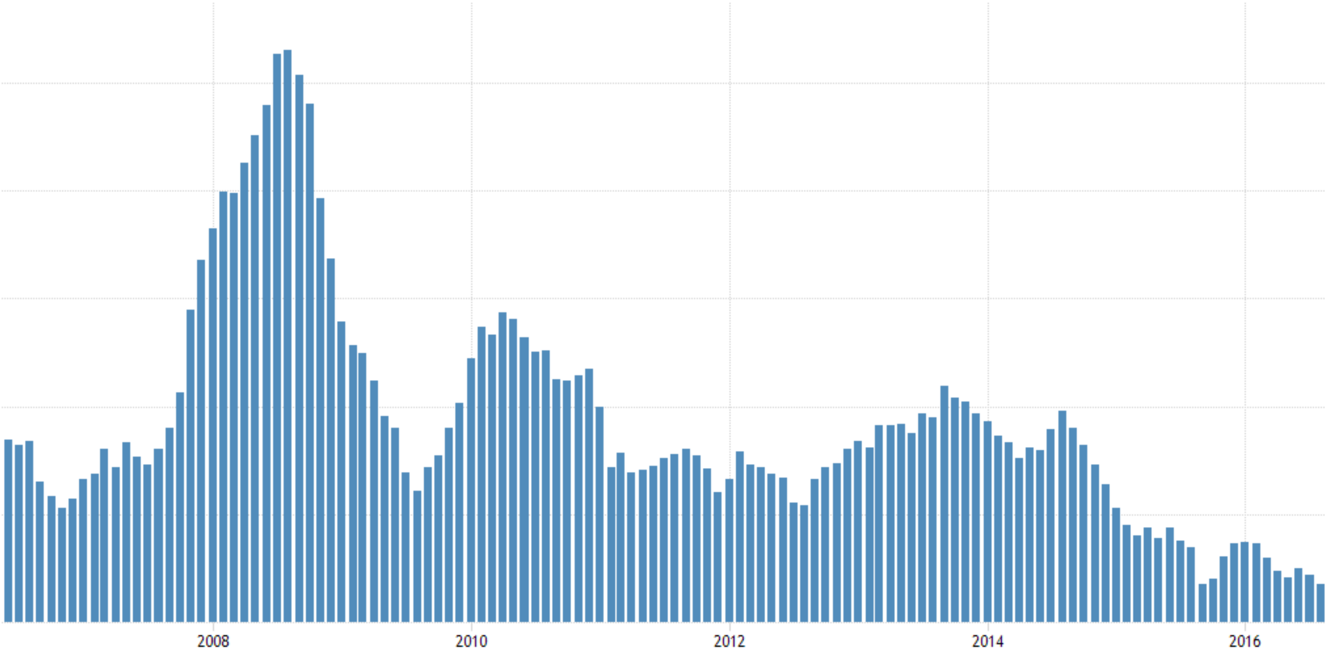
Source: World Bank. 2016. World Bank Country Data: Jamaica.
Accessed from: http://data.worldbank.org/country/Jamaica

Figure 3.3: Jamaica's debt to GDP ratio 2006-2014



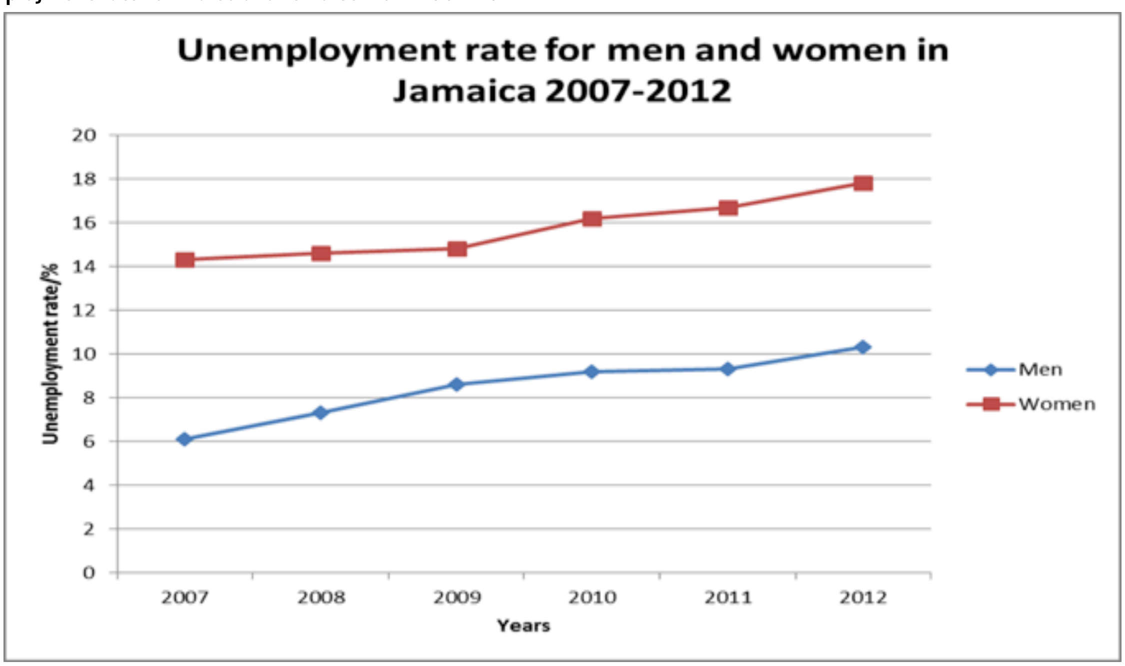
Source: Trading Economics. 2016. Jamaica government debt to GDP.
Accessed from:http://www.tradingeconomics.com/jamaica/government-debt-to-gdp.
Data Source: Statistical Institute of Jamaica.

Figure 3.4 Inflation rate in Jamaica 2006-2016



Source: Trading Economics. 2016. Jamaica inflation rate.
Accessed from: http://www.tradingeconomics.com/jamaica/inflation-cpi.
Data Source: Statistical Institute of Jamaica

Figure 3.5: Unemployment rate for males and females from 2007-2012



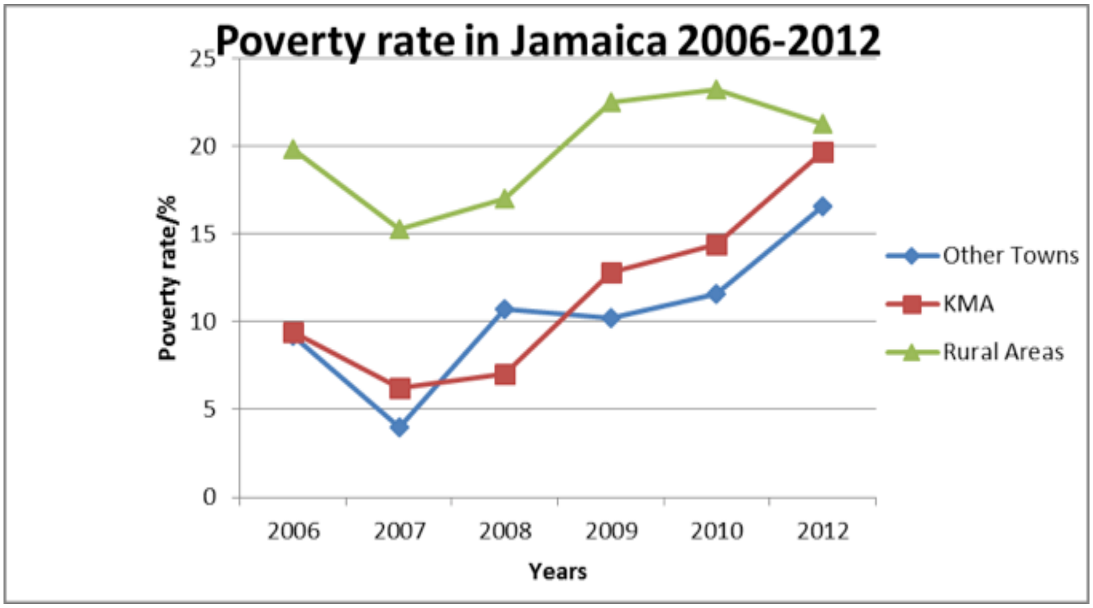
Source: Economic and Social Survey Jamaica (PIOJ 2012)[32].

Since 2006, the average unemployment rate has been steadily increasing from close to 10% in 2006 and almost reached 14% by 2012, according to World Bank Data, with females more consistently underemployed than their male counterparts as shown in Figure 3.5.

In Jamaica, the rate of poverty has increased steadily since 2007. The increase was in all regions of Jamaica except for the rural area which has a slight dip in 2012 as shown in Figure 3.6.

32 PIOJ. 2012. Ibid.

Figure 3.6 Poverty in Jamaica from 2006-2012 in Kingston Metropolitan area (KMA), rural areas and other towns



Source: Jamaica Survey of Living Conditions 2012[33]

In 2012, the proportion of Jamaica's population living below the poverty line was close to 20%, up from 9.9% in 2007. These persons will be the least able to adapt

to climate change. This all suggests that Jamaicans are becoming less able to adapt to climate change because of increasing poverty and similarly women, because of their average economic status, are less able to adapt to climate change. The ability of the government to assist in times of disaster is limited by its high debt to GDP ratio.

2.7 Agriculture

The launch of Vision 2030 in 2009 precipitated a major policy review of the agricultural sector, resulting in a renewed focus on sustainable and urban rural development and making the best use of agricultural land[34].

The policy review included and resulted in a Draft Agricultural Land Use Policy (2012) that promotes the assessment of the potential impacts of climate change on agriculture and recognises the importance of farming techniques that are adaptable to climate change.

To support this adaptation process, the policy will include provisions for recording the impacts of climate change on agricultural production and productivity in a database that supports informed decision making for future policymaking efforts. This policy also focuses on enhancing the GIS capacity of the Agriculture Mapping Unit (in areas such as agro-climatic and crop-suitability data sets) and ensuring that the Rural Agricultural Development Agency (RADA) is strengthened to transfer climate smart agriculture to the farming community.

Figure 2.3 shows that most of the land used for agriculture lies in the southern parishes of St. Catherine, Clarendon, St. Elizabeth and Westmoreland. These are the areas that will be more heavily impacted by climate change since all four parishes are more prone to flooding, as seen in Figure 5.6, and at the same time, the areas more prone to drought are in the first three named parishes, as seen in Figure 5.1 (Section 5, below).

By impacting agriculture negatively, climate change will seriously impact economic growth. The greatest economic growth in a single quarter in the last 14 years, which occurred in 2016, has been largely attributed to growth in agriculture[35]. In 2012, the agricultural contribution to GDP grew from 5.3% in 2005 to 7.2%. This was attributed to the local agricultural sector receiving a major revival due to efforts by the Ministry of Agriculture to increase agricultural land use with the promotion of agricultural parks or 'Agro Parks'. Agro Parks are fully integrated agricultural production systems that cover all aspects of the agricultural value chain from pre-production planning through to marketing. These parks support farming cooperatives in an effort to increase local production and food processing by cultivating inactive farms, improving food security, diversifying local crop output and reducing the dependence on foreign goods[36].

33 Jamaica Survey of Living Conditions. 2012. Ibid.
34 NEPA. 2015. Ibid.
35 Johnson, Jovan. "Big Growth for Jamaica - Economy Sees Strongest Performance Over Single Quarter in 14 Years," Jamaica Gleaner, November 2, 2016. Retrieved from: http://jamaica-gleaner.com/article/lead-stories/20161102/big-growth-jamaica-economy-sees-strongest-performance-over-single
36 NEPA. 2015. Ibid.

3.0 Coastal Zone and Settlement:

3.1 Hurricanes and storm surges

Much of Jamaica's population and economic infrastructure lies along or near to the coastline (Figure 2.3 above). This amounts to approximately 82% of the population and 70% of all major industries. The coastal zone is integral to the economy of the island, particularly due to the presence of most of the island's ports and tourist activity. Sea and air ports are very often situated in low-lying coastal areas and wetlands, and are necessary for maintaining supply routes to and from the island. Major tourist resorts are often located within similar areas, sites of note being Montego Bay, Ocho Rios, and Negril.[37] The coastal zone, however, is highly sensitive and vulnerable to climate related hazards, such as hurricanes and storm surges, as well as more slowly occurring changes such as sea level rise. Table ES3.2[38] shows that in 2007, Hurricane Dean, which gave Jamaica a glancing blow (Figure ES3.7), caused over J$23 billion worth of damage amounting to 3.4% of GDP.

Table ES3.2: Impact of Extreme Climate-related Events on Jamaica's GDP 2007-2012.

	Year	Cost (J$B)	Impact (% GDP)
Hurricane Dean	2007	23.8	3.4
Tropical Storm Gustav	2008	15.5	2
Tropical Storm Nicole	2010	20.6	1.9

Source: Government of Jamaica, 2015.

Figure ES3.7: Storm surge fuelled by Hurricane Dean, which gave Jamaica a glancing blow in 2007, flows onto the coastal road carrying all kinds of large debris, including rocks, logs and other trash, resulting in road damage.

Source: http://www.stormchaser.ca/Hurricanes/Dean/Dean.html

37 *Government of Jamaica. 2015. Climate Change Policy Framework for Jamaica. The Ministry of Water, Land, Environment and Climate Change. Climate Change Division. GoJ/EU/UNEP Climate Change Adaptation and Disaster Risk Reduction (CCADRR) Project. Kingston, Jamaica.*

38 *Government of Jamaica. 2015. Ibid.*

3.2 Sea Level Rise and storm surges

Sea level rise (SLR) will be a constant threat, becoming worse with the passage of time. Indeed, it can be described as an existential threat. CARIBSAVE[39] collected and analysed primary data to assess the vulnerability of the livelihoods of residents in Port Antonio and surrounding areas (Orange Bay, Buff Bay, Hope Bay, Boundbrook to Drapers and Snow Hill) to climate change and extrapolated to the rest of Jamaica; and to project sea level rise and storm surge impacts on the coast of Portland Parish. Table 3.3 shows the beach area lost for various scenarios of sea level rise and Figure 3.8 depicts the losses at Hope Bay, Portland.

The vulnerability of the livelihoods of residents who were assessed included:

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

The fishing industry, which is important to the economy and food supply of Jamaica as a small island, employs about 23,300 registered fisher-folks and many other unregistered individuals.

Table 3.3: Beach area lost in four sea level rise scenarios across study sites in Portland Parish, Jamaica

Sea Level Rise Scenario (metre/s)	Beach Area Lost To SLR m^2	Beach Area Lost (%)
Frenchman's Cove (Portland)		
0.5	933	36%
1.0	1609	61%
2.0	2621	100%
3.0	2621	100%
Hope Bay (Portland)		
0.5	3242.76	47%
1.0	5198.18	75%
2.0	6834.21	98%
3.0	6973.68	100%
Long Bay (Westmoreland)		
0.5	28771	44%
1.0	30241	46%
2.0	58170	88%
3.0	61289	93%
St. Margaret' s Bay (Portland)		
0.5	14113	30%
1.0	21715	46%
2.0	43525	92%
3.0	46926	99%
Winnifred's Beach (Portland)		
0.5	2181	69%
1.0	2979	94%
2.0	3186	100%
3.0	3186	100%

Source: CARIBSAVE. 2011

39 *CARIBSAVE. 2011. The CARIBSAVE Climate Change Risk Atlas (CCCRA) Jamaica Final Draft Country Risk Profile. Funded by UK Department for International Development (DFID) and the Australian Agency for International Development (AusAID).*

Figure 3.8 Loss of land at Hope Bay, Portland for the various SLR scenarios.

Source: CARIBSAVE. 2011

It contributes approximately 3% of the country's exports through artisanal fishing done by individuals who fish offshore or near to the mainland in small boats.

A summary of estimated physical impacts on tourism and infrastructure due to SLR and erosion in Jamaica is given in Table 3.4. A 1 m SLR places 8% of the major tourism properties at risk, with an additional 10% at risk with a 2 m SLR. Figure 3.9 shows a typical coastal roadway that is vulnerable to SLR and erosion.

Table 3.4: Impacts associated with 1m and 2m Sea Level Rise (SLR) and 50m and 100m beach erosion in Jamaica.

		Major Tourism Resorts	Sea Turtle Nesting Sites	TRANSPORTATION INFRASTRUCTURE		
				Airports	Road Networks	Ports
SLR	1m			20%	2%	100%
	2m	18%	32%	60%	2%	100%
Erosion	50m	32%	43%	-	-	-
	100m	50%	57%	-	-	-

Source: CARIBSAVE. 2011

Figure ES3.9 Coastal Road Networks Vulnerable to Erosion and Sea Level Rise.

Source: CARIBSAVE. 2011

4.0 Energy Sector

4.1 Renewable Energy

Since the Second National Communication (2011), the percentage of renewable energy in the mix has improved. However, the exact figures are hard to come by. According to Worldwatch Institute, which has done the most comprehensive study of renewable energy in Jamaica thus far, hydro accounted for 3.3% and wind 1.4% of the energy mix for electricity generation in 2009[40]. However, the amount of biomass is not included since most of the energy generated by this source was not connected to the grid.

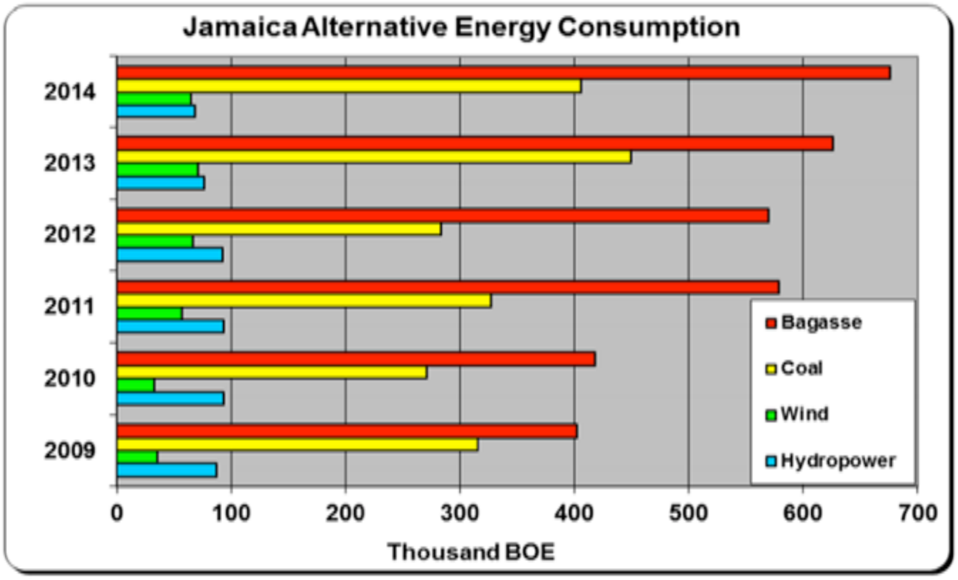
In 2012, it was estimated that renewables were responsible for about 9% of electrical energy produced in Jamaica, with hydro producing about 3.7%, wind 2.6% and biomass 2.9%[41].

According to figures provided by the Energy Economics and Planning Unit, Energy Division, Ministry of Science, Technology, Energy and Mining in 2015, the contribution of wind energy to electricity generation has increased since 2009, while that from hydro has been on the decline since 2012, as seen in Figure 3.10.

40 *Makhijani, S., Ochs. A., et al. 2013. Jamaica Sustainable Energy Roadmap: Pathways to an Affordable, Reliable, Low-Emission Electricity System. Worldwatch Institute, Washington, DC.*

41 *See: https://en.wikipedia.org/wiki/List_of_countries_by_electricity_production_from_renewable_sources*

Figure 3.10 Jamaica's Alternative Energy Consumption, including Coal and Bagasse



Prepared by the Energy Economics and Planning Unit, Energy Division, Ministry of Science, Technology, Energy and Mining – 2015.

The National Energy Policy 2009-2030 and the draft National Renewable Energy Policy 2010-2030, aim for 20% of renewable in the energy mix by 2030.

In November 2012, in keeping with the Government of Jamaica's vision of having 12.5% electrical energy from renewable energy sources by 2015 as set out in the above policies, the Office of Utility Regulation (OUR) issued a request for proposal for up to 115 MW of power to be provided by renewable resources, of which approximately 37 MW were reserved for firm energy. Three bidders were selected for energy only projects totalling 78 MW. They were: Blue Mountain Renewables LLC (BMR), to supply 34 MW of capacity from wind power at Munro in St. Elizabeth; Wigton Windfarm Limited (Wigton), to supply 24MW of capacity from wind power at Rose Hill in Manchester; and WRB Enterprises Inc. (WRB), to supply 20MW of capacity from Solar PV from facilities in Content Village in Clarendon. The scheduled commissioning date for the three projects is July 2016.

Of the remaining 37 MW, 33.1 MW have since been awarded to Eight Rivers Energy Company (EREC) Limited to build, own, and operate an energy only solar photovoltaic (PV) energy generation facility at Paradise Park in Westmoreland.

Incentives for promoting behind the meter use of renewables, solar water heaters and energy efficiency based items were provided by the Government of Jamaica, through several entities and agencies, by the following:

- National Housing Trust (NHT): loan facility available to homeowners for the installation of solar water heaters and PV systems at residential dwellings[42] since 2006 and 2008 respectively.

- Development Bank of Jamaica (DBJ): grant and loan facility available to commercial clients through approved financial institutions (AFI) since 2012[43];

- Ministry of Finance and Planning (MoFP): list of General Consumption Tax (GCT) exempted and Common External Tariff (CET) suspended for renewable energy and energy efficiency based items. The exemptions will run from January 1, 2013, to December 31, 2017[44].

- Ministry of Science, Technology, Energy and Mining (MSTEM), Jamaica Public Service (JPS) and Office of Utilities Regulations (OUR): net billing is accommodated on the national grid. Customers who have this arrangement in place and generate electricity using renewable energy source (wind, water, solar, biomass) receive a premium of 15% when they sell electricity to JPS. The programme was introduced in 2012 and suspended in 2014 pending review, after which a new programme will be launched[45][46], .

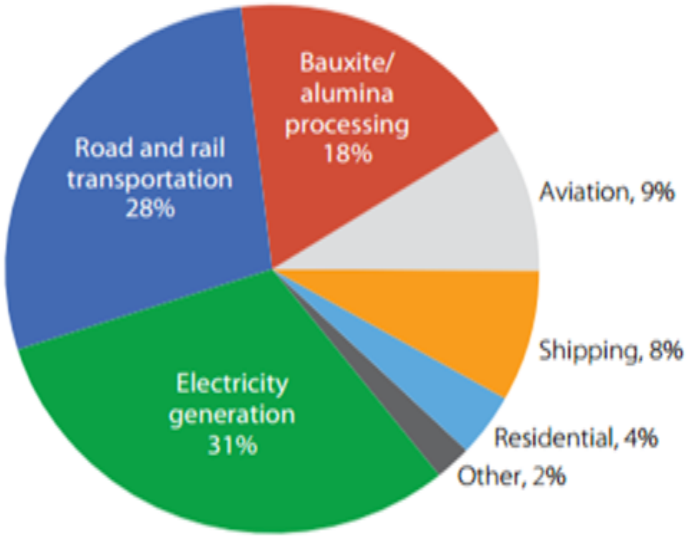
42 *NHT. "Solar Water Heater Loan." Last Modified October 14, 2016. Retrieved from: http://www.nht.gov.jm/loans/need-a-loan/solar-water-heater*
43 *DBJ. "The DBJ launches Energy Loans for Householders," March 30, 2012. Retrieved from: http://dbankjm.com/news/dbj-launches-energy-loans-householders*
44 *Banks, Amanda. "Jamaica Suspends Tariffs On Energy-Saving Products," Tax-News.com, February 22, 2013.Retrieved from: http://www.taxnews.com/news/Jamaica_Suspends_Tariffs_On_EnergySaving_Products___59887.html*
45 *Lobban, Brandon. "New Net Billing Programme to be launched," JPS News, May 14, 2015. Retrieved from: http://www.myjpsco.com/news/new-net-billing-programme-to-be-launched/*
46 *It was re-launched in 2016.*

4.2 Electricity Generation

In 2010, electricity generation accounted for the greatest share of petroleum consumption, as shown in Figure 3.11. Other major consumption sources were road and rail transportation and bauxite alumina processing, although the latter consumption has declined since the slump in aluminium prices[47].

Jamaica's sole grid operator is The Jamaica Public Service Company (JPS), which had a 20-year monopoly (to 2027) on electricity transmission and distribution in the country through the 2001 All-Island Electricity License.

Figure 3.11 Share of Petroleum Consumption by Activity, 2010[48]



The legality of the license was challenged in the Jamaican Court and was recently upheld by the Appeals Court[49].

In 2013, JPS had an installed electrical capacity of 625.5 MW, 96 % of which was generated by petroleum-based power plants running off diesel and/or heavy fuel oil[50].

The remaining 26 MW of capacity comprised eight "run of river" small hydro units and a 3 MW wind farm.

JPS also purchases electricity for distribution from two independent power producers running on diesel and heavy fuel oil (189.9 MW and 60MW capacity respectively) and from a 38.7 MW wind farm (Wigton). A subsidiary of the Petroleum Corporation of Jamaica (PCJ), the Wigton Windfarm currently comprises Wigton I, which was commissioned in 2004 and is rated at 20.7 MW, and the 18MW Wigton II commissioned in 2010. A third phase, 24 MW Wigton III, went online in June 2016 (See Figure 3.12).

Thus, Jamaica has approximately 940MW of generation capacity with a base-load demand of approximately 400MW. Unlike in industrialized nations, the peak demand period for Jamaica is from 6-9 pm, when the demand for energy for cooking, air conditioning and entertainment then rises. The evening peak-load is up to 640MW. Jamaica has one of the highest energy intensity rates in Latin America and the Caribbean. A Rapid Assessment done by Sustainable Energy for All[51] attributed this partly to the high-energy use of the bauxite and alumina sector and to Jamaica's general inefficiency in the use of energy. However, with lower oil prices in 2015 and more efficient operation, JPS has managed to reduce the cost of electricity from approximately US40 cents to US25cents[52].

47 *Bloomberg. "Aluminium Slump Means 25% of Smelters Losing Money: Commodities," November 09, 2011. Retrieved from: http://www.bloomberg.com/news/articles/2011-11-09/aluminum-slump-means-25-of-global-smelters-now-losing-money-commodities*

48 *Makhijani, S., Ochs. A., et al. 2013. Ibid.*

49 *Jamaica Gleaner. "Appeals Court Rules JPS' Exclusive Licence Is Valid," January 16, 2015. Retrieved from: http://jamaica-gleaner.com/article/news/20150116/appeals-court-rules-jps-exclusive-licence-valid*

50 *Makhijani, S., Ochs. A., et al. 2013. Ibid.*

51 *Sustainable Energy for All Americas (SE4ALL). 2013. Sustainable Energy for All: Jamaica: Rapid Assessment and Gap Analysis. Inter-American Development Bank. Retrieved from: http://www.se4all.org/wp-content/uploads/2015/05/Jamaica_RAGA.pdf*

52 *Lobban, Brandon. "Electricity Cost Down to Five-Year Low of US 25 cents per kWh," JPS News, April 14, 2016. Retrieved from: http://www.myjpsco.com/news/electricity-cost-down-to-five-year-low-of-us-25-cents-per-kwh/*

Jamaica Public Service Company Limited (JPS), received formal approval from the Jamaican Government for its proposal to proceed with the construction of a 190 MW natural gas operated plant to replace the company's existing units at the Old Harbour power station, located on the southern coast of Jamaica. JPS is also converting its 120 MW power plant in Western Jamaica, at Bogue, Montego Bay, to run on gas instead of automotive diesel oil. Both initiatives will reduce fossil fuel emissions.

Figure ES3.12 Wigton Wind Farm, Rose Hill, Jamaica.

Source: http://jamaica-gleaner.com/article/news/20161012/wigton-wind-farm-be-divested

5.0 Transportation

The transportation sector plays a critical role in the movement of resources, goods and services. Hence, transportation also contributes to GDP. On the other hand, negative balance of payment due to transportation increased from –US$426.5 million in 2006 to –US$752.5 million in 2012[53]. Transportation is also a major source of fossil fuel consumption, using almost as much fossil fuel as electricity generation (See Figure 3.11). Moderate measures have been put in place to reduce Jamaica's carbon footprint in the transportation sector. In 2009, MTBE was phased out of all gasoline blends and replaced with 10% ethanol. Later, ultra-low sulphur diesel fuel was introduced[54,55] into the retail system.

The highway network has recently been expanded and will allow more efficient movement of persons and goods across the island. The East-West highway was completed in 2004, the Portmore toll road opened in 2006 and the North-South highway opened in 2016[56]. However, more positive measures, such as policies, will be required.

The Jamaican National Energy Policy for 2009-2030 aims to design and implement cost-saving measures to boost energy efficiency and conservation across the public sector, including a strategy proposed for more efficiency and conservation in the transportation sector.

The Government is to spend $US695 million in the 2017-18 fiscal year to enhance Jamaica's Energy Efficiency (EE) and Energy Conservation (EC) measures in the public sector.

The National Transport Policy will soon be reviewed, and it is anticipated that issues related to greenhouse gas emissions from the transportation sector and the related climate change impacts will be addressed in the revised document[57].

A school bus scheme aimed at reducing carbon emissions and reducing cost and man-hours lost is suggested in Section 11.

6.0 Health Sector

Not much activity in the area of climate change and health has taken place since the Second National Communication (2011). There was to have been a follow-up by the Ministry of Health on a proposed early warning system for dengue outbreaks based on the research project described in 'Climate Change Impact on Dengue: The Caribbean Experience'[58]. However, this did not materialise, presumably because of lack of funding.

The University of Technology has instituted a position of Professor of Public Health, Environment and Climate Change.

7.0 Tourism Sector

Tourism remains one of the most important sectors to the nation's development, given the substantial linkages with other sectors viz. agricultural production (as a local market for local farmers), water sector, coastal and marine resources, and fisheries. The effect of climate change on tourism, especially storm surges, sea level rise and droughts, is therefore multi-linked, as shown in detail in Chapter 5, and has a definite effect on GDP. Gross foreign exchange earnings from tourism is about US$1.9 billion[59,60]. Table 3.5 shows tourism revenue as percentages of export and of GDP obtained from the World Travel and Tourism Council[61]. Thus, a loss of tourism revenue due to hurricanes, storm surges and sea level rise could have a devastating effect on Jamaica.

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53 PIOJ. 2012. Ibid.
54 Hibbert, Kimberly. "New diesel fuel now at pumps," Jamaica Observer, June 25, 2013.
55 Diesel-powered cars generally have a better fuel economy than equivalent gasoline engines and produce less greenhouse gas emission. See: https://en.wikipedia.org/wiki/Diesel_fuel
56 See: https://en.wikipedia.org/wiki/Highway_2000,_Jamaica
57 Jamaica Observer. "Gov't taking action to reduce emissions from transport sector," July 29, 2015. Retrieved from: http://www.jamaicaobserver.com/latestnews/Gov-t-taking-action-to-reduce-emissions-from-transport-sector
58 Chen, A.A., Chadee, D.D., and S.C. Rawlins (Eds). 2006. Climate Change Impact on Dengue: The Caribbean Experience. Editors: Climate Studies Group Mona, University of the West Indies, ISBN976-41-0210-7.
59 Bartlett, E. Sectoral Debates 2008: Ministry of Tourism. Address by Minister of Tourism, Hon. Edmund Bartlett at the 2008 Sectoral Debates, May 17, 2008. Retrieved from: http://www.jtbonline.org/resources/Presentations/MoT%20to%20Sectoral%20debate%202008.pdf
60 Government of Jamaica. 2015. Climate Change Policy Framework for Jamaica. Ibid.
61 World Travel and Tourism Council. 2015. Investment (Capital investment): Percentage of exports. Retrieved from: http://www.wttc.org/datagateway/

Table 3.5: Tourism revenue as percentage of export and GDP.

Year	% of export (foreign spending)	% of GDP
2006	43.7	28.5
2007	42.1	27.2
2008	38.6	26.0
2009	49.5	28.5
2010	50.6	27.6
2011	47.0	25.0
2012	47.1	25.3
2013	49.1	26.2
2014	52.9	27.2

Source: World Travel and Tourism Council

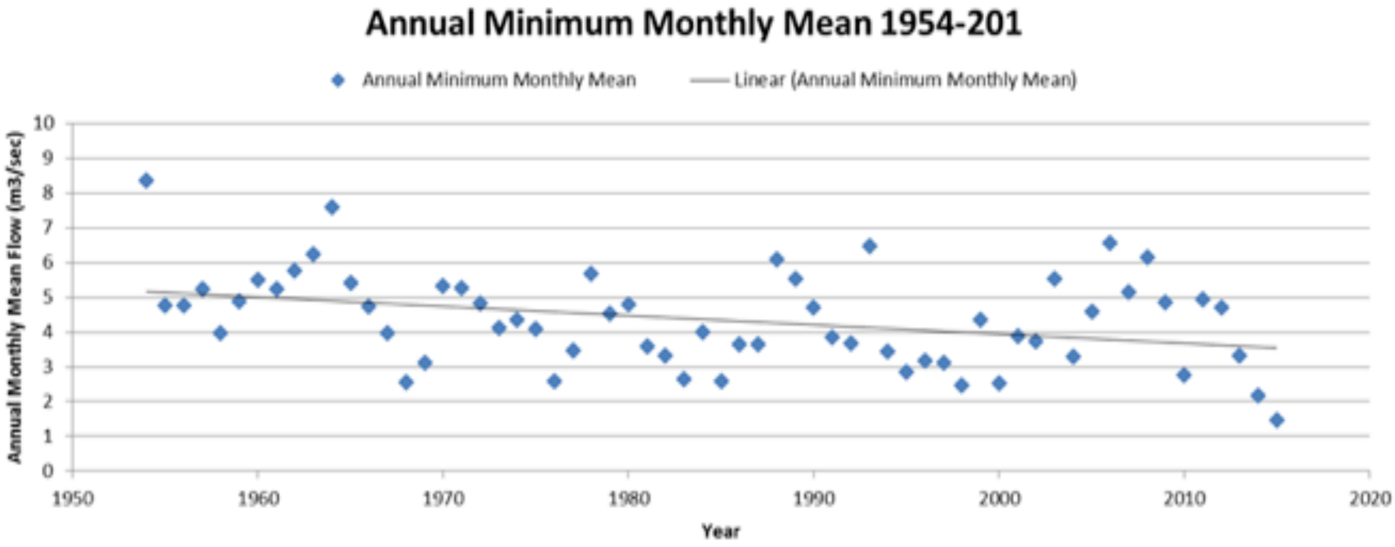
8.0 Water Sector

The update of much of the analysis given in the Second National Communication is pending funding from the International Development Bank (IDB)[62] in 2016. The following graph (Figure 3.13), giving the annual monthly mean for Rio Cobre combined flows from 1954 to 2015, was updated by the Water Resources Authority (WRA). It can be seen that the declining trend in the flow is continuing.

In the SNC, an analysis of future climate risks for Jamaican water resources determined that the three critical basins of Kingston, Rio Cobre, and Rio Minho would be in deficit by 2015. As of 2015, the Kingston Basin and the Rio Cobre Basin have been in deficit, with the Rio Cobre in deficit for several years now. While the Rio Minho cannot be said to be in deficit pending further investigation, it is under stress due to saline intrusion and over pumping[63].

When ground water is taken into consideration, the water resources potential is brighter. According to a 2015 report[64] Water Resources Authority (WRA), the island's water management and regulatory body, estimates that Jamaica uses only 25% of available groundwater resources and 11% of its accessible surface water. However, sourcing this resource is problematic, due mainly to nitrate contamination from "soak-away" pits, waste water[65] and saline intrusion[66]. The high cost of electricity for pumping water is also a deterrent[67]. The situation is compounded by the proliferation of hillside "informal" communities in de informal communities in the watersheds that has been the result of the poor planning over the years.

Figure 3.13: Declining Rio Cobre Combined Flows.



62 Marshall, Geoffrey. Senior Hydrogeologist, Water Resources Authority. Private Communication.

63 Marshall, Geoffrey. Senior Hydro-geologist, Water Resources Authority. Private Communication.

64 Neufville, Zadie. "Jamaica's aging water systems falter under intense heat and drought," Caribbean360, November 18, 2015. Retrieved from: http://www.caribbean360.com/news/jamaicas-aging-water-systems-falter-under-intense-heat-and-drought#ixzz4N4Uf3j79

65 Williams, Paul H. "All Is Not 'WELL' As NWC Hunts More Water," Jamaica Gleaner, July 5, 2015. Retrieved from: http://jamaica-gleaner.com/article/news/20150705/all-not-well-nwc-hunts-more-water

66 McCaulay, Diana. "Our water problems are our own making," Jamaica Observer: Letter to the Editor, September 08, 2014. Retrieved from: http://www.jamaicaobserver.com/mobile/letters/Our-water-problems-are-our-own-making_17503812

67 Poyser, Andre. "Costly Wells - NWC Spending Millions To Reactivate Water Sources," Jamaica Gleaner, August 11, 2015. Retrieved from: http://jamaica-gleaner.com/article/lead-stories/20150811/costly-wells-nwc-spending-millions-reactivate-water-sources

On the positive side, an Artificial Aquifer Recharge facility to secure the sustainable abstraction of water from the aquifer by treating and returning excess water into natural underground storage is ongoing[68]. Meanwhile, however, water lock-offs in various parts of the island during the dry season have become a norm[69], and droughts take a yearly toll on farmers, especially in the south-central parish of St. Elizabeth, which is considered to be the 'bread basket of Jamaica'[70].

Contamination of the watershed, mentioned above (Section 2.2 Land), is a major problem[71]. The deteriorating standard of water quality is illustrated in Table 3.6 below.

While all WMUs met standard for nitrates and phosphates in 2009, the number declined in 2013, especially in the case of phosphates. More than half the WMUs failed to meet the standard for BOD and Faecal Coliform in 2009. Although there were significant improvements in 2013, there were still some WMUs failing.

Table 3.6: Number of Water Management Units (WMUs) meeting Water Quality Standards in 2009 and 2013.

Parameters	No. of WMUs monitored (bi-annually)	Standard (range) (mg/L)	No. of WMUs meeting standard at monitoring sites	
			2009	2013
Nitrate	23	0.10-7.5	23	22*
Phosphate	23	0.01-0.8	23	16*
BOD	23	0.80-1.70	10*	14*
Faecal Coliform	23	-	9*	18*
*Includes two WMUs with no data available				

Source: NEPA

8.1 Water Policy

The Second National Communication (SNC) also stated that National Environment and Planning Agency (NEPA), with whom the management of watershed protection is principally invested, produced a National Watershed Policy to address the most severe constraints to watershed management and to seek to employ strategies to ensure the sustainable use and development of watersheds. The policy that was drafted in 2003 remains in draft stage. A new draft water policy and implementation plan also remains in draft stage, but it is reported to be in an accelerated stage. Indeed, the finalisation of this policy is critical, due to the prospects of more frequent droughts[72].

68 *Jamaica Observer. "NWC completes 25 water and sewerage projects," April 30, 2015.*
69 *See e.g., http://www.jamaicaobserver.com/news/Water-lock-off-in-Corporate-Area-as-storage-level-falls*
70 *See e.g., http://www.jamaicaobserver.com/news/Drought-takes-toll-in-St-Elizabeth--Manchester-_19221321*
71 *NEPA. 2015. Ibid.*
72 *Status as at December 31, 2016.*

9.0 Private Sector

9.1 UNDP Conference

An attempt was made to engage the interest of the private sector in the issues of climate change by the United Nations Development Programme (UNDP) in Jamaica by organising a Climate Change Learning Conference that took place on 17 July, 2014 at the Jamaica Pegasus Hotel. The conference also sought to explain current Jamaican Government strategies, in particular the Draft Climate Change Policy Framework and Action Plan, developed under the Climate Change Adaptation and Disaster Risk Reduction Project funded by the United Nations Environment Programme (UNEP) and the European Union (EU). The Conference also enlightened the audience on options for green energy loans through two lending institutions, the Development Bank of Jamaica and the Inter-American Development Bank.

Overall, findings from an evaluation revealed that the learning conference had some success. Participants were interested and willing to be part of the dialogue regarding climate change. Persons reported that they would be interested in future sessions related to climate change presented in different forums and would like to see sessions held in conjunction with private sector associations, such as Jamaica Manufacturing Association (JMA), Small Business Association of Jamaica (SBAJ) and Jamaica Exporters' Association (JEA). It was also recommended that continued evaluation of the private sector's involvement in climate change activities should be monitored to develop other programmes. However, there has been no follow-up in any of these matters and no interaction or interest from JMA, SBAJ or JEA.

10.0 Public sector (Post 2012 Development)

10.1 Ministry with responsibility for Jamaica's response to Climate Change

In January 2012, Jamaica's climate change portfolio was assigned to the newly established Ministry of Water, Land, Environment and Climate Change (MWLECC). In 2016, the Government assigned the climate change portfolio to the newly establishes Ministry of Economic Growth and Job Creation.

10.2 Climate Change Advisory Committee/ Board

A Climate Change Advisory Committee was constituted to provide advice to the Minister with responsibility for Climate Change. Currently, there is a Climate Change Advisory Board with members who were appointed by the Most Honourable Prime Minister to provide advice to the current Minister with responsibility for Climate Change. The Climate Change Division of the Ministry of Economic Growth and Job Creation is the Board's secretariat.

10.3 Climate Change Division (CCD)

A Climate Change Division (CCD), which will operate as a Division in the first phase, was established under MWLECC[73] It is the focal institution to coordinate existing and proposed initiatives in addressing climate change.

10.4 Creation of Climate Change Focal Point Network (CCFPN)

Climate change focal points were appointed in all ministries, selected departments and agencies and representation was invited from civil society groups and the private sector. The focal points will be responsible for coordinating the development and implementation of their respective sectoral strategies and actions with respect to climate change, and the mainstreaming of climate change considerations into their respective policies, plans and programmes. (See 7.3 for further discussion.)

10.5 Other Government Ministries and Agencies directly involved in climate change issues

10.5.1 Forestry Department

The Forestry Department, as a statutory body, was established in and mandated by the Forest Act 1996 to support the sustainable management of forests on Crown lands in forest reserves and estates, among other functions and will soon celebrate its 80th anniversary.

73 *The Climate Change Division remains in place following the change of government.*

10.5.2 Meteorological Service

The Meteorological Service is responsible for observing and forecasting weather conditions over and around the island, and for maintaining a current database of the climate of Jamaica and for the utilisation of this data in informing productive sectors of the country. At present, the focal point for the UNFCCC as well as the IPCC resides in the Meteorological Service.

10.5.3 National Environment & Planning Agency (NEPA)

The National Environment and Planning Agency (NEPA) was established in April 2001 as an Executive Agency under the Executive Agencies Act. NEPA was founded to carry out the technical (functional) and administrative mandate of three statutory bodies: "the Natural Resources & Conservation, Authority (NRCA), the Town & Country Planning Authority (TCPA), and the Land Development & Utilisation Commission (LDUC)[74]". NEPA has recently released the "2013 State of the Environment Report", which is one of the sources of the information contained in this report[75].

10.5.4 National Water Commission (NWC)

The National Water Commission (NWC) was formally established in 1980 through the amalgamation of the Kingston and St. Andrew Water Commission and the rurally focused, National Water Authority. NWC is charged with the responsibility of being the main provider of potable water supply and the collection, treatment and disposal of wastewater services to the people of Jamaica.

10.5.5 Office of Disaster Preparedness and Emergency Management (ODPEM)

The ODPEM provides disaster management functions in Jamaica, which include the identification of disaster threats and risks throughout the country and the formulation and execution of plans to create a state of readiness to meet the needs of victims when a disaster strikes.

10.5.6 Planning Institute of Jamaica (PIOJ)

The PIOJ is currently the major planning, policy coordination and economic management entity of the Jamaican government. Along with coordinating such national developmental priorities as the Vision 2030 National Development Plan, the main functions of the Institute include[76]:

- Advising the Government on major issues relating to economic, environmental and social policy;
- Managing external cooperation agreements and programmes; and
- Collaborating with external funding agencies in the identification and implementation of development projects.

In addition, the institute supports, coordinates and hosts numerous initiatives and projects that deal with the priority issues facing the country. These include developmental, economic, policy, and social issues, as well as climate. The PIOJ is currently involved in, or is otherwise the implementing agency for many of the island's major climate-related programmes, such as The Government of Jamaica Adaptation Fund Programme, the Pilot Programme for Climate Resilience, the Strategic Programme for Climate Resilience, and the Climate Change Adaptation and Disaster Risk Reduction Project (See Chapter 10).

10.5.7 Water Resources Authority (WRA)

The Water Resources Authority (WRA) was established by the Water Resources Act of 1995, which repealed the Underground Water Control Act and the Water Act. The WRA thereafter replaced the Underground Water Authority as Jamaica's premiere hydrologic agency. The duty of WRA is to regulate, allocate, conserve, and otherwise manage the water resources of Jamaica.

74 *NEPA. "Agency Profile: Overview." Last modified September 19, 2016. Retrieved from: http://www.nepa.gov.jm/new/about/overview.php*
75 *NEPA. 2015. Ibid.*
76 *Planning Institute of Jamaica Website: http://www.pioj.gov.jm/Home/tabid/37/Default.aspx*

11.0 Science, Education and Technology Sector

11.1 Meteorological Service

The Meteorological Service, mentioned above, has an Applied Meteorology Section that processes the needs of clients, which include crop water requirements, design criteria for hydrologists and engineers, and climatological information for resolving weather-related legal and insurance issues.

11.2 Physics Department and Climate Studies Group, Mona (CSGM) at the University of the West Indies (UWI)

The Physics Department, UWI, has a long history of research in wind and solar energy resources and turbine monitoring. The Climate Studies Group Mona (CSGM) was formed within the Physics Department at the University of the West Indies in 1994. The CSGM, comprising faculty members, consultants, technical staff and postgraduate students, conduct research into the dynamics of local and regional climate variability and climate change.

11.3 University of Technology, Jamaica (UTech)

Over the past three years, UTech has embarked on programmes that address carbon emissions through projects, research and increased education in sustainable energy and climate change.

11.4 Caribbean Maritime Institute (CMI)

CMI has embarked on a number of energy-based projects which are managed and executed through the Institute's Renewable Energy and Productivity Centre under the School of Advanced Skills.

11.6 School of Education (SOE), University of the West Indies School of Education

The School of Education, UWI, has participated in a number of climate change activities, including a UNESCO-developed climate change education course.

12.0 Establishment of a sex-disaggregated data management system

This section discusses the need for establishing a data management system that is disaggregated according to gender to quantify the respective vulnerabilities of the different genders and strengthen the conclusions of previous studies in order to build greater resilience to climate change.

It looks mainly at studies done by the Institute of Gender and Development Studies, University of the West Indies, which demonstrates that women, men, rural households, female-headed households, and the younger population all have different levels of vulnerability to disasters. Climate change will, therefore, affect genders differently and exacerbate the gender roles and structural inequality between men and women that prevail within the society.

A meaningful adaptation or resilience-building effort would, therefore, involve the inclusion of a sex disaggregated data management system. At the same time, while the argument for the inclusion of gender consideration in planning for climate change is forceful, many of the statements do not appear to be based on sound data. There is, therefore, an added need for a sex disaggregated data management system to support the conclusions, so that gender can be mainstreamed into climate change planning and policies.

12.0 Socio-economic impacts related to the adverse effects of climate change

Socio-economic impacts related to climate change in Jamaica were reported in the 'State of the Jamaican Climate (2012): Information for Resilience Building', produced by the Climate Study Group, Mona (CSGM)[77]. These impacts were extracted from other studies and put in tabular form, with detailed references. The tables were:

- Impacts of Climate Change on Freshwater Resources
- Impacts of Climate Change on Energy
- Impacts of Climate Change on Agriculture and Food Security
- Impacts of Climate Change on Human Health
- Impacts of Climate Change on Marine and Terrestrial Biodiversity and Fisheries
- Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements
- Impacts of Climate Change on Tourism Sector
- Impacts of Climate Change on Society
- Impacts of Climate Change on Gender
- mpacts of Climate Change on Poverty
- Impacts of Climate Change on Development
- Impacts of Climate Change on Natural Disaster Management

77 *Climate Studies Group, Mona (CSGM). 2012. Ibid.*

The most vulnerable sectors will be those impacted by (1) drought conditions, given the expected drying in Jamaica induced by climate change, (2) sea level rise, with a significant percentage of Jamaicans living near the coastline, and (3) floods and storms, given the likelihood that more intense rainfall will occur, though less frequently.

12.1 Areas impacted by drought are:

- Freshwater resources, affecting domestic water supply
- Agricultural sector, which depends on rain-fed and irrigated supply, leading to loss of production and food shortage
- Health sector, because of inefficient sanitation, breeding of mosquitoes in water storage drums, and malnutrition due to food shortage
- Tourism sector, which depends on a continuous supply of fresh water and food
- Energy sector, because of an increased demand for pumping water
- Social and economic development will be impacted
- Poverty and gender
- Forests prone to fires

Figure 5.1 shows areas in Jamaica that are prone to drought, including agricultural lands in the parishes of St. Catherine, Clarendon, Manchester and St. Elizabeth (Jamaica's 'bread basket') in the south of the island, and in the parishes of St. Ann, Trelawny and St. James in the north. Figure 5.2 shows forested areas prone to fires. The area in red on the far right was the site of an extensive bush fire in the parish of St. Thomas which destroyed large crops of Blue Mountain Coffee[78].

12.2 Areas impacted by sea level rise are:

- Underground freshwater resources, which will be affected by saline intrusion
- Infrastructure located near the coastline, including airports and sea ports, utilities, hotels, public buildings and private dwellings
- Beaches, thereby affecting the tourism industry
- Degraded wetlands and mangroves

Figure 5.3 shows the impact of sea level rise on Jamaica's coastline due to a sea level rise of 10 metres. Kingston and other major cities in St. Catherine, Clarendon, St. Elizabeth and Westmoreland (including the tourist town of Negril) would be inundated. Figure 5.4 shows the impact of sea level rise on the Montego Bay area due to a sea level rise of 2 metres. The runway of Donald Sangster International Airport would be completely under water. Figure 5.5 shows the impact of sea level rise on the Negril coast due to a sea level rise of 2 metres. The entire seven-mile beach front of Negril would be lost.

It is estimated that Kingston and Montego Bay will require about 60 km and 20 km of coastal protection through the construction of new levees or new sea walls.

12.3 Areas impacted by storms and floods:

- Energy sector
- Tourism sector
- Agriculture sector
- Freshwater Resources
- Health sector
- Coastal, marine and terrestrial Ecosystems
- Poverty and gender

Figure 5.6 shows areas of Jamaica prone to river flooding during heavy rains. Much of the flooding would occur in prime agricultural areas.

12.4 Most Vulnerable

Among the population, the poor will be the most affected, as they will be the least able to adapt. Unfortunately, they are a growing number as shown in Figure ES3.5, which shows the percentage of the population at or below the national poverty line. In 2012, the proportion of Jamaica's population living below the poverty line was close to 20%, up from 9.9% in 2007. Poverty is linked to the employment rate. Since 2006, the unemployment rate has been steadily increasing, as shown in Figure ES3.4. It stood close to 10% in 2006 and almost reached 14% by 2012, according to World Bank data. The ability of the Government to assist the vulnerable in times of disasters is limited, due to its present economic state. Figure ES3.2 gives the growth in Gross Domestic Product (GDP) according to World Bank data from 2006 to 2015, showing a slump from 2005 to 2009, with subsequent recovering in 2011, but struggling thereafter. The debt to GDP ratio was between 110% and 130% from 2006 to 2009, but over 130% thereafter.

78 *Jamaica Gleaner. "Government Help St. Thomas Farmers," July 17, 2015. Retrieved from: http://jamaica-gleaner.com/article/news/20150717/government-help-st-thomas-farmers*

Figure 5.1: Average rainfall over Jamaica. Areas in red and orange are prone to drought

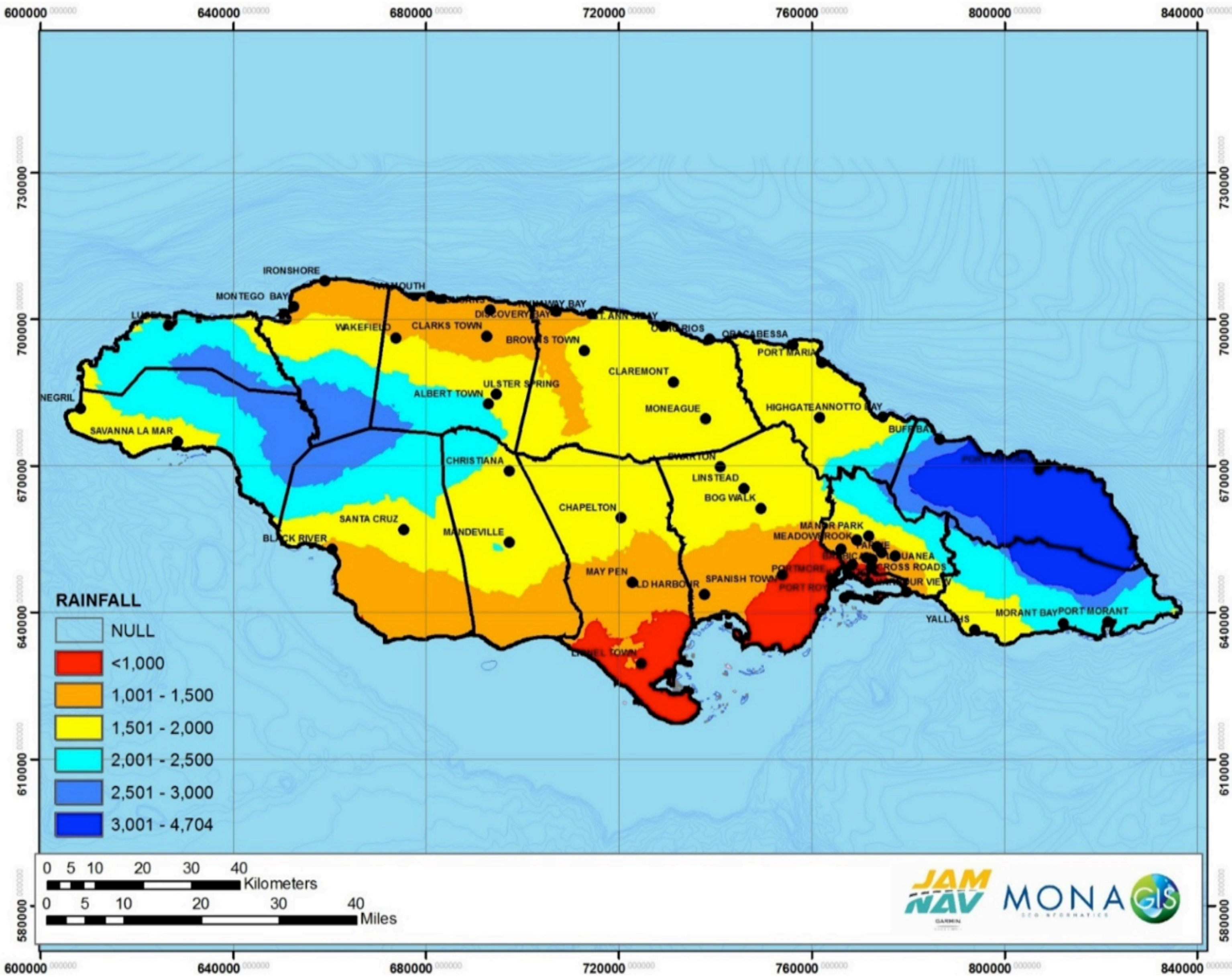


Figure 5.2 Forested areas with average or below average rainfall prone to forest fires in years of below average rainfall.

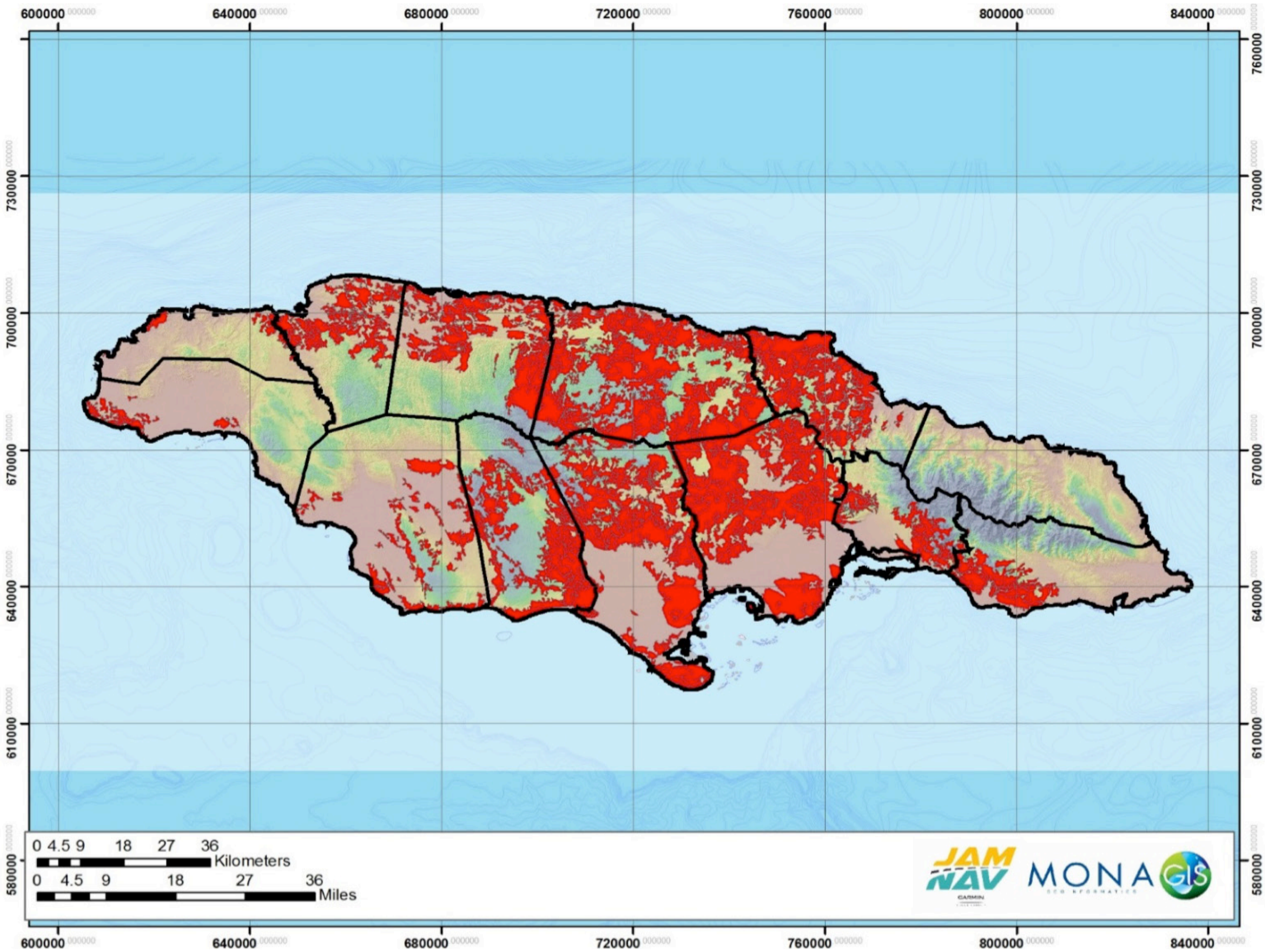


Figure 5.3: Extent of the impact of sea level rise on Jamaica's coast line due to a sea level rise of 10 metres.

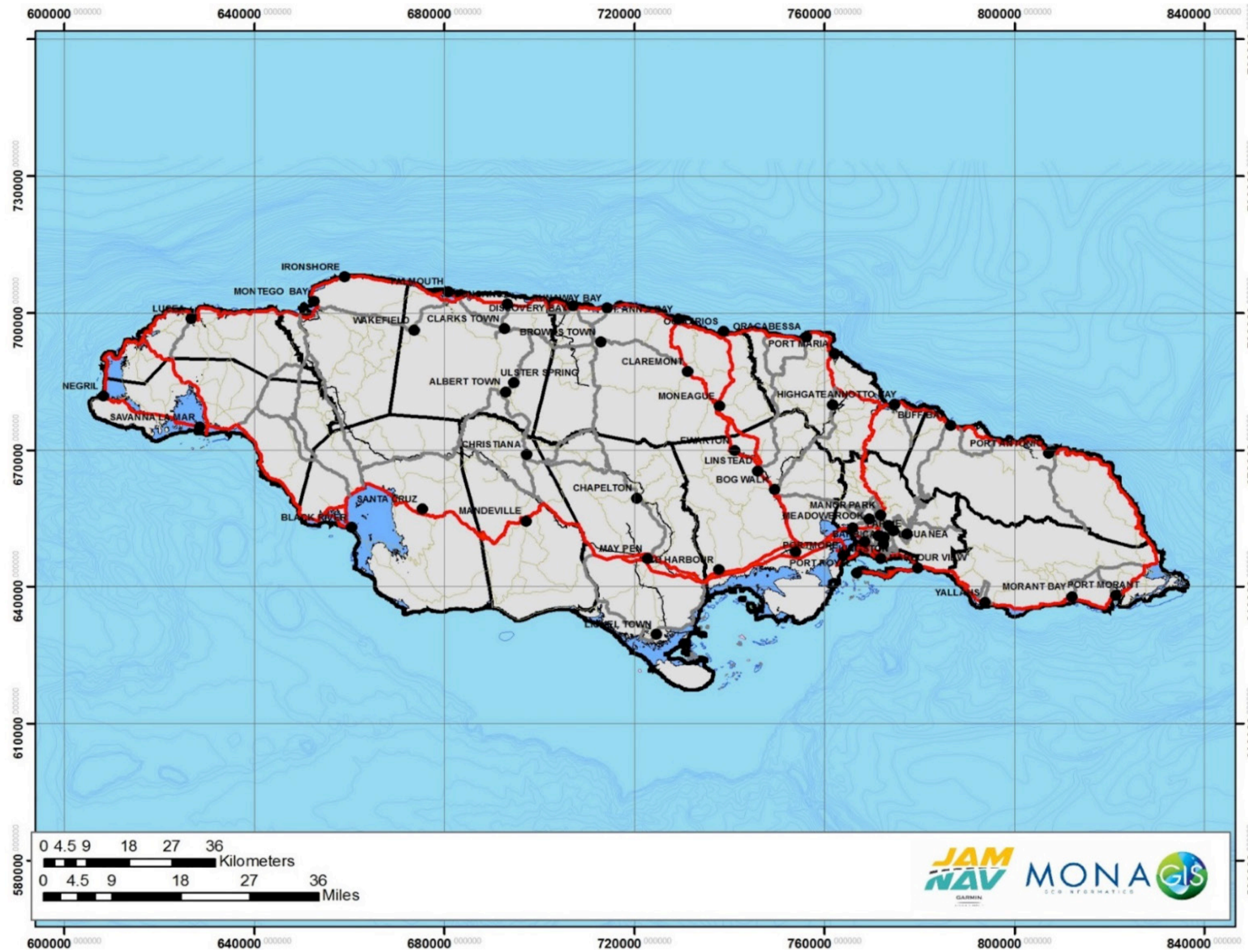


Figure 5.4: Extent of the impact of sea level rise on the Montego Bay area due to a sea level rise of 2 metres

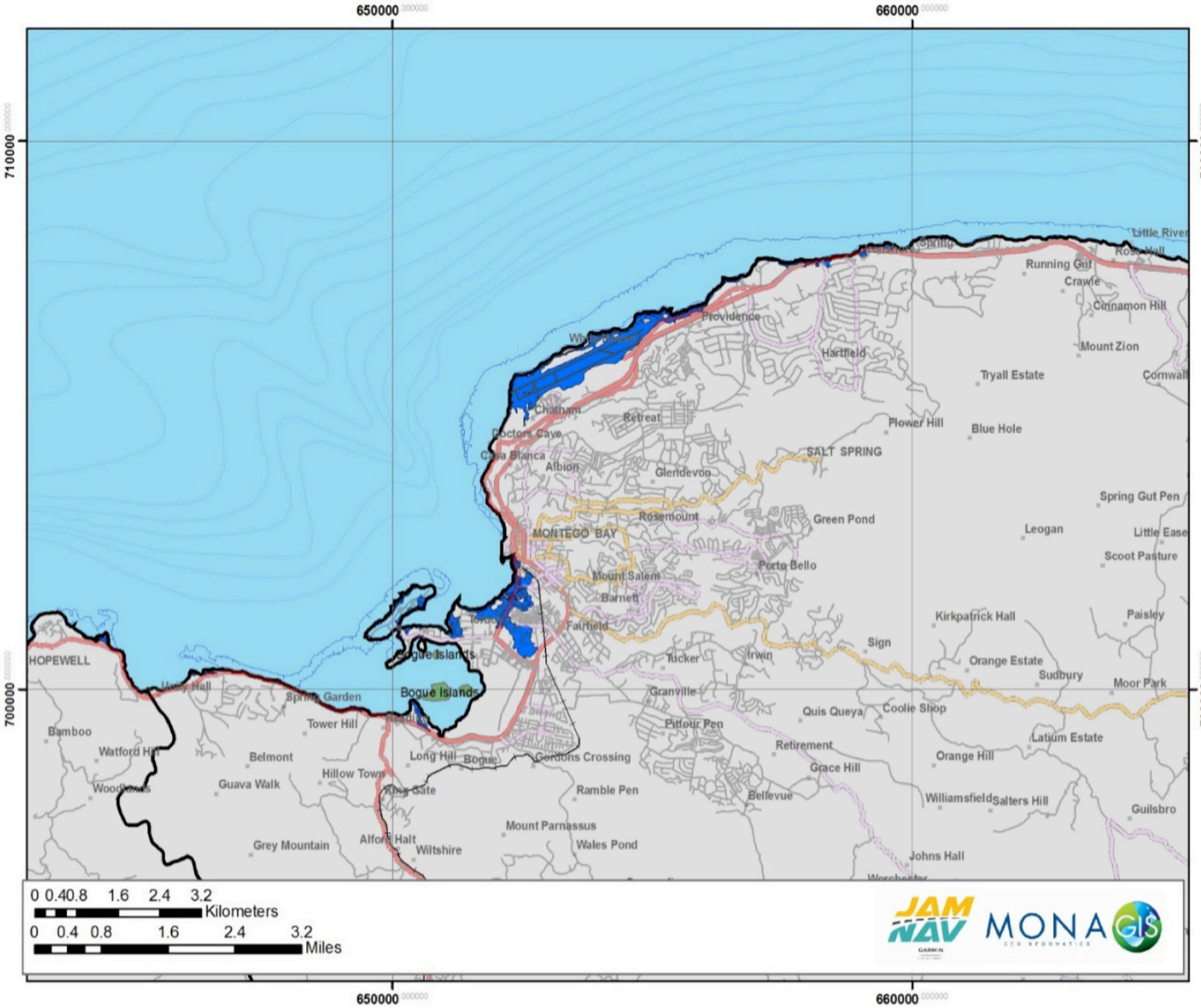


Figure 5.5: Extent of the impact of sea level rise on the Negril coast due to a sea level rise of 2 metres.

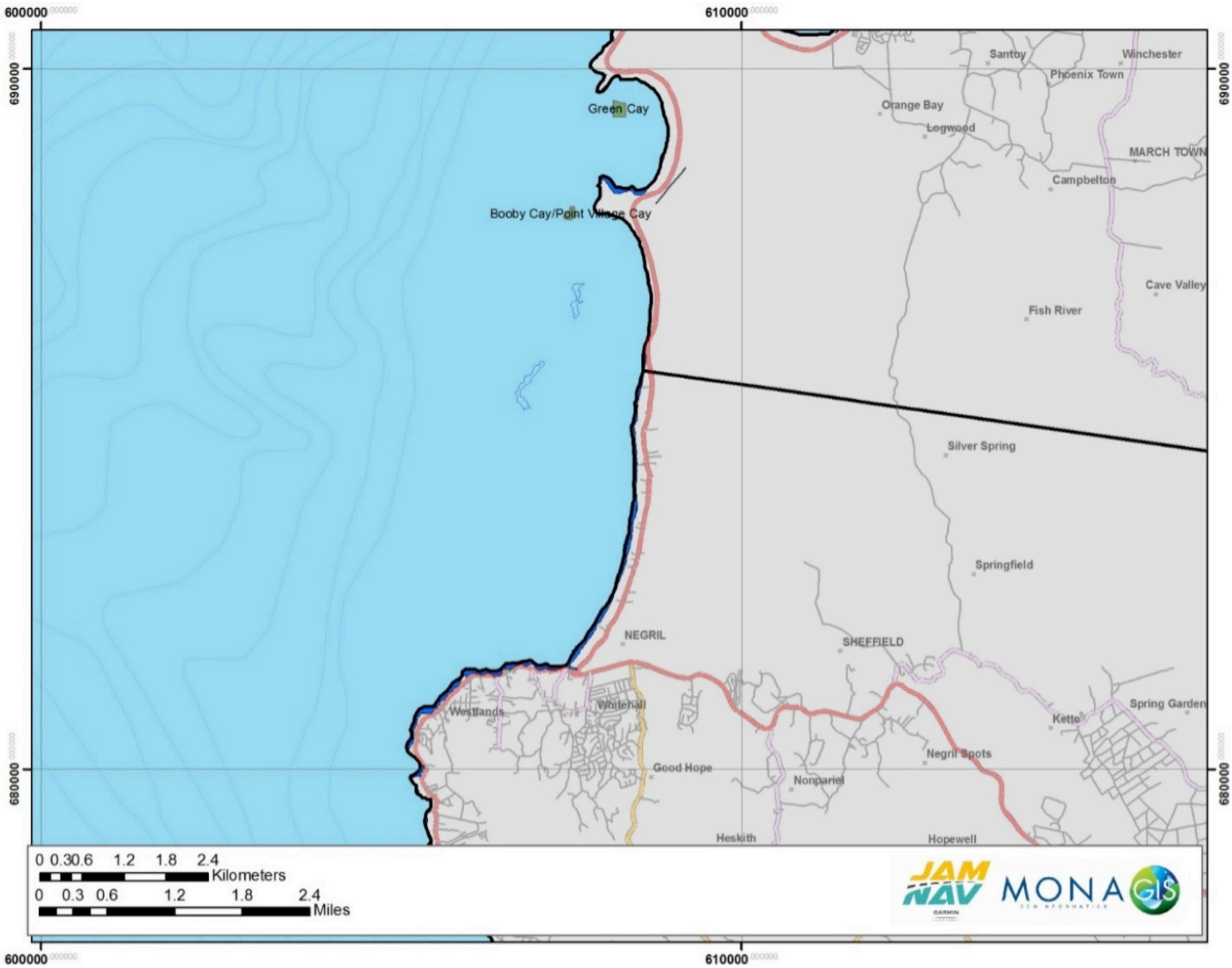
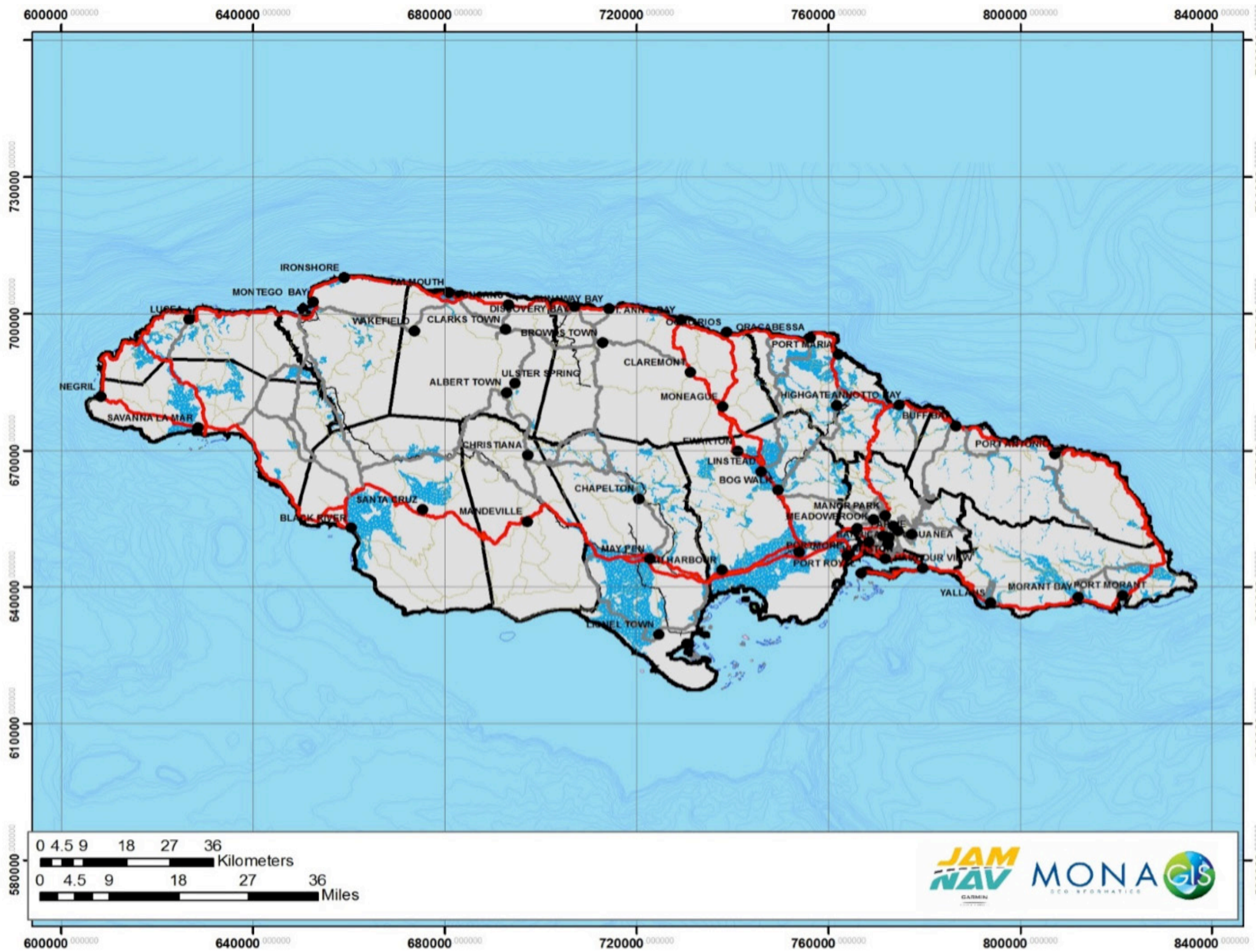


Figure 5.6: Areas shown in blue prone to river flooding, much of it in prime agricultural areas.



13.0 Specific needs and concerns arising from the adverse impacts of climate change and Strategies/ Recommendations for response measures

The data for this section were gathered from a questionnaire administered to participants at the launch of the Third National Communication. The Second National Communication addressed the needs and concerns arising from the impacts of climate change and made over 130 recommendations for dealing with climate change, mostly in the energy and water sectors. Just over 80 of these were said to be implemented, but only 50 of these were verified as implemented.

Main reasons as suggested by responses to the questionnaire	
Main reasons for the non-implementation of the recommendations	• Recommendations were not passed on to the relevant offices. • Ministries or Agencies involved do not collaborate on climate change issues. • The necessary institutional collaboration could not be arranged. • Guidelines could not be adequately defined. • Recommendations were deemed inadequate or unnecessary. • The timeframe was not sufficient for efficient execution. • Government does not consider climate change to be an important issue. • Person(s) responsible do not consider climate change to be an important issue. • Person(s) responsible did not take appropriate action. • The required funding was not available. • Materials, equipment, data or other resources could not be obtained. • Public resistance prevented acceptance of the proposed measures.

Those attending the launch considered the following to be priority actions for the
Third National Communication:

- Government must regard climate change as a priority and an overarching issue for all ministries' comments.
- The staff complement of the Climate Change Division should be increased and there should be more collaboration with the Climate Change Focal Points in the ministries/agencies.
- Capacity building measures must be undertaken e.g. formal training in climate change for climate change focal points.
- Government must state its Intended Nationally Determined Contributions (INDC) to greenhouse gas mitigation, i.e. government must state its greenhouse gas mitigation target[79].
- Government should be a strong advocate of an Apollo-type climate change programme at the COP[80].
- The Government of Jamaica needs to improve public transportation system so that it is safe and convenient in order to reduce the number of cars on the road and thereby reduce fossil fuel emissions.
- The Government of Jamaica should introduce a school bus system to transport children and cut down on the number of cars on the road and loss of man hours.
- The Government of Jamaica needs to promote Jamaica as a site for pilot projects in renewable energy.
- The Government of Jamaica needs to move more urgently in increasing the use of renewable energy e.g. by increasing the return rate on net-billing.

79 This has since been done for COP21.
80 See: https://www.theguardian.com/environment/2015/jun/02/apollo-programme-for-clean-energy-needed-to-tackle-climate-change

- The Government of Jamaica needs to promote lifestyle changes to reduce fossil fuel emissions, e.g. promote carpooling, discontinue the burning of yard trash and energy conservation
- With the increasing prospects of more droughts in a changing climate, the government must immediately act on adaptation plans for water management and agriculture.
- The government must immediately act on adaptation plans for sea level rise.
- More funding sources must be identified and approached to implement climate change adaptation and mitigation.
- Integrate climate change into the education curriculum from the basic through tertiary level.
- Public education programmes must be developed, e.g. community workshops on the impact of climate change on diseases.
- Optimise building codes and/or setbacks to account for climate change and regulations.

The following were seen as possible impediments to acting on the above priorities:

- Recommendations will not be passed on to the relevant offices.
- Government does not consider climate change to be an important issue.
- Climate change adaptation is not a priority issue for Jamaicans, i.e., climate change is not an issue we have to deal with now.
- Climate change mitigation is not a priority issue for Jamaicans since they consider our carbon footprint to be insignificant[81].
- Public perception that climate change is an issue for developed countries since they are the cause of the problem.
- Monetary issues are more important than climate change issues, e.g., cheaper coal is more important than cleaner air.
- Person(s) responsible will not take appropriate action.
- Ministries or Agencies involved will not collaborate on climate change issues.
- The necessary institutional collaboration will not be arranged.
- The required funding will not be available.
- Public resistance will prevent acceptance of the proposed measures.
- Guidelines will not be adequately defined.
- Materials, equipment, data or other resources will not be obtained.
- Recommendations will be deemed inadequate or unnecessary.
- The time frame will not be sufficient for efficient execution.
- Appropriate personnel will not be identified for completion of the project.

Participants were asked if there were any special needs, concerns, or strategies that should be considered. Among those suggested were:

- Proper linkages between climate change adaptation and disaster risk reduction
- Engage with formal education system
- Engage youth organisations
- Engage with churches
- Internal funding (i.e. budget allocation) for climate change is absent or inadequate
- Further sensitisation of political directorate on a regular basis (quarterly updates and basic information)
- When thinking of capacity building, e.g. training, it should include more than government employees, but also the private sector, NGOs, CBOs, church youths etc.

14.0 Gaps, Needs and Constraints

The material in this section was gleaned from questionnaires and face-to-face interviews with stakeholders.

14.1 Awareness Gaps

The Climate Change Division (CCD) and PANOS Caribbean have done a great deal to promote awareness of climate change in Jamaica. Despite this, it can be concluded that, although the majority of the Jamaican population knows about climate change, not enough individuals know what to do about it.

A recent meeting with the UN Economic Centre for Latin America and the Caribbean (UNECLAC), pointed out that Jamaica has not yet done a sufficient job in raising awareness about climate change. There is relatively good knowledge through the public sector, but not throughout society, especially among the private sector.

Importantly, most Jamaicans are not cognisant of the cause of climate change and the need to mitigate greenhouse gases. Maybe this stems from the predominant concern about adaptation, which mainly has to do with protecting the environment, so that the general population thinks that the protection of the environment is sufficient to mitigate climate change.

This is particularly true of a small country like Jamaica with a relatively small carbon footprint compared to the big emitters. Most Jamaicans are not aware that Jamaica has a relatively high per capita GHG emission, and that our total emission is comparable to that of Uruguay and Georgia and higher than that of Albania. They do not think that Jamaica needs to mitigate, and they are of the opinion that it should all be left up to the big polluters.

Without an appreciation among the population that it is necessary for Jamaica to mitigate, the decision-makers who react to social pressures will not be greatly concerned about mitigation, and yet according to the Paris

81 It is not. See ES7.1.

Agreement, which was signed in December and will go into effect shortly, all countries agree to achieve a low-carbon economy and that there should be little or no fossil fuel emission by the middle of the century.

14.2 Awareness Needs

The foremost awareness gap to be filled is for greater climate change knowledge of the political directorate. There is a need to develop ways to engage the political directorate more in the climate change discussion. Personnel at every level must be sensitised to climate change, e.g., programmes aimed at cabinet sensitisation to climate change, permanent secretaries, etc.

At the moment, many public servants still think of climate change as an environmental issue, so the full sweep of effects is not fully understood. They need to understand that climate change is a development issue with potential positive effects on energy and energy security, and implications for livelihood, imports, tourism, etc.

Awareness efforts should be fostered by the Climate Change Division through the National Focal Point Network, and by the Planning Institute of Jamaica (PIOJ), through the thematic working groups coordinated through Vision 2030, such as the Specific Climate Change Thematic Working Group. In addition, the Climate Change Division must make "the man on the street" aware of what climate change is and the need for Jamaica to mitigate greenhouse gases to the point of zero emission as required by the Paris Agreement.

Other awareness needs are:

- Making greater use of the formal education system to develop awareness. Data should be shared with teachers through different media, e.g. online discussions, meetings and a formal curriculum, which would help them to integrate climate change into their own curriculum.
- Similarly, churches, service clubs and the private sector need to be involved in raising awareness at the national and community levels.

14.3 Capacity Building: Gaps and Needs

The greatest need for capacity building lies in the Climate Change Division. The Division and the Climate Change Focal Point Network were conceived to be the engines of climate change action, but the Division needs to be fully staffed and the Network is in a process of upgrading. The CCD wants to go beyond simply representing Jamaica at international meetings and participating in international fora, but lack of staff currently prevents this. More staff is needed at many levels, including higher management levels, particularly for the development of Strategy and Action Plans for the various sectors.

A key unit within or associated with the CCD would be an economic unit, which is needed to evaluate the cost of impacts, the feasibility of climate change action, the value added by climate change action, the economic cost of inaction, the amount of financing needed for climate change actions, the options for insurance, as well as other economic considerations.

The focal point network is so important that CCD should have a staff member working with the focal points to help facilitate the work they need to do. Such a person could be a "Partnership Development Specialist", because CCD needs to develop partnerships so that agencies/ministries will have the wherewithal to integrate climate change into everyday activities without making it feel like irrelevant intrusion or too much extra work.

The Climate Change Focal Point network itself is not being used effectively. Very often, the focal points are officers within the ministry and not decision-makers. Ideally, they would be able to coordinate among various agencies and so should have decision-making powers or at least a management position. It would be ideal that the focal point be a senior officer who has influence on a department and on policy or that he/she be someone in a policymaking position. Ideally, there would be a team within each department rather than one person.

The Focal Point Network would not require more staff in each ministry but, since Focal Points need to have more than a basic understanding of climate change to appreciate climate change as a national and development issue, and since most are not specially trained, there needs to be a training programme for them. CCD does not have a resident person with the requisite climate change expertise to effectively train others in climate change. Possible training solutions could be:

- A course to force exposure to climate change issues at one of the tertiary education institutions.
- Training can be done through workshops, but these may have to be done in phases.
- Through 5Cs (C-Coral) or USAID and other organisations that can provide training.

Training, though, must be streamlined and coordinated, which can be done by CCD.

To increase manpower available to the CCD, and to add some required expertise, a merger of the CCD and Meteorological Service has been proposed. There are certain advantages:

- The combination of the two would help to fill some capacity needs:
    - Met Service collects climate data that forms basis of analyses, so this would improve lack of capacity in data collection;

- Met Service could help with awareness building since it has the staff to do this;
- Met service would bring with it an accounting department and could bolster administrative capacity. Because of the size of the Met Service, they already have much of the facility they need. This would relieve some of CCD's administrative responsibilities;

- In engagement with international services, Met Service also represents the country, so capacity in that area would be increased as well, along with the pool of experience. Currently, Met Service is Jamaica's IPCC and UNFCCC focal point, but CCD will now take over that role.

Overall, the merger has challenges:

- The merger may not help specific needs noted above, such as the need for someone to oversee a project to get Sector Strategies and Action Plans completed and the need for a "Partnership Development Specialist", so that additional staff will be required.
- Although the Met Service has expertise to help with meteorology-related research, other areas of research will be needed such as those related to economics, coastal zone management, energy sources and food production. It has been suggested that a university be engaged as the research arm of the CCD. Besides technical expertise, a university would add fund-raising expertise.

15.0 Capacity Building: Database Establishment

One of the aims of the Climate Change Division (CCD) is to establish a climate change clearing house into which would be placed all climate change-related data. The following are some of the gaps and needs in achieving this:

- The Information Technology skillset of CCD is not currently adequate/varied enough to manage a climate change clearing house. CCD can overcome this by making use of other databases, resources and personnel in other agencies, e.g. National Spatial Database, Climate Risk Information Platform under Pilot Project for Climate Resilience (PPCR), Jamaica Disaster Vulnerability Reduction Project (DVRP), Climate Innovation Centre or the Met Office climate database CLIDATA.
- It is not necessary to develop something entirely new, but one that will harness information from all other sources. Having an all-inclusive database would ensure that data is more accessible. However, there would need to be coordination between the users and producers of these data to facilitate getting output in the most useful format. Technical consultation on how best to structure the database is necessary
- The database should have information on all climate change-related projects executed in Jamaica, evaluation of the projects and lessons learnt. This will allow it to serve as a basis for project developers, project coordinators and funding agents. It would therefore serve as a basis on which to build, and not rehash projects.

16.0 Technology Needs in Adaptation

Some of the technology needs in adaptation are:

- A scientific and engineering investigation, most likely involving an oceanographer, is needed to determine the best method for combating beach erosion. The need was evident in the recent impasse between the Planning Institute of Jamaica and some Negril stakeholders. Beach erosion is occurring at many places in Jamaica and proper adaptation is needed.
- Jamaica will become drier due to the impact of climate change. Methods for enhancing the water resources for domestic and agricultural uses are needed.
- Agricultural production will be affected by a hotter and dryer climate and by saline intrusion due to sea level rise. Methods of adaptation, such as plant and livestock breeding, are needed.

16.1 Technology Needs in Mitigation:

16.1.2 Storage of Energy

The primary need in mitigation is for the transfer the technology of storage of electricity to Jamaica. This follows from the need to fulfil Jamaica's Intended Nationally Determined Contributions and Jamaica's commitment to the Paris Agreement.

16.1.3 Jamaica's (Intended) Nationally Determined Contribution

Jamaica's Intended Nationally Determined Contributions (INDCs) will 'mitigate the equivalent of 1.1 million metric tons of carbon dioxide per year by 2030 versus the BAU scenario'. This is a reduction of 7.8% of emissions versus BAU. '**This target is predicated on the current level of implementation of the National Energy Policy and the existing pipeline of renewable energy projects.**'

Without the storage of energy, Jamaica is unlikely to meet this target. Jamaica has one electrical grid system owned and operated by the Jamaica Public Service, which is not connected to any other grid system and cannot rely on another grid system for backup in cases where a part of its generating system fails.

The Jamaica grid system must have its own backup, which is currently done by having a spinning reserve fuelled by fossil fuel, i.e., standby power is being generated by fossil fuel in case it needs to be called upon, and is referred to as spinning reserve. Because of its variability, any renewable energy system added to the grid has to be backed up by this spinning reserve.

Admittedly, when the spinning reserve is just on standby it will be using less power, but power nonetheless. Because renewable energy is intermittent, this spinning reserve will be called upon to come on full power more often than if it were backing up firm energy such as fossil fuel. We, therefore, have a situation where we add renewable energy to the grid and that renewable energy will replace a certain amount of fossil fuel. However, because the renewable is variable or intermittent, it has to be backed up by fossil fuel if there is no storage of electricity, and the backup process will occur more often than in the case where a fossil fuel plant with firm energy is being backed up by spinning reserve.

The only clean energy solution is to store excess electricity generated by the renewable sources, which can then be called upon during times of intermittence. Storage can take the form of pumped storage, batteries or more exotic forms such as hydrogen storage. Without storage, Jamaica is very unlikely to meet its INDC, no matter how much renewable it adds to the grid.

16.1.4 Paris Agreement

Jamaica has committed itself to a low-carbon economy by the middle of the century. The pathways to a low-carbon economy outlined by the IPCC include Carbon Capture and Storage (CCS), Bioenergy and Carbon Dioxide Capture and Storage (BECCS), nuclear energy, renewables and conservation. Because of its geographical formation and absence of natural storage reservoirs for gases, CCS and BECCS are out of the question for Jamaica.

Nuclear energy would be an option for Jamaica only if it came in small modular sizes. These modular nuclear units are just coming on stream and are yet to be fully evaluated.

The only clear options for Jamaica are renewable energy and conservation. As indicated in the previous section, storage of electricity would be necessary for intermittent renewable, even more so for a low-carbon economy where renewable energy would be the dormant part of the energy mix. So, unquestionably, storage of electricity would be necessary for Jamaica to embark on a path of a low-carbon economy.

16.1.5 Monitoring Greenhouse Gas Emissions

The Climate Change Division needs capacity and technology for monitoring greenhouse gases.

16.2 Technology Needs in Climate Modelling and Data

- More impact modelling is needed. Impact modelling gives the greatest opportunity to test what the future would look like without physical experimentation, which is costly, e.g. crop modelling allows one to see what success transplanting a variety from another location would have without having to invest in cultivating the plant itself.
- Meteorological Service needs more real-time weather stations, but further work must be done to determine optimum weather station distribution by looking at topography and other factors affecting microclimate. In the same vein, security for weather stations is needed so that they can be securely placed at the sites at which they will be more useful.
- Meteorological Service needs to acquire long time series of data for analysis.

16.3 Technology Needs in the Agriculture Sector

Besides adapting agricultural production to climate change as previously outlined, the following needs are noted:

- Data for agricultural-resilience projects are needed, e.g. data on the best crops for particular extremes in particular areas, soil types, best animal feed in particular climate extremes (e.g. using local materials in the absence of water and grass), and climate information more specific to agriculture (e.g. agricultural drought information specific to particular areas being included in weather reports, rather than vague evaluations of general rainfall distribution across the island).

- There is a need for the use of solar and wind energy in agriculture, such as in pig farms, poultry farms, water pumping, shallow wells, etc. The sector is currently focused on using fossil fuels, but there is a need to move more into using renewable energy, e.g. retrofitting storage facilities, farms, poultry houses and piggeries to be more energy efficient to keep costs down.
- Many adaptation projects will focus on water harvesting from rainwater, but other sources are available that currently cannot be made useful because of a lack of technology, e.g. springs and streams cannot be used because of a lack of pumps.

17.0 Financial Needs in Adaptation and Mitigation

Undoubtedly, financial assistance will be needed to adapt to the impacts of climate change to which we are already committed because the financial state of the nation is not strong enough to provide funding for all the necessary projects. These include adapting agricultural production to drier and hotter conditions, and protecting against beach erosion.

However, it must also be realised that fossil fuel emissions are the causes of climate change and, without mitigation of fossil fuels, climate change will worsen and no amount of adaptation will stop it. In fact, if the problem of fossil fuel is not solved, humanity will have to adapt to higher and higher temperatures until it is unable to adapt anymore, so that finances are also needed for mitigation. The Green Climate Fund recognises this and has allocated the funds based on a 50-50 allocation to adaptation and mitigation.

There have been suggestions in the Caribbean that the funds should be applied more to adaptation than mitigation[82]. However, the argument against tipping the balance of climate financing toward adaptation is multi-fold.

Firstly, the argument against funds for mitigation, such as wind and solar, is that investments in these energy sources are profitable and can attract investors, but this is not always the case. Wind energy is site specific and solar energy depends on atmospheric conditions, such as the amount of cloud cover. Thus, there will be some nations and places where these sources of energy cannot be used economically. Secondly, it follows that in many cases the sources of energy, be it wind, solar, hydro, biomass, wave or tidal, will need government subsidy, which in most cases will have to come from climate financing, such as the Green Climate Fund (GCF) or the Global Environment Facility (GEF).

Thirdly, and most importantly, it must be remembered that the aim of mitigation globally is to eliminate the use of fossil fuels worldwide and this cannot be accomplished by developing countries without financial assistance, as will be discussed below.

Most Jamaicans feel that Jamaica is a small emitter and does not need to mitigate greenhouse gases. While Jamaica is a small emitter compared to major developed or developing countries, its emission is relatively high compared to many small nations and is comparable to many larger countries. For example, Jamaica's emission is as large as that of Georgia in Europe and Uruguay in South America, and is larger than that of Albania in Europe. It will be the responsibility of all nations to mitigate. No nation can claim exemption.

As discussed in Section 7.6, the only sensible alternative source of energy for Jamaica to replace fossil fuels is renewable energy, such as wind, solar, wave, and hydro. For these sources to provide a firm supply of energy, storage of energy is required to be brought online when the renewable resource drops off, as in the case of calm winds or cloudy periods. Renewable energy plus storage is not cheap, and no one will invest in it without subsidy. No investor at present will invest in renewable energy plus storage because he will not immediately make a profit, if at all. Such subsidy can come from sources, such as the GCF or the GEF. For this reason, there should be no shifting of the balance of GCF away from mitigation.

17.1 Financial needs in the public sector:

- At present, there is no set budget for climate change, although there may be sections of the overall budget that deal with climate change issues. For example, the Ministry of Finance has embraced risk management and resilience building as an important element, and are looking at different kinds of risk, so climate change should be considered as an element of risk in all sectors. But climate change is also a development issue and it needs to be tied to corporate targets to ensure that the medium-term plan included climate change. Tying climate change into targets would force climate change to be accounted for.
- A 'debt for environment swap' can be implemented to divert payment of loans into environmental protection.
- There is a need for a climate insurance scheme because, when there is a climate event, 'build back better' works only if you have a good insurance scheme.

82 *CCCCC. "Dr Ulric Trotz: Let's Re-imagine GCF Resources (article and interview)," Caribbean Climate Podcast, May 31, 2016. Retrieved from: https://caribbeanclimateblog.com/2016/05/31/dr-ulric-trotz-s-re-imagine-gcf-resources-article-and-interview/*

18.0 Constraints in filling gaps and needs in awareness, capacity building, technology transfer and finances

From responses to questionnaires issued at the workshop to launch the Third National Communication, the following were seen as major impediments in implementing recommendations, similar to those in Section 6:

- Recommendations will not be passed on to the relevant offices.
- Government does not consider climate change to be an important issue.
- Climate change adaptation is not a priority issue for Jamaicans, i.e., climate change is not an issue we have to deal with now.
- Climate change mitigation is not a priority issue for Jamaicans since our carbon footprint is considered small[83].
- Public perception that climate change is an issue for developed countries since they are the cause of the problem.
- Monetary issues are more important than climate change issues, e.g., cheaper coal is more important than cleaner air, and consideration for human health and environment.
- Person(s) responsible will not take appropriate action.
- Ministries or agencies involved will not collaborate on climate change issues.
- The required funding will not be available, i.e., a lack of fiscal space.

18.1 Other constraints in finances

- Although money is available, it may not be easy to access. For example, Jamaica's GDP designation does not allow it to access all sources of funding because many funding opportunities are decided on based on the state of the economy rather than on ecosystem needs.
- The Finance Ministry may impose restrictions on fiscal space despite availability of funds.
- There is often discord between funding priorities of GEF and local needs/issues so that funding priorities sometimes do not address causes of issues and projects do not end up as successful as they could be.
- Although PIOJ has been reaccredited as the National Implementation Agency for the Adaptation Fund, the approval process is also often rigorous for national funding and capacity is lacking, both in preparing project proposals or project documents and in implementation.

19.0 Effects on Jamaica from the external implementation of measures to respond to climate change and a strategy to counter these effects

19.1 Effects

Of immediate concern to Jamaica would be a tax on aviation emission, which is one of the fastest-growing sources of greenhouse gas emissions. The EU is acting to reduce aviation emissions in Europe by including the aviation sector in the EU Emissions Trading System (ETS) and working with the international community to develop measures with global reach[84].

More recently, the International Air Transport Association (IATA) expressed optimism for an agreement on a Carbon Offset and Reduction Scheme for International Aviation (CORSIA) when governments meet for the 39th Assembly of the International Civil Aviation Organisation[85]. It is, therefore, likely that this sort of emission reduction scheme will be increased and enforced. Taxes on the emission from aviation and shipping could well follow suit.

These considerations do not yet appear to be a consideration for market research by shipping and tourism agencies in the Caribbean. However, preliminary studies show that price-sensitive travel destinations could face a reduction in tourism of between 2.4 and 7%. Barbados could face a loss of up to 1 – 2% of its GDP as a result of a fall in tourism[86].

Fossil fuel divestment campaigns, such as the Guardian's 'Keep it in the Ground' campaign, gained ground leading up to the COP 21 Meeting in Paris. One method of forcing the issue is the use of a carbon tax, such as that advocated by James Hansen[87].

In addition to these mitigation measures, there is the possibility of some international adaptation measures that may have negative impacts on Jamaica. Among these could be higher insurance costs due to re-insurers taking climate change impacts, such as hurricanes and storms or droughts, into consideration. Another possibility could be a ban on exportation of food, e.g., rice or wheat, by a country that is a normal exporter, but has been hit with a food shortage due to droughts. If Jamaica relied on this country for its imports, Jamaica would face a food shortage.

83 See 7.1
84 EU webpage: https://ec.europa.eu/clima/policies/transport/aviation/index_en.htm
85 IATA. "Historic Aviation Carbon Agreement Moves a Step Closer," IATA Press Release, September 6, 2016. Retrieved from: http://www.iata.org/pressroom/pr/Pages/2016-09-06-02.aspx
86 Leal Filho, W., Mannke, F., Mohee, R., Schulte, V., Surroop, D. (Eds). 2013. Climate-Smart Technologies - Integrating Renewable Energy and Energy Efficiency in Mitigation and Adaptation Responses. ISBN 9783642377525. Springer, Berlin.
87 Hansen, J. 2009. Carbon Tax & 100% Dividend vs. Tax & Trade: Testimony of James E. Hansen to Committee on Ways and Means United States House of Representatives.

19.2 Strategies

Jamaica can help to mitigate GHG from air and sea travel in small ways. For example, advertisements could be focused on North America to promote Jamaica as a closer destination, compared to Europe or the Far East, so that North American tourists would be responsible for less emission by vacationing in Jamaica rather than travelling farther afield. Such advertisement would be enhanced if Jamaica were to also promote itself as a green destination. This is done by Costa Rica under its Green Trademark[88], or to promote other activities like community tourism, that is advertised by Villages As Businesses,[89] in order to widen the visitors' experience.

The use of a carbon tax should be explored as Jamaica makes every effort to convert to a green, low-carbon economy as soon as possible. There is not much that can be done by Jamaica to reduce the cost of insurance, but Jamaicans should become more resilient to storms, floods and fire so that they can lessen their insurance coverage. To counter possible food shortages, Jamaica should become more self-sufficient in food production, producing more of its staples, such as rice, and finding substitutes, such as cassava, for wheat and other staples. Jamaica should realise that there are mitigation and adaptation measures taken by other countries that may adversely affect the island and should be prepared to address them.

20.0 Other Information

20.1 Costs of disasters in general and estimated cost of future climate change disasters

20.1.1 Disasters in General

Jamaica is vulnerable to disasters caused by droughts, fires, floods, storms, sea level rise, and storm surges. Not all disasters are due to climate change, and ascribing disasters to climate change requires sophisticated statistical analysis and modelling[90] not yet done for any disaster in Jamaica. Nevertheless, since there is the likelihood that more and more future disasters will be linked to climate change as projected by modelling, the costs of damage and loss due to past disasters are indicative of the costs of future disasters on an event-by-event basis. Tables 9.1 and 9.2, giving historical damage and loss assessment due to floods in 2002 and storms and hurricanes between 2004 and 2012, were compiled from assessments provided by the Planning Institute of Jamaica.[91] The total cost is well over $113 billion Jamaican dollars or over $877 million US dollars, as some costs are not available. Tables 9.3 and 9.4 give the cost of relief after the disasters and the population affected by the disasters. Again, the tables are incomplete.

20.1.2 Projected costs of climate change damage and loss

Projected cost of damage and loss due to climate change will be higher because impacts are expected to become more severe with time and almost all costs will be included. Table 9.5 gives the annual and capital costs to Jamaica for sea level rise scenarios (mid and high range) in 2050 and 2080 developed by CARIBSAVE[92]. Tables 9.6 and 9.7 give some adaptation costs prepared for the Ministry of Economic Growth & Job Creation[93]. Details for most costing are not given. Regardless, the cost will be high.

20.1.3 Cultural Practices that can impinge on climate change action

Culture can condition behavior in such a way as to be a help or hindrance to tackling climate change and so has an important role to play in the implementation of climate change actions, I particular, awareness raising.

20.1.4 Religious Culture in Jamaica

Faith tradition has the potential for helping climate change action in the Jamaica where the majority profess to be Christian. While some use Genesis 1:28 to foster selfish capitalism, others interpret this tradition as a call for environmental stewardship since it implies that man rules creation in God's stead and must do so according to his divine will[94].

Pope Francis' Environmental Encyclical, 'Laudato Si' is in this mode. Unfortunately, the Catholic hierarchy in Jamaica has not seized the

88 Oviedo et al. 2015. Costa Rica's development from good to better: systematic country diagnostic. International Bank for Reconstruction and Development / The World Bank, Washington, DC, USA.

89 Villages As Businesses Website: http://www.jamaica-no-problem.com/villages-as-businesses.html#sthash.EzoxYhbV.xGXnUZB7.dpbs

90 The science of ascribing extreme events to climate change is young but developing. See e.g., Herring, S. C., M. P. Hoerling, J. P. Kossin, T. C. Peterson, and P. A. Stott, Eds., 2015: Explaining Extreme Events of 2014 from a Climate Perspective. Bull. Amer. Meteor. Soc., 96 (12), S1–S172.

91 See http://pioj.gov.jm/ResearchandData/DLAResources/tabid/136/Default.aspx

92 Simpson, M.C., Scott, D., Harrison, M., Sim, R., Silver, N., O'Keeffe, E., Harrison, S., Taylor, M., Lizcano, G., Rutty, M., Stager, H., Oldham, J., Wilson, M., New, M., Clarke, J., Day, O.J., Fields, N., Georges, J., Waithe, R., McSharry, P. 2010. Quantification and Magnitude of Losses and Damage Resulting from the Impacts of Climate Change: Modelling the Transformational Impacts and Costs of Sea Level Rise in the Caribbean (Full Document). United Nations Development Programme (UNDP), Barbados, West Indies.

93 Silva, Homero. 2016. Final Report on Health Impacts by Climate Change. Prepared for Ministry of Economic Growth & Job Creation.

94 See: http://www.acton.org/public-policy/environmental-stewardship/theology-e/environmental-stewardship-judeo-christian-tradition occasion. However, some individuals are trying to use this to make a difference. In 2011, the Jamaica Baptist Union published its Environmental Stewardship Series, which is a seven-series publication intended to promote environmental conservation among members of the Christian community, included a section on climate change.

Table 9.1 Costs of damage and loss due to disasters 2002-2012 (J$million). (PIOJ, 2016)

Name of Event	Date of Occurrence	SECTOR										TOTAL
		Agriculture (crops)	Livestock & Fisheries	Housing	Roads/Bridges	Irrigation	Health	Education	Urban/Municipal Infrastructure	Govt. Infrastructure	Others: Environment, Tourism,	
2002 Flood Rains	22 May to 2 June, 2002	419.2	99.9	58.9	1,491.8	n/a	42.8	3.2	84.3	n/a	n/a	2,200.3
Hurricane Ivan	10 Sept to 12 Sept, 2004	6,002.9	1,100.6	11,163.3	3,199.1	88.9	758.4	806.9	4,602.7	n/a	6,356.2	34,079.0
Hurricanes Dennis & Emily	18 July to 5 Aug, 2005	349.9	395.2	203.7	4,271.9	30.4	55.4	1.0	523.8	n/a	120.1	5,951.3
Hurricane Wilma	13 Oct to 20 Oct, 2005	206.4	42.4	36.0	3,200.0	17.4	45.2	n/a	88.7	n/a	n/a	3,636.1
Hurricane Dean	19 Aug, 2007	8,917.3	460.1	5,961.7	2,047.0	17.2	298.5	727.9	1,542.9	86.4	2,193.7	22,252.6
Tropical Storm Gustav	28 Aug to 29 Aug, 2008	1,601.6	105.8	1,026.5	11,530.0	51.1	423.8	200.1	510.4	6.4	13.2	15,468.9
Tropical Storm Nicole	26 Sept to 2 Oct, 2010	544.1	32.4	274.3	17,616.5	n/a	270.4	1,097.0	501.1	n/a	172.5	20,508.2
Hurricane Sandy	22 Oct to 24 Oct, 2012	1,427.0	185.4	4,270.8	1,739.4	61.9	341.7	17.0	949.7	56.2	n/a	9,048.9

Table 9.2 Costs of damage and loss to sectors classified as "Other" in Table 1 due to disasters 2002-2012 (J$ million) (PIOJ, 2016)

Name of Event	Environment	Mining	Manufacturing	Tourism	INFRASTRUCTURE		
					Electricity	Water Supply and Sanitation	Telecommunications
2002 Flood Rains	n/a	n/a	0.6	1.2	1.2	78.7	4.5
Hurricane Ivan	2,560.6	1,030.0	n/a	1,590.7	1,397.9	678.7	1,535.3
Hurricanes Dennis and Emily	68.9	n/a	48.7	2.5	70.0	400.0	42.2
Hurricane Wilma	n/a	n/a	n/a	n/a	n/a	58.7	30.0
Hurricane Dean	120.0	2,030.0	0.0	43.7	1,073.3	202.0	267.7
Tropical Storm Gustav	13.2	0.0	0.0	n/a	108.0	397.1	5.3
Tropical Storm Nicole	8.0	0.0	0.0	164.5	92.4	270.0	136.9
Hurricane Sandy	0.0	0.0	0.0	0.0	644.0	215.1	70.0

Table 9.3 Costs of Emergency Relief after disasters 2002-2012 (J$ million). (PIOJ, 2016)

Name of Event	Government	International (including Red Cross)
2002 Flood Rains	8.3	n/a
Hurricane Ivan	277.6	182.7
Hurricanes Dennis and Emily	25.6	n/a
Hurricane Wilma	2.6	n/a
Hurricane Dean	801.0	1.4
Tropical Storm Gustav	13.0	n/a
Tropical Storm Nicole	71.0	10.0
Hurricane Sandy	683.0	n/a

Table 9.4 Population affected by disasters 2002-2012 (PIOJ, 2016)

Name of Event	Affected Population	Deaths	Injuries
2002 Flood Rains	50.0%	9	n/a
Hurricane Ivan	14.0%	17	n/a
Hurricanes Dennis and Emily	12.5%	7	n/a
Hurricane Wilma	13.6%	3	12
Hurricane Dean	6.7%	6	628
Tropical Storm Gustav	6.0%	10	n/a
Tropical Storm Nicole	18.7%	14	42
Hurricane Sandy	25.2%	2	291

Table 9.5 Annual and capital costs for sea level rise scenarios 2050 and 2080. (Simpson et al. 2010)

Slr Scenario	Gdp (Us $Million)	Tourism	Agriculture	Industry	Total	Airports	Ports	Roads	Power Plants	Property	Tourist Resorts	Dry-Land Loss	Wetland Loss	Total
Mid-Range														
2050	138,287	1,075	14	14	1,102	43	1,223	8	-	129	535	1,015	1	2,954
2080	318,642	4,334	114	55	4,502	98	4,010	19	-	305	1,261	4,094	3	9,789
High-Range														
2050	211,674	2,516	52	24	2,592	215	3,167	16	309	376	1,902	3,027	3	9,016
2080	419,213	8,720	170	85	8,974	761	18,408	58	309	1,191	6,029	10,492	11	37,259

Table 9.6 Adaptation Measures Cost (US$ million). (Silva 2016)

Adaptation Measures	2016 to 2030	2030 to 2050	2016 to 2050
Health Promotion Programme	266.9	359.3	626.2
Repair National Water Commission Leaks	1213.3	0.0	1213.3
20% Water Improvement by 2050	93.5	124.6	218.1
20% Sanitation Improvement by 2050	12.1	16.2	28.3
Housing	7300.0	0.0	7300.0
Built Environment	7451.0	8512.4	15963.4
Employment Reduction	2149.1	2876.8	5025.9
Violence*	0.0	0.0	0.0
Total Cost Adaptation	18486.0	11889.4	30375.3

**Violence adaptation measure is included in employment reduction.*

Table 9.7 Total Cost of Damage caused by Hurricanes periods 2016 to 2030 and 2031 to 2050 (US$ million). (Silva 2016)

Costs of Hurricanes	2016 to 2030	2031 to 2050	2016 to 2050
Health	58.30	83.30	145.81
Education	76.90	109.90	192.27
Housing	631.00	901.50	1577.6
Water	63.00	89.90	157.41
Total	829.20	1184.60	2073.09

20.1.5 Culture of burning

In Jamaica, there is a well-accepted culture of burning refuse and tree trash in front and back yards and of using of firewood as a source of energy. Both practices produce additional CO2 and hinder ecological and climate change action.

Approximately 30% of Jamaican households that do not have waste management services dispose of their garbage by burning[95]. Besides CO2 emissions, burning of waste can also release dangerous pollutants, including dioxins, depending on the type of refuse burnt.

Firewood is still used for cooking, especially in the form of charcoal. In some communities, coal pots using charcoal are still used for cooking, oftentimes to acquire the authentic taste of Jamaican favorites, like fried fish, roasted breadfruit and mannish water.

"Burning" is prohibited by the Country Fires Act of 1942, which speaks to the burning of crops and trash around the island, but it has rarely been enforced and Government should give serious consideration to this. An added incentive for reducing burning is that particulates released from burning pollute the atmosphere and significantly reduce the amount of direct sunlight that reaches the surface, thereby making solar energy devices less efficient.

20.1.6 Clearing agricultural land by open burning

Small farmers often practice environmentally harmful techniques like "slash and burn" agriculture to clear the land. This type of agriculture reduces forest cover which aggravate the impact of extreme events like droughts and flooding[96], and adds to the CO2 stock of the atmosphere. Persons live and carry out "slash and burn" practices in rural areas in Jamaica where land zoning is not always in place and as a result they are able to freely move into various areas and practice informal farming. This persistent problem will continue because the Rural Agricultural Development Authority (RADA) will not send their extension officers into these informal settlements where proper zoning is indeed lacking.

20.1.7 Consumption of "parrotfish"

"Parrotfish" is among the fish species that are harvested for its fleshy meat. Jamaicans enjoy having parrotfish in "escoveitched" or fried fish dishes. Parrotfish plays a very important role in the marine ecosystem, because it cleans the reef of algae. The continual harvesting of these fish contributes to the growth of algae on coral reefs which choke the coral polyps. The coral reef then becomes degraded. These degraded ecosystems are thus unable to perform their role as natural barriers, i.e. protecting the coastlines by reducing the impact of storm surges before they reach the land[97].

21.0 Millennium Development Goals (MDG) and the Sustainable Development Goals (SDG)

21.1 Millennium Development Goals (MDG) and poverty reduction

MDG expired in 2015 and Jamaica had already succeeded in some, but failed to achieve other targets. Many of the goals were not the most pressing for Jamaica and other mid-income states of the Caribbean, though they were for countries, such as in Sub-Saharan Africa. Caribbean Policy Research Institute (CaPRI) has argued that, given the limited public resources, it was more appropriate to apply resources to more pressing problems, such as the increase in non-communicable diseases, crime and violence.

21.2 SDG and Climate Change

All seventeen goals are suitable for Jamaica except, some may argue, goal 5, "Achieve gender equality and empower all women and girls. Goal 13, "Take urgent action to combat climate change and its impacts (taking note of agreements made by the UNFCCC forum)" and Goal 14, "Conserve and sustainably use the oceans, seas and marine resources for sustainable development" are particularly important for Jamaica. It can be argued that all the other goals depend on the success of attaining Goal 13. Jamaica should, therefore, seek to achieve these goals.

95 *Jamaica Survey of Living Conditions. 2012. Ibid.*
96 *Environmental Solutions Limited. 2009. Ibid.*
97 *CARIBSAVE. 2009. Ibid.*

22.0 National, Regional and International Programmes

22.1 Important national policies, plans and gaps

The basic policies to take climate change into account in Jamaica's development have been promulgated. These are:

- Vision 2030 (2009)
- Climate Change Policy Framework for Jamaica (2015)

Vision 2030 is a strategic road map to guide the country to achieve its goals of sustainable development and prosperity by 2030. Climate change is addressed specifically in its sectoral plan, 'Natural Resources and Environmental Management & Hazard Risk Reduction and Climate Change' (2009). The 400-page document[98] outlines its strategy with four national goals and several national outcomes, shown in Figure 0.1, all of which will be impacted by climate change in one way or another.

National Goals	National Outcomes
1 Jamaicans are empowered to achieve their fullest potential	1. A Healthy and Stable Population
	2. World-Class Education and Training
	3. Effective Social Protection
	4. Authentic and Transformational Culture
2 The Jamaican society is safe, cohesive and just	5. Security and Safety
	6. Effective Governance
3 Jamaica's economy is prosperous	7. A Stable Macroeconomy
	8. An Enabling Business Environment
	9. Strong Economic Infrastructure
	10. Energy Security and Efficiency
	11. A Technology-Enabled Society
	12. Internationally Competitive Industry Structures • Agriculture • Manufacturing • Mining and Quarrying • Construction • Creative Industries • Sport • Information and Communications Technology • Services • Tourism
4 Jamaica has a healthy natural environment	13. Sustainable Management and Use of Environmental and Natural Resources
	14. Hazard Risk Reduction and Adaptation to Climate Change
	15. Sustainable Urban and Rural Development

Source: Vision 2010

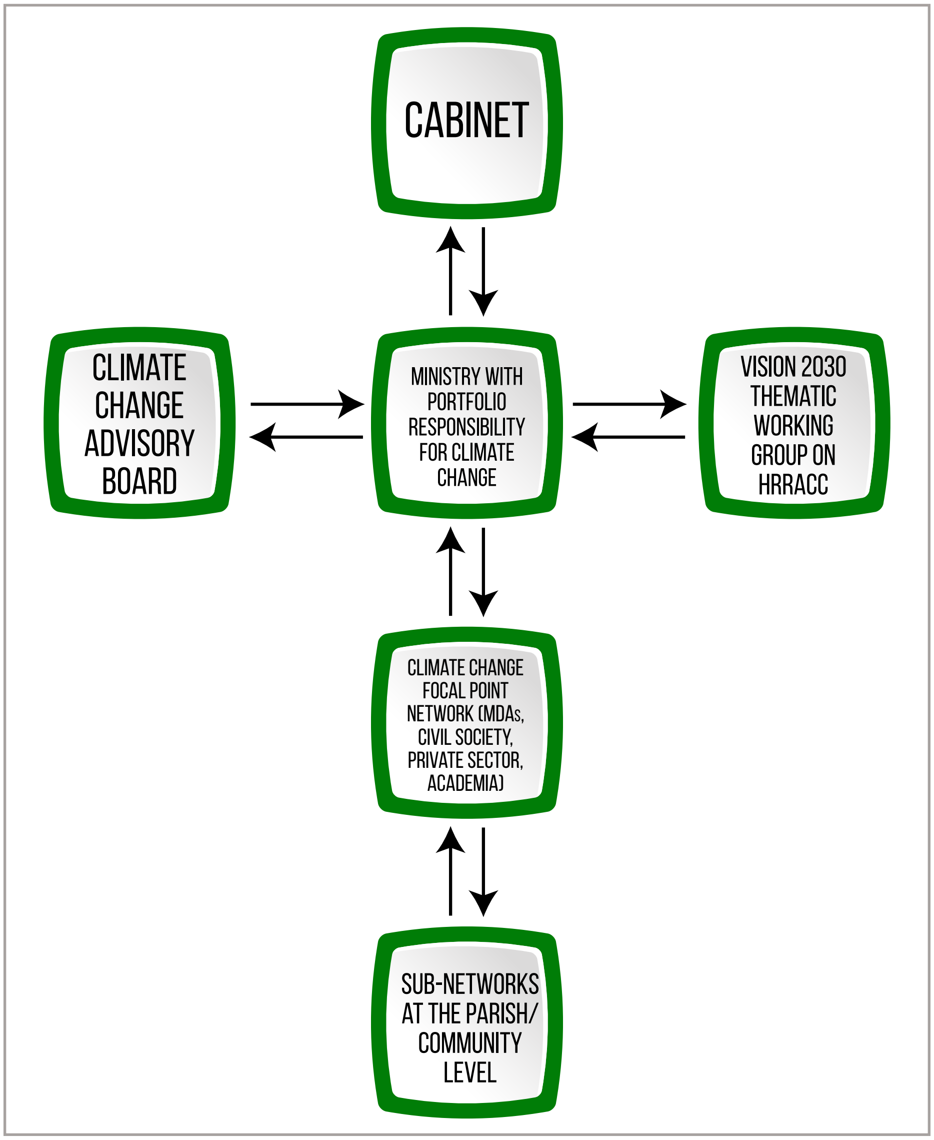
98 Planning Institute of Jamaica. 2009. Vision 2030 Jamaica National Development Plan. Planning Institute of Jamaica, Kingston, Jamaica. Retrieved from: http://www.vision2030.gov.jm/Portals/0/NDP/Vision%202030%20Jamaica%20NDP%20Full%20No%20Cover%20(web).pdf

Figure 10.1 National Goals and Outcomes of Vision 2030 The 'Climate Change Policy Framework and Action Plan of Jamaica[99], which lays out the framework for Jamaica's respond to climate change, was adopted as a Green Paper in 2013 and the policy was finalised in 2015[100]. The primary intent of this policy framework is to support Vision 2030 by reducing the risks posed by climate change to all of Jamaica's sectors and development goals through the Hazard Risk Reduction and Adaptation to Climate Change (HRRACC) thematic working group.

The strategies and action plans of the Climate Change Policy Framework and Action Plan give details on how it is going to address these issues in different sectors. Generally, information based on modelled and downscaled data is used to determine vulnerability for the sector, and these strategies are then used to minimise the impact of climate change. The strategies and action plans target five priority sectors, including water, tourism, agriculture, health, coastal resources, and human settlements. Other sectors include: transport, energy, forestry, fisheries, finance, and waste management. For each sector, a strategy and action plan will be established in accordance with the Climate Change Policy Framework and Action Plan. There are 12 sectors in total and a strategy and action plan will be devised for all of them.

The policy will be implemented by the Climate Change Division (CCD), which is required to conduct its work with the sectors through their designated Climate Change Focal Points. Guidance and supervision of implementation is conferred to the establishment of the national Climate Change Advisory Board (CCAB) involving representatives from public and private sectors (including a representative from the Finance Ministry), academia and NGOs. The institutional arrangement is set out in Figure 10.2.

Figure 10.2 Institutional arrangement to implement the Climate Change Policy.



99 *See: http://www.japarliament.gov.jm/attachments/440_Climate%20Change.pdf*
100 *See: http://www.mwh.gov.jm/information-resources/policies/finish/8-policies/243-climate-change-policy-framework*

Besides the Strategies and Action Plans of the Climate Change Policy Framework of Jamaica (2015), other policies and plans to combat climate change include:

- The National Energy Policy (2009 – 2030) and
  - Sub-Policies (2009):
    - » Draft Renewable Energy Sub-Policy
    - » Draft National Energy Conservation and Efficiency Sub-Policy
    - » Draft Biofuels Sub-Policy
    - » Draft Trading of Carbon Credits Sub-Policy
    - » Draft National Energy-from-Waste Sub-Policy

- Jamaica's Intended Nationally Determined Contributions Communicated to UNFCCC (2015)

However, there are still many gaps in policies, plans, legislation and implementation. The 2012 publication 'Review of Policy, Plans, Legislation, and Regulations for Climate Resilience in Jamaica' suggested that there were 17 gaps in plans, polices and legislation with 10 areas of legislation that needed to be put in place.

So far, public records indicate that the Ocean and Coastal Zone Management Policy, the Mangrove and Coastal Zone Wetlands Protection Policy, Towards a Beach Policy for Jamaica, Coral Reef Protection and Preservation Policy and Towards a Watershed Policy for Jamaica have not been revised[101]. The draft Water Sector Policy of 2014 still does not include the phrase 'climate change [102]'. However, the green paper on Forest Policy of 2015 now includes climate change considerations. The Water Resources Development Master Plan [103] will include climate change considerations. Jamaica needs to have in place Sector Strategies and Action Plans that will provide details on policies, initiatives and programmes to be put in place in each sector for climate resilience.

23.0 Mitigation and Adaptation Programmes and Projects:

23.1 Mitigation Projects

The locally implemented mitigation projects include: (a) converting fuel for electricity generation from oil to gas, (b) increasing renewable to 20% of energy mix by 2030, (c) Jamaica Sustainable Energy Roadmap project: Pathways to an Affordable, Reliable, Low-Emission Electricity System, (d) Jamaica energy security and efficiency enhancement project, (e) net billing and (f) Municipal Climate Partnerships by 2015 – Climate Partnership Portmore (Jamaica) – Hagen (Germany). There are three components to the energy security and efficiency enhancement project, viz., (I) strengthening the regulatory and institutional framework to improve sector performance, increase private investment and transition to cleaner fuels, (ii) developing energy efficiency and renewable energy potential, and (iii) project management, monitoring and evaluation. The second component included the installation of solar control film at 19 public sector buildings, the installation of cool-roof solution at 11 public institutions, installation of energy efficient air conditioning at four facilities and the installation energy efficient lighting, air conditioning and solar panels in public libraries, schools and healthcare centres.

Under the net billing scheme, JPS customers who have this arrangement in place and generate electricity using renewable energy source (wind, water, solar, biomass) receive a premium of 15%.

The aim of the Climate Partnership Portmore – Hagen programme is to strengthen the professional cooperation between the German municipality of Hagen and the municipality of Portmore in south St. Catherine in the field of climate change mitigation and adaptation.

23.2 Adaptation Projects

There are several adaptation projects funded by several sources including the Adaptation Fund, Climate Investment Fund, USAID, EU, UNEP, UNDP and GEF. These projects seek to protect lives, livelihoods and ecosystems in targeted communities affected by climate change through interventions that drive adaptation and build resilience, to improve climate data and information management projects, to increase resilience and reduce risks associated with natural hazards in vulnerable areas and to enhance sustainable land management.

There are also adaptation projects funded by the United Nations Development Programme/Global Environmental Facility/Community Based Adaptation Project Fund and by Australian Government Overseas Aid/ Community-Based Adaptation Programme and Small Grants Programme respectively. These are smaller projects to cope with droughts and floods, prevent land degradation, protect the ecosystem and apply renewable energy.

Several adaptation projects regionally administered by the Caribbean Community Climate Change Centre (CCCCC) have been implemented as well as UN-REDD Programme and other Regional Projects funded by European Union and Caribbean Regional Strategic Programme for Climate Resilience to build regional capacity in energy and environmental management in the private sector and mainstream climate risk resilience.

101 Only the Ocean and Coastal Zone Management Policy was finalized and promulgated
102 Status of the water policy at December 31, 2016
103 Linton, Latonya. "Work to Get Underway on Water Development Master Plan," Jamaica Information Service, April 22, 2016. Retrieved from: http://jis.gov.jm/work-get-under-way-water-development-master-plan/

23.3 Project Shortcomings

Although many projects on climate change adaptation and mitigation have been executed or are about to be executed in Jamaica, there are shortcomings. What is lacking in the development, implementation and assessments of these projects includes:

- A centralised database of past and ongoing projects.
- A method of assessing which projects get priority.
- A method for assessing lessons learnt and steps to be taken to ensure improvement.
- A method of determining sustainability of projects.

24.0 Projects

Climate change caused by global warming is literally an existential threat to the entire globe, which must be tackled by mitigation and adaptation. Below are some suggestions for projects.

24.1 Pilot project to achieve more than 30% renewable energy in the energy mix:

The current target for renewable energy, according to Jamaica's energy policy, is 20% by 2030. Without the storage of energy to provide back-up at times when there is absence of wind or sunlight, this target cannot be more than about 30%. There are various technologies for storing energy from renewable sources to be used when these sources are down, such as pumped storage, compressed air, conversion to hydrogen and batteries. Most research and development in the area of storage is in battery technology and significant cost reductions are expected in about a decade [104].

Jamaica should not be left behind. Jamaica should take immediate steps to become involved in the process of storage of energy, and to become a leader in this regard, thereby obtaining the advantages that a leadership role would bring. This could take the form of a pilot project in renewable energy storage in partnership with a global financial institution, such as the World Bank, the Green Climate Fund, and a leader in battery technology, such as Tesla.

A possible project would be to add storage to the 20 MW WRB Enterprises Solar Plant or to the 33 MW Eight Rivers Solar Plant to provide about 45% of the plant's maximum generation capacity over the course of one minute, for use in smoothing out the "ramp rate" of power coming on and off with changes in sunlight, similar to that mandated in Puerto Rico for regulating frequency fluctuation. A more ambitious project would be to add storage to provide electricity for about 3 hours to help meet evening peak demand. A preliminary calculation, outlined in Section 11.3 of Chapter 11, shows that the lifetime cost of producing electricity from storage by flow batteries is about US$0.05 per kilowatt-hour, if the batteries were charged by the existing capacity (20 MW or 33MW). If extra panels were used to charge the batteries, the total cost of storage plus extra panels would be about US$0.08 per kilowatt-hour. When the expected decline of the cost of battery storage is taken into consideration, the preliminary calculation augments well for the future of battery storage, so we should be fully prepared for it.

The estimated cost for installing batteries alone and for batteries plus extra PV panels for charging the batteries at a 33 MW solar plant for various storage times are given in Table 11.1, and the calculations shown in Section 11.3 of Chapter 11. The 10-minute storage would be adequate for regulating frequency fluctuation and ramping up during voltage variation, and would be a good starting point.

Experts in battery storage, renewable energy, power generation and grid operation would be needed to design such a project.

24.2 Pilot Project in Public Transportation – A Pilot School Bus System:

Jamaica can reduce its fossil fuel emission by cutting down on emissions from transportation. This can be done in a variety of ways, including enhancing the public transportation system so as to encourage more passengers to ride rather than drive, re-introducing the train network, establishing a school bus system or making it viable to use electric cars in Jamaica.

Calculations were done for a pilot school bus system. A school bus system for the Half-Way-Tree area was considered and extended to the entire Corporate Area. The calculations show that the reduction in fuel cost, man-hours and greenhouse gas emissions are 88%, 96% and 96% respectively, and that the project could return on this investment in seven years. In absolute values, if all or nearly all students use the bus system, the fuel cost reduction is approximately US$53,000 daily across the Kingston and St. Andrew area, the daily man-hour loss reduction 130,000 hours and the daily reduction in greenhouse gas emissions is 123 tonnes.

104 *Eckhouse, Brian. "Energy Storage Costs Expected to Slide 41% by 2020, GTM Says," Bloomberg News, January 4, 2016. Retrieved from: http://www.bloomberg.com/news/articles/2016-01-04/energy-storage-costs-expected-to-slide-41-by-2020-gtm-says*

Table 11.1 Approximate Cost of storage for various storage times with and without extra PV

Storage time	Cost at 33MW solar plant without extra PV	Cost at 33MW solar plant with extra PV
3 hours	$50M	$80 M
2 hours	$33	$54 M
1 hour	$17	$27 M
10 minutes	$2.8	$4.4 M

The approximations made are simplistic and the values obtained are gross approximations, but show that a school bus system is worth considering. Such a project would have to be designed and analysed by experts in marketing, transportation and greenhouse gas emissions.

24.3 Energy Project in Wind Energy

As part of the 'Capacity Development for Energy Efficiency and Security in Jamaica', a study called 'Wind Power for Domestic/Community Feasibility Study and Regulatory Review' was submitted to the Ministry of Science, Technology, Energy, and Mining (MSTEM) in 2014[105]. Part of the scope of the project was a feasibility study, based on wind modelling software using all existing wind measurements available in Jamaica, for local capacity for production of electricity by small-scale wind systems. Communities with capacity for production of energy by wind turbines were identified in St. Thomas, Manchester, St. Elizabeth, Trelawny, St. Ann, and Clarendon. A programme to establish wind systems in some of these communities may prove to be beneficial, depending on the needs of the communities. Project developers and funding agencies would find these results useful.

24.4 Project in plant and animal breeding and agro-ecology

Higher temperatures and drier conditions can lead to lower crop yield and diseases, and to heat stresses on animals. In view of this, projects to make crops and animals more resilient to climate change should be developed. Research to build resilience into crops and animals needs to be designed by crop and animal breeders, agro-ecologists, biochemists and even genetic engineering, if acceptable. However, such research will require substantial funding and focus.

24.5 Project in Water Resources and Sea Level Rise at Alligator Pond, South St. Elizabeth

24.5.1 Water resources: Desalination by reverse osmosis powered by renewable energy

The Manchester Local Sustainable Development Plan suggested that, by 2015, the community of Alligator Pond will have an estimated population of 2,444. The amount of water needed by the community is estimated to be approximately 333,000 gallons per day. It is suggested that a reverse osmosis desalination powered by renewable energy may be worthwhile to provide water to the Alligator Pond Community.

24.6 Sea level rise: Storm surges attenuated by Wave Attenuation Devices (WADs)

Wave attenuation devices (WADs), such as seen in Figure 11.1, are concrete constructions designed to disperse the energy of incoming waves, reducing the erosion on coastal regions [106]. WADs also provide a habitat for fish and marine life. The installation of WADs along the coast of Alligator Pond may help to reduce the effects of coastal erosion and sea level rise on the community, while supporting a feeding ground for marine life that adds to the community's fishing industry. WADs have been installed in other coastal communities, such as Old Harbour, St. Catherine and Long Bay, Negril. It is estimated from these previous projects that WAD installation may cost approximately US$125,000.

Other projects include:

- Potential for Mitigation of Greenhouse Gas Emissions in the Tourism Sector
- Additional Applications for Renewable Energy
- Modelling Sea Level Rise and Storm Surge at Negril

105 *MSTEM. 2014. Final Report on Wind Power for Domestic/Community Feasibility Study and Regulatory Review, submitted to MSTEM. MSTEM and UNDP.*

106 *See: Terminal Report, Installation of Wave Attenuation Devices for Old Harbour Bay, St. Catherine, Jamaica, Prepared by Underwater Service Co. Limited In Association with TEM Network, November 8, 2013*

25.0 Report on Information on Actions Taken or Envisaged to Implement the Convention

With the use of Article 4 subsection 1 of the UNFCCC as a template, Jamaica is fulfilling its commitments to the UNFCCC in the following ways:

a. Develop, periodically update, publish and make available to the Conference of the Parties, in accordance with Article 12, national inventories of anthropogenic emissions:
   - The Second National Communication contained an extensive survey of Jamaica's GHG inventory, including those in the energy sector, industrial processes, agriculture, forestry, other land uses and the water sector;
   - One of the aims of the newly formed Climate Change Division is to monitor and report on GHGs on a regular basis.

b. Formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to mitigate climate change by addressing anthropogenic emissions.
   - JPS is also converting its 120-megawatt power plant in Western Jamaica, at Bogue, Montego Bay, to run on gas instead of automotive diesel oil; and
   - Activities contained in The National Energy Policy (2009 – 2030) and Sub-Policies.

c. Promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions:
   - In 2009, MTBE was phased out of all gasoline blends and replaced with 10% Ethanol;
   - The National Transport Policy will soon be reviewed and it is anticipated that issues related to GHG emissions from the transportation sector and the related climate change impacts will be addressed in the revised document;
   - Also, see section (b) above.

d. Promote sustainable management, and promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all GHGs:
   - Jamaica has become a partner programme country of UN-REDD.

e. Cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone management, water resources and agriculture:
   - An assessment of the vulnerability of agricultural sector is contained in Chapter 3: Measures to facilitate adaptation using improved tools and methodologies;
   - An assessment of vulnerability of coastal zone and water resources is contained in Chapter 3: Measures to facilitate adaptation using improved tools and methodologies;

f. Take climate change considerations into account, to the extent feasible, in their relevant social, economic and environmental policies and actions, and employ appropriate methods:
   - Vision 2030 (2009).
   - Climate Change Policy Framework and Action Plan for Jamaica (2015).

f. Promote and cooperate in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system such as the Meteorological Service, Water Resources Authority, Climate Study Group, Mona and others

g. Promote and cooperate in the full, open and prompt exchange of relevant scientific, technological, technical, socio-economic and legal information

h. Promote and cooperate in education, training and public awareness related to climate change and encourage the widest participation in this process, including that of non-governmental organisations.

f. Communicate to the Conference of the Parties information related to implementation.

26.0 National Stakeholders' Consultation

26.1 First Workshop to launch the Third National Communication (TNC):

The first workshop was held in the Blue Room, Mona Visitors' Lodge, University of the West Indies, Mona on 29th September, 2015. Of the 117 stakeholders who were invited, 68 registered and attended. The workshop proceeded with an introduction to Component 1 of the Third National Communication and Biennial Update Report to the United Nations Framework Convention on Climate Change, an update of Intergovernmental Panel on Climate Change 5th Assessment, and an update of impacts of climate change on Jamaica. Stakeholders were asked to fill out a questionnaire, which was distributed prior to the workshop, concerning recommendations from the SNC and priorities for the TNC. The final session consisted of a discussion on answers to the questionnaire.

26.2 Second Stakeholder Workshop in Kingston:

The Second TNC workshop was held on 29th March 2016 in the Kingston area, in the south of the island, at Mona Visitors' Lodge, University of the West Indies, to present Outcomes 1 and 3, and the Biennial Update Report. Seventy participants attended the workshop.

Figure ES13.1 Stakeholders answering the questionnaire in Kingston

26.3 Third Stakeholder Workshop in Mandeville:

The Third TNC workshop was held on 7th June 2016 at St. John Bosco Catering Hall, Hatfield, Green Vale, in the Mandeville area, located in the middle of the island. In addition to the usual stakeholders, farmers were invited since one of the subjects discussed was climate change and agriculture. There were 29 participants at the workshop.

26.4 Fourth Stakeholder Workshop in Montego Bay:

The fourth workshop was held in the Montego Bay area, in the north of the island, which is a centre of tourism. In addition to the usual stakeholders, persons from the tourism sector were invited since one of the subjects discussed was climate change and tourism. Forty-seven participants attended the workshop. Much of the discussion centred on the need to preserve green spaces and the ecosystem.

27.0 Stocktaking and Summing Up

Jamaica faces serious and present danger from droughts, floods and higher temperatures linked to climate change. Jamaica and other small islands also face a very real threat from sea level rise, yet these threats are not widely recognised because of a lack of awareness among the population and complacence is the order of the day.

Jamaica is currently recovering from two years (2014 and 2015) of severe drought, which acutely affected agricultural produce and livestock. What research has shown is that these droughts are related to El Niño and climate models show that climate change drives El Niño to occur more often. Models also show a drying of the region, meaning that droughts will become more severe. At the same time, storms, although less frequent, will intensify. Gradual sea level rise will make storm surges more destructive. Further down the road, we face an existential threat.

Jamaica should view mitigation as a development issue. By the middle of the century, petroleum sources of energy need to be replaced worldwide to limit temperature rise to no more than 2ºC (1.5ºC is the aspiration). Jamaica has signed the Paris Agreement and this will commit Jamaica to a low-carbon economy by mid-century.

Jamaica should use this as an opportunity for development. Electricity generation and road and rail transportation account for over 50% of Jamaica's petroleum consumption and 15% of our GDP is used to purchase petroleum.

Inventory Year:	2012			
Greenhouse gas source and sink categories	CO2 Emissions (Gg)	CO2 Removals (Gg)	CH4 (Gg)	N2O (Gg)
Total National Emissions and Removals	5761.13		40.58	21.27
1 - Energy	6909.33		1.41	0.24
1A - Fuel Combustion Activities	6909.05		1.41	0.24
1A1 - Energy Industries	2824.93		0.11	0.02
1A2 - Manufacturing Industries and Construction (ISIC)	1990.01		0.20	0.04
1A3 - Transport	1743.19		0.49	0.17
1A4 - Other Sectors	350.92		0.61	0.01
1A5 - Other	NO		NO	NO
1B - Fugitive Emissions from Fuels	0.28		0.00	0.00
1B1 - Solid Fuels	NO		NO	NO
1B2 - Oil and Natural Gas	0.28		0.00	0.00
2 - Industrial Processes	436.56		0.00	0.00
2A - Mineral Products	434.76		NA	NA
2B - Chemical Industry	NO		NO	NO
2C - Metal Production	NO		NO	NO
2D - Other Production	1.80		NO	NO
2E - Production of Halocarbons and Sulphur Hexafluoride				
2F - Consumption of Halocarbons and Sulphur Hexafluoride				
2G - Other (please specify)	NO		NO	NO
3 - Solvent and Other Product Use	0.00		0.00	0.00
4 - Agriculture			12.87	20.88
4A - Enteric Fermentation			8.23	
4B - Manure Management			4.39	6.83
4C - Rice Cultivation			0.01	
4D - Agricultural Soils				6.68
4E - Prescribed Burning of Savannas			NO	NO
4F - Field Burning of Agricultural Residues			0.24	0.01
4G - Other (please specify)	2.50		NO	7.36
5 - Land-Use Change & Forestry	-1625.88			0.00
5A - Changes in Forest and Other Woody Biomass Stocks	-1777			
5B - Forest and Grassland Conversion	83			
5E - Other (please specify)	68			
6 - Waste	38.62		26.30	0.15
6A - Solid Waste Disposal on Land			22.05	
6B - Wastewater Handling			3.63	0.13
6C - Waste Incineration	5		0.00	0.00
6D - Other (open bruning and biological treatment)	33		0.62	0.01
7 - Other (please specify)	0.00		0.00	0.00
Memo Items				
International Bunkers	1365.79		0.06	0.04
1A3a1 - International Aviation	739.34		0.01	0.02
1A3d1 - International Marine (Bunkers)	626.45		0.06	0.02
CO2 emissions from biomass	586.92			

e of Emissions

CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)	HFCs (Gg CO2 EQ) HFC - 23	HFC - 134	Other	PFCs (Gg CO2 EQ) CF4	C2F6	Other
82.45	43.98	29.65	16.00	0	52.39	39.43	0	0	0
69.06	33.58	9.88	15.99						
69.06	33.58	9.88	15.99						
0.54	4.51	0.07	13.11						
10.84	13.36	2.05	2.63						
44.75	14.48	6.43	0.13						
12.93	1.23	1.33	0.11						
NO	NO	NO	NO						
0.00	0.00	0.00	0.00						
NO	NO	NO	NO						
0.00	0.00	0.00	0.00						
0.00	0.00	3.08	0.00	0	52.39	39.43	0	0	0
NA	NA	NA	NA						
NO	NO	NO	NO						
NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
NO	NO	NO	NO						
NA	NA	NA	NA	NO	NO	NO	NO	NO	NO
NA	NA	NA	NA	NO	52.39	39.43	NO	NO	NO
NO	NO	3.08	NO						
0.00	0.00	14.01	0.00						
8.07	10.09	1.67	0.00						
NA	NA	NA	NA						
NA	IE	1.61	NA						
NA	NA	NA	NA						
NA	9.87	0.07	NA						
NO	NO	NO	NO						
8.07	0.22	NE	NE						
NO	NO	NO	NO						
0.00	0.00	0.00	0.00						
NA	NA	NA	NA						
NA	NA	NA	NA						
NA	NA	NA	NA						
5.33	0.31	1.01	0.01						
0.00	0.00	0.87	0.00						
0.00	0.00	0.00	0.00						
0.00	0.00	0.02	0.00						
5.33	0.30	0.12	0.01						
0.00	0.00	0.00	0.00	NO	NO	NO	NO	NO	NO
				NO	NO	NO	NO	NO	NO
1.97	19.12	0.63	4.23						
0.49	3.29	0.08	0.23						
1.48	15.83	0.54	4.00						

CHAPTER 2

NATIONAL INVENTORY REPORT (2006-2012)

2.1.0 Summary of Emissions Estimates

The table below presents emissions of direct and indirect GHGs for the most recent year of the emissions inventory, 2012. Similar tables of emissions for earlier years (2006 – 2011 inclusive) are presented in Appendix 1. Different aspects of the emissions inventory are considered in sections 2.1 to 2.4. The results from the emissions inventory are considered in Sections 2.5 and 2.6, where the emission trends for each direct and indirect GHG are presented and considered.

2.1.1 Sector and Pollutant Coverage

The emissions inventory has been compiled to give as complete a dataset as possible with the available inputs. The following table provides a summary of the pollutant emission estimates from each source sector.

Table 0.2 List of categories and emissions estimated

CRF code	Sector	CO_2	CH_4	N_2O	HFC	CO	NOx	NMVOC	SO_2
1 Energy									
1A1a	Public Electricity and Heat Production	✓	✓	✓		✓	✓	✓	✓
1A1b	Petroleum Refining	✓	✓	✓		✓	✓	✓	✓
1A2b	Mining/Bauxite	✓	✓	✓		✓	✓	✓	✓
1A2e	Sugar and Other Food/Drink Manufacturing	✓	✓	✓		✓	✓	✓	✓
1A2f	Cement	✓	✓	✓		✓	✓	✓	✓
1A2gvii	Industry, Mobile Machinery	✓	✓	✓		✓	✓	✓	✓
1A2gviii	Industry Other, Stationary	✓	✓	✓		✓	✓	✓	✓
1A3aii(i)	Domestic Aviation LTO (civil)	✓	✓	✓		✓	✓	✓	✓
1A3b	Road Transport	✓	✓	✓					
1A3bi	Cars					✓	✓	✓	✓
1A3bii	LDVs					✓	✓	✓	✓
1A3biii	HGVs					✓	✓	✓	✓
1A3biv	Motorcycles					✓	✓	✓	✓
1A3d	Domestic Shipping/National Navigation	✓	✓	✓		✓	✓	✓	✓
1A4ai	Commercial/Institutional: Stationary	✓	✓	✓		✓	✓	✓	✓
1A4aii	Commercial/Institutional: Mobile	✓	✓	✓		✓	✓	✓	✓
1A4bi	Residential: Stationary	✓	✓	✓		✓	✓	✓	✓
1A4cii	Agriculture/Forestry/Fishing: Mobile	✓	✓	✓		✓	✓	✓	✓
1B2aiv	Refinery flaring	✓	✓	✓		✓	✓	✓	✓
2 IPPU									
2A1	Cement	✓							
2A2	Lime	✓							
2F	HFC Consumption				✓				
2G	Non-Energy Products	✓						✓	
2G	Food & Drink							✓	
3	Solvent Use								
3	Domestic Solvent Use							✓	
3	Coating Applications							✓	
3	Dry Cleaning							✓	
4	Agriculture								
4A	Breeding Swine - Enteric		✓						
4A	Dairy Cattle - Enteric		✓						
4A	Goats - Enteric		✓						
4A	Horses - Enteric		✓						
4A	Market Swine - Enteric		✓						
4A	Mules/Asses - Enteric		✓						
4A	Other Cattle - Enteric		✓						
4A	Sheep - Enteric		✓						
4B	Livestock Manure Management							✓	
4B	Breeding Swine		✓	✓					
4B	Dairy Cattle		✓	✓					

CRF code	Sector	CO_2	CH_4	N_2O	HFC	CO	NOx	NMVOC	SO_2
4B	Goats		✓	✓					
4B	Horses		✓	✓					
4B	Market Swine		✓	✓					
4B	Mules/Asses		✓	✓					
4B	Other Cattle		✓	✓					
4B	Poultry - Chickens (Broilers)		✓	✓					
4B	Poultry - Chickens (Layers)		✓	✓					
4B	Poultry - Ducks & Geese		✓	✓					
4B	Poultry - Turkeys		✓	✓					
4B	Rabbit		✓	✓					
4B	Sheep		✓	✓					
4C	Rice		✓						
4D	Crop Residues			✓					
4D	Cultivated Soils							✓	
4D	Drained/Managed Organic soils			✓					
4D	Grazing Animals			✓					
4D	Lime Application	✓							
4D	NO From Managed Soils						✓		
4D	Organic N Fertiliser			✓					
4D	Synthetic N Fertiliser			✓					
4D	Urea Fertiliser Application	✓							
4F	Field Burning		✓	✓		✓	✓		
4G	Manure - Atm. Deposition			✓					
4G	Manure - Leaching/runoff			✓					
4G	Soils - Atm. Deposition			✓					
4G	Soils - Leaching/Runoff			✓					
5 LULUCF									
5A	Forest Land Remaining Forest Land	✓							
5B	Land Converted to Forest Land	✓							
5B	Land Converted to Grassland	✓							
5E	Land Converted to Cropland	✓							
5E	Land Converted to Settlement	✓							
5E	Other Land Remaining Other Land	✓							
5E	Land Converted to Other Land	✓							
6 Waste									
6A	Solid Waste Disposal on Land		✓					✓	
6B	Domestic Wastewater Handling		✓	✓					
6B	Industrial Wastewater Handling		✓						
6C	Waste Incineration	✓	✓	✓		✓	✓	✓	✓
6D	Biological Treatment of Waste		✓						
6D	Open Burning of Waste (Backyards)	✓	✓	✓		✓	✓	✓	✓
6D	Open Burning of Waste (Landfills)	✓	✓	✓		✓	✓	✓	✓

2.1.2 Temporal Coverage

The emissions inventory data presented are for the years 2006-2012. However, data was also collected for the earlier years of 2000-2005 as far as resources allowed (as well as 2013), and emission estimates were calculated. This was done in an attempt to generate a longer time series to better illustrate emission trends. However, the data that was obtained for these earlier years were not of a good level of completeness, and this, therefore, significantly restricts the uses of the data in these earlier years. So throughout this report, the years 2006-2012 are presented.

The limited data from years before 2006 also meant that it was not possible to undertake a detailed comparison with the GHG emissions inventory for Jamaica reported in the Second National Communication (2NC) covering the years 2000 – 2005 (Final Report Jamaica's Greenhouse Gas Emissions Inventory 2000 to 2005, Davis et al 2008). Comparing the different versions of the inventory provides a valuable quality check, highlighting and significant revisions to the emission estimates that arise either from improved input data or the use of more detailed emission estimation methodologies.

2.1.3 Methodology, Parameters and Emission Factors

Attempts were made to source country-specific emission factors (EFs) and parameters at the most detailed level available. However, it became evident that little country specific data exist. As a result, the EFs and other key parameters required for estimating emissions were taken from the 2006 IPCC Guidelines for the vast majority of individual source emission estimates. Country-specific data were available regarding the properties of some fossil fuels.

In addition, while country specific calculations were required for processing some of the input data before it was used in emission estimation calculations, no country-specific approaches or methodologies had been developed for estimating emissions. As a result, methodologies for estimating emissions were all taken from the 2006 IPCC Guidelines, Volumes 2-5, and the 2006 GPG-LULUCF.

Guidance specifically relating to the compilation of emissions inventories in BURs has been made available from the UNFCCC (UNFCCC BUR Guidelines, 2011). This indicates that methodologies from the 1996 IPCC Guidelines "should" be used. However, the guidance does recognise that there may be national circumstances which influence this decision. For the emissions inventory presented in this report, methodologies have all been taken from the 2006 IPCC Guidelines and the IPCC Good Practice Guidance for LULUCF (2006). This decision was made after careful consideration of the existing plans in Jamaica:

- It was recognised that significant resources have been made available for the compilation of the 2006-2012 inventory presented here. It may not be possible to attract similar levels of funding in the future. It is, therefore, sensible to deliver an emissions inventory which is "future-proofed" as far as practicable.
- Jamaica wishes to implement a programme of continuous improvement for the emissions inventory, and this proposes that the most up-to-date, available guidance is used to support inventory compilation.

The BUR guidance (UNFCCC BUR Guidance, 2011) indicates that the global warming potential (GWP) of GHGs "should" be taken from the IPCC Second Assessment Report (IPCC, 1995), rather than the updated GWPs published in the Fourth UNFCCC Assessment Report (IPCC, 2007). This guidance was followed, on the basis that it allows consistency with a large number of other emission inventories, and, in particular, those reported by other non-Annex 1 parties to the UNFCCC. It was also noted that updating the GWPs is a relatively simple change to make in future years, when it becomes appropriate to do so.

2.1.4 Activity Data

Collection of high-quality data is a critical success factor in completing a high-quality GHG emissions inventory. The process of collecting data can be a very challenging exercise in developing countries, and countries which are not particularly data rich. It can also be challenging to assess the quality of the collected data.

A substantial amount of effort was invested in sourcing activity data. Details are included in each of the sector-specific chapters that follow.

The availability of high-quality activity data (in particular good levels of transparency, completeness, consistency and accuracy) was very variable across the source sectors.

For example:

- National energy balance tables were available from 2006 onwards, and as is typical, the data is considered to be generally high in completeness and accuracy.
- Data on crop production were available in detail for 2000 to 2013, providing a high-quality input dataset. Livestock numbers were also available for this time period, but data had to be sourced from different institutes for different parts of the time series. As a result, it is thought that some internal inconsistencies have been introduced into the time series data.
- There was very limited information on the use of HFCs in refrigeration and air conditioning. HFC import data were made available, but it was challenging to estimate the total amounts of HFC in products in Jamaica, and hence emissions to air. This is not unusual, as in general, specific surveys and bespoke datasets are needed as input into HFC emission calculations.

- CO_2 emissions and uptake from land-use change and forestry were estimated to a high level of completeness. However, a number of key assumptions and extrapolation is used to generate input data for the entire time series. This is expected to have a significant impact on the quality of the input data.

These and other examples are presented in this report in the more the detail sector-specific chapters that follow. Improving the availability of high-quality activity data features very strongly in the emissions inventory improvement activities listed in each of the sector chapters. There are also improvements that can be made to the national system that will help support the provision of high quality activity data. Review of, and recommendations for improvement to, the national system will be included in a separate report under this project (Third National Communication (TNC) and Biennial Update Report (BUR) to the United Nations Framework Convention on Climate Change (UNFCCC)" IC/2015/1).

2.2.1 Emissions of Direct GHGs

The following table presents a summary of emissions of GHGs, expressed as CO_2 equivalents. Emissions of CO_2 dominate the total, and arise almost exclusively from fuel combustion activities. Emissions of N_2O make a substantial contribution to the emission total, and are almost exclusively from agricultural activities. CH_4 makes a small contribution to the total emission, emissions arising from agricultural activities and landfill sites. HFC makes a very small contribution to the total, being emitted from refrigeration and air conditioning equipment in use, during refill and when scrapped.

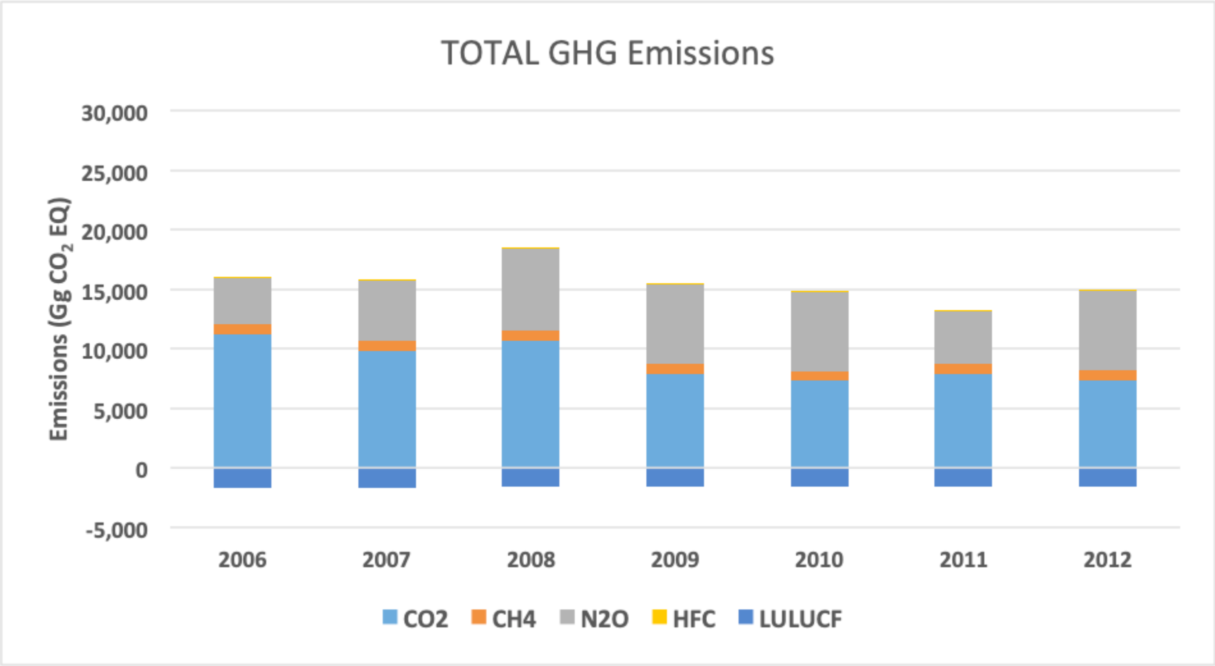
Land Use, Land Use Change and Forestry (LULUCF) is a net sink. The LULUCF total is a combination of several components, some of which are very large sources and sinks – particularly in the forestry sector. However, the net total from LULUCF is a sink that does not make a particularly large contribution to the total GHG emissions.

Table 0.3 Emissions of Greenhouse Gases (Gg CO_2 EQ)

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

The trend of the total emission is downwards and is dominated by reductions in CO_2 emissions with time (see figure below). Emissions N_2O vary across the time series - this is a result of significant year-to-year variations in livestock numbers, with numbers being noticeably lower in 2006 and 2011.

Emission trends are considered in more detail, on a pollutant by pollutant basis, in the following sections, and show that the reduced fuel consumption in the mining/bauxite industrial sector is the dominant component in determining the changes in emissions of CO_2 across the time series, which, in turn, dominates the changes across the time series of total GHG emissions.



2.2.2 Emissions of CO2

The following table summarises the emissions of CO2 across the 2006 – 2012 time series. These data are also presented in the figure below.

Table 0.4 Emissions of CO2 (Gg CO2)

	2006	2007	2008	2009	2010	2011	2012
Public electricity and heat production	3,004	3,171	3,062	3,130	3,093	3,062	2,825
Mining/Bauxite	4,600	2,964	4,146	1,547	1,239	1,673	1,525
Other Industrial Combustion	361	457	573	393	264	434	465
Road Transport	2,062	1,993	1,889	1,979	1,886	1,876	1,726
Other Transport/Mobile	49	42	39	19	25	18	17
Commercial, Residential (incl. Ag/For)	539	703	361	319	321	332	351
Energy	10,614	9,330	10,070	7,387	6,828	7,394	6,909
Cement & Lime	542	478	535	482	414	433	435
Other (Flaring, Non-E Prod Agriculture, Waste)	49	49	53	49	43	43	43
Total Excluding LULUCF	11,205	9,857	10,658	7,918	7,285	7,870	7,387
Land-Use Change - Forest remaining Forest	-1,834	-1,786	-1,779	-1,770	-1,767	-1,766	-1,777
Land-Use Change - Other	148	148	147	148	149	150	151
LULUCF	-1,685	-1,638	-1,631	-1,622	-1,618	-1,616	-1,626
Total including LULUCF	9,520	8,219	9,026	6,296	5,667	6,254	5,761

Emissions of CO2 are dominated by fossil fuel combustion sources, the largest components being electricity generation, industrial combustion (dominated by the mining/bauxite industry) and road transport. Almost all sources are relatively constant across the time series, showing only small decreases with time. However, the exception to this is the mining/bauxite industry, which shows very large year-to-year variations, and this consequently dominates the trend with time.

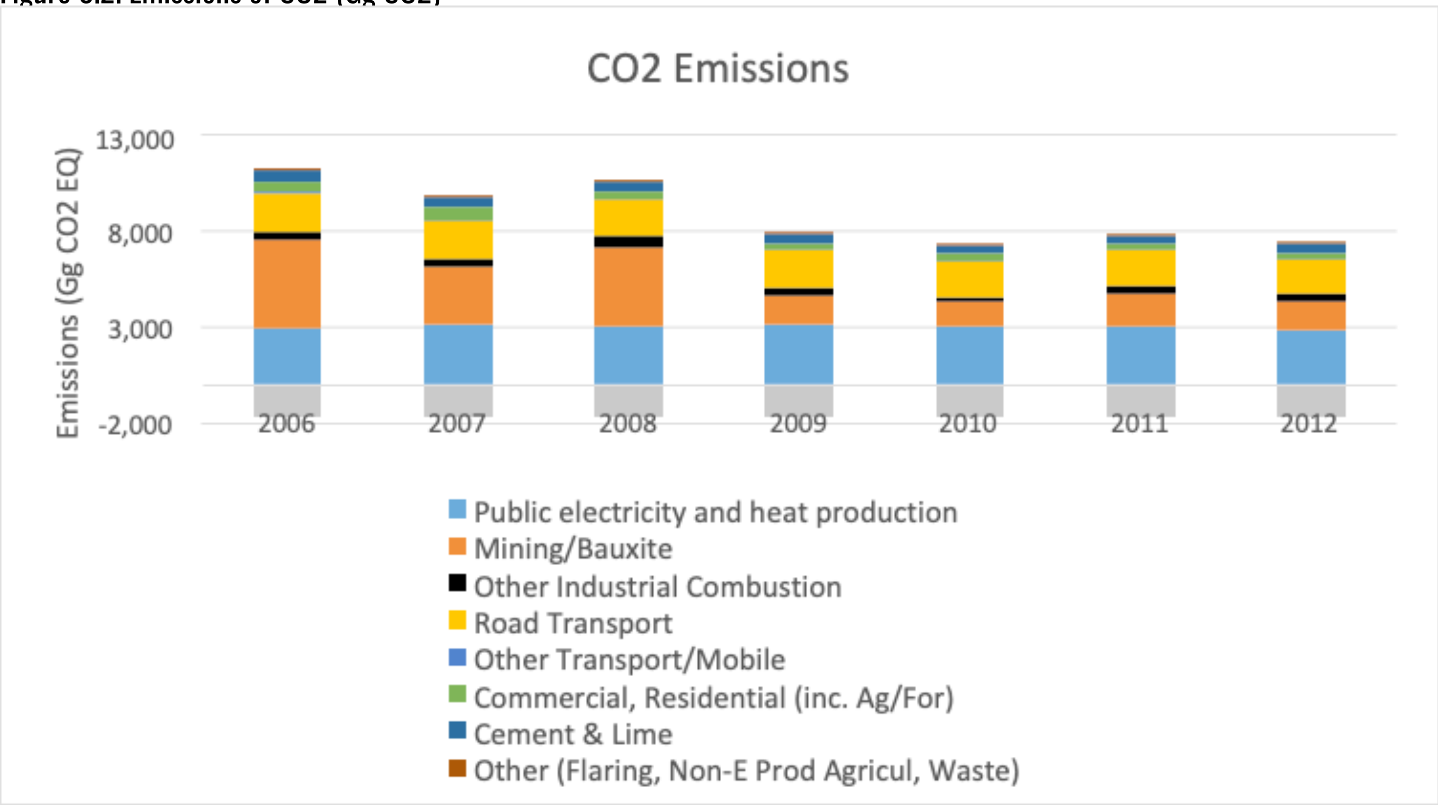
These large year-to-year variations in the mining/bauxite sector are considered to be a genuine representation of the changes in the quantities of fuel oil used for plant operations, and hence changes in the output levels from the industry. Changes across the time series are attributed to economic factors, and, in particular, the substantial decrease in emissions from 2008 to 2009 represents the impact of the global economic downturn on the industry. Similar trends with time are evident in the other industrial combustion emissions, although the absolute emissions are smaller.

CO2 emissions from electricity generation have decreased by relatively small amounts since 2009. This is a direct representation of lower levels of fuel oil and diesel oil consumption (and is independent of changes in electricity generating efficiencies). Emissions from oil refining is also included within this sector.

Emissions from road transport have decreased across the time series. This has been caused by a combination of several different factors. Gasoline consumption across the time series has reduced by 22%, although this is offset by an increase in the diesel consumption. Whilst diesel consumption accounts for considerably less than gasoline, it has increased across the time series by 19%. The emissions calculations are based on fuel consumption, and do not use vehicle kilometre data. The results therefore do not reflect improvements in the fuel economy (kilometres per litre of fuel used) of the road vehicle fleet which are likely to occur across the time series, merely changes in the amounts of fuel used. However, improved fuel economy is likely to be one of the several factors that influences the fuel consumption across the time series, along with changes in fuel prices and levels of disposable income across the general population.

LULUCF makes a significant contribution to the total CO2 emissions. However there is very little year-to-year variability of the LULUCF emissions, meaning that this source has very little impact on the emissions trend. LULUCF emissions are high in uncertainty, in particular, when compared with fuel combustion sources, which are typically very well characterised. More details can be found in the uncertainty analysis presented in Section 9.

Figure 0.2. Emissions of CO2 (Gg CO2)



2.2.3 Emissions of CH4

The following table summarises the emissions of CH4 across the 2006 – 2012 time series. These data are also presented in the figure below.

Table 0.5 CH4 emissions (Gg CO2 EQ)

	2006	2007	2008	2009	2010	2011	2012
Fuel Combustion	35	33	35	34	31	30	30
Enteric Fermentation	173	181	174	168	161	154	173
Manure Management	92	101	107	103	99	85	92
Agriculture - Other	5	6	5	5	5	5	5
Landfill	400	412	422	456	468	468	463
Waste - Other	113	102	97	92	83	89	89
TOTAL	818	835	841	857	847	831	852

Table 0.6. CH4 emissions (Gg CH4)

	2006	2007	2008	2009	2010	2011	2012
Fuel Combustion	1.66	1.57	1.67	1.63	1.46	1.44	1.41
Enteric Fermentation	8.26	8.63	8.31	7.98	7.66	7.33	8.23
Manure Management	4.36	4.80	5.10	4.89	4.72	4.03	4.39
Agriculture - Other	0.25	0.26	0.26	0.23	0.25	0.25	0.25
Landfill	19.05	19.64	20.11	21.71	22.30	22.29	22.05
Waste - Other	5.39	4.85	4.60	4.39	3.96	4.26	4.25
TOTAL	38.97	39.75	40.03	40.82	40.36	39.59	40.58

The largest contributions to the total CH4 emission come from the agriculture sector (primarily enteric fermentation and manure management) and from landfills. Overall, the year-to-year variability of emissions is small, although emissions from landfill show a steady increase across the time series (16% increase from 2006 to 2012), and emissions from agriculture are more variable from year-to-year than other source sectors.

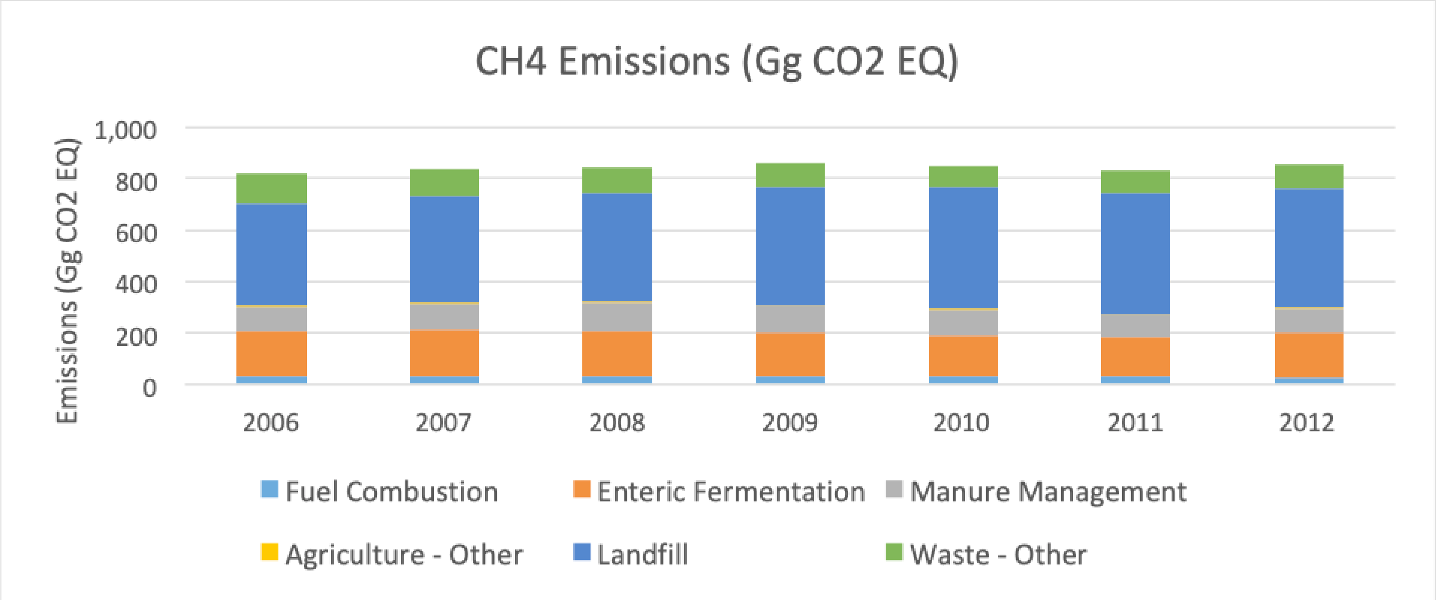
CH4 emissions from agricultural activities are dominated by enteric fermentation. The largest component of the CH4 emissions from enteric fermentation is non-dairy cattle, followed by dairy cattle. Enteric fermentation emissions per head of dairy cattle are larger than non-dairy, but the substantially greater number of non-dairy cattle means that emissions from non-dairy cattle are approximately four times the emissions from dairy cattle. Similarly, goats emit lower levels of CH4 per head compared to cattle. However the larger number of animals means that the total CH4 enteric emissions are approximately 50% higher than those from dairy cattle.

Emissions of CH4 from manure management are approximately half of the emissions from enteric fermentation. Pigs and poultry make the largest contributions to the total CH4 from manure management, collectively accounting for nearly three quarters of the total CH4 emissions from manure management in 2012.

Emissions from landfill are the largest component of CH4 emissions, and result from the breakdown of organic waste under anaerobic conditions. CH4 emissions from waste that is landfilled in a specific year occur across a long time period. Consequently the emissions in any given year represents the sum of emission contributions from waste that has been landfilled across many years previously.

Emissions from other sources in the waste sector include industrial and domestic waste water treatment, and small emissions from anaerobic digestion and waste burning (open burning and waste incineration).

Figure 0.3. Emissions of CH4 (Gg CO2 EQ)



2.2.4 Emissions of N_2O

The following table summarises the emissions of N2O across the 2006 – 2012 time series. These data are also presented in the figure below.

Table 0.7. N_2O emissions (Gg CO2 EQ)

	2006	2007	2008	2009	2010	2011	2012
Fuel Combustion	94	88	91	87	77	79	76
Manure Management	1,230	1,606	2,243	2,175	2,164	1,413	2,118
Agricultural Soils - Other	1,298	1,626	2,155	2,078	2,073	1,425	2,072
Agriculture - Indirect	1,202	1,620	2,338	2,277	2,285	1,464	2,284
Waste	46	46	47	46	45	45	45
Total	3,870	4,985	6,874	6,662	6,643	4,426	6,594

Table 0.8. N_2O emissions (Gg)

	2006	2007	2008	2009	2010	2011	2012
Fuel Combustion	0.30	0.28	0.29	0.28	0.25	0.25	0.24
Manure Management	3.97	5.18	7.24	7.02	6.98	4.56	6.83
Agricultural Soils – Other	4.19	5.24	6.95	6.70	6.69	4.60	6.68
Agriculture – Indirect	3.88	5.23	7.54	7.35	7.37	4.72	7.37
Waste	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Total	12.48	16.08	22.17	21.49	21.43	14.28	21.27

Emissions of N2O are dominated by the agriculture sector (accounting for 98% of total N2O emissions in 2012). Calculation of N2O emissions in the agriculture sector uses a nitrogen flow approach. This requires all input and output terms to be evaluated throughout the entire agriculture sector, and allows a more accurate evaluation of the different emission terms. More detail can be found in Section 5 of this report.

N2O emissions from each of the three main agricultural sectors (manure management, agricultural soils and indirect emissions) are broadly similar in magnitude. Manure management includes emissions from animal housing and during handling/storage of the manure. Emissions from agricultural soils include several components:

- Emissions from the application of synthetic fertilisers and manure (organic fertiliser) to crops;
- Emissions from manure deposited to fields from grazing animals;
- Emissions from the crop residues incorporated into the soil;
- Emissions from drained or managed organic soils.

Indirect emissions also arise through a number of different routes or mechanisms:

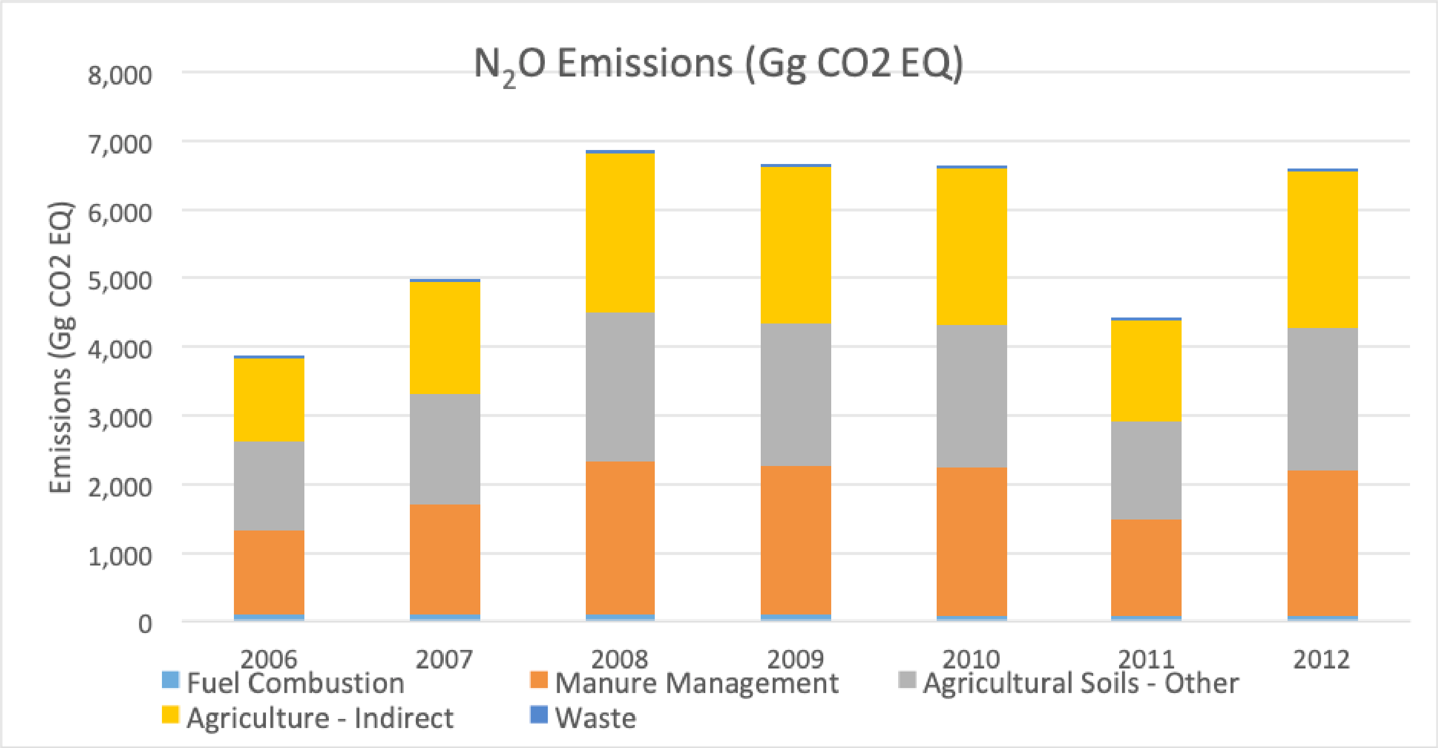
- A fraction of agricultural N emissions deposited back to land, and a fraction of the deposited N is re-emitted as N2O;
- N2O is emitted from N that leaches or runs-off from agricultural fields;
- N2O is emitted from N that leaches or runs-off from manure during storage;
-

Some of the interactions between these different pathways are complex, which is why better levels of accuracy is generally attained by evaluating the flow of N through the entire agriculture sector.

N2O emissions do vary considerably across the time series. This is largely driven by the changes in livestock numbers, and hence the total amount of N being generated from livestock farming. This impacts not just on manure management emissions, but also emissions from soils because it determines the amount of manure available for use as organic fertiliser. The amounts of synthetic fertiliser used annually were also available, and also impact on the year-to-year emissions from soils.

It was not possible to obtain any reliable information on changes to practices in either livestock of arable farming, and so this was assumed to be constant across the time series. As a result, the emission trend presented here does not incorporate any potential impact from changes to farming practices across the time series.

Figure 0.4 Emissions of N2O (Gg CO2 EQ)



2.2.5 Emissions of HFC

The following table summarises the emissions of HFC across the 2006 – 2012 time series, broken out by HFC species. Emissions are estimated to arise solely from refrigeration and air conditioning. These data are also presented in the figure below.

Table 0.9. HFCs emissions (Gg CO2 EQ)

	2006	2007	2008	2009	2010	2011	2012
HFC-23	4.31	5.47	6.60	7.70	8.78	9.84	10.89
HFC-125	12.43	12.94	13.09	12.92	12.49	11.83	11.49
HFC-134a	44.32	49.14	52.22	53.82	54.15	53.42	52.39
HFC-143a	16.04	18.14	19.16	19.29	18.64	17.35	16.31
HFC-152a	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HFC-227ea	1.69	1.43	1.22	1.03	0.88	0.75	0.64
HFC-236fa	0.28	0.24	0.20	0.17	0.15	0.13	0.11
Total	79.07	87.36	92.49	94.94	95.10	93.32	91.81

Emissions of HFC for refrigeration and air conditioning increase from 2006 – 2010, and then fall from 2010 to 2012. This is a reflection of the emission trend for HFC134a, which is the largest component of the total HFC emission. The emission trend is high in uncertainty, because import data has been interpolated for 2006 to 2012. But the trend does represent emissions that arise from the increasing importation of HFC up to 2005, and then a steady decline in the importation of HFC134a.

HFCs are typically used in, and emitted from, a number of bespoke applications in addition to air conditioning and refrigeration equipment, as outlined below. However, it is known that many sources are either not occurring in Jamaica, or it is not possible to quantify the HFC emissions arising. For the reasons indicated below, the emissions inventory reports the emissions to arise solely from air conditioning and refrigeration (as presented above).

2.2.5.1 Air Conditioning & Refrigeration

All imports of HFC were assumed to be used for refrigeration and air conditioning. This assumption is supported by the detailed analysis of the import data (which in some cases indicates cylinders designed for use with road vehicle air conditioning units), and local expert judgement that indicated that several of the other common uses of HFCs did not occur in Jamaica (see below).

- Refrigeration and air-conditioning systems can be broken down by type or use (UNEP-RTOC, 2003), as indicated below:
- Domestic (i.e., household) refrigeration (typically < 375kW)
- Commercial refrigeration including different types of equipment, from vending machines to centralised refrigeration systems in supermarkets (typically < 1000 kW)
- Industrial processes including chillers, cold storage, and industrial heat pumps used in the food, petrochemical and other industries (typically > 1000 kW)
- Transport refrigeration, including equipment and systems used in refrigerated trucks and containers
- Stationary air conditioning including air-to-air systems, heat pumps, and chillers for building and residential applications
- Mobile air-conditioning systems used in vehicles.

There are different approaches that can be used for estimating emissions, the two most common approaches consider the stock of different types of equipment, and a simpler approach that assumes that imported HFC is used to replace leakage. The method used for estimating emissions from refrigeration and air conditioning is detailed in Section 4.3.3.2.

2.2.5.2 Foam Blowing

All imports of HFC were assumed to be used for refrigeration and air conditioning, and consequently HFC emissions from foam blowing are assumed to be “not occurring”. This is consistent with the approach used in the 2NC.

2.2.5.3 Fire Suppression Equipment

Some of the HFCs imported are species used in fire suppression equipment as well as refrigeration and air conditioning. However, it was not possible to identify whether the imported HFC was specifically for use in fire suppression applications, and the 2NC indicates that there was only one occasion when a HFC was imported for fire suppression in the 2000-2005 period.

It was decided to assume that no HFC imports were for fire suppression equipment for 2006-2012, and this source is, therefore, considered as "not occurring" in the emissions inventory.

2.2.5.6 Aerosols, Metered Dose Inhalers and Solvents

No information was available to identify any import or use of HFCs for aerosols or metered dose inhalers. Consequently this source is considered as "not occurring" in the emissions inventory.

The SNC does identify some importation of HFC-245fa for use as a solvent (a surfactant in paint). However, no HFC-245fa was included in the available import data for 2006-2012, and consequently emissions from this source are considered to be "not occurring".

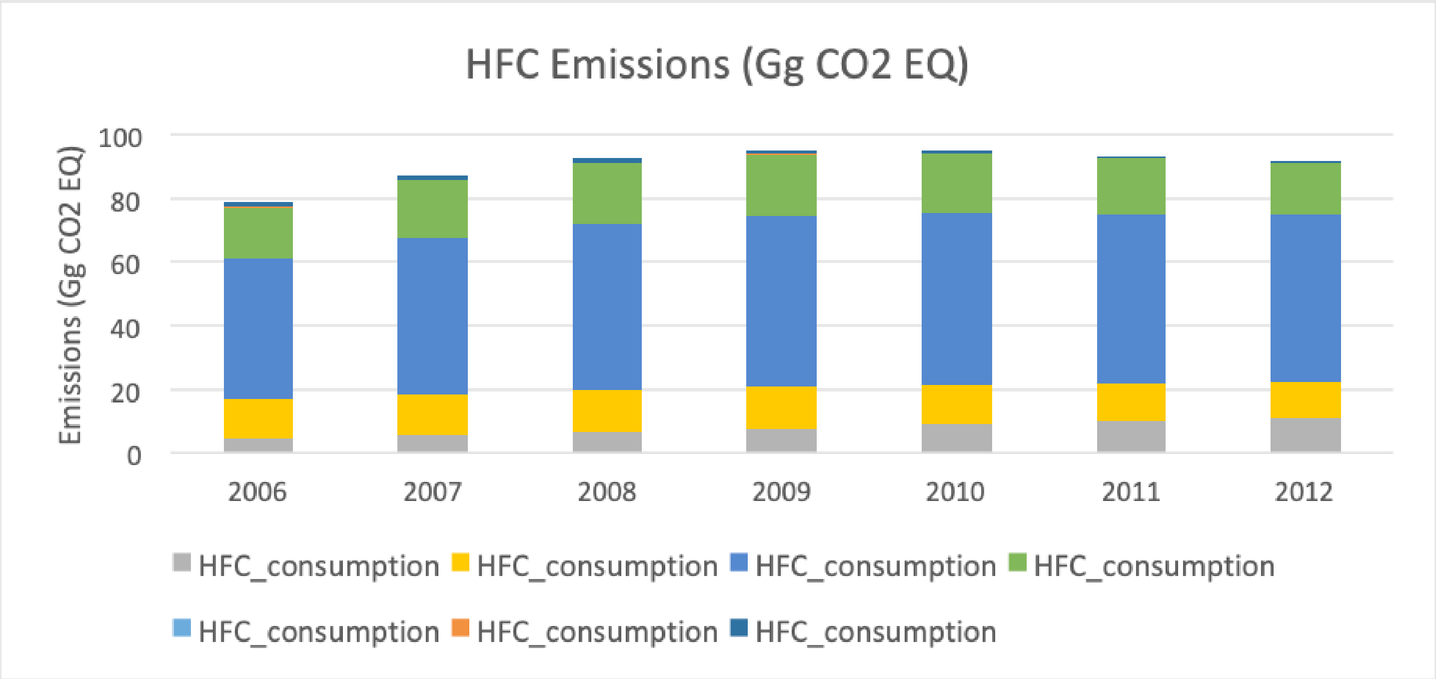
2.2.5.7 Precision Cleaning and Semi-conductor Manufacture

Local expert knowledge indicated that there are no known precision cleaning or semi-conductor manufacture operations in Jamaica that would use HFCs. Consequently no imported HFCs were allocated to this application, and emissions from this source are considered to be "not occurring".

2.2.5.8 Semiconductor Manufacture, Electrical Insulation, Training Shoes, One Component Foams

Local expert knowledge indicated that there are no known precision-cleaning operations in Jamaica that would use HFCs. Consequently no imported HFCs were allocated to this application, and emissions from this source are considered to be "not occurring".

Figure 0.5 Emissions of HFC (Gg CO_2 EQ)



2.2.6 Emissions of PFC, SF6 and NF3

Emissions of PFC, SF6 and NF3 arise from some bespoke applications and products. Each of the potential sources was reviewed, and whilst it was not possible to source data in many cases, local experts concluded that many of the sources do not occur in Jamaica.

2.2.6.1 Production of PFC, SF6 and NF3

There is no known production of PFC, SF6 or NF3 in Jamaica, and so it has been assumed that emissions are "not occurring".

2.2.6.2 Fire extinguishers (PFCs)

It was not possible to obtain information on the import of PFC, or whether PFC is used in any fire extinguisher systems installed in Jamaica. However, information from the 2NC indicates that no PFCs were used in fire extinguisher systems. Therefore, this source is reported as "not occurring".

2.2.6.3 Semiconductor manufacture and Electronics (PFC, SF6, NF3)

Local experts indicated that there is no manufacture of semi-conductors in Jamaica, and therefore this source is assumed to be "not occurring".

2.2.6.4 Electrical equipment (SF6)

SF6 is used in high voltage electrical switchgear, and in-use leakage can arise as well as during disposal. It was not possible to obtain any data on this source, however it is likely that SF6 is present in some high-voltage electrical switchgear in Jamaica. Therefore, this source is currently included in the inventory as "not estimated". This will need to be addressed in the future, and is captured as an action in the improvement programme.

2.2.6.5 Training shoes (SF6, PFC)

Some training shoes include SF6 or PFC in the cushioning. Whilst the practice stopped several years ago, it is still possible that emissions arise from shoes purchased when SF6 and PFC were being used.
There is no manufacture of training shoes in Jamaica, so the emissions from the manufacturing component is assumed to be "not occurring". Emissions during use are typically assumed to be negligible (UK National Inventory Report on GHG Emissions, 2015), and therefore are also assumed to be "not occurring". However, emissions would arise after end-of-life i.e. once the shoes have been landfilled. It has not been possible to obtain any data on this source, and it is therefore included in the inventory as "not estimated". This expected to be a small source, but review of data availability has been included in the improvement programme.

2.2.6.6 Scientific tracer gas (SF6)

SF6 is used as a scientific tracer gas, for example to investigate atmospheric mixing and dispersion. There is no know use of SF6 for this application in Jamaica, and local expert opinion was that this source is "not occurring".

2.2.7 Emissions of Indirect GHGs

2.2.7.1 Emissions of NOx

The following table summarises the emissions of NOx across the 2006 – 2012 time series. These data are also presented in the figure below.

Table 0.10. NOx emissions (Gg NO_2)

	2006	2007	2008	2009	2010	2011	2012
Electricity Generation	4.81	5.10	4.91	5.02	4.99	4.92	4.51
Mining/Bauxite	30.49	19.65	27.48	10.25	8.21	11.09	10.11
Other Industrial Combustion	2.46	3.07	4.61	3.07	1.96	2.77	3.26
Transport	18.82	16.72	17.26	16.38	15.48	15.09	14.48
Commercial, Residential (including Agriculture/Forestry/Fishing)	1.99	2.94	1.50	1.26	1.22	1.21	1.23
Agriculture (& Waste)	6.21	7.92	10.81	10.38	10.37	6.99	10.40
Total	64.77	55.40	66.57	46.36	42.23	42.06	43.98

Emissions of NOx arise almost exclusively from combustion sources, the main exception being the agriculture sector. As a result, the use of fuels in different sectors has a large influence on the relative contributions to the total emission from the different source sectors.

Whilst the energy balance tables do provide information on the use of fuels in different sectors, there are some limits to the detail that is available, and in particular whether the fuel is used in stationary sources or mobile machinery. This is particularly relevant for liquid fuels, which are used in both stationary sources and mobile machinery across many sectors. NOx EFs are different for stationary and mobile sources, so the fuel allocation to stationary/mobile sources does impact on the total emission estimate.

However, it is possible to make assumptions regarding the allocation of fuel to stationary and mobile sources - gasoline and diesel oil are assigned to mobile machinery, and other fuels are assigned to stationary sources.

2.2.7.2 Mining/Bauxite

Whilst the 2012 emissions from the mining/bauxite sector are not the largest in absolute terms, as with other pollutants, the trend in emissions is one of the most important in determining the trend of total NOx emissions. The large variations in NOx emissions across the time series is a reflection of the large variations in fuel consumption in the mining/bauxite sector. The substantial decrease in levels of production between 2008 and 2009 is reflected in the total NOx emissions.

2.2.7.3 Transport

This sector includes emissions from road transport, aviation and domestic shipping (emissions from railways are included elsewhere as explained in section 3.6.3). Emissions from all sources have been in steady decline across the time series.
Road transport is the largest component of the transport sector, and NOx emissions have declined by 20% from 2006 to 2012. Although smaller in absolute terms, larger percentage reductions are observed in the aviation and shipping sectors (55% and 66% reductions respectively). These reductions are driven by decreasing fuel consumption across the time series.

2.2.7.4 Agriculture

NOx emissions (more specifically NO emissions) arise from managed soils. The emission estimates have been made in detail using a nitrogen balance approach. Year to year variations in the emissions reflect the changes to the amount of nitrogen being input into managed soils from several sources – e.g. manure application as an organic fertiliser, application of synthetic fertiliser, incorporation of crop residues back into the soil and other smaller sources. This directly influences the NOx emissions to air.
Figure 0.6 Emissions of NOx (Gg NO2)

2.2.8 Emissions of NMVOC

The following table summarises the emissions of NMVOC across the 2006 – 2012 time series. These data are also presented in the figure below.

Table 0.11. NMVOC emissions (Gg NMVOC)

	2006	2007	2008	2009	2010	2011	2012
Stationary Combustion	3.05	2.61	3.11	2.93	1.58	2.13	2.12
Transport	8.03	7.15	7.40	7.20	6.74	6.61	6.43
Commercial, Residential	1.34	1.37	1.46	1.43	1.42	1.33	1.33
Food & Drink	3.13	3.28	3.11	2.96	2.90	3.09	3.08
Solvent Use	14.25	14.40	14.28	14.19	13.89	14.04	14.01
Other	2.21	2.44	3.04	2.86	2.74	2.20	2.68
Total	32.01	31.24	32.38	31.57	29.26	29.41	29.65

Emissions of NMVOC arise from a wide variety of different sources e.g. fuel combustion, and evaporative sources from the use of solvents, from food and drink manufacture and from the use of products.

2.2.8.1 Transport

Most of the NMVOC sources are relatively constant across the time series, the main exception being road transport. As a result, the trends in NMVOC emissions from road transport primarily determine the trend in the total NMVOC emissions across the time series - even though, in absolute terms, it is a smaller source than solvent use.

Emissions from petrol cars are the largest component of the transport emissions, accounting for nearly two thirds of the emissions from transport (domestic aviation, road vehicles and domestic shipping combined). Emissions have been decreasing with time, and this is a reflection of the lower levels of fuel consumption, rather than improvements in emissions abatement. This is because the method for estimating emissions has not been able to take into account the changes in technology of the vehicle fleet across the time series. This is an important improvement for the future, but relies on being able to obtain more detailed information on the road vehicle fleet.

2.2.8.2 Food and Drink

NMVOC emissions arise from the manufacture of a range of products in the food and drink sector. The largest NMVOC emissions come from the manufacture of flour, sugar and animal feed.

The manufacture of alcoholic beverages, and particularly spirits, features strongly in the food and drink sector in Jamaica. However emissions from these sources are a relatively small component of the food and drink sector overall. This is because of the loss of product through evaporation is undesirable, and hence there are controls put in place to minimise the emissions to air.

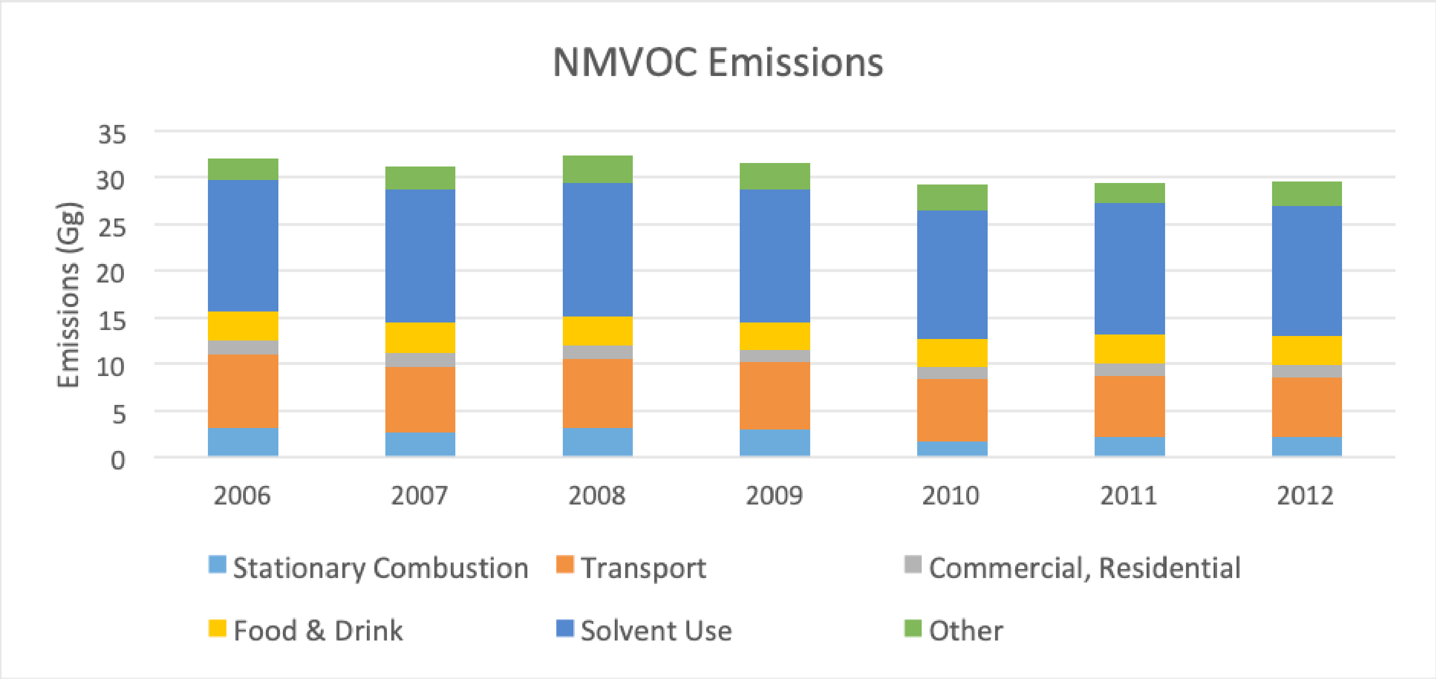
2.2.8.3 Solvent Use

Solvent use is the single largest source sector or NMVOC. Emissions are relatively constant across the time series, reflecting the fact that many of the sources within this sector only vary significantly with population. There are many individual sources within this source sector, but these are readily summarised by allocating them into one of three main sub-categories:

- The use of products in the domestic sector e.g. cosmetics, cleaning products, and pharmaceuticals;
- The use of paints, varnishes, other coatings and adhesives, and solvent use for e.g. degreasing and cleaning; and
- Dry cleaning.

It was not possible to obtained detailed information on whether there have been material changes in the characteristics of these sources across the time series (e.g. how the solvent content of paint may have decreased). So changes in emissions are primarily driven by changes in population.

Figure 0.7 Emissions of NMVOC (Gg NMVOC)



2.2.9.0 Emissions of CO

The following table summarises the emissions of CO across the 2006 – 2012 time series. These data are also presented in the figure below.

Table 0.12. CO emissions (Gg CO)

	2006	2007	2008	2009	2010	2011	2012
Public electricity and heat production	0.58	0.61	0.59	0.60	0.60	0.59	0.54
Mining/Bauxite	3.92	2.53	3.54	1.32	1.06	1.43	1.30
Other Industrial Combustion	10.44	11.62	10.88	11.80	8.42	8.85	9.54
Transport	56.93	50.60	51.89	50.42	47.16	45.34	44.75
Commercial, Residential (including Agriculture/Forestry/Fishing)	13.33	12.83	13.68	13.32	12.71	13.12	12.93
Other (Flaring, Non-E Prod Agriculture Waste)	14.67	14.92	15.47	13.64	13.22	13.32	13.40
Total	99.88	93.11	96.05	91.11	83.17	82.65	82.45

Emissions of CO arise completely from combustion sources, and, in particular, the incomplete combustion of fuel to CO rather than CO2. The CO emissions total is dominated by the transport component, although combustion in other sectors also sum to make a significant contribution to the total emission.

2.2.9.1 Transport

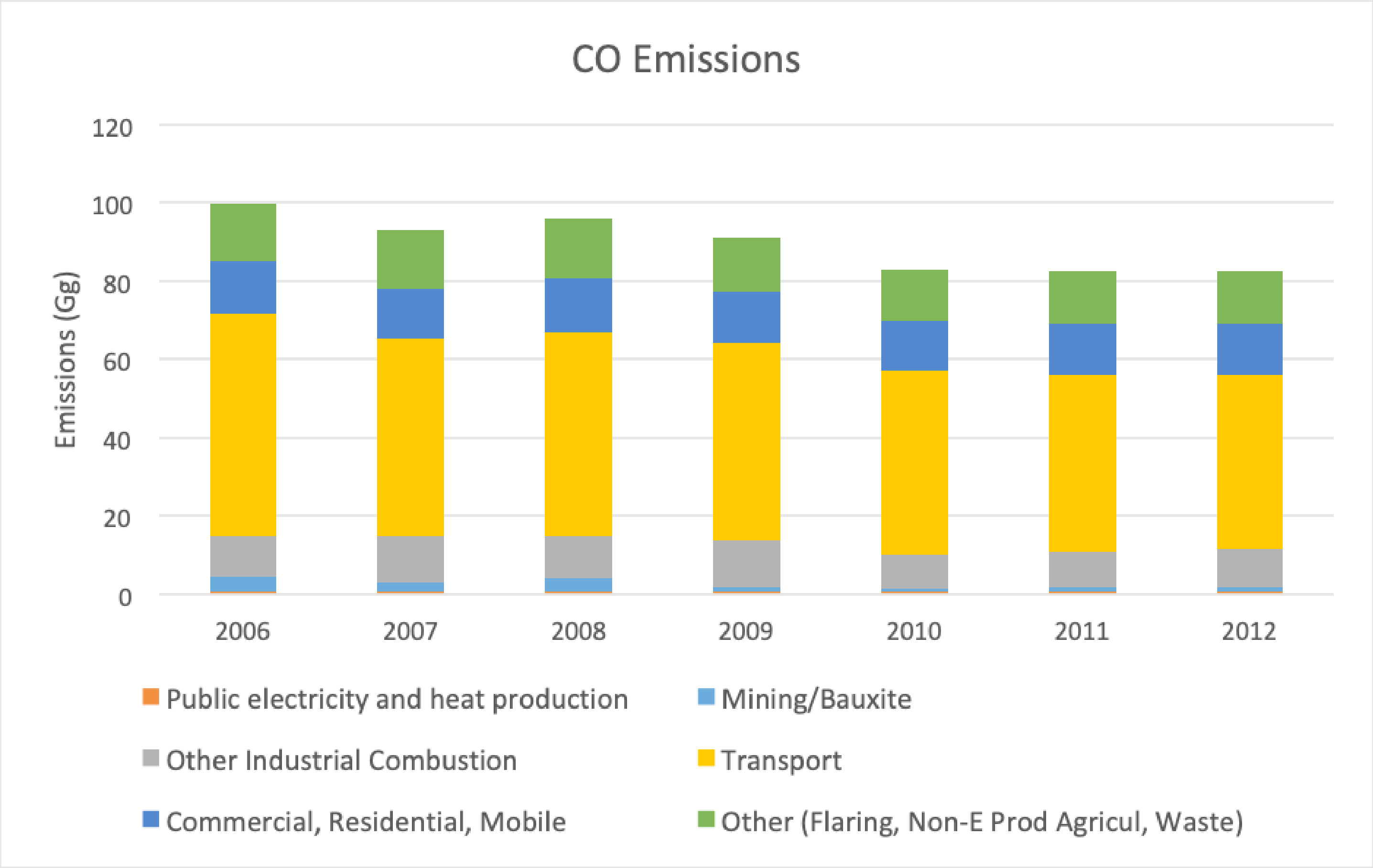
The CO emission from the transport sector is both the largest source sector in absolute terms, and the largest contributor to the overall trend with time. Emissions from petrol cars account for three quarters of the total sector emissions, and the variation with time is very much dominated by the amount of fuel consumption.

Emission controls for CO have been introduced into road vehicle fleets in the form of different generations of the three-way catalyst and improved engine management systems. However it has not been possible to obtain the required detailed information to account for the penetration of these different technological advancements into the road vehicle fleet. Hence the emission trends are primarily driven by the trends in fuel consumption.

2.2.9.2 Commercial, Residential and Agriculture/Forestry/Fishing

This category includes both stationary combustion and mobile machinery sources within Commercial and Residential, and mobile sources in agriculture and forestry. The two largest components by far are the use of wood in the residential sector, and mobile machinery in agriculture and forestry (accounting for more than 40% and 50% of the emissions from this category respectively).

Figure 0.8 Emissions of CO (Gg CO)



2.2.10.0 Emissions of SO_2

The following table summarises the emissions of SO_2 across the 2006 – 2012 time series. These data are also presented in the figure below.

Table 0.13. SO_2 emissions (Gg SO_2)

	2006	2007	2008	2009	2010	2011	2012
Public electricity and heat production	14.28	15.17	14.51	14.87	14.84	14.51	13.11
Mining/Bauxite	2.79	1.80	2.52	0.94	0.75	1.02	0.93
Other Industrial Combustion	1.10	1.47	1.18	1.26	0.75	1.86	1.71
Transport	0.32	0.28	0.27	0.15	0.18	0.15	0.13
Commercial, Residential, Mobile	0.20	0.32	0.14	0.12	0.11	0.11	0.11
Other (Flaring, Non-E Prod Agricul, Waste)	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total	18.71	19.05	18.63	17.34	16.65	17.66	16.00

Emissions of SO2 are typically dominated by combustion sources, the sulphur in the fuel being converted into SO2 and emitted to air during fuel combustion. There are some non-combustion sources of SO2, but these do not occur in Jamaica, and hence all of the SO2 emissions in the inventory are from fuel combustion (sources included in "Other" in the table above are flaring and the burning of waste).

Emissions of SO2 are expected to be less uncertain than the emission of other indirect GHGs. This is because the SO2 emission is readily determined from the sulphur content of the fuel and the amount of fuel used – both terms that are generally well characterised. Emissions of other indirect GHGs are affected by the combustion conditions, and are therefore considerably more variable from source to source, and hence less well characterised. Uncertainties associated with emissions of each pollutant have been calculated, and are presented in Section 9.

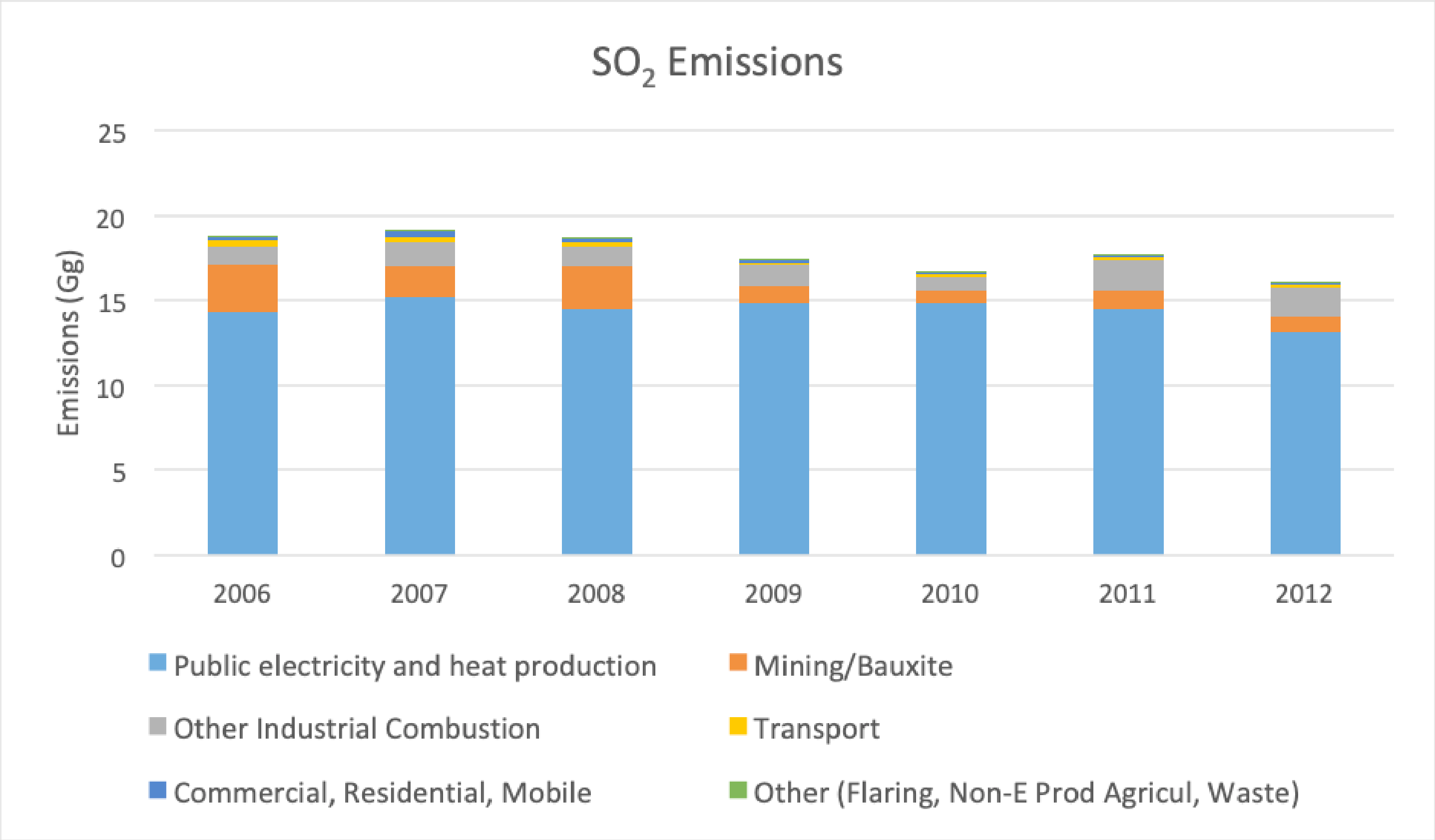
2.2.10.1 Public Electricity and Heat Production

Emissions of SO2 are dominated by the emissions from electricity generation, both in terms of the absolute emissions and the contribution to the trend with time. Fuel oil and diesel oil are both used for electricity generation, the former being the larger component. The sulphur content of fuel oil is approximately an order of magnitude higher than that of diesel oil, and as a result, SO2 emissions from fuel oil are considerably larger than those from diesel oil, accounting for 97% of the total emissions from public electricity and heat production.

2.2.10.2 Transport

Transport accounts for less than 1% of the emission total in 2012. Whilst road transport is the largest consumer of fuel in the transport sector, there are stringent controls on the sulphur content that is allowed in gasoline and diesel used for road vehicles. The permitted levels of sulphur in fuels used for shipping are higher by several orders of magnitude, and as a result, it is domestic shipping which is the largest emitter in the transport sector. However, controls on the sulphur content of fuel used in shipping will come into effect from 2015 in the US and Canada. It is, therefore, expected that the fuel available for use in the Caribbean will also be lower in sulphur content, substantially reducing SO2 emission from domestic shipping.

Figure 0.9 Emissions of SO_2 (Gg SO_2)



2.2.11.0 Energy Sector

2.2.11.1 Description of the Sector

The energy sector encompasses a wide range of different sources, and is typically the largest contributor to a GHG emissions inventory. The energy sector can be regarded as consisting of four primary areas. The following types of activities, as outlined below, represent the categories:

- Exploration and development of primary energy sources;
- Transmission and distribution of fuels;
- Conversion of primary energy sources into more usable energy forms, both in the refining and in the electricity power plant; and
- Use of fuels in both stationary and mobile application.

From these activities, various forms of emissions arise, as a result of combustion. In addition, emissions can occur as fugitive emissions107, and the use of fuel in non-combustion activities, although both of these emission types are typically very small when compared with emissions from the combustion of fuels. The largest emission sources of almost all national GHG emissions inventories are the emission of CO2 from fuel combustion in stationary and mobile sources.

The Common Reporting Format (CRF) for reporting GHGs provides a clear reporting format that allows comparability across countries. The table below provides a summary of emissions arising in Jamaica in the energy sector, and how these are allocated to categories of the CRF.

Table 0.1. Emission Sources in the Energy Sector by CRF

CRF	CRF Category Name	Present in Jamaica
1A1	Fuel Combustion Activities – Energy Industries	
1A1a	Public Electricity and Heat Production	Y – Electricity generating stations
1A1b	Petroleum Refining	Y – Emissions from the refinery
1A1c	Manufacture of Solid Fuels and Other Energy Industries	N
1A2	Fuel Combustion Activities - Manufacturing Industries and Construction	
1A2a	Iron and Steel	N
1A2b	Non-Ferrous Metals	Y – Fuel used for bauxite/aluminium manufacture (mining activities also included in this sector)
1A2c	Chemicals	N
1A2d	Pulp, Paper and Print	N – This may occur, but fuel use was not resolved from other industrial sectors
1A2e	Food Processing, Beverages and Tobacco	Y – Fuel used for sugar and other food & drink manufacture
1A2f	Non-Metallic Minerals	Y – Fuel used for cement manufacture
1A2g	Other Industrial Mobile Machinery and Other Stationary	Y – Fuel used for mobile machinery and industrial sectors not allocated to specific sectors
1A3	Transport	
1A3a	Civil Aviation	Y – Domestic aviation
1A3b	Road Transport	Y – Emissions from all road vehicle types
1A3c	Railways	Y – Fuel use, & hence emissions included in the inventory, but included elsewhere
1A3d	Domestic Shipping/National Navigation	Y – Domestic shipping and fishing
1A3e	Other Navigation	N – No specific sources identified. Any emissions are expected to be captured in 1A3d

107 Fugitive emissions occur as leaks or other unintended or irregular emission.

CRF	CRF Category Name	Present in Jamaica
1A4	Fuel Combustion Activities – Commercial, Institutional, Residential, Agriculture/Forestry/Fishing	
1A4a	Commercial / Institutional	Y – Stationary and mobile machinery
1A4b	Residential	Y – Residential stationary combustion
1A4c	Agriculture / Forestry / Fishing	Y – Emissions from mobile machinery
1A5	"Other" Fuel Combustion	N
1B1	Fugitive Emissions - Solid	N
1B2	Fugitive Emissions - Oil and Natural Gas	
1B2a	Fugitive Emissions from Fuels – Oil &Natural Gas – Oil	Y – Flaring from the refinery
1B2b	Fugitive Emissions from Fuels – Oil & Natural Gas - Natural gas	N
1C	CO_2 Transport and Storage	N

2.2.11.2 Activities in Jamaica

Activities in the energy sector that are/aren't present in Jamaica have not significantly changed across the last decade, although there have been significant changes to emissions from some sources with time:

- **1A1 Electricity Generation and Refinery Emissions:** There has not been any substantial change in that electricity generating stations in Jamaica are oil fired, and refinery activities continue in parallel with the importation of oils and other fuels.

- **1A2 Fuel Combustion in Industry:** There is little heavy industry in Jamaica. The emissions from this sector are very much dominated by the bauxite/aluminium industry. It has not been possible to resolve these activities from mining, and hence mining and bauxite are included together. There have been significant changes in the activity levels of the bauxite/aluminium plant across the time series.

- **1A3 Transport:** Whilst there have been changes to emissions across the time series from transport sources, there have not been any new sources introduced in recent years, and none of the existing sources have ceased. Aviation has fluctuated, depending on a number of factors including tourism (very much influenced by the health of the global economy). Fuel used in the road transport sector has shown a steady decline.

- **1A4 Commercial, Institutional, Residential:** In the residential sector, wood and LPG are main fuel types, being used primarily for cooking, and small amounts for heating. LPG and charcoal are the main fuel types used in the Commercial/Institutional sector.

- **1A4 Agriculture/Forestry/Fishing:** The main fuel use in these sectors is gasoline and diesel oil for a wide variety of types of mobile machinery.

2.2.11.3 Methodological Overview

Various methods can be used to estimate emissions or removal from most sources and sink categories when conducting GHG Inventory. The methodologies applied in undertaking the GHG Inventory for Jamaica was guided by the 2006 IPCC Guidance (Volume 2 Energy), within the framework presented by emissions inventory good practice given in 2006 IPCC Guidance (Volume 1 General Guidance).

The method to be applied will depend on the desired degree of estimation detail. It also depends on the availability of human and financial resources, as well as the time available to complete the inventory. The simplest or lowest ranking method is referred to as Tier 1. The more elaborate methods are Tier 2 and Tier 3, where country-specific information, point source emissions data and potentially detailed modelling are used in the emission calculations.

The country-specific information that was obtained for use in the inventory for the energy sector was limited. Most of the fuel properties were default values taken from the 2006 IPCC Guidance, and whilst this may be regionally specific, the emission methodologies should be considered as Tier 1 methods.

2.2.11.4 Activity Data

In the energy sector, data is supplied from both the public and private sectors, the former including a number of ministries, departments and agencies (MDAs).

The Ministry of Science, Technology and Energy (MSTEM) has a mandate to provide energy statistics and information on various aspects of the energy sector, and is therefore one of the most important data providers for the emissions inventory. It is the main repository for energy related data: petroleum, electricity and bio-energy types. Some of the other Ministries which supply information include the Ministry of Transport and Works (MTW), Ministry of Agriculture and Fisheries (MOAF), Ministry of Land, Water, Environment and Climate Change (MWLECC) and the Ministry of Industry, Investment and Commerce (MIIC).

There are also some other agencies that played a critical role in the data supply process. These include the Petroleum Cooperation of Jamaica (PCJ), Petrojam Limited (Refinery), Planning Institute of Jamaica (PIOJ), National Environment and Planning Agency (NEPA), Office of Utilities Regulation (OUR), Statistical Institute of Jamaica (STATIN), among others.

Some of the private sector entities included the Jamaica Chamber of Commerce (JCC), Private Sector Organisation of Jamaica (PSOJ), Jamaica Exporters' Association (JEA), Jamaica Public Service Company Limited (JPS), among others. Where these entities were not willing to share information, formal requests were issued by the Climate Change Division of the MWLECC (now the Ministry of Economic Growth and Job Creation). Some of these entities also prepare annual reports, which can provide the data being sought.

2.2.11.5 National Energy Balance Tables

In order to estimate GHG emissions from the energy sector, it is essential to have high-quality fuel consumption data. National Energy Balances for Jamaica for 2006 to 2012 were made available by the Ministry of Science, Technology, Energy and Mining (MSTEM, 2015).The data from the national energy balance tables were studied in detail. Some errors were established in the way the fuel types were allocated to different source sectors. Corrections were, therefore, made before use in emissions inventory.

A summary of the data is provided in the following tables.

Table 0.2 Fuel consumption (Thousand Barrels of Oil Equivalent – KBOE)

Sector		2006	2007	2008	2009	2010	2011	2012
Electricity Generation	Diesel oil	1,713	1,761	1,739	1,772	1,687	1,722	1,646
Electricity Generation	Fuel Oil	4,842	5,150	4,921	5,042	5,042	4,923	4,440
Petroleum Refining	Diesel oil	0.6	0.7	0.7	0.7	0.7	0.8	0
Petroleum Refining	Fuel Oil	255	276	281	280	280	294	320
Mining/Bauxite	Fuel Oil	10,306	6,641	9,289	3,466	2,776	3,748	3,416
Sugar	Fuel Oil	26	28	20	14	9	5	5
Sugar	Bagasse	602	591	589	1,049	418	579	570
Cement	Coal	224	305	241	259	159	402	370
Cement	Fuel Oil	16	21	27	13	5	5	26
Industry, Mobile machinery	Gasoline	69	76	66	64	58	44	51
Industry, Mobile machinery	Diesel oil	257	373	750	405	301	392	532
Industry, Other Stationary	Fuel Oil	204	209	188	116	55	100	45
Industry, Other Stationary	LPG	15	14	14	15	12	14	13

Sector		2006	2007	2008	2009	2010	2011	2012
Aviation, Local	Avgas						0.2	2
Aviation, Local	Turbo						0.0	4
Road Transport	Gasoline	4,036	3,593	3,724	3,634	3,399	3,334	3,214
Road Transport	Diesel oil	1,079	1,331	964	1,259	1,261	1,297	1,058
Shipping/National Navigation	Diesel oil	56	29	31	7	22	19	12
Shipping/National Navigation	Fuel Oil	43	55	50	30	28	21	21
Public/Commercial/Institutional	Gasoline	0	51	26	0	0	0	0
Public/Commercial/Institutional	Diesel oil	33	250	49	38	34	37	35
Public/Commercial/Institutional	Fuel Oil	92	0	0	0	16	0	0
Public/Commercial/Institutional	LPG	269	238	260	264	272	284	298
Public/Commercial/Institutional	Charcoal	130	130	191	191	191	134	134
Public/Commercial/Institutional	Kerosene	180	256	0	8	5	5	20
Residential	Kerosene	239	339	17	9	6	6	22
Residential	LPG	358	401	346	308	321	335	351
Residential	Wood	222	222	228	228	228	228	228
Agriculture, Mobile	Gasoline	71	64	72	69	63	69	67
Agriculture, Mobile	Diesel oil	115	154	165	134	120	130	122
Aviation, International	Turbo						1,752	1,771
Shipping, International	Diesel Oil	437	228	241	56	168	147	146

Table 0.3 Fuel Consumed by Emissions Inventory Sector (TJ, except Barrels il for Refinery Flaring).

Sector	Fuel	2006	2007	2008	2009	2010	2011	2012
Public Electricity and Heat Production	Fuel oil	27,919	29,696	28,377	29,075	29,075	28,389	25,604
Public Electricity and Heat Production	Diesel oil	9,836	10,109	9,984	10,174	9,686	9,887	9,450
Petroleum Refining	Fuel oil	1,470	1,592	1,619	1,615	1,612	1,698	1,847
Petroleum Refining	Diesel oil	4	4	4	4	4	4	0
Mining/Bauxite	Fuel Oil	59,430	38,296	53,566	19,987	16,008	21,613	19,699
Sugar	Fuel oil	151	159	115	81	52	29	29
Sugar	Bagasse	3,613	3,547	3,535	6,297	2,509	3,475	3,421
Cement	Fuel oil	93	119	156	75	29	29	150
Cement	Coal	1,108	1,510	1,193	1,282	787	1,990	1,831
Industry Other, Stationary	LPG	86	81	82	88	70	82	76
Industry Other, Stationary	Fuel oil	1,178	1,205	1,084	669	317	577	259
Industry, Mobile Machinery	Gasoline	396	434	378	367	333	253	292
Industry, Mobile Machinery	Diesel Oil	1,474	2,140	4,306	2,325	1,725	2,251	3,054

Sector	Fuel	2006	2007	2008	2009	2010	2011	2012
Domestic aviation LTO (civil)	Avgas	27	23	17	14	13	1	12
Domestic aviation LTO (civil)	Turbo	52	44	33	28	26	0	23
Road Transport	Gasoline	23,126	20,590	21,338	20,822	19,476	19,103	18,416
Road Transport	Diesel Oil	6,194	7,639	5,535	7,228	7,240	7,447	6,074
Railways	Diesel oil	0	0	0	0	0	0	0
Railways	Diesel oil	0	0	0	0	0	0	0
Domestic Shipping/National Navigation	Diesel Oil	324	168	178	42	124	108	69
Domestic Shipping/National Navigation	Fuel Oil	246	317	290	171	163	123	120
Commercial/Institutional: Mobile	Gasoline	0	292	149	0	0	0	0
Commercial/Institutional: Mobile	Diesel oil	187	1,433	281	218	195	212	201
Commercial/Institutional: Stationary	Fuel Oil	531	0	0	0	92	0	0
Commercial/Institutional: Stationary	LPG	1,573	1,393	1,523	1,546	1,593	1,664	1,746
Commercial/Institutional: Stationary	Kerosene	1,051	1,493	0	47	29	29	117
Commercial/Institutional: Stationary	Charcoal	794	794	1,165	1,165	1,165	817	817
Residential: Stationary	Kerosene	1,393	1,979	99	53	35	35	128
Residential: Stationary	LPG	2,099	2,351	2,027	1,804	1,880	1,962	2,056
Residential: Stationary	Wood	1,335	1,333	1,369	1,369	1,369	1,369	1,369
Agriculture/Forestry/ Fishing: Mobile	Gasoline	407	369	413	395	361	395	384
Agriculture/Forestry/ Fishing: Mobile	Diesel oil	658	884	947	769	689	746	700
Refinery Flaring	Flared gases and vapours	3,351	2,882	1,021	4,864	3,083	670	777

These fuel use data by emissions inventory source represent the activity data for the emission calculations in the energy sector. Whilst some assumptions were required regarding the allocation of fuel from the energy balance tables to specific emission inventory sources (see Sections 3.6.2 and 3.6.3), the data itself is considered to be of good quality in terms of accuracy, completeness and consistency.

Whilst the data in the energy balance tables is presented as national level data, the tables are not entirely compiled using a top-down approach. For example, it is known that the data in the energy balance tables for e.g. electricity-generating stations and other large industrial sources are compiled from point source data.

2.2.11.6 Properties of Fuels

The national energy balance tables present data in terms of thousand barrels of oil equivalent (K BOE). The IPCC Guidance expresses emissions factors in energy terms, but uses TJoules (on a net energy basis). Therefore to convert from K BOE to TJoules, it is not only necessary to perform a K BOE to TJoules conversion, but to also take into account the ratio of Net calorific value (CV) to Gross CV on a fuel by fuel basis.

The net and gross CVs that were used in the conversion for each fuel are included in the table below. The CVs for fuel oil and gas oil are country specific. For all other fuels, the literature was searched to find CVs considered to be most appropriate for the fuel used in Jamaica.

Table 0.4 Fuel Properties – Calorific Values.

Fuel	Net CVs (GJ/tonne)	Reference	Gross CVs (GJ/tonne)	Reference
Fuel Oil	40.5	Country specific CV	42.9	Country specific CV
Diesel Oil	42.6	Country specific CV	45.4	Country specific CV
Gasoline	44.3	IPPC, 2006, Chapter 1, Table 1.2	47.3	Engineering Toolbox [2]
Kerosene	44.1	IPPC, 2006, Chapter 1, Table 1.2	46.2	Engineering Toolbox [2]
Coal	26.7	IPPC, 2006, Chapter 1, Table 1.2	33.0	Engineering Toolbox [2]
Charcoal	29.5	IPPC, 2006, Chapter 1, Table 1.2	29.6	Engineering Toolbox [2]
Wood	15.6	IPPC, 2006, Chapter 1, Table 1.2	15.9	Engineering Toolbox [2]
LPG	47.3	IPPC, 2006, Chapter 1, Table 1.2	49.4	UK Digest of Energy Statistics [3]
Bagasse	7.6	FAO [1]	7.7	Assumed to be the same NCV/GCV ratio as that for wood

[1] http://www.fao.org/docrep/003/s8850e/s8850e03.htm)
[2] http://www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html
[3] https://www.gov.uk/government/uploads/system/.../dukesa_1-a_3.xls

The value of these CVs directly influences the resulting fuel in TJoules. Consequently, selection is particularly important in giving accurate fuel consumption data for use in emission calculations. Whilst there is little variation in the literature for CVs of most fuel types, there are some which can vary by several per cent, and subtleties associated with the details and definitions of some fuels. Whilst care has been taken in selecting appropriate CVs from the available literature, there is scope for improving this step of the emission calculations. Drawing more extensively on local expertise and knowledge would better support decisions, and also may be able to improve the extent to which country-specific values are used.

2.2.11.7 Sectoral and Reference Approaches

The most common method of estimating emissions in the energy sector is to consider the fuel used by each different source. These can then be summed to give sector totals. This is known as the "Sectoral Approach", and is a "bottom-up" approach. The advantage of this approach is that it typically uses the most detailed fuel consumption data.

In the energy sector, for CO2, it is also possible to use fuel import/export data at the national scale without considering where it is used. This is known as the "Reference Approach", and is a "top-down" approach, using a country's energy supply data to calculate the emissions of CO2 from combustion of mainly fossil fuels.

It is good practice to apply both a sectoral approach and the reference approach to estimate a country's CO2 emissions from fuel combustion and to compare the results of these two independent estimates. The 2006 IPCC Guidelines (Volume 2, Energy) provides detail on how the comparison of the reference and sectoral approaches can be used as a verification exercise, explaining that any significant differences in emissions calculated by the two different approaches requires explanation.

In Jamaica, it was not possible to collate complete information on fuel consumption at the individual sectoral level. As a result, the national energy balance tables provided the single source of fuel consumption data for use in the emissions inventory. It is known that the national energy balance tables are compiled using a combination of a "top-down" approach with national level fuel data being allocated to different source sectors, and a "bottom-up" approach where fuel from specific sources are summed to give sectoral fuel consumption estimates. This ensures that there is consistency between assumed fuel consumption and import/export data, but also draws on the source specific detailed information where available. So, whilst there are not two independent sources of information on fuel consumption that can be checked against each other, the national energy balance tables can be regarded as a good quality dataset.

In line with good practice, a reference approach calculation of emission was undertaken for verification purposes (as outlined in the 2006 IPCC Guidelines). The reference approach is based on data for fuel production, import, export and stock change. The following steps were therefore required:

- The fuel data in the national energy balance tables was converted from thousand barrels of oil equivalent to Tera Joules (using the same net and gross calorific value conversions as the inventory).
- These energy data were then combined with carbon contents for each fuel (expressed as kg of carbon/Tera Joule, and consistent with the calculations in the emissions inventory undertaken at the sector level).
- The resulting carbon was then converted into an emission of CO^2.

The table below provides the time series for these two approaches, and a time series of the difference that can be seen between them

Table 0.5. Emission Sources in the Energy Sector by CRF (Mg CO^2)

		2006	2007	2008	2009	2010	2011	2012
Reference Approach	Mg CO_2	10,614,323	9,330,185	10,069,586	7,386,723	6,827,920	7,393,837	6,909,053
Sectoral Approach	Mg CO_2	10,614,323	9,330,185	10,069,586	7,386,723	6,827,920	7,393,837	6,909,053
Difference	%	0%	0%	0%	0%	0%	0%	0%

The fuel data used in the top-down approach is also used to calculate Jamaica's sectoral inventory, and therefore there should be no difference between the sectoral and reference approaches. This is the case as shown in the table above. This verification process has provided a transparent means of checking the sectoral approach. In the future, if Jamaica are able to incorporate bottom-up data within their inventory, sourced separately to the national energy balance tables, this verification process can be used to examine the completeness and consistency of these bottom-up data.

The first step for the sectoral approach is to typically collect actual consumption data on a sector by sector basis. This is done by fuel type, economic sector and combustion technology types. For example, public electricity, petroleum refining, manufacturing of solid fuels and other energy industries. Efforts were made to collect data on a sector by sector basis, and whilst information was made available to support emission estimate calculations, the national energy balance tables were used for all fuel consumption data in the emissions inventory.
More detail is provided in Sections 3.6.1 to 3.6.5 which outline the methodologies and data used on a sector by sector basis.

2.2.11.8 Calculation Methodologies

Efforts were made to obtain detailed data at the sectoral level, with the aim of using a Tier Two approach as far as possible. Data needs were broken out into various components (as outlined in the reporting format). These are as follows:

- 1.A.1 Energy Industries
- 1.A.2 Manufacturing Industries and Construction
- 1.A.3 Transport
- 1.A.4 Commercial, Institutional, Residential and Agriculture/Forestry/Fishing
- 1.A.5 Other(not specified elsewhere)
- Memo Items
- 1.B Fugitive Sources
- 1.A.1 Energy Industries

This sector includes public electricity and heat production, petroleum refining and manufacture of solid fuels.

1A1a Public Electricity

For public electricity, data was requested on fuel consumption by type and location of power plant. The main supplier (JPS) and independent power producers were included. Individual plat are listed in the table below, and the fuel consumption data are shown in Tables 3.2 and 3.3.

No plant specific emissions or emission factors (EFs) were available. So emissions were calculated by combining the fuel consumption data with default EFs from the 2006 IPCC Guidance.

Emissions from manufacturing industries that generate their own electricity (known as "autogeneration") are reported under 1A2 Manufacturing Industries and Construction, in accordance with the 2006 IPCC Guidance.

1A1b Petroleum Refining

Annual own-use fuel consumption for petroleum refining, by fuel, is not included in the national energy balance tables, so the data were requested from Petro Jam's refinery at Hunt's Bay. The data provided (Petrojam, 2015a) had limited breakdown by fuel type, and was only available for 2011-2012, so assumptions and extrapolation was required to obtain a complete dataset. The fuel consumption data for this source sector are shown in Tables 3.2 and 3.3.

Table 0.6 Electricity Generating Stations

	Location	Fuel type
Jamaica Public Service Company	Hunts Bay	HFO Fired Steam
	Old Harbour	HFO Fired Steam
	Bogue	ADO Fired Gas Turbine
Jamaica Energy Partners	Hunts Bay	ADO Fired Gas Turbine
	Old Harbour	HFO Fired Steam
Jamaica Private Power Company	Rock Fort	ADO

Own-use fuel consumption in the refinery was combined with default EFs from the 2006 IPCC Guidance to obtain emission estimates.

1A1c Manufacture of Solid Fuel

The production of charcoal is a sensitive ecological issue in Jamaica. Local experts indicated that manufacture is typically undertaken at a small scale, rather than a large commercial operation. Some further work is required to be able to estimate the emissions from the charcoal manufacture, and allocate it to the most appropriate source sector within the inventory, ensuring that there is no double-counting with e.g. land use change.

Emissions from the use of charcoal are included in the inventor

1A4a commercial/institutional (see Section 3.6.4).

1A2 Manufacturing Industries and Construction

This sector includes emissions from manufacturing industries, and in Jamaica this includes activities in the Bauxite/Aluminium sector, sugar manufacture, cement manufacture and other non-specific industrial activities.
Emissions are included here for both autogeneration and fuel use directly relating to the manufacturing process. Emissions are included from both stationary sources and mobile machinery used in the corresponding industrial sector.

1A2b Bauxite/Aluminium

Aluminium manufacture is an important industrial sector in Jamaica, and is present due to the natural deposits of bauxite (aluminium containing ore). Aluminium manufacture is very energy intensive, and therefore this makes a significant contribution to the total GHG emissions in Jamaica.

There are a number of different sources associated with aluminium manufacture:

- Emissions from bauxite mining activities (both stationary and mobile machinery),
- Emissions from the fuel combustion in the aluminium manufacture
- Emissions from fuel used for electricity generation specifically for aluminium manufacture
- Emissions from mobile machinery used in aluminium manufacture.

Data were gathered from the following bauxite/aluminium companies regarding fuel consumption (including fuel consumption for electricity generation from specific plant): Jamalco, Alpart, Windalco and Norando. These data were incorporated into the energy balance tables.

However, these data do not resolve the fuel oil used in stationary combustion sources for mining activities and activities associated with processing the ore to make aluminium. As a result, all emissions associated with stationary combustion are included within this aluminium manufacturing emissions category.

Emissions associated with both autogeneration and manufacture should be reported within manufacturing. So including all of the fuel, and hence emissions, within this source category does not create an issue regarding allocation to the correct source category.

It has been assumed that all of the gasoline and diesel oil consumed in the mining/bauxite sector relate to mobile machinery. Associated emissions have been grouped with other industrial mobile machinery and allocated to 1A2gvii Other Industrial Mobile Machinery (see sub-section below).

The fuel consumption data for this source sector are shown in Tables 3.2 and 3.3.

Emission estimates were calculated by combining the fuel oil used in the bauxite/aluminium sector with default EFs from the 2006 IPCC Guidance.

1A2e Sugar Manufacture

Sugar manufacture from sugar cane remains an important industry in Jamaica. Some of the sugar factories use little or no petroleum products, using it only during plant start-up. However, there are also sugar factories that rely solely on petroleum use for the operation of the factory.

Bagasse (a biomass fuel made from the sugar cane as a by-product) is used extensively as a fuel in the sugar manufacturing plant. However, as a renewable fuel, no emissions of CO2 are reported from the burning of bagasse as a fuel (although other pollutants are included in the emissions inventory).

Fuel consumption data were incorporated into the energy balance tables, and included diesel and bagasse used by Monymusk, and bagasse used by Long Pond. The fuel consumption data for this source sector are shown in Tables 3.2 and 3.3.

Emission estimates were calculated by combining the fuel consumption data with default EFs from the 2006 IPCC Guidance. There are no EFs in the guidance specifically for bagasse, so EFs for "other primary solid biomass" were used.

1A2f Cement Manufacture

The cement manufacture is a very energy intensive process. The Caribbean Cement Company in Jamaica uses coal and fuel oil fuel for both the manufacture of cement and autogeneration (as well as purchasing electricity from JPS, the public supplier). The fuel consumption data for this source sector are shown in Tables 3.2 and 3.3.

Emission estimates were calculated by combining the fuel consumption data with default EFs from the IPCC 2006 Guidance. For the purpose of emissions calculations, it was assumed that "coal" was equivalent to anthracite.

1A2gviii Other Industry – Stationary Sources

The national energy balance tables do not categorise all of the fuel being used in the industrial sector, and a significant amount is assumed to "other industry". It was assumed that, of this fuel, LPG and fuel oil are used in stationary combustion. The fuel consumption data for this source sector are shown in Tables 3.2 and 3.3.

Emission estimates were calculated by combining the fuel consumption data with default EFs from the 2006 IPCC Guidance. For the purpose of emissions calculations.

1A2gvii Other Industry – Mobile Sources

The national energy balance tables do not categorise all of the fuel being used in the industrial sector, and a significant amount is assumed to "other industry". It was assumed that, of this fuel, all gasoline and diesel oil are used in mobile combustion. The fuel consumption data for this source sector are shown in Tables 3.2 and 3.3.
Emission estimates were calculated by combining the fuel consumption data with default EFs from the 2006 IPCC Guidance.

1A3 Transport

This source sector includes all modes of transport (but not non-road mobile machinery, which is included in the inventory under 1A5b Other Mobile). Sources included here are:

- Civil Aviation (Domestic)
- Road Transportation
- Railways
- Domestic Navigation (Shipping)
- Other Transport

These are all outlined in more detail in the following sections.

1A3a Domestic Civil Aviation

Emissions from domestic activities are included in this source sector. Emissions from international aviation activities are estimated, but are not included in the emissions inventory totals (they are reported as a memo item – see Section 3.8).

The emissions from aviation are determined as two components - landing & take-off (LTO) and cruise.

Fuel used for aviation was available for the whole time series, but this was only resolved into domestic and international for 2011-2012. Avgas and aviation turbo fuel were used. Estimates of fuel use for years prior to 2011 were generated by scaling the fuel use in 2012 according to the trend in aircraft movement data, which was available in detail for the entire time series (sourced from MWLECC).

Table 0.7. Domestic Commercial Aircraft Movements (LTOs)

		2006	2007	2008	2009	2010	2011	2012
Domestic Commercial Aircraft Movements	LTOs	17,474	14,841	10,976	9,331	8,577	7,436	7,770

The full time series of calculated fuel consumption data for this source sector are shown in Tables 3.2 and 3.3. Given that domestic flights in Jamaica are all of short distances, it was assumed that planes do not reach cruising altitude, and start their approach part of the landing phase after completing climb out from the take-off phase. As a result, cruise emissions are assumed to be zero. Hence emission estimates for LTO were calculated by combining the total fuel consumption of both Avgas and aviation turbo fuel data with default EFs from the 2006 IPCC Guidance (Volume 1, Chapter 3, tables 3.6.4 and 3.6.5 giving the emissions per unit of fuel consumed). This approach was used because no information could be sourced on the aircraft movement data split by different classes of aircraft.

The assumption that cruise emissions are zero was tested. It was assumed that, as a small jet plane, a Saab2000 might be representative of the aircraft fleet. The fuel consumption per LTO for a Saab2000 (taken from the 2013 EMEP/EEA Guidebook Chapter 1A3a and accompanying spreadsheet annex) was combined with the number of domestic LTOs. This allowed an estimate to be made of the fuel required for all of the domestic flights in the movement data. The value of the fuel estimated was similar to, but slightly larger than, the actual fuel consumption reported in 2012.

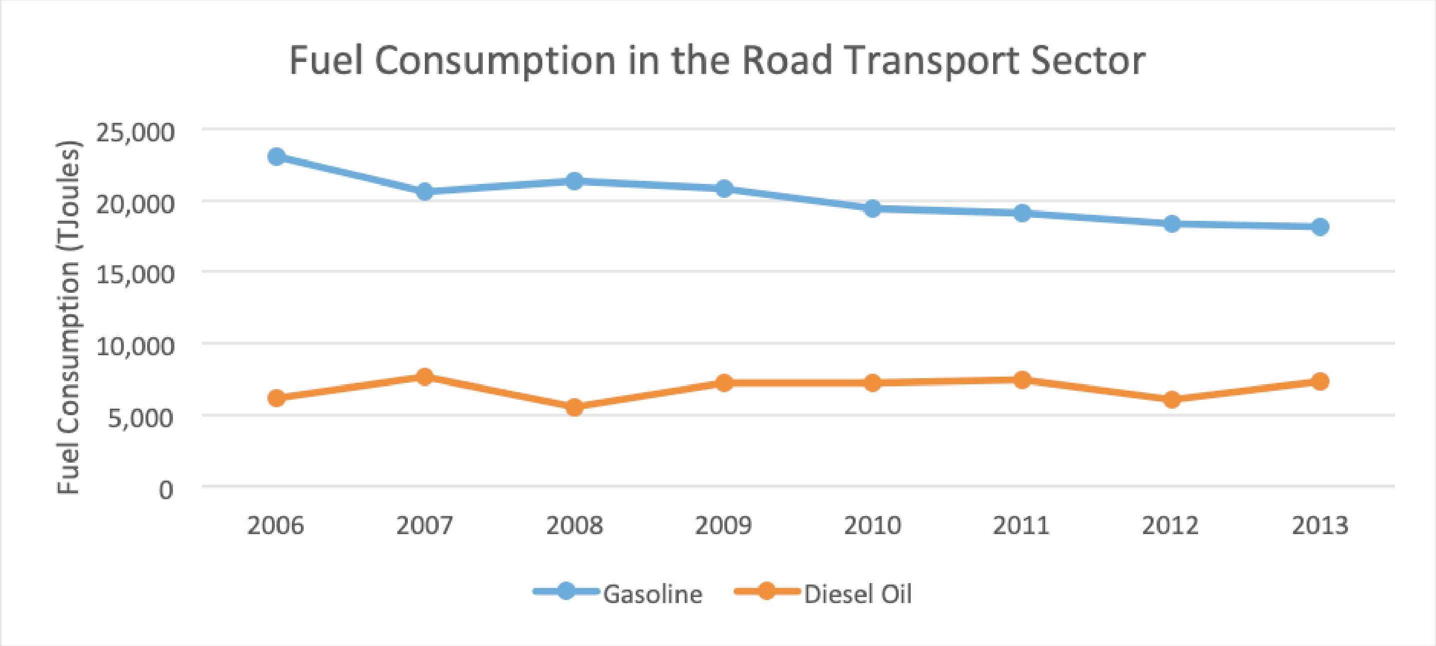
So in conclusion, it appears reasonable to make the assumption that, for domestic aviation, there are no emissions in the cruise phase, and all fuel and emissions can be assigned to the LTO phase.

1A3b Road Transportation

Estimating emissions of CO2 from road transport is relatively straightforward, in that it can be assumed that the carbon in the fuel is released as CO2. However, to accurately determine emissions of other pollutants, an extensive amount of information is required on the road vehicle fleet: the number of different vehicle types, vehicle ages, engine technologies, etc. It was possible to obtain some information on the vehicle fleet to allow more than a simple methodology to be used, but there are still several important improvements that could be made to the calculation.

The fuel consumption data of gasoline and diesel oil for this source sector are shown in Tables 3.2 and 3.3, and are plotted in the figure below. It is surprising to note that consumption of gasoline has been declining with time. The consumption of diesel oil shows little trend with time - although the year-to-year fluctuations are large relative to the total, making it difficult to identify any time trend.

Figure 0.1 Fuel Consumption in the Road Transport Sector (TJoules)



Emission estimates for CO2, CH4 and N2O from gasoline and diesel oil consumption were calculated separately by combining the fuel data with default EFs from the 2006 IPCC Guidance.

Table 0.8. GHG Emissions from Road Transport (Mg)

Pollutant	Fuel	Units	2006	2007	2008	2009	2010	2011	2012
CO_2	Gasoline	Mg	1,602,606	1,426,859	1,478,718	1,442,981	1,349,667	1,323,857	1,276,208
CO_2	Diesel	Mg	459,003	566,043	410,121	535,624	536,475	551,791	450,112
CH_4	Gasoline	Mg	578	515	533	521	487	478	460
CH_4	Diesel	Mg	24	30	22	28	28	29	24
N_2O	Gasoline	Mg	185	165	171	167	156	153	147
N_2O	Diesel	Mg	24	30	22	28	28	29	24

For estimating emissions of indirect pollutants, a more sophisticated approach is required, because emissions are very dependent on vehicle type, age, engine technologies, etc.
The number of registered road vehicles was available for 2010 to 2012 as presented below. Simple extrapolation was used to extend these data to the complete 2006-2012 time series. The trends in the data for 2010 to 2012 were noted to be minimal, and hence the vehicle numbers were kept constant across earlier years of the time series.

Local expert judgement was used to consider how the fleet numbers should be adjusted to account for the fact that vehicles are in use but not officially registered, and that some registered vehicles are off the road. It was considered that increasing the official data by 12% would account for unregistered vehicles in use (estimated to be 15%), and "several" per cent of the registered vehicles not in use. This expert opinion was based on national studies that have been undertaken, but it was not possible to cite specific references.

Assumptions were then made regarding the percentage of each vehicle type that uses gasoline or diesel oil. It was assumed that 1% of cars uses diesel, and that of the goods vehicles, 50% are diesel heavy goods vehicles, 45% are diesel light duty vehicles, and the remaining 5% are gasoline light duty vehicles. This provided "on the road" vehicle numbers, by class, and by fuel type, presented in the table below.

Whilst these adjustments to the official fleet data drew on local expertise, it is recognised that there are steps that are highly uncertain without any supporting information that can be clearly referenced. Hence these steps in the methodology are in need of improvement.

Table 0.9. "On the Road" Vehicle Numbers

Vehicle Type	Fuel	2006	2007	2008	2009	2010	2011	2012
Cars	Gasoline	280,409	280,409	280,409	280,409	280,409	280,483	288,026
LDVs	Gasoline	4,322	4,322	4,322	4,322	4,322	4,306	4,310
Motorcycles	Gasoline	8,090	8,090	8,090	8,090	8,090	8,235	8,724
Cars	Diesel	2,832	2,832	2,832	2,832	2,832	2,833	2,909
LDVs	Diesel	38,898	38,898	38,898	38,898	38,898	38,758	38,790
HGVs	Diesel	43,220	43,220	43,220	43,220	43,220	43,064	43,100

It was then necessary to distribute the total gasoline and diesel oil to the different vehicle types. No information was available on the relative annual mileage or typical annual fuel consumption across the different vehicle types. So it was assumed that each vehicle in the fleet consumes the same amount of fuel. This is a significant simplification, and is in need of improvement, but allows the generation of fuel consumption for each vehicle type. These fuel consumption data are then combined with EFs taken from the 2013 EMEP/EEA Guidebook to give emission estimates for NOx, NMVOC, CO and SO2 for each vehicle and fuel type. Emission estimates are presented in the table below.

Table 0.10. Indirect GHG Emissions from Road Transport (Mg)

Pollutant	Vehicle Type	Fuel	Unit	2006	2007	2008	2009	2010	2011	2012
NOx	Cars	Gasoline	Mg	4,364	3,886	4,027	3,929	3,675	3,603	3,472
NOx	LDVs	Gasoline	Mg	102	91	94	92	86	84	79
NOx	Motor-cycles	Gasoline	Mg	96	85	88	86	81	80	80
NOx	Cars	Diesel	Mg	235	209	217	211	198	195	192
NOx	LDVs	Diesel	Mg	3,709	3,302	3,422	3,340	3,124	3,064	2,951
NOx	HGVs	Diesel	Mg	9,224	8,212	8,511	8,305	7,768	7,618	7,338
NMVOC	Cars	Gasoline	Mg	5,024	4,473	4,636	4,524	4,231	4,148	3,997
NMVOC	LDVs	Gasoline	Mg	112	100	104	101	95	92	87
NMVOC	Motor-cycles	Gasoline	Mg	1,895	1,687	1,749	1,706	1,596	1,592	1,583
NMVOC	Cars	Diesel	Mg	13	11	12	11	11	11	10
NMVOC	LDVs	Diesel	Mg	383	341	353	345	323	316	305
NMVOC	HGVs	Diesel	Mg	531	473	490	478	447	438	422
CO	Cars	Gasoline	Mg	42,341	37,698	39,068	38,124	35,659	34,961	33,686
CO	LDVs	Gasoline	Mg	1,173	1,045	1,083	1,057	988	965	906
CO	Motor-cycles	Gasoline	Mg	7,178	6,391	6,623	6,463	6,045	6,032	5,995
CO	Cars	Diesel	Mg	60	54	56	54	51	50	49
CO	LDVs	Diesel	Mg	1,841	1,639	1,699	1,658	1,550	1,520	1,464
CO	HGVs	Diesel	Mg	2,095	1,865	1,933	1,886	1,764	1,731	1,667
SO_2	Cars	Gasoline	Mg	30	27	28	27	25	25	24
SO_2	LDVs	Gasoline	Mg	0	0	0	0	0	0	0
SO_2	Motor-cycles	Gasoline	Mg	1	1	1	1	1	1	1
SO_2	Cars	Diesel	Mg	1	0	1	0	0	0	0
SO_2	LDVs	Diesel	Mg	7	7	7	7	6	6	6
SO_2	HGVs	Diesel	Mg	8	7	8	7	7	7	7

It was not possible to estimate NMVOC evaporative emissions with the limited information available.

1A3c Railways

A rail passenger service is no longer operated in Jamaica, the railway being used for freight - primarily activities associated with the bauxite/aluminium sector.

Fuel consumption for railway activities was sought, but it was not possible to obtain information on fuel consumption specifically for rail activities. However, the fuel used is included in the national energy balance tables, and more specifically will be included in 1A2gvii Other Industry, Mobile (see section 3.6.2).

The inclusion of railway activities in Other Industry will not impact on the emission estimates of CO_2. However, EFs for indirect GHGs do vary according to machinery type, and hence improvements in accuracy as well as transparency would be achieved if the fuel used in the rail sector could be specifically identified. This should be included in the emissions inventory improvement programme.

1A3d Domestic Navigation (Shipping)

Emissions from domestic shipping activities, excluding fishing, are included in this source sector. Emissions from fuel sold for international shipping are estimated, but are not included in the emissions inventory totals (they are reported as a memo item – see Section 3.8).

Fuel used specifically for domestic shipping (fuel oil and diesel oil) was made available from MWLECC (MWLECC, 2015) for 2011 ad 2012. Estimates of fuel use for domestic shipping for years prior to 2011 were generated by scaling the fuel use in 2011 according to the trend in the total fuel use for shipping, which was available for the entire time series from the national energy balance tables.

The full time series of calculated fuel consumption data for this source sector are shown in Tables 3.2 and 3.3.

Emission estimates were calculated by combining the total fuel consumption of diesel oil and fuel oil with default EFs from the 2006 IPCC Guidance (EFs for gas oil and residual fuel oil were used). EFs for the indirect GHGs were sourced from the 2013 EMEP/EEA Guidebook. This approach was used because no information was available on the use of fuel by different types of vessel.

Emissions from fishing boats should be reported in 1A4ciii Fishing. But it was not possible to resolve the fuel used in shipping to allow this. So emissions from fishing boats is included in this sector.

1A3e Other Transport

This source category is included for other vehicle types which are not included in the four categories explained above. There are likely to be some which are present in Jamaica, for example aircraft support vehicle, however none have been specifically identified as itemised. It is likely that the fuel used by these vehicles is assigned to the road transport sector (see sub-section above), or industrial mobile machinery (see Section 3.6.2).

1A4 Commercial and Institutional Combustion, Residential Combustion, Combustion in Agriculture/Forestry/Fishing

This section addresses fuel use that can be readily divided into three categories:

- **Commercial and institutional buildings:** These may be equipped with their own generators, and/or use fuel for fuel for heating and cooking. The use of mobile machinery in the commercial/institutional sector is also included.

- **Residential buildings and houses:** In Jamaica the majority of fuel consumption in stationary sources in the residential sector is for cooking, although some is also used for other purposes such as heating and in small generators. Some mobile sources are also expected.

- **Agriculture/Forestry/Fishing:** Limited stationary combustion activities, with emissions primarily arising from mobile machinery.

1A4a Commercial and Institutional Combustion

The national energy balance tables identify the fuel that is used in "Services", which can be equated to the Commercial and Institutional sector. The following fuels are used: fuel oil, kerosene, LPG, charcoal, gasoline and diesel oil. These fuels are assumed to be used in stationary combustion, with the exception of gasoline and diesel oil, which are assumed to be used entirely in mobile machinery. The fuel consumption data for this source sector are shown in Tables 3.2 and 3.3.

Emission estimates were calculated by combining the fuel consumption data with default EFs for mobile machinery from the 2006 IPCC Guidance for gasoline and diesel oil, and default EFs for stationary combustion sources for other fuel types. Charcoal is a "renewable" fuel, and therefore CO_2 emissions are not included in the emissions inventory (but are reported as a memo item), although emissions of other pollutants are included. EFs for the indirect GHGs are taken from the 2013 EMEP/EEA Guidebook (Chapter 1A4, Commercial/Institutional, tables 3.8-3.10).

1A4b Residential Combustion

The national energy balance tables identify the fuel that is used in "Household", which can be equated to the Residential sector. The following fuels are used: kerosene, LPG and wood. These fuels are assumed to be used in stationary combustion. The fuel consumption data for this source sector are shown in Tables 3.2 and 3.3.

Emission estimates were calculated by combining the fuel consumption data with default EFs from the IPCC 2006 Guidance for stationary combustion sources. Wood is a "renewable" fuel, and, therefore, CO2 emissions are not included in the emissions inventory (but is reported as a memo item), although emissions of other pollutants are included. EFs for the indirect GHGs are taken from the 2013 EMEP/EEA Guidebook (Chapter 1A4, Residential, tables 3.4-3.6).

The national energy balance tables indicate that the use of gasoline and diesel oil in the Household sector is zero (with the exception of small levels of consumption in 2007 alone). So no fuel has been allocated to mobile machinery in the residential sector, and hence emissions are zero. It is assumed that this is because fuel used for mobile machinery in the residential sector is allocated elsewhere in the energy balance tables. Emissions are therefore likely to be included in 1A2gvii Other Industry – Mobile Machinery.

1A4c Combustion in Agriculture, Forestry and Fishing

The national energy balance tables identify the fuel that is used in "Agriculture", is considered to also include the use of machinery in forestry. The following fuels are used: gasoline and diesel oil. These fuels are assumed to be used in mobile machinery only. The fuel consumption data for this source sector are shown in Tables 3.2 and 3.3.

Emission estimates were calculated by combining the fuel consumption data with default EFs from the IPCC 2006 Guidance for mobile machinery in the Agriculture/Forestry sectors (Table 3.2.1 and 3.2.2). EFs for the indirect GHGs are taken from the 2013 EMEP/EEA Guidebook (Chapter 1A4, Agriculture/Forestry/Fishing, table 3.1).

Fuel used in fishing boats, and hence resulting emission, is not specifically resolved from the fuel used in all types of shipping. So emissions from fishing boats are included with emissions from all ships and boats in 1A3d Domestic Navigations (see Section 3.6.3).

There is no information on fuel used for stationary combustion sources in the fishing sector, and this is likely to be included in 1A2gviii Other Industrial stationary combustion.

1B Fugitive Emissions from Oil and Natural Gas

Fugitive emissions occur as leaks or other unintended or irregular emission. Emissions from venting and flaring in the oil and gas sector are considered to be a fugitive emission because emissions arise from the burning of fuel, but this does not, and is not intended to, generate heat or electricity.

Information on the amount of flaring from the refinery was provided by Petro Jam (Petrol Jam, 2015b pers comm). The data were provided in terms of barrels of oil equivalent of "gases and vapours". The typical composition of gases and vapours flared was therefore requested, and this was also provided.

The majority of the mass of released gases and vapours was determined to be hydrogen. The composition information allowed the hydrocarbon content to be determined, and it was established that the majority of the hydrocarbon content was either methane or short-chain hydrocarbons. The "fuel" data for this source sector are shown in Tables 3.2 and 3.3.
Emission estimates were calculated by combining the mass of hydrocarbons released with an EF that was an average of CH4 and LPG – this being considered to be a good representation of the hydrocarbon mix of the release. The CH4 and LPG EFs were sourced from the 2006 IPCC Guidance.

The CO2 emissions that result from this source are very small compared to the vast majority of emissions from fuel combustion sources.

2.2.11.9 Source Sector Emission Estimates

The following tables summarise the emissions from the Energy sector by source sector for each pollutant.

Table 0.11 CO_2 emissions (Mg CO2)

Sector	Fuel	2006	2007	2008	2009	2010	2011	2012
Public Electricity and Heat Production	Fuel oil	421.58	448.40	428.50	439.03	439.03	428.67	386.61
Public Electricity and Heat Production	Diesel oil	159.34	163.76	161.74	164.81	156.91	160.16	153.10
Petroleum Refining	Fuel oil	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Petroleum Refining	Diesel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining/Bauxite	Fuel Oil	3,922.40	2,527.56	3,535.33	1,319.14	1,056.53	1,426.46	1,300.11
Sugar	Fuel oil	9.97	10.50	7.61	5.33	3.43	1.90	1.90
Sugar	Bagasse	2,059.67	2,022.04	2,015.20	3,589.03	1,430.14	1,980.98	1,950.19
Cement	Fuel oil	6.13	7.88	10.28	4.95	1.90	1.90	9.90
Cement	Coal	1,031.81	1,406.01	1,110.62	1,193.57	732.73	1,852.56	1,705.09
Industry Other, Stationary	LPG	2.48	2.34	2.38	2.55	2.04	2.38	2.21
Industry Other, Stationary	Fuel oil	77.76	79.54	71.55	44.15	20.93	38.06	17.13
Industry, Mobile machinery	Gasoline	6,885.17	7,552.77	6,576.29	6,377.01	5,799.09	4,402.13	5,081.68
Industry, Mobile machinery	Diesel Oil	371.39	539.15	1,084.66	585.71	434.59	566.91	769.38
Domestic Aviation LTO (civil)	Turbo	1,420.87	1,206.77	892.50	758.74	697.43	0.00	631.81
Domestic Aviation LTO (civil)	Avgas	719.38	610.99	451.87	384.15	353.11	38.14	319.88
Domestic Aviation, cruise	Turbo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic Aviation, cruise	Avgas	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Road Transport	Gasoline	42,341.21	37,697.94	39,068.05	38,123.87	35,658.51	34,961.48	33,685.81
Road Transport	Diesel Oil	1,173.48	1,044.79	1,082.76	1,056.60	988.27	965.19	906.38
Railways	Diesel oil	7,177.80	6,390.66	6,622.93	6,462.87	6,044.93	6,031.84	5,995.13
Domestic Shipping/National Navigation	Diesel Oil	60.32	53.71	55.66	54.31	50.80	50.02	49.43
Domestic Shipping/National Navigation	Fuel Oil	1,840.88	1,639.01	1,698.58	1,657.52	1,550.34	1,520.49	1,464.49
Commercial/Institutional: Mobile	Gasoline	2,095.18	1,865.42	1,933.21	1,886.49	1,764.50	1,730.53	1,666.79
Commercial/Institutional: Mobile	Diesel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Commercial/Institutional: Stationary	Fuel Oil	9,632.30	12,429.14	11,366.09	6,681.57	6,365.40	4,826.47	4,680.86
Commercial/Institutional: Stationary	LPG	12,363.10	6,434.29	6,811.83	1,594.83	4,748.46	4,144.76	2,648.92
Commercial/Institutional: Stationary	Kerosene	0.00	17.50	8.94	0.00	0.00	0.00	0.00

Sector	Fuel	2006	2007	2008	2009	2010	2011	2012
Commercial/Institutional: Stationary	Charcoal	11.20	85.98	16.88	13.09	11.71	12.75	12.06
Residential: Stationary	Kerosene	31.83	0.00	0.00	0.00	5.54	0.00	0.00
Residential: Stationary	LPG	45.61	40.40	44.17	44.85	46.21	48.24	50.62
Residential: Stationary	Wood	63.03	89.56	0.00	2.80	1.75	1.75	7.01
Agriculture/Forestry/ Fishing: Mobile	Gasoline	452.50	452.50	663.80	663.80	663.80	465.70	465.70
Agriculture/Forestry/ Fishing: Mobile	Diesel oil	79.39	112.78	5.66	3.00	2.00	2.00	7.32
Refinery flaring	Flared gases and vapours	54.59	61.12	52.70	46.91	48.89	51.02	53.46

Table 0.12 CH4 emissions (Mg CH4)

Sector	Fuel	2006	2007	2008	2009	2010	2011	2012
Public Electricity and Heat Production	Fuel oil	83.76	89.09	85.13	87.23	87.23	85.17	76.81
Public Electricity and Heat Production	Diesel oil	29.51	30.33	29.95	30.52	29.06	29.66	28.35
Petroleum Refining	Fuel oil	4.41	4.78	4.86	4.85	4.84	5.09	5.54
Petroleum Refining	Diesel oil	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Mining/Bauxite	Fuel Oil	178.29	114.89	160.70	59.96	48.02	64.84	59.10
Sugar	Fuel oil	0.45	0.48	0.35	0.24	0.16	0.09	0.09
Sugar	Bagasse	108.40	106.42	106.06	188.90	75.27	104.26	102.64
Cement	Fuel oil	0.28	0.36	0.47	0.22	0.09	0.09	0.45
Cement	Coal	11.08	15.10	11.93	12.82	7.87	19.90	18.31
Industry Other, Stationary	LPG	0.09	0.08	0.08	0.09	0.07	0.08	0.08
Industry Other, Stationary	Fuel oil	3.53	3.62	3.25	2.01	0.95	1.73	0.78
Industry, Mobile machinery	Gasoline	9.90	10.86	9.45	9.17	8.34	6.33	7.31
Industry, Mobile machinery	Diesel Oil	5.75	8.35	16.79	9.07	6.73	8.78	11.91
Domestic Aviation LTO (civil)	Turbo	0.03	0.02	0.02	0.01	0.01	0.00	0.01
Domestic Aviation LTO (civil)	Avgas	0.01	0.01	0.01	0.01	0.01	0.00	0.01
Domestic Aviation, cruise	Turbo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic Aviation, cruise	Avgas	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Road Transport	Gasoline	578.14	514.74	533.45	520.56	486.89	477.58	460.39
Road Transport	Diesel Oil	24.16	29.79	21.59	28.19	28.24	29.04	23.69
Railways	Diesel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic shipping/National Navigation	Diesel Oil	2.26	1.18	1.25	0.29	0.87	0.76	0.49
Domestic shipping/National Navigation	Fuel Oil	1.72	2.22	2.03	1.19	1.14	0.86	0.84
Commercial/Institutional: Mobile	Gasoline	0.00	2.92	1.49	0.00	0.00	0.00	0.00
Commercial/Institutional: Mobile	Diesel oil	1.87	14.33	2.81	2.18	1.95	2.12	2.01
Commercial/Institutional: Stationary	Fuel Oil	5.31	0.00	0.00	0.00	0.92	0.00	0.00
Commercial/Institutional: Stationary	LPG	7.86	6.96	7.62	7.73	7.97	8.32	8.73
Commercial/Institutional: Stationary	Kerosene	10.51	14.93	0.00	0.47	0.29	0.29	1.17
Commercial/Institutional: Stationary	Charcoal	158.77	158.77	232.91	232.91	232.91	163.40	163.40
Residential: Stationary	Kerosene	13.93	19.79	0.99	0.53	0.35	0.35	1.28
Residential: Stationary	LPG	10.50	11.75	10.13	9.02	9.40	9.81	10.28
Residential: Stationary	Wood	400.48	399.78	410.57	410.57	410.57	410.57	410.57
Agriculture/Forestry/Fishing: Mobile	Gasoline	4.07	3.69	4.13	3.95	3.61	3.95	3.84
Agriculture/Forestry/Fishing: Mobile	Diesel oil	6.58	8.84	9.47	7.69	6.89	7.46	7.00
Refinery Flaring	Flared Gases and Vapours	0.10	0.09	0.03	0.14	0.09	0.02	0.02

Table 0.13 N2O emissions (Mg N2O)

Sector	Fuel	2006	2007	2008	2009	2010	2011	2012
Public Electricity and Heat Production	Fuel oil	16.75	17.82	17.03	17.45	17.45	17.03	15.36
Public electricity and Heat Production	Diesel oil	5.90	6.07	5.99	6.10	5.81	5.93	5.67
Petroleum Refining	Fuel oil	0.88	0.96	0.97	0.97	0.97	1.02	1.11
Petroleum Refining	Diesel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining/Bauxite	Fuel Oil	35.66	22.98	32.14	11.99	9.60	12.97	11.82
Sugar	Fuel oil	0.09	0.10	0.07	0.05	0.03	0.02	0.02
Sugar	Bagasse	14.45	14.19	14.14	25.19	10.04	13.90	13.69
Cement	Fuel oil	0.06	0.07	0.09	0.04	0.02	0.02	0.09
Cement	Coal	1.66	2.27	1.79	1.92	1.18	2.98	2.75
Industry Other, Stationary	LPG	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Industry Other, Stationary	Fuel oil	0.71	0.72	0.65	0.40	0.19	0.35	0.16
Industry, Mobile Machinery	Gasoline	3.17	3.47	3.03	2.93	2.67	2.03	2.34
Industry, Mobile Machinery	Diesel Oil	5.75	8.35	16.79	9.07	6.73	8.78	11.91
Domestic Aviation LTO (civil)	Turbo	0.10	0.09	0.07	0.06	0.05	0.00	0.05
Domestic Aviation LTO (civil)	Avgas	0.05	0.05	0.03	0.03	0.03	0.00	0.02
Domestic Aviation, Cruise	Turbo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic Aviation, Cruise	Avgas	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Road Transport	Gasoline	185.01	164.72	170.70	166.58	155.81	152.83	147.33
Road Transport	Diesel Oil	24.16	29.79	21.59	28.19	28.24	29.04	23.69
Railways	Diesel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic shipping/National Navigation	Diesel Oil	0.65	0.34	0.36	0.08	0.25	0.22	0.14
Domestic shipping/National Navigation	Fuel Oil	0.49	0.63	0.58	0.34	0.33	0.25	0.24
Commercial/Institutional: Mobile	Gasoline	0.00	0.17	0.09	0.00	0.00	0.00	0.00
Commercial/Institutional: Mobile	Diesel oil	0.11	0.86	0.17	0.13	0.12	0.13	0.12
Commercial/Institutional: Stationary	Fuel Oil	0.32	0.00	0.00	0.00	0.06	0.00	0.00
Commercial/Institutional: Stationary	LPG	0.16	0.14	0.15	0.15	0.16	0.17	0.17
Commercial/Institutional: Stationary	Kerosene	0.63	0.90	0.00	0.03	0.02	0.02	0.07
Commercial/Institutional: Stationary	Charcoal	0.79	0.79	1.16	1.16	1.16	0.82	0.82
Residential: Stationary	Kerosene	0.84	1.19	0.06	0.03	0.02	0.02	0.08
Residential: Stationary	LPG	0.21	0.24	0.20	0.18	0.19	0.20	0.21
Residential: Stationary	Wood	5.34	5.33	5.47	5.47	5.47	5.47	5.47
Agriculture/Forestry/Fishing: Mobile	Gasoline	0.24	0.22	0.25	0.24	0.22	0.24	0.23
Agriculture/Forestry/Fishing: Mobile	Diesel oil	0.39	0.53	0.57	0.46	0.41	0.45	0.42
Refinery flaring	Flared gases and vapours	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 0.14 NOx emissions Mg NO2

Sector	Fuel	2006	2007	2008	2009	2010	2011	2012
Public Electricity and Heat Production	Fuel oil	3,964.56	4,216.76	4,029.57	4,128.65	4,128.65	4,031.21	3,635.70
Public Electricity and Heat Production	Diesel oil	639.31	657.08	648.98	661.29	629.57	642.63	614.27
Petroleum Refining	Fuel oil	208.78	226.05	229.96	229.37	228.92	241.05	262.25
Petroleum Refining	Diesel oil	0.24	0.26	0.27	0.27	0.27	0.28	0.00
Mining/Bauxite	Fuel Oil	30,487.71	19,646.03	27,479.17	10,253.29	8,212.10	11,087.52	10,105.38
Sugar	Fuel oil	77.51	81.65	59.16	41.42	26.62	14.79	14.79
Sugar	Bagasse	328.83	322.82	321.72	572.99	228.32	316.26	311.35
Cement	Fuel oil	47.63	61.24	79.87	38.46	14.79	14.79	76.91
Cement	Coal	191.73	261.27	206.38	221.79	136.16	344.25	316.84
Industry Other, Stationary	LPG	6.33	5.98	6.07	6.50	5.20	6.07	5.64
Industry Other, Stationary	Fuel oil	604.37	618.27	556.15	343.16	162.70	295.82	133.12
Industry, Mobile Machinery	Gasoline	63.61	69.78	60.75	58.91	53.57	40.67	46.95
Industry, Mobile Machinery	Diesel Oil	1,135.84	1,648.92	3,317.30	1,791.34	1,329.13	1,733.84	2,353.07
Domestic Aviation LTO (civil)	Turbo	4.74	4.02	2.97	2.53	2.32	0.00	2.11
Domestic Aviation LTO (civil)	Avgas	2.40	2.04	1.51	1.28	1.18	0.13	1.07
Domestic Aviation, cruise	Turbo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic Aviation, cruise	Avgas	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cars	Petrol	4,364.09	3,885.51	4,026.73	3,929.41	3,675.31	3,603.47	3,471.98
LDVs	Petrol	101.86	90.69	93.99	91.72	85.78	83.78	78.68
Motorcycles	Petrol	95.76	85.26	88.36	86.22	80.65	80.47	79.98
Cars	Diesel	234.76	209.02	216.61	211.38	197.71	194.66	192.37
LDVs	Diesel	3,709.13	3,302.38	3,422.40	3,339.69	3,123.72	3,063.59	2,950.75
HGVs	Diesel	9,223.77	8,212.26	8,510.73	8,305.05	7,767.98	7,618.44	7,337.84
Railways	Diesel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic Shipping/National Navigation	Fuel oil	482.10	622.08	568.87	334.41	318.59	241.57	234.28
Domestic Shipping/National Navigation	Diesel Oil	596.67	310.54	328.76	76.97	229.17	200.04	127.84
Commercial/ Institutional: Mobile	Gasoline	0.00	149.62	76.42	0.00	0.00	0.00	0.00
Commercial/ Institutional: Mobile	Diesel oil	95.72	735.15	144.32	111.92	100.14	108.98	103.09
Commercial/ Institutional: Stationary	Fuel Oil	272.16	0.00	0.00	0.00	47.33	0.00	0.00

Sector	Fuel	2006	2007	2008	2009	2010	2011	2012
Commercial/ Institutional: Stationary	LPG	116.39	103.08	112.70	114.44	117.91	123.11	129.18
Commercial/ Institutional: Stationary	Kerosene	538.95	765.73	0.00	23.97	14.98	14.98	59.92
Commercial/ Institutional: Stationary	Charcoal	72.24	72.24	105.98	105.98	105.98	74.35	74.35
Residential: Stationary	Kerosene	71.03	100.90	5.06	2.68	1.79	1.79	6.55
Residential: Stationary	LPG	107.07	119.89	103.37	92.01	95.90	100.08	104.86
Residential: Stationary	Wood	106.80	106.61	109.48	109.48	109.48	109.48	109.48
Agriculture/ Forestry/Fishing: Mobile	Gasoline	65.45	59.28	66.28	63.52	57.99	63.52	61.68
Agriculture/ Forestry/Fishing: Mobile	Diesel oil	541.68	727.44	779.90	633.38	567.20	614.47	576.66
Refinery flaring	Flared gases and vapour	1.47	1.27	0.45	2.14	1.36	0.29	0.34

Table 0.15 NMVOC emissions (Mg NMVOC)

Sector	Fuel	2006	2007	2008	2009	2010	2011	2012
Public Electricity and Heat Production	Fuel oil	64.21	68.30	65.27	66.87	66.87	65.29	58.89
Public Electricity and Heat Production	Diesel oil	7.87	8.09	7.99	8.14	7.75	7.91	7.56
Petroleum Refining	Fuel oil	0.48	0.52	0.53	0.53	0.53	0.55	0.60
Petroleum Refining	Diesel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining/Bauxite	Fuel Oil	1,485.76	957.41	1,339.14	499.67	400.20	540.33	492.46
Sugar	Fuel oil	3.78	3.98	2.88	2.02	1.30	0.72	0.72
Sugar	Bagasse	1,084.04	1,064.23	1,060.63	1,888.97	752.70	1,042.62	1,026.42
Cement	Fuel oil	2.32	2.98	3.89	1.87	0.72	0.72	3.75
Cement	Coal	98.42	134.11	105.93	113.84	69.89	176.70	162.63
Industry Other, Stationary	LPG	1.97	1.86	1.89	2.02	1.62	1.89	1.75
Industry Other, Stationary	Fuel oil	29.45	30.13	27.10	16.72	7.93	14.42	6.49
Industry, Mobile machinery	Gasoline	157.32	172.57	150.26	145.71	132.50	100.58	116.11
Industry, Mobile machinery	Diesel Oil	117.25	170.21	342.43	184.91	137.20	178.98	242.90
Domestic Aviation LTO (civil)	Turbo	22.50	19.11	14.13	12.01	11.04	0.00	10.00
Domestic Aviation LTO (civil)	Avgas	11.39	9.67	7.15	6.08	5.59	0.60	5.06
Domestic Aviation, cruise	Turbo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic Aviation, cruise	Avgas	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cars	Petrol	5,023.96	4,473.01	4,635.58	4,523.55	4,231.03	4,148.32	3,996.96
LDVs	Petrol	112.42	100.09	103.73	101.22	94.67	92.46	86.83
Motorcycles	Petrol	1,895.04	1,687.23	1,748.55	1,706.29	1,595.95	1,592.49	1,582.80
Cars	Diesel	12.68	11.29	11.70	11.42	10.68	10.51	10.39
LDVs	Diesel	383.10	341.09	353.49	344.94	322.64	316.43	304.77
HGVs	Diesel	530.71	472.51	489.68	477.85	446.94	438.34	422.20
Railways	Diesel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic Shipping/National Navigation	Fuel oil	16.41	21.18	19.37	11.39	10.85	8.22	7.98
Domestic Shipping/National Navigation	Diesel Oil	21.28	11.08	11.73	2.75	8.17	7.14	4.56
Commercial/ Institutional: Mobile	Gasoline	0.00	7.29	3.72	0.00	0.00	0.00	0.00
Commercial/ Institutional: Mobile	Diesel oil	4.66	35.83	7.03	5.45	4.88	5.31	5.02
Commercial/ Institutional: Stationary	Fuel Oil	13.26	0.00	0.00	0.00	2.31	0.00	0.00
Commercial/ Institutional: Stationary	LPG	36.17	32.04	35.03	35.57	36.65	38.26	40.15
Commercial/ Institutional: Stationary	Kerosene	26.26	37.32	0.00	1.17	0.73	0.73	2.92

Sector	Fuel	2006	2007	2008	2009	2010	2011	2012
Commercial/ Institutional: Stationary	Charcoal	238.16	238.16	349.37	349.37	349.37	245.11	245.11
Residential: Stationary	Kerosene	0.96	1.37	0.07	0.04	0.02	0.02	0.09
Residential: Stationary	LPG	3.99	4.47	3.85	3.43	3.57	3.73	3.91
Residential: Stationary	Wood	800.96	799.56	821.13	821.13	821.13	821.13	821.13
Agriculture/Forestry/Fishing: Mobile	Gasoline	161.87	146.62	163.92	157.09	143.43	157.09	152.54
Agriculture/Forestry/Fishing: Mobile	Diesel oil	52.03	69.87	74.91	60.84	54.48	59.02	55.39
Refinery flaring	Flared gases and vapours	0.46	0.39	0.14	0.66	0.42	0.09	0.11
Residential: Stationary	Wood	64.21	68.30	65.27	66.87	66.87	65.29	58.89
Agriculture/Forestry/Fishing: Mobile	Gasoline	7.87	8.09	7.99	8.14	7.75	7.91	7.56
Agriculture/Forestry/Fishing: Mobile	Diesel oil	0.48	0.52	0.53	0.53	0.53	0.55	0.60
Refinery flaring	Flared gases and vapours	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 0.16 CO emissions (Mg CO)								
Sector	Fuel	2006	2007	2008	2009	2010	2011	2012
Public Electricity and Heat Production	Fuel oil	421.58	448.40	428.50	439.03	439.03	428.67	386.61
Public Electricity and Heat Production	Diesel oil	159.34	163.76	161.74	164.81	156.91	160.16	153.10
Petroleum Refining	Fuel oil	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Petroleum Refining	Diesel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining/Bauxite	Fuel Oil	3,922.40	2,527.56	3,535.33	1,319.14	1,056.53	1,426.46	1,300.11
Sugar	Fuel oil	9.97	10.50	7.61	5.33	3.43	1.90	1.90
Sugar	Bagasse	2,059.67	2,022.04	2,015.20	3,589.03	1,430.14	1,980.98	1,950.19
Cement	Fuel oil	6.13	7.88	10.28	4.95	1.90	1.90	9.90
Cement	Coal	1,031.81	1,406.01	1,110.62	1,193.57	732.73	1,852.56	1,705.09
Industry Other, Stationary	LPG	2.48	2.34	2.38	2.55	2.04	2.38	2.21
Industry Other, Stationary	Fuel oil	77.76	79.54	71.55	44.15	20.93	38.06	17.13
Industry, Mobile machinery	Gasoline	6,885.17	7,552.77	6,576.29	6,377.01	5,799.09	4,402.13	5,081.68
Industry, Mobile machinery	Diesel Oil	371.39	539.15	1,084.66	585.71	434.59	566.91	769.38
Domestic Aviation LTO (civil)	Turbo	1,420.87	1,206.77	892.50	758.74	697.43	0.00	631.81
Domestic Aviation LTO (civil)	Avgas	719.38	610.99	451.87	384.15	353.11	38.14	319.88
Domestic Aviation, Cruise	Turbo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic Aviation, Cruise	Avgas	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cars	Petrol	42,341.21	37,697.94	39,068.05	38,123.87	35,658.51	34,961.48	33,685.81
LDVs	Petrol	1,173.48	1,044.79	1,082.76	1,056.60	988.27	965.19	906.38
Motorcycles	Petrol	7,177.80	6,390.66	6,622.93	6,462.87	6,044.93	6,031.84	5,995.13
Cars	Diesel	60.32	53.71	55.66	54.31	50.80	50.02	49.43
LDVs	Diesel	1,840.88	1,639.01	1,698.58	1,657.52	1,550.34	1,520.49	1,464.49
HGVs	Diesel	2,095.18	1,865.42	1,933.21	1,886.49	1,764.50	1,730.53	1,666.79
Railways	Diesel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic Shipping/ National Navigation	Fuel oil	44.99	58.05	53.09	31.21	29.73	22.54	21.86
Domestic Shipping/ National Navigation	Diesel Oil	56.25	29.27	30.99	7.26	21.60	18.86	12.05
Commercial/ Institutional: Mobile	Gasoline	0.00	17.50	8.94	0.00	0.00	0.00	0.00
Commercial/ Institutional: Mobile	Diesel oil	11.20	85.98	16.88	13.09	11.71	12.75	12.06
Commercial/ Institutional: Stationary	Fuel Oil	31.83	0.00	0.00	0.00	5.54	0.00	0.00

Table 0.16 CO emissions (Mg CO)								
Sector	Fuel	2006	2007	2008	2009	2010	2011	2012
Commercial/ Institutional: Stationary	LPG	45.61	40.40	44.17	44.85	46.21	48.24	50.62
Commercial/ Institutional: Stationary	Kerosene	63.03	89.56	0.00	2.80	1.75	1.75	7.01
Commercial/ Institutional: Stationary	Charcoal	452.50	452.50	663.80	663.80	663.80	465.70	465.70
Residential: Stationary	Kerosene	79.39	112.78	5.66	3.00	2.00	2.00	7.32
Residential: Stationary	LPG	54.59	61.12	52.70	46.91	48.89	51.02	53.46
Residential: Stationary	Wood	5,339.76	5,330.41	5,474.22	5,474.22	5,474.22	5,474.22	5,474.22
Agriculture/ Forestry/ Fishing: Mobile	Gasoline	7,084.46	6,416.86	7,174.13	6,875.21	6,277.37	6,875.21	6,675.93
Agriculture/ Forestry/ Fishing: Mobile	Diesel oil	169.09	227.08	243.45	197.71	177.06	191.81	180.01
Refinery Flaring	Flared gases and vapours	0.58	0.50	0.18	0.84	0.53	0.12	0.13

Table 0.17 SO2 emissions (Mg SO2)								
Sector	Fuel	2006	2007	2008	2009	2010	2011	2012
Public Electricity and Heat Production	Fuel oil	13,820.11	14,699.28	14,046.75	14,392.14	14,392.14	14,052.46	12,673.76
Public electricity and Heat Production	Diesel oil	457.35	470.06	464.27	473.08	450.39	459.73	439.44
Petroleum Refining	Fuel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petroleum Refining	Diesel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining/Bauxite	Fuel Oil	2,793.22	1,799.93	2,517.58	939.39	752.38	1,015.82	925.83
Sugar	Fuel oil	7.10	7.48	5.42	3.79	2.44	1.36	1.36
Sugar	Bagasse	39.75	39.02	38.89	69.26	27.60	38.23	37.64
Cement	Fuel oil	4.36	5.61	7.32	3.52	1.36	1.36	7.05
Cement	Coal	997.46	1,359.20	1,073.63	1,153.82	708.33	1,790.88	1,648.32
Industry Other, Stationary	LPG	0.06	0.05	0.05	0.06	0.05	0.05	0.05
Industry Other, Stationary	Fuel oil	55.37	56.64	50.95	31.44	14.91	27.10	12.20
Industry, Mobile machinery	Gasoline	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industry, Mobile machinery	Diesel Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic Aviation LTO (civil)	Turbo	0.95	0.80	0.59	0.51	0.46	0.00	0.42
Domestic Aviation LTO (civil)	Avgas	0.48	0.41	0.30	0.26	0.24	0.03	0.21
Domestic Aviation, cruise	Turbo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic Aviation, cruise	Avgas	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cars	Petrol	29.99	26.70	27.68	27.01	25.26	24.77	23.86
LDVs	Petrol	0.46	0.41	0.43	0.42	0.39	0.38	0.36
Motorcycles	Petrol	0.87	0.77	0.80	0.78	0.73	0.73	0.72
Cars	Diesel	0.54	0.48	0.50	0.49	0.46	0.45	0.45
LDVs	Diesel	7.46	6.64	6.89	6.72	6.29	6.16	5.94
HGVs	Diesel	8.29	7.38	7.65	7.47	6.98	6.85	6.60
Railways	Diesel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic Shipping/National Navigation	Fuel oil	121.59	156.89	143.47	84.34	80.35	60.92	59.09
Domestic Shipping/National Navigation	Diesel Oil	152.02	79.12	83.76	19.61	58.39	50.96	32.57
Commercial/Institutional: Stationary	Gasoline	0.00	13.71	7.00	0.00	0.00	0.00	0.00
Commercial/Institutional: Stationary	Diesel oil	8.77	67.35	13.22	10.25	9.17	9.98	9.44
Commercial/Institutional: Stationary	Fuel Oil	0.16	0.00	0.00	0.00	0.03	0.00	0.00
Commercial/Institutional: Stationary	LPG	0.47	0.42	0.46	0.46	0.48	0.50	0.52
Commercial/Institutional: Stationary	Kerosene	0.70	1.00	0.00	0.03	0.02	0.02	0.08
Commercial/Institutional: Stationary	Charcoal	8.73	8.73	12.81	12.81	12.81	8.99	8.99
Residential: Stationary	Kerosene	97.50	138.50	6.95	3.68	2.45	2.45	8.99

Table 0.17 SO2 emissions (Mg SO2)								
Sector	Fuel	2006	2007	2008	2009	2010	2011	2012
Residential: Stationary	LPG	0.63	0.71	0.61	0.54	0.56	0.59	0.62
Residential: Stationary	Wood	14.68	14.66	15.05	15.05	15.05	15.05	15.05
Agriculture/Forestry/Fishing: Mobile	Gasoline	19.15	17.34	19.39	18.58	16.97	18.58	18.04
Agriculture/Forestry/Fishing: Mobile	Diesel oil	46.06	61.85	66.31	53.85	48.23	52.25	49.03
Refinery flaring	Flared gases and vapours	0.01	0.01	0.00	0.02	0.01	0.00	0.00

2.2.12 Memo Items

2.2.12.1 International Aviation

Emissions from international aviation are not included within the national emissions inventory total, but have been estimated, and are reported as a "memo item".

The emissions from international aviation are determined as two components: landing & take-off (LTO) and cruise. Only aviation turbo fuel is used in this source sector. The approached used to estimate the emissions from these two components was to estimate fuel used in LTO from aircraft movements, and subtract this from the total to give the amount of fuel remaining for use in the cruise mode. This approach was used because no information could be sourced on the aircraft movement data split by different classes of aircraft.

Aircraft movement data were available through MWLECC (now the Ministry of Economic Growth and Job Creation) for the complete time series 2006 – 2012 (MWLECC, 2015). The international component was determined by summing all of the components other than "Domestic Commercial" i.e. "International Scheduled Commercial", "International Non-Scheduled Commercial" and "Private" aircraft movements. Military flights were not included in the emissions inventory.

The international aircraft movement data were combined with information from the 2013 EMEP/EEA Guidebook, which indicates typical fuel consumption per LTO cycle for the types of aircraft used in international flights. This allows an estimate of the fuel consumption for LTO to be estimated from the aircraft movement data.

Table 0.18. International Aircraft Movements (LTOs) and Derived Fuel Use 012

International Aircraft Movements	LTOs	56,472	56,586	57,201	50,997	54,155	53,728	54,669
Aviation turbo fuel consumed (LTO)	Tjoules	4,027	4,035	4,079	3,637	3,862	3,831	3,898

The fuel use data was combined with default EFs from the IPCC 2006 Guidance to give emissions estimates for the GHGs. A similar approach was used for estimating indirect GHG emissions, using EFs from the 2013 EMEP/EEA Guidebook (Aviation Chapter, Tables 3-3).

The fuel used for LTO was then subtracted from the total fuel consumption to give the amount of fuel remaining, for assigning to the cruise phase. EFs were similarly sourced from the IPCC 2006 Guidance for GHGs and from the 2013 EMEP/EEA Guidebook (Aviation Chapter, Tables 3-3) for indirect GHGs to allow the calculation of emissions during the cruise phase.

It is recognised that this methodology uses a relatively simple approach. So a sanity check was performed on the results, comparing the fuel use and emissions during LTO with those during cruise. Fuel use, and CO2 emissions, during the cruise phase were approximately 160% those of the fuel consumption and CO2 emissions during LTO. Evidently this represents a generalisation, but indicates that the proportion of fuel used during LTO in comparison to that during cruise is within reasonable bounds.

Table 0.19. International Aircraft Emissions (Mg)

Pollutant	Units	2006	2007	2008	2009	2010	2011	2012
LTO Emissions								
CO_2	Mg	287,931	288,512	291,648	260,016	276,117	273,940	278,738
CH_4	Mg	2	2	2	2	2	2	2
N_2O	Mg	8	8	8	7	8	8	8
Cruise Emissions								
CO_2	Mg	481,094	482,065	487,305	434,452	461,355	457,718	460,598
CH_4	Mg	3	3	3	3	3	3	3
N_2O	Mg	13	13	14	12	13	13	13
LTO Emissions								
NOx	Mg	1,468	1,471	1,487	1,326	1,408	1,397	1,421
NMVOC	Mg	11	11	11	10	11	11	11
CO	Mg	344	345	349	311	330	328	333
SO_2	Mg	90	91	92	82	87	86	87
Cruise Emissions								
NOx	Mg	1,953	1,957	1,978	1,764	1,873	1,858	1,870
NMVOC	Mg	76	76	77	69	73	73	73
CO	Mg	168	168	170	152	161	160	161
SO_2	Mg	153	153	155	138	146	145	146

2.2.12.2 International Shipping

Emissions from international shipping are not included in the emissions inventory totals, but have been estimated and are reported as a memo item.

Fuel used specifically for international shipping (fuel oil and diesel oil) was made available from MWLECC for 2011 ad 2012 (MWLECC, 2015). Estimates of fuel use for years prior to 2011 were generated by scaling the fuel use in 2011 according to the trend in the total fuel use for shipping, which was available for the entire time series from the national energy balance tables.

Emission estimates were calculated by combining the total fuel consumption of diesel oil and fuel oil with default EFs from the 2006 IPCC Guidance (EFs for gas oil and residual fuel oil were used). EFs for the indirect GHGs were sourced from the 2013 EMEP/EEA Emissions Inventory Guidebook. This approach was used because no information was available on the use of fuel by different types of vessel.

Table 0.20. International Aircraft Emissions (Mg)

Pollutant	Units	2006	2007	2008	2009	2010	2011	2012
CO_2	Mg	1,515,810	1,812,704	1,671,628	946,410	950,218	728,680	626,453
CH_4	Mg	138	164	152	86	86	66	57
N_2O	Mg	39	47	43	24	25	19	16
NOx	Mg	38,293	45,847	42,273	23,948	24,024	18,420	15,832
NMVOC	Mg	1,311	1,565	1,443	816	821	630	542
CO	Mg	3,578	4,281	3,947	2,235	2,244	1,720	1,479
SO_2	Mg	9,670	11,569	10,668	6,041	6,064	4,650	3,997

2.2.12.3 Sectoral Uncertainties

The 2006 IPCC Guidelines (Volume 1) provide guidance on identifying uncertainties for source categories. These guidelines were observed in the process of undertaking an uncertainty assessment.

CO_2 emissions from fuel combustion are typically much better characterised than other sources. This is because the amount of fuel used is generally known with a high degree of accuracy, and the EF (the carbon content of the fuel) is also known and does not typically vary much from international default values.

In Jamaica, the national energy balance tables provide comprehensive data on the fuel use. Whilst it has not been possible to obtain quantified information on the uncertainties of these data, expert opinion has provided a good insight into the variability of the uncertainties. Some data is compiled on a plant by plant basis, and is considered to be particularly reliable. This is generally the case for the stationary sources which are consuming the largest quantities of fuel. Consequently the amounts of fuel can be generally considered to be relatively accurate.

However, for some source-fuel combinations, a number of assumptions have had to be made which increases the levels of uncertainty. For example, it has been assumed that fuel used in stationary and mobile sources within sectors can easily be determined by allocating all of the gasoline and diesel oil to the mobile sources. This illustrates the extent to which uncertainties can arise in the allocation of the fuel in the energy balance tables to the emissions inventory sources.

There are different levels of uncertainty across the fuels as well as across the different sources sectors. For example, in the residential sector, wood consumption is considerably more uncertain than LPG use. This is because the amounts of LPG can be estimated from import data and sales data. For wood use, estimates are typically based on surveys that collect estimates of annual consumption, and this is much higher in uncertainty than information from sales or exports.

Carbon EFs for fuel combustion are typically very low in uncertainty. This is because the carbon content of fuel is generally well characterised, and e.g. liquid fuels made in a country do not generally vary from international default values by more than a few per cent. Therefore, even when country-specific information is not available, the use of international default values from the 2006 IPCC Guidance is considered to give appropriate representative values. The carbon content of solid fuels is more variable, and it can be sourced from different providers.

EFs for CH_4 and N_2O from fuel combustion are high in uncertainty. This is because the emissions are dependent on the conditions and efficiency of the combustion. However, emissions of CH_4 and N_2O from fuel combustion are small, so this relatively high EF uncertainty does not have a large impact on the uncertainty of the emission totals.

Detailed results of the uncertainty assessment carried out on the whole emissions inventory are presented in Section 9.

2.2.12.4 Quality Assurance and Quality Control

There are a number of sector-specific QA/QC procedures that have been undertaken as part of the emissions inventory compilation:

- **Reference vs Sectoral approaches:** The emissions estimates from both the sectoral and reference approaches have been compiled and compared. The two approaches draw on the same fuel consumption data (because it has not been possible to obtain fuel consumption data that is independent of the national energy balance tables). Demonstrating that the emissions give the same results therefore acts as a useful QC check.

- **Handling activity data:** At all stages of the compilation, a programme of QC checks have been included that are specific to the way the activity data are handled in the emissions inventory.
- **Assumptions:** It has been necessary to use assumptions in estimating emissions from a number of different sources. In all cases, the opinion of local experts has been sought to the extent possible.

2.2.12.5 Recommendations for Improvement

The vast majority of the methodologies used in this sector are Tier 1 methodologies. Best practise dictates that Tier 2 or better methodologies are used for key categories – many of which are included in the energy sector. There is therefore a need to improve the input data in general to allow Tier 2 methodologies to be used, and more specifically improvements to EFs and activity data.

In estimating emissions from all sources, default emission factors have been used from international guidance material. There is a clear need for the use of more country specific data, particularly on the information relating to the properties of fuels, which directly determines the CO_2 emission estimates. This would allow Tier 2 methodologies to be used.

The activity data has almost all been drawn from the national energy balance tables. The data is considered to be accurate, but there are a number of examples where more detail is required to allow Tier 2 methodologies to be used. In addition, a better understanding of how the data is compiled to form the national energy balance tables is needed. This would then support activities to compile two independent datasets using the reference and sectoral approaches (top-down and bottom-up respectively).

Examples of sector specific improvements include the following:

1A1a Electricity Generation – a better understanding of the information used in the national energy balance tables is needed. It may be that emissions from individual point sources is available for use, which would help with transparency, and could demonstrate the use of a Tier 2 and 3 approach.

1A1b Refinery – provision of data covering the full time series, with detailed fuel specific data, would be an improvement.

1A2 Manufacturing Industries – More detail is needed on the fuel used in the bauxite/aluminium sector to resolve mining activities.

1A2-4 Mobile Machinery – It has been assumed that all gasoline and diesel oil use in the industry, commercial and residential sectors is for mobile machinery. More detailed information is needed to confirm this assumption and allow emissions to be better allocated to respective source sectors.

1A3a Civil Aviation – The availability of fuel used in domestic aviation for the complete time series would allow improvements. The assumption that the cruise phase is zero for domestic flights requires more rigorous investigation.

1A3b Road Transport – Whilst the fuel consumption data is considered to be accurate, much more information is needed on the vehicle fleet to allow emissions to be calculated with improved certainty and at a more detailed level.

1A3c Railways – Obtaining information on the fuel use in the rail sector would allow emissions to be better disaggregated and reported in the correct source category.

1A3d Domestic Navigation – Data was not available for the entire time series, and it was not possible to resolve the fuel used for fishing from the domestic shipping total. Sourcing more complete and detailed data would allow improved accuracy and improved reporting of emission estimates to the relevant source sectors.

2.2.13.0 Industrial Processes and Product Use

2.2.13.1 Description of the Sector

The Industrial Processes and Product Use (IPPU) sector addresses emissions that are released from industrial applications that physically or chemically transform inputs into emissions or from the use of products that contains GHGs that are released into the atmosphere. It does not include those processes related to energy combustion, processing, extraction and transport of fuels as those are estimated under the relevant sub-category under the Energy Sector.

Industries such as Cement and Lime production release CO_2 into the atmosphere from the manufacturing process, as well as from fuel combustion. So corresponding emissions are reported in source categories under 1A Energy, as well as under 2 IPPU.

Emissions of CO_2 arise from the unintentional oxidation of products such as lubricants and grease. These are captured in the emissions inventory. The use of various household products, chemicals and solvents are a significant source of NMVOC (an indirect GHG) into the air. Hence emission estimates from these sources are also included in the emissions inventory.

Refrigerators and Air Conditioning (AC) units (including AC in road vehicles), are also a source of GHGs, releasing hydrofluorocarbons (HFCs) into the atmosphere. Emissions arise from several stages: during manufacture (not relevant for Jamaica, leakage that arises during the use of the product, emissions during refilling/recharging of the HFC, and emissions during the disposal of the product. The magnitude of the emissions are very much dependent on the processes in place to minimise emissions to air.

NMVOC emissions are produced from a wide variety of processes in other manufacturing industries. Most are not relevant for Jamaica, but emissions arise during the manufacture of a range of food and beverages. Emissions are included in the emissions inventory.

The table below provides a summary of source sectors where emissions arise (of GHGs and indirect GHG) and are included in the inventory.

Table 0.1 Emission Sources in the IPPU Sector by CRF

CRF	CRF Category Name INDUSTRIAL PROCESSES AND PRODUCT USE	Present in Jamaica
2A	Mineral industry	
2A1	Cement production	Y - emissions from cement manufacture
2A2	Lime production	Y – emissions from lime manufacture
2A3	Glass production	N
2A4	Other process uses of carbonates	N
2B	Chemical industry	N
2C	Metal industry	N
2D	Non-energy products from fuels and solvent use	
2D1	Lubricant use	Y – use of lubricants (non-combustion)
2D2	Paraffin wax use	N
2D3	Other	Y – use of solvents
2E	Production of Halocarbons and SF_6	N
2F	Consumption of Halocarbons and SF_6	
2F1	Refrigeration and air conditioning	Y – emissions from refrigeration & air conditioning
2F2	Foam blowing agents	N
2F3	Fire protection	N
2F4	Aerosols	N
2F5	Solvents	N
2F6	Other applications	N
2G	Other	
2H1	Pulp and paper	N
2H2	Food and beverages industry	Y
2H3	Other (please specify)	N

2.2.13.2 Methodological Overview

Efforts were made to obtain detailed data at the sectoral level, with the aim of using a Tier 2 methodologies from the 2006 IPCC Guidance as far as possible. However, it provide challenging to obtain relatively simple data for use in Tier 1 methodologies, and other than activity data, virtually no country specific information was available to support the calculation of emission estimates. The consequence is that most of the emission sources in the IPPU sector are based on 2006 IPCC Guidance Tier 1, although some use Tier 2 methodologies.

The main focus of effort was on trying to maximise the completeness of the inventory, and to obtain data on all sources known to exist, or thought to potentially exist in Jamaica. Focus on improving the accuracy of emissions (e.g. by obtaining more detailed input data) will need to be addressed as part of future improvements.

However, it is recognised that whilst there are a number of areas where improved input data could provide better quality emission estimates, it is possible that improvements in other source sectors will be prioritised over those in the IPPU sector. This is because the emissions from the IPPU sector make a relatively small contribution to the total GHG emission.

2.2.13.3 Calculation Methodologies

2A Mineral Industry

Cement and lime are produced in Jamaica by the calcination of limestone. Cement is used in the construction industry. Lime is used mostly in the processing of bauxite into alumina, in the sugar industry, and can also be applied to agricultural soils for pH control.

There has been a steady decline in bauxite/alumina production in Jamaica from 2008 onwards, and hence the demand for lime in Jamaica. Plant have closed due to the global economic decline and the resulting reduction in the world demand for aluminium. In addition, the high cost of production in Jamaica due to high energy costs has had an impact on the competitiveness of the sector.

2A1 Cement Production

The Caribbean Cement Company Limited, located in Rockford, Kingston, is the only manufacturer of "Portland" cement in Jamaica, and produces cement from high quality limestone and uses local shale and gypsum. All of the materials used in the manufacturing process are obtained locally, i.e. there are no imports of raw materials.

Annual clinker production data (as well as imports) were provided by the Caribbean Cement Company. There were no imports of clinker over the time period under consideration.

Activity data were collected directly from the plant and compared with data from national statistics. A complete set of data from 2000-2014 were collected. Activity data were compared to data available from ESSC reports 2000-2013 as well as from the company website in form of the company's annual reports. No major challenge was encountered with the data gathering and calculation of estimates from the cement sub-sector.

The method used is classed as a Tier 2 method, as the GHG emission estimates are made by using the national clinker production as the activity data. These production data are considered accurate and reliable, being taken directly from weight measurements at the production plant. A default correction factor for Cement Kiln Dust (CKD) was used, taken from equation 2.4 in the 2006 IPCC Guidance (IPPU sector - chapter –mineral industry), to give emission estimates of CO2.

2A2 Lime Production

The production of lime by the calcination (heating) of limestone produces CO2. Most lime kilns are located at bauxite/alumina plants where usage of lime was greatest, and provided straightforward access. The local sugar factories are also heavy users of lime. However, since 2008 there has been major closure of the bauxite/alumina plants due decline in world demand as well as the high cost of energy in Jamaica. As a result, most of the lime kilns have closed. The sugar industry in Jamaica has also been in general decline.

CEMEX Jamaica Limited was established in 1998 and is the only local production company supplying remaining two alumina plants and seven sugar factories with quicklime. Lime kilns that were located at alumina plants have closed down operations and are buying lime directly from the CEMEX plant, which has a capacity of 120,000 tonnes/year. Activity data were collected from national statistics (STATIN, 2015a) as well as the Minerals Yearbook 2000-2011. A complete set of data from 2000-2008 were collected. However, the data from 2008-2012 was estimated from (extrapolation) from the previous year's data set. Activity data from CEMEX that was requested was not provided.

Clinker and lime production data are given in the table below.

Table 0.2 Production of Clinker and Lime (tonnes)

Year	Clinker Production	Lime Production
2006	604,174	303,795
2007	519,598	276,800
2008	578,067	312,669
2009	742,208	128,384
2010	629,444	115,141
2011	628,287	141,845
2012	652,579	127,226

Emissions from lime production were calculated using a Tier 2 methodology from the 2006 IPCC Guidance (Volume 3), and using a default value for the Lime Kiln Dust correction factor.

The calculated emissions of CO2 from cement and lime production are presented in the table below.

Table 0.3 Emissions of CO_2 from Cement and Lime Production (Mg CO_2)

Year	Clinker Production	Lime Production	Total
2006	314,170	227,846	542,017
2007	270,191	207,600	477,791
2008	300,595	234,502	535,097
2009	385,948	96,288	482,236
2010	327,311	86,356	413,666
2011	326,709	106,384	433,093
2012	339,341	95,420	434,761

2D Non-energy Products from Fuels and Solvent Use

2D1 Lubricant Use

Lubricants and grease are mostly used in industrial and transportation applications. The emissions that arise from the unintentional oxidation of lubricants and grease are not included in 1A Energy, because the lubricants and grease are not considered to be a fuel. So emissions are included in the IPPU Sector.

The CO2 emissions were estimated using the Tier 1 methodology from the 2006 IPCC Guidance. More detailed data on the amounts of each type of lubricant and the associated ODUs (Oxidised during Use) would be required for Tier 2 methodology to be used.

The default carbon content and ODU factor were used for both lubricants and grease (0.2 carbon content and 0.05 ODU). It was necessary to convert the quantities of lubricants and grease from energy to mass terms. A net calorific value of 40.4 GJ/tonne was used. This is considered to be a reasonable estimate for lubricants, and whilst it may not be particularly representative of grease, lubricants are by far the largest component.

Activity data for the production of a lubricants/grease total were available from Petro Jam for 2011 and 2012 (Petro Jam, 2015). Consumption for earlier years of the time series were estimated by using simple extrapolation. It was necessary to use default data to divide the total consumption into the two separate components. A 90-10% the split for oil-grease was assumed (see 2006 IPCC Guidance, Vol 3, Chapter 5, Table: 5-2).

The consumption of lubricants and grease is presented in the table below.

Table 0.4 Consumption of Lubricants and Grease (Mg of product)

Year	Lubricating Oil	Grease
2006	597.47	16.60
2007	597.47	16.60
2008	597.47	16.60
2009	597.47	16.60
2010	597.47	16.60
2011	927.44	25.76
2012	554.79	15.41

The CO^2 emissions from the use of lubricants and grease are presented in the table below.

Table 0.5 CO_2 Emissions from the Use of Lubricants and Grease (Mg CO_2)

Year	Lubricating Oil	Grease
2006	1,884.02	52.33
2007	1,884.02	52.33
2008	1,884.02	52.33
2009	1,884.02	52.33
2010	1,884.02	52.33
2011	2,924.54	81.24
2012	1,749.44	48.60

The disposal route for waste lubricants/grease that is not oxidised during use is not known with certainty. So no CO2 emissions have been calculated, or included in the emissions inventory, from the un-oxidised waste lubricant/grease.

2D3 Asphalt Production and Use

Asphalt is used widely in road paving and roofing operations, and NMVOC emissions arise. Activity data of the amount of asphalt produced were obtained from Petro Jam (Petro Jam, 2015a).

For the purposes of the calculation of the estimates asphalt was assume to have the properties similar to Fuel Oil with a conversion factor of 40 GJ/tonne. An EF of 16g NMVOC/Mg (2013 EMEP/EEA Emissions Inventory Guidebook, 2D3b Table 3-1) was used to calculate the NMVOC estimates.

The table below presents the asphalt production, and the resulting NMVOC emission estimates

Table 0.6 Asphalt production (Mg)g

2006	18,178.02	0.29
2007	18,178.02	0.29
2008	18,178.02	0.29
2009	18,178.02	0.29
2010	18,178.02	0.29
2011	19,331.43	0.31
2012	19,419.24	0.31

2F Consumption of Halocarbons and SF6

HFCs, PFCs, SF6 and NF3 are used in a range of applications, as summarised in sections 2.5.4 – 2.5.5. However, after careful consideration by local experts, the only source that could be identified and estimated were the emissions of HFCs from refrigeration and air conditioning.

2F1 Refrigeration and Air Conditioning

HFCs are used in refrigeration and air conditioning, and emissions arise at a number of different stages:

- **Manufacture:** The handling of HFCs, and charging of units, during manufacture leads to emissions.
- **Use:** Leakage of HFC during the use of units occurs throughout the lifetime of the equipment.
- **Refill:** Following HFC leakage from the equipment during use, some units (particularly air conditioning in road vehicles) are refilled. Emissions arise from this process, and the size is highly dependent on the infrastructure in place to ensure that only trained personnel undertake this, and under conditions to minimise emissions to air.
- **Disposal:** Emissions arise from equipment during disposal. The size of the emission is very much dependent on whether recovery programmes are in place. Jamaica does have a system in place for the recovery of HFCs from equipment being scrapped, but expert view was that the system was not rigorously applied to all equipment being removed from operation.

Information was sought on the number of different types of refrigeration units and air conditioning units in an attempt to estimate the amount of HFC that was held in equipment. But it was not possible to compile information that was considered to be accurate of complete enough. Consequently it was necessary to use a different approach.

HFC import data were obtained from STATIN by individual HFC species for 2012 and 2013. The manufacture of HFCs in Jamaica is known to be zero, and hence the import provides the main input term (along with HFC in imported equipment). The import data were available for 2012 and 2013 only, and assumptions were made to interpolate between these data, and information on the GHG emissions inventory compiled for the Second National Communication, covering 2000-2005 (Davis et al, 2008).

The imported data were used with the Tier 1 f-gas emissions calculation tool provided by the UNFCCC. This uses the import data to build up a total "bank" or pool of HFC in equipment. The bank can be calculated on a yearly incremental basis by accounting for HFC added in the form of imports or new equipment, and removals in the form of HFCs recovered from scrapped equipment and emissions to air. An IPCC default EF of 15% is used to determine the emissions from installed equipment.

HFC emission estimates are given in the following table.

Table 0.7 HFC Emissions (tonnes of CO_2 EQ)

2006	4.31	12.43	44.32	16.04	0.00	1.69	0.28	79.07
2007	5.47	12.94	49.14	18.14	0.00	1.43	0.24	87.36
2008	6.60	13.09	52.22	19.16	0.00	1.22	0.20	92.49
2009	7.70	12.92	53.82	19.29	0.00	1.03	0.17	94.94
2010	8.78	12.49	54.15	18.64	0.00	0.88	0.15	95.10
2011	9.84	11.83	53.42	17.35	0.00	0.75	0.13	93.32
2012	10.89	11.49	52.39	16.31	0.00	0.64	0.11	91.81

2.2.13.4 Other Possible Sources of F-Gases

There are a number of other possible sources of F-gases. Each source is considered here, with an explanation of why they have not been included in the emissions inventory, and qualitative comments on the levels of certainty associated with the associated assumptions.

2F2 Foams: F-gases are used in some foam blowing. No specific activities were identified where f-gases were being used, and whilst it is possible that some of the imported HFC was for use in foam blowing, it is considered unlikely.

2F3 Fire protection: F-gases are used in some fire suppression equipment, and import of F-gases for this purpose was noted in the second national communication (for 2000-2005). It has been assumed that all of the HFC import was for use in air conditioning and refrigeration, but it is possible that small amounts were for use in fire suppression.

2F4 Aerosols and Metered Dose Inhalers: Most aerosols use hydrocarbon propellants, and HFCs are used only in a few applications such as air dusters and pipe freezing products, so it is reasonable to assume that the usage in Jamaica is negligible. Metered dose inhalers (MDIs) are used to deliver certain pharmaceutical products as an aerosol. MDIs originally used CFC propellants but, as with industrial aerosols, concern over ozone destruction led to attempts to replace CFCs with HFCs. It has not been possible to quantify the extent of the use of these products in Jamaica.

2F5 Solvents: F-gases can be used for precision cleaning, but this is typically in the electronics industry and is not relevant for Jamaica.

2G1 Electrical equipment: SF6 is used as an insulator in high voltage electrical switch gear. JPS were approached about the use and potential leakage of SF6 from the electricity infrastructure, but were not able to provide any information. It is considered likely that SF6 is in use in Jamaica in electrical switchgear, and that the inability to make an emission estimate from this source constitutes an omission. So this source is reported as “NE” – not estimated.

2G2 Bespoke Military and Scientific Applications: These are not considered to be relevant for Jamaica.

2G3 N2O from product uses: N2O is used as an anaesthetic in some medical and dental practices. It was not possible to obtain any information on the use of N2O, and hence no emissions have been estimated. This is typically a small source, but efforts should be made to include it as the emissions inventory is improved.

2G Food and Beverage Manufacture

Emissions of NMVOC arise from the manufacture of specific food and beverages. The Tier 1 methodology for estimating the emissions of NMVOC uses a straightforward combination of production data of specific food/beverage types with default emission factors from the 2013 EMEP/EEA Guidebook.

Production data were obtained from Economic and Social Survey of Jamaica reports for 2000-2013 (Planning Institute of Jamaica, 2015), and are presented in the table below.

Table 0.8 Food and Beverage Production Data (tonnes)

2006	7,581	378,165	5,021	129,322	146,882	22,940	86,955	8,500
2007	7,676	377,029	5,704	124,928	164,387	21,850	86,946	9,159
2008	7,967	390,929	4,525	132,397	140,872	22,620	85,985	9,243
2009	6,417	390,221	3,868	136,782	125,818	22,636	69,204	8,716
2010	6,517	381,432	4,386	136,798	121,806	18,494	65,516	9,337
2011	7,047	402,201	3,864	134,510	139,594	19,367	58,343	11,101
2012	6,903	408,139	3,648	136,132	136,645	22,747	50,226	11,461

Table 0.9 NMVOC Emissions from Food and Beverage Production Data (tonnes)

2006	75.81	378.17	50.21	1,034.58	1,468.82	91.76	30.43	2.98
2007	76.76	377.03	57.04	999.42	1,643.87	87.40	30.43	3.21
2008	79.67	390.93	45.25	1,059.18	1,408.72	90.48	30.09	3.24
2009	64.17	390.22	38.68	1,094.26	1,258.18	90.54	24.22	3.05
2010	65.17	381.43	43.86	1,094.38	1,218.06	73.98	22.93	3.27
2011	70.47	402.20	38.64	1,076.08	1,395.94	77.47	20.42	3.89
2012	69.03	408.14	36.48	1,089.06	1,366.45	90.99	17.58	4.01

2.2.13.5 Solvent Use

Solvent use is a source sector in its own right, rather than a sub-sector of IPPU. However it is included here for convenience because methodologies similar to those for IPPU are used for estimating emissions. In addition, the only emissions estimated are those for NMVOC, rather than direct GHGs.

The use of some solvents and certain consumer products can represent significant sources of emissions of NMVOCs. The table below provides a summary of source descriptions and the methodologies used for estimating the emissions of NMVOC.

Table 0.10 Sources Involving Solvent Usevent

Comments		
Domestic solvent use including fungicides	Solvents are used in a variety of applications in the manufacturing of chemicals and chemical products including fungicides and personal care products	Estimates were based on population data from 2000-2013 Emission Factor of 2700g/person was used based on the 2013 EMEP/EEA Guidebook 2013, 2D3a Domestic Solvent Use including pesticides, Table 3-1
Coating Applications –Paints	Coating operations, mixing, and use of thinning solvents	Estimates for emissions from paints were based on the local production of decorative paints, production are given in 000'litres however figures were converted to Kg using density of 0.5 g/m^3
Degreasing applications	Surface cleaning/degreasing operations	Not included in the inventory, as no solvent use data were readily available
Dry Cleaning operations	Use of specific chemical in fabric cleaning	Local expert estimate 3.5 kg of clothes dry cleaned per month. This was scaled to an annual figure for Jamaica and combined an EF from the 2013 EMEP/EEA Guidebook.
Chemical Products	Solvents are used in a variety of applications in the manufacturing of chemicals and chemical products. Textile fabric printing, polyester resin plastic products manufacture, tank and drum cleaning and degreasing	Not included in the inventory, as no solvent use data were readily available
Printing	Press operations, lithography, and use of thinning solvents	Not included in the inventory, as no solvent use data were readily available

The tables below summarise the estimates of solvent use for domestic activities, and the resulting NMVOC emissions.

Table 0.11 Consumption of Solvents for Domestic Activities

	POPULATION 1000 hab	PAINT APPLIED Tonnes	TEXTILE TREATED tonnes
2006	2,658	17,397	111,628
2007	2,667	18,092	112,022
2008	2,677	17,034	112,421
2009	2,686	16,151	112,816
2010	2,696	13,874	113,211
2011	2,704	14,648	113,572
2012	2,712	14,219	113,883

Table 0.12 Emissions of NMVOC from Solvent Use (Mg NMVOC)

2006	7,176.06	2,609.55	4,465.10
2007	7,201.44	2,713.80	4,480.90
2008	7,227.09	2,555.10	4,496.86
2009	7,252.47	2,422.65	4,512.65
2010	7,277.85	2,081.10	4,528.44
2011	7,301.07	2,197.20	4,542.89
2012	7,321.05	2,132.85	4,555.32

NMVOC that is released into the air will eventually breakdown into CO2, and as such the NMVOC emissions contribute to the total CO2 emissions. However, no information was readily available on the carbon content of the solvents, and therefore a CO2 emission estimate was not included in the emissions inventory. This source was not given a high priority because the CO2 emission is very small when compared to numerous other sources of CO2, but would be a simple addition to future versions of the inventory.

2.2.13.6 Sectoral Uncertainties

The 2006 IPCC Guidance (Vol 1) provide guidance on identifying uncertainties for source categories. These guidelines were observed in the process of undertaking an uncertainty assessment.

However, it was challenging to obtain any quantitative data in the uncertainties associated with input data for estimating emissions from sources within the IPPU sector.

Activity data for industrial processes (e.g. clinker production, lime production, food and drink manufacture) were generally considered to be of good quality. However it was not possible to obtain any plant specific emissions, and hence calculation methodologies relied on using default EFs from the 2006 IPCC Guidance. Whilst these EFs are considered to be generally representative, it does result in larger uncertainties.

Emissions of F-gases are known to be particularly uncertain, when compared to emissions of most other sources. In addition, it was not possible to use a calculation methodology that considered the numbers and types of fridges and air conditioning units in use. The limited input data meant that the methodology used only import data, which results in emission estimates with relatively high uncertainties.

As no quantified data on the uncertainties associated with activity data were available, it was necessary to use expert judgement. Uncertainties associated with EFs were taken from the 2006 IPCC Guidance.

A detailed uncertainty analysis was undertaken across all sources of the emissions inventory, and results are presented in Section 9.

2.2.13.7 Quality Assurance and Quality Control

There are a number of sector specific QA/QC procedures that have been undertaken as part of the emissions inventory compilation:

In some cases it was possible to compare national production statistics with internationally published literature. Data provided at the national level was considered to be more reliable, but a degree of validation.

Handling activity data: At all stages of the compilation, a programme of QC checks have been included that are specific to the way the activity data are handled in the emissions inventory. Assumptions: It has been necessary to use assumptions in estimating emissions from a number of different sources. In all cases, the opinion of local experts has been sought to the extent possible.

2.2.13.8 Recommendations for Improvement

Emissions from the IPPU sector make a small contribution to the total GHG emission, although emissions from cement and lime manufacture are identified as key categories (see Section 8), as is the total HFC emission from refrigeration and air conditioning. Whilst there are areas where methodologies could be significantly improved, it is likely that prioritisation of the available resources will direct improvement resources to other sectors of the inventory.

However, it is possible to make a number of observations about improvements that could be made to the emission estimates for the IPPU sector:

- Emissions from cement and lime manufacture are estimated using a Tier 2 methodology. It would be possible to improve this by using indusial plant specific data – but this is considered to be of low priority.
- Emissions of HFC from refrigeration and air conditioning uses a very simple methodology due to the lack of input data and characterisation of the sector, and improvements to the methodology used for estimating this source should be considered a priority. A more sophisticated approach could be used for estimating the emissions of F-gases from this sector by compiling information on the number of units of different types that are in operation. Obtaining more complete import data would also bring improvements to the accuracy of the current methodology. Furthermore, it is known that there are activities in Jamaica to recover f-gases from scrapped equipment. The impact of this on reducing emissions could be taken into account if or when a more sophisticated methodology is used for estimating emissions.
- Emissions from food and drink could be improved. However the emissions are only an important contributor to the NMVOC emissions total, and as an indirect GHG, this is generally given a lower priority.

2.2.14 Agriculture

2.2.14.1 Description of the Sector

The agricultural sector is considered to be one of Jamaica's main drivers of economic growth, as it contributed approximately 6.8% to the island's gross domestic product (GDP) in 2012. However in 2012 the agriculture sector suffered damage of Jamaican $1.452B from the effects of Hurricane Sandy. Jamaica has a much decentralised agriculture sector, with over one hundred and seventy thousand registered farmers.

The characteristics of agriculture in Jamaica have been compared in some detail to the regional categorisation in the 2006 IPCC Guidance material. It was decided that the agricultural practices in Jamaica were best characterised by assuming activities mid-way between North America and Latin America (intensive and extensive) farming practices as described in the 2006 IPCC guideline.

The following list provides a summary of the categories and GHG emissions estimated in the emissions inventory:

Livestock:

Enteric fermentation – CH_4
Manure management – CH_4 and N_2O
Indirect emissions from manure management – N_2O

Agricultural Soils:

Direct emissions from managed soils – N_2O
Indirect emissions from managed soils – N_2O
Liming – CO_2
Urea application – N_2O
Rice cultivation – CH_4
Biomass burning – CO, NOx, N_2O, CH_4, NMVOC
Indirect GHG: NOx and NMVOC

2.2.14.2 Methodological Overview

In order to ensure the best attainable levels of quality, as defined by the IPCC Good Practice Guidance 2006, the methodologies in the 2006 IPCC Guidance were reviewed. In general, little country specific information was available regarding the management of livestock and crops. However, country specific information was supplemented by local expert opinion to allow more sophisticated methodologies (Tier 2) to be used for many of the different sources in the agriculture sector. Emission of N2O in particular were determined using a more sophisticated methodology, which assessed the complete flow of all different N species through the entirety of the Agriculture sector.

A number of assumption were needed to obtain data that allowed Tier 2 methodologies to be used, and in particular one important assumption was that the farming practices in Jamaica could be represented by calculating EFs as an average of those for North America and Latin America, as presented in the 2006 IPCC Guidance.

2.2.14.3 Activity Data

In order to ensure appropriate levels of accuracy of this report, the 2006 IPCC Guidance were used to advise the type of activity data that will be needed to complete this inventory report. Activity data were obtained for annual estimates over the period of 2006-2012 for the following categories:

- Livestock population
- Crop production
- Synthetic Nitrogen Fertiliser
- Urea consumption
- Lime consumption

Livestock population and crop production are activity data that are used in several emission source categories and they are presented in the sections that follow.

2.2.14.4 Livestock Population

Several sources were used to capture the population data as there was not one central source with all of the required data. As far as possible, the detail of the livestock categorisation was retained to allow the emission estimates to be calculated at the most detailed level possible.

2.2.14.5 Cattle Data

Cattle data were obtained from: The Rural Agricultural Development Authority (RADA) provided data for years 2011, and 2012, and the Statistical Institute of Jamaican (STATIN) 2007 Preliminary Agricultural Census provided data for year 2007. Due to the lack of data for the other years, interpolation was used to generate estimates for 2006 and 2008-2010 using the 2005 and 2007 data, and 2007 and 2011 data respectively.

2.2.14.6 Goats and Sheep Data

The population data collected for goats and sheep were obtained from: the 2007 STATIN – preliminary agricultural census report for year 2007, RADA provided data for years 2011-2012, and interpolation of 2005 and 2007 data was undertaken to obtain 2006 data, and of 2007 and 2011 data to obtain 2008-2010 data.

2.2.14.7 Horses, Mules and Asses

Data was not available for Mules and Asses, however, extrapolation from the 2005 data from the second national communication was conducted to obtain an estimate of numbers for the entire time series.

Preliminary data were received for Horses from the Jamaica Racing Commission, however the data received only represent the mares, and thus data was rescaled by using data from the previous emissions inventory. The Commission later indicated that they had recently relocated thus the data needed was not available.

2.2.14.8 Pigs Data

The pigs data were obtained from: the 2007 STATIN – preliminary agricultural census report for year 2007, the Pig Farmers Survey conducted in 2012 by the MOAF for year 2012, interpolation for year 2006 and 2008-2010, using data from year 2005 and 2007, and 2007 and 2012 respectively.

2.2.14.9 Poultry Data

Poultry data were obtained from: The Ministry of Agriculture and Fisheries - Agriculture Marketing and Information Division (MOAF-AMID) for the years 2008-2012 (broiler), STATIN 2007 preliminary agricultural census report for 2007 (layers), RADA for years 2011 to 2013 (layers). Interpolation of 2005 and 2008 was used to obtain 2006-2007 broiler data, and for layers interpolation of 2005 and 2007 data was undertaken to obtain 2006 data, and of 2007 and 2011 data to obtain data for 2008-2010. Extrapolation of 2012 broiler data was used to obtain 2013 data.

The time series for other poultry was obtained by using broilers as a good indication (surrogate data) of the general trend for other poultry. The data for other poultry was further assumed to contain 10% turkey and 40% ducks and geese and the remaining balance would be birds such as pigeons and peacocks – based on local expert judgement.

2.2.14.10 Other Farmed Animals

Rabbit data was obtained from RADA for years 2011-2012. However, because of the lack of data for the rest of the time series, extrapolation was needed to obtain data for 2000-2010.

Table 0.1 Livestock population (Heads)

Dairy	14,514	11,728	12,747	13,766	14,784	15,803	16,174
Other Cattle	74,993	83,236	79,270	75,304	71,338	67,372	83,424
Buffalo							
Sheep	6,628	7,255	8,534	9,814	11,093	12,372	16,884
Goats	466,173	482,345	448,343	414,341	380,339	346,337	337,632
Horses	19,795	20,044	20,292	20,541	20,790	21,039	21,287
Asses & Mules	9,083	9,083	9,083	9,083	9,083	9,083	9,083
Market Swine	181,098	201,559	186,936	172,313	157,690	143,067	128,444
Breeding Swine	20,122	22,395	20,771	19,146	17,521	15,896	14,272
Poultry- Chickens (Layers)	573,280	765,959	710,882	655,806	600,729	545,652	638,028
Poultry- Chickens (Broilers)	29,198,772	41,042,344	64,729,488	63,404,068	64,062,114	38,492,644	63,854,063
Poultry- Turkeys	5,840	8,208	12,946	12,681	12,812	7,699	12,771
Poultry- Ducks & Geese	23,359	32,834	51,784	50,723	51,250	30,794	51,083
Rabbit	14,934	14,934	14,934	14,934	14,934	12,372	16,884

2.2.14.11 Crop Production

Crop production data were all obtained from the MOAF-AMID, except for: the 2006 data (for broccoli, squash, other vegetables, and cantaloupe). These data were not available thus extrapolation from the 2007 was undertaken to obtain them. The Food and Agriculture Organisation (FAO) estimated data were used to obtain the rice data between the years 2007 to 2009 as country specific data were not available.

These data were used to estimate N emissions from managed soils and CH4 emissions from rice cultivation. Appendix 2 contains tables of production (tonnes) and harvested (hectares) for crops present in Jamaica, by type.

Table 0.2. Fertiliser Consumption, calculated as import – export (Kg of compound)

Year	2006	2007	2008	2009	2010	2011	2012
Ammonium Nitrate	903,299	1,353,454	934,513	1,223,657	527,946	887,299	1,287,904
Ammonium Sulphate	1,732,123	5,488,709	13,452,207	6,132,562	18,554,233	12,223,102	18,324,450
Urea	3,142,552	6,193,290	4,729,177	2,148,139	3,167,771	2,467,708	6,367,484
Urea + Ammonium Nitrate[1]	19,223	0	0	22,443	17,439	21,044	18,331
Double Salts and Mixture of Ammonium Sulphate and Ammonium Nitrate	60	30	40	0	250	40	130
Double Salts and Mixture of Calcium Nitrate and Ammonium Nitrate	1,200	5	21,556	23,115	30,496	22,311	34,221
Mixture of Ammonium Nitrate with Calcium Carbonate or other Inorganic non-fertiliser substitute.	21,557	0		224,132	345,295	99,021	254,667
Other Nitrogenous fertiliser or mineral	0	0	1,132,000	0	945,622	1,325,670	2,176,423
Fertiliser with NPK	1,556,302	3,936,902	2,545,221	1,328,990	4,357,223	1,433,343	4,967,221
Diammonium Phosphate	18,452,321	1,830	2,143,352	5,437,543	3,214,556	54,688	12,536,678
Monoammonium phosphate	3,540	0		2,134	0	8,453	12,009
Other Fertiliser with N+P	17,234	7,019	23,314	24,870	0	12,909	6,500
Ammonium based fertiliser	0	0			0	0	
Other Ammonium Base fertiliser	62,004	40,068	32,221	23,144	43,000	38,332	50,300
Other Mineral or Chemical Fertiliser	0	0	1,690,665	2,327,523	1,543,770	2,367,530	3,354,890
Nitrates + Phosphates	18,423	0	0	12,554	0	5,600	15,110
TOTAL	25,929,838	17,021,307	26,704,266	18,930,806	32,747,601	20,967,050	49,406,318

The following sections presents the emissions for Agriculture sector.

2.2.14.12 Fertilisers

Fertiliser usage influences the emission of CO2 and N2O from soils both directly and indirectly.

The STATIN provided the annual import and export data for synthetic fertilisers containing nitrogen (data for years 2009, 2010 and 2013 are preliminary). These data were used to estimate the amount of N consumed locally, using the difference between the amount exported and that imported, and the percentage nitrogen each fertiliser contained. Data are presented in the tables below.

Table 0.3. Content of N in Each Fertiliser Type

Fertiliser Type	% N
Ammonium Nitrate	34
Ammonium Sulphate	21
Urea	46
Urea + Ammonium Nitrate	40
Double Salts and Mixture of Ammonium sulphate and Ammonium Nitrate	27.5
Double Salts and Mixture of Calcium Nitrate and Ammonium Nitrate	31
Mixture of Ammonium Nitrate with Calcium Carbonate or other Inorganic non-ferti subst.	31
Other Nitrogenous fertiliser Or mineral	30
Fertiliser with NPK	15
Diammonium phosphate	18
Monoammonium phosphate	11
Other fertiliser with N+P	15
Ammonium-based fertiliser	21
Other Ammonium Base fertiliser	21
Other mineral or chemical fertiliser	15
Nitrates + Phosphates	15

2.2.14.13 Enteric Fermentation

2.2.14.14 Methodology

The general operation of the livestock industry in Jamaica allows for little accountability in terms of the collection of detailed disaggregated population data. As a result, the input data only allows for the 2006 IPCC Tier 1 methodology to be used in the calculation of the emission estimates.

The activity data collection and detail levels are outlined in the section above. EFs used in the inventory for enteric fermentation are presented in the table below.

Table 0.4 Default Emission Factors, with Uncertainty Levels (Source: 2006 IPCC Guidelines)

	EF. *kg CH_4 / head / year*	Uncertainty level/Range	Remarks
Dairy Cattle	72	30-50%	Average between North and Latin America was used for both Cattles assuming that this is representative of the agricultural practices in Jamaica
Other Cattle	56		
Sheep	5		
Goat	5		
Swine	1		
Horse	18		
Mules and Asses	10		

2.2.14.15 Category Emissions

CH_4 emissions from enteric fermentation are presented in the table below, and show an increase of 4.5 % and 12.2% between the years 2006 to 2007, and 2011 to 2012 respectively. However, there was a decrease between 2007 and 2011 of 15%. This fluctuation was mainly influences by the livestock category "other cattle" (i.e. non-dairy cattle) as praedial larceny has severely affected this sub-sector.

CH_4 emissions from dairy cattle show a slight increase during the last three years of the reporting period, reflecting recent efforts to increase production. The sheep industry is also being encouraged to grow, and there is an observable increase in CH_4 emissions from sheep across the time series. Praedial larceny is also a major problem for goats, hence there has been a decrease in production resulting in a corresponding decrease in CH_4 emissions. Swine numbers have decreased across the time series due to the high cost of production, and emissions have decreased accordingly.

Table 0.5 Emissions of CH_4 from Enteric Fermentation (Gg CH_4)

	2006	2007	2008	2009	2010	2011	2012
Dairy Cattle	1.05	0.84	0.92	0.99	1.06	1.14	1.16
Other Cattle	4.20	4.66	4.44	4.22	3.99	3.77	4.67
Buffalo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sheep	0.03	0.04	0.04	0.05	0.06	0.06	0.08
Goats	2.33	2.41	2.24	2.07	1.90	1.73	1.69
Horses	0.36	0.36	0.37	0.37	0.37	0.38	0.38
Mules/Asses	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Market Swine	0.18	0.20	0.19	0.17	0.16	0.14	0.13
Breeding Swine	0.02	0.02	0.02	0.02	0.02	0.02	0.01
TOTAL	8.26	8.63	8.31	7.98	7.66	7.33	8.23

3B Manure Management – CH_4

2.2.14.16 Methodology

The 2006 IPCC Guidelines were used to obtain the direct emissions from manure management. Livestock numbers were obtained as explained in sections above. As detailed country-specific data regarding livestock were unavailable, it was necessary to use the 2006 IPCC Guideline Tier 1 methodology to obtain the total CH4 emissions from manure management.

Table 0.6 Default Emission Factors, with Uncertainty Levels (Source: 2006 IPCC Guidelines)

	EF. *kg CH_4 / head / year*	Uncertainty level/Range	Remarks
Dairy Cattle	53.5	±30%	Average between North and Latin America was used for both Cattle. An Average temperature of 26 degrees Celsius was used.
Other Cattle	1.5		
Sheep	0.2		
Goat	0.22		
Market swine	12		
Breeding swine	21.5		
Horse	2.19		
Mules and Asses	1.2		
Poultry	0.02		

Intensive livestock manure management is not a common practice in Jamaica. However, the manure management practices are assumed to include: anaerobic lagoon, liquid/slurry, solid storage, dry lot, pasture, poultry manure with litter and other practices. These management practices were fractioned by using local expert judgment.

Table 0.7 Manure Management Systems - (% Usage)

Livestock Category	Liquid/Slurry	Solid Storage	Dry lot	Pasture, Range, Paddock	Poultry Manure	Other
Dairy	5	0	35	60	0	0
Other Cattle	0	0	30	70	0	0
Market Swine	60	0	20	0	0	20
Breeding Swine	60	0	20	0	0	20
Poultry-Layers	0	70	0	0	30	0
Poultry-Broilers	0	80	0	0	20	0
Poultry-Turkeys	0	80	0	0	20	0
Poultry-Ducks &Geese	0	40	0	60	0	0
Sheep	0	0	30	70	0	0
Goats	0	0	30	70	0	0
Horses	0	0	20	70	0	10
Mules/Asses	0	0	20	70	0	10
Rabbit	0	50	50	0	0	0

Most livestock manure management is undertaken in a confined area, however, only little decomposition occurs anaerobically. Most manure management is undertaken as solid storage, and less methane is produced when compared to liquid management.

2.2.14.17 Category Emissions

Market swine and broilers make the largest contribution to CH_4 emission from manure management. Over the inventory period the trend in emissions is observed to have fluctuated. This is driven by changes in livestock numbers, and in particular those for pigs and poultry. This trend with time also reflects that fact that there is typically little investment in manure management on the relatively small-scale farming compared to developed countries.

Emissions of CH_4 from manure management are presented in the table below.

Table 0.8 Emission of CH_4 from Manure Management (Gg CH_4)

	2006	2007	2008	2009	2010	2011	2012
Dairy Cattle	0.78	0.63	0.68	0.74	0.79	0.85	0.87
Other Cattle	0.11	0.12	0.12	0.11	0.11	0.10	0.13
Buffalo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sheep	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goats	0.10	0.11	0.10	0.09	0.08	0.08	0.07
Horses	0.04	0.04	0.04	0.04	0.05	0.05	0.05
Mules/Asses	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Market Swine	2.17	2.42	2.24	2.07	1.89	1.72	1.54
Breeding Swine	0.43	0.48	0.45	0.41	0.38	0.34	0.31
Poultry- Chickens (Layers)	0.11	0.15	0.14	0.13	0.12	0.11	0.13
Poultry- Chickens (Broilers)	0.58	0.82	1.29	1.27	1.28	0.77	1.28
Poultry-Turkeys	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poultry-Ducks & Geese	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Rabbit	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	4.36	4.80	5.10	4.89	4.72	4.03	4.39

3B Manure Management – N_2O

2.2.14.18 Methodology

To obtain the N2O emissions from manure management, the EMEP 2013 guidelines Tier 2 methodology was used (these guidelines have been specifically created to be consistent with the IPCC 2006 Guidance). The approach is to characterise the flow of N throughout the entire agriculture sector, establishing emissions to air of the different N species at the different stages of manure management. Emissions of N2O are established as a sum of the following different components that can be divided into two groups:

Emissions from livestock:

- Emissions from housed animals
- Emissions from manure that is collected and stored

Table 5.9 EF and Parameters used in the Tier 2 Approach for estimating N_2O

Livestock Category	PRR %	Burned/Not Used %	Building %	Yard %	Grazing %	Proportion of TAN %	Building manure: Slurry %	Building manure: Solid %	NH3 EF- Building: Slurry	NH3 EF- Building: Solid (kg NH3-N / kg TAN)	NH3 EF- Yard: Solid (%)	N added, straw (kg N/place/year)	Frac building manure stored: Slurry	Frac building manure stored: Solid	NH3 EF- Storage: Slurry	NH3 EF- Storage: Solid (kg NH3-N / kg TAN)	NH3 EF- Spreading: Slurry	NH3 EF- Spreading: Solid (kg NH3-N / kg TAN)	NH3 EF- Grazing: Solid (kg NH3-N / kg TAN)
Dairy	60	0	0.4	0	0.6	0.6	0.125	0.875	0.2	0.19	0.3	6	1	1	0.2	0.27	0.55	0.79	0.1
Other Cattle	70	0	0.3	0	0.7	0.6	0	1	0.2	0.19	0.53	2	1	1	0.2	0.27	0.55	0.79	0.06
Buffalo	0	0	1	0	0	0.5	0.01	0.99	0.2	0.2	0.3	6	1	1		0.17		0.55	0.13
Market Swine	0	0	1	0	0	0.7	0.2	0.8	0.28	0.27	0.53	0.8	1	1	0.14	0.45	0.4	0.81	0.25
Breeding Swine	0	0	1	0	0	0.7	0.8	0.2	0.22	0.25		2.4	1	1	0.14	0.45	0.29	0.81	0.25
Poultry - Chickens (Layers)	0	0	1	0	0	0.7	0.6	0.4	0.41	0.41			1	1		0.14		0.69	
Poultry - Chickens (Broilers)	0	0	1	0	0	0.7	0	1		0.28			1	1		0.17		0.66	
Poultry - Turkeys	0	0	1	0	0	0.7	0.513	0.487		0.35			1	1		0.24		0.54	
Poultry - Ducks & Geese	60	0	0.4	0	0.6	0.7	0.2	0.8		0.405			1	1		0.2		0.495	
Sheep	70	0	0.3	0	0.7	0.5	0	1		0.22	0.75	0.08	1	1		0.28		0.9	0.09
Goats	70	0	0.3	0	0.7	0.5	0	1		0.22	0.75	0.08	1	1		0.28		0.9	0.09
Horses	70	0	0.3	0	0.7	0.6	0	1		0.22		2	1	1		0.35		0.9	0.35
Asses & Mules	70	0	0.3	0	0.7	0.6	0	1		0.2		2	1	1		0.35		0.9	0.35
Rabbit	0	0	1	0	0	0.6	0	1		0.27			1	1		0.09			0.35

Source: Table 3-8 EMEP/EEA Guidebook 2013

Emissions from soils

- Emissions during application of manure to soils as organic fertiliser
- Emissions from manure deposited to soils from animals in the field
- Emissions from synthetic fertiliser applied to soils
- Emissions from the N that is incorporated into the soil from crop residues

It was assumed that the farming practices in Jamaica could be represented by taking an average of the literature values relating to North America and Latin America. The total number of animals in each category was combined with the average nitrogen excretion rate between North America and Latin America (from the 2006 IPCC Guidelines). This gives the total amount of N excreted, which is one of the main input terms into the N flow. Knowledge of the animal housing and manure management/storage, then allows relevant EFs to be applied to generate emission estimates from animal housings and from manure stores, and the amount of N that remains in the system to be applied to fields as organic fertiliser.

As the methodology quantifies all of the N flow terms, it is also necessary to estimate emissions to air of NO and N2, and to include these removal terms in the overall N flow calculations. The following table presents the EFs for NO and N2 from manure storage, and N that can be lost to soils during manure storage.

Table 0.9. Emission factors NO and N2 (Fraction of TAN)

EF	Portion of TAN
NO Storage_slurry	0.0001
N2 Storage_slurry	0.003
NO Storage_solid	0.01
N2 Storage_solid	0.3
N Leachate/Unit TAN	0.12

Source: EMEP/EEA Guidebook 2013

The following table presents the emissions of N_2O calculated by livestock type from manure management.

The trend of N_2O emission from manure management shows an increase in emissions of 72.2%. As can be observed in the table above, the majority of the N_2O emissions come from broilers, and this dominates the trend as more broilers is being produced and consumed.

Table 0.10 Direct N_2O Emissions from Animal Waste Management (Gg N_2O)

	2006	2007	2008	2009	2010	2011	2012
Dairy Cattle	0.01	0.01	0.01	0.01	0.01	0.02	0.02
Other Cattle	0.06	0.07	0.06	0.06	0.06	0.05	0.07
Buffalo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Market Swine	0.41	0.46	0.42	0.39	0.36	0.32	0.29
Breeding Swine	0.02	0.03	0.02	0.02	0.02	0.02	0.02
Poultry - Chickens (Layers)	0.11	0.15	0.14	0.13	0.12	0.11	0.13
Poultry - Chickens (Broilers)	2.65	3.72	5.87	5.75	5.81	3.49	5.79
Poultry - Turkeys	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poultry -Ducks & Geese	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Sheep	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Goats	0.37	0.38	0.35	0.33	0.30	0.27	0.27
Horses	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Mules/Asses	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Rabbit	0.01	0.01	0.01	0.01	0.01	0.02	0.02
TOTAL	3.97	5.18	7.24	7.02	6.98	4.56	6.83

3B Indirect Emission from Manure Management

2.2.14.19 Methodology

There are also "indirect" emissions which arise during manure management. There are two terms, explained as follows:

- A fraction of the N species emissions during animal housing and manure storage deposit back to the surface. A fraction can then be re-emitted.
- During manure handling and storage, a fraction of the N can be lost to soil or water courses. Emissions can then arise from this N that has been "lost" from the system.

2.2.14.20 Category emissions

Indirect emissions of N_2O during manure management are presented in the table below.

Table 0.11 Indirect N_2O Emissions from Manure Management (Gg N_2O).

	2006	2007	2008	2009	2010	2011	2012
Atmospheric Deposition	2.25	3.08	4.51	4.39	4.39	2.77	4.37
Leaching/runoff	0.59	0.80	1.18	1.15	1.15	0.72	1.14
Total	2.83	3.88	5.68	5.53	5.54	3.49	5.51

3C Rice Cultivation

2.2.14.21 Methodology

CH_4 is produced from flooded rice fields where decomposition of organic matter occurs anaerobically and produces CH_4 that is transported through the rice plant. Where rice is planted in Jamaica, no organic amendments are added as indicated by RADA.

Rice cultivation is not a large enough source to be a key category, thus, the 2006 IPCC Guidelines Tier 1 methodology was used to calculate the amount of CH_4 emission from rice cultivation, using the default adjusted daily EF and the relevant scaling factors from the same Guidelines.

2.2.14.22 Category emissions

Emission estimates of CH_4 from rice production are presented in the table below. There is a general increase of approximately 6000% over the inventory period. This huge increase was driven by a crop expansion programme that the MOAF was carrying out to aid in food security by degreasing the reliance of imported rice.

Table 0.12 Emissions from rice cultivation (Gg CH_4)

	2006	2007	2008	2009	2010	2011	2012
Rice cultivation	0.0002	0.0052	0.0071	0.0088	0.0133	0.0105	0.0145

3D Emission from Managed Soils

2.2.14.23 Methodology

N_2O is emitted both directly and indirectly from soils. Direct emissions occur through the application of synthetic and organic fertiliser application, deposited manure from grazing livestock, crop residues and the application of sewage sludge. Indirect emissions are explained in the following section.

An increase in the available N enhances nitrification and de-nitrification. To assist in obtaining the emissions, using the 2006 IPCC guidelines Tier 1 method the following data was required:

- N applied to soils as synthetic fertiliser, and the subsequent N2O emission from synthetic N fertilisers (FSN) application.
- N applied to soils as organic fertiliser (that going to field from the manure stores), and the subsequent N2O emission from organic N applied as fertiliser (FON). It has been assumed that only the nitrogen collected as part of the manure management process is applied as organic fertiliser and only seventy five per cent of it is applied to the soil.
- N deposited on pasture, range and paddock by grazing animals and the subsequent emission of N2O (FPRP);
- N incorporated into the soil from crop residues, and the subsequent N2O emission from crop residues (FCR);
- N mineralisation associated with loss of soil organic matter resulting from change of land use or management of mineral soils (FSOM); and
- Drainage/management of organic soils (i.e., Histosols) (FOS).

To calculate the emissions from crop residues the annual crop production data provided by the MOAF-AMID was used and grouped into the crop type listed below. However, because of the disaggregated data obtained, crops such as vegetables that did not fit in the crop categories provided, assumptions were used to obtain the parameters required for emission calculation. See Appendix 2 for details.

It is assumed that there is no managed/drained organic soil, as all of the organic soils are located in swampy areas. In calculating the emissions from sugarcane, discussion held with the Sugar Industry Research Institute indicate that approximately 60-70% of sugarcane is burnt prior to harvest.

The N input terms were determined, and the N_2O emissions were calculated by using default EFs from the 2006 IPCC Guidelines.

2.2.14.24 Category Emissions

The table below presents the direct N_2O emissions from managed soils. No data was available for the emissions from N mineralisation associated with loss of soil organic matter, thus extrapolation of the activity data in the second national communication was used over this inventory period. However, organic nitrogen fertiliser and animal grazing were the major drivers of the amount of N_2O emitted over the inventory period; this can be associated with the high drive to increase crop production in order to reduce the fresh produce import bills, and the use of organic fertilisers as an alternative source to high cost synthetic fertiliser.

Table 0.13 Direct N_2O from managed soils (Gg N_2O)

	2006	2007	2008	2009	2010	2011	2012
Synthetic N fertiliser	0.09	0.08	0.11	0.07	0.12	0.08	0.18
Organic N fertiliser	2.76	3.77	5.49	5.34	5.34	3.38	5.31
Grazing animals	1.10	1.16	1.13	1.06	0.99	0.90	0.95
Crop residues	0.02	0.02	0.02	0.02	0.02	0.02	0.02
N mineralised from mineral soils as a result of loss of soil carbon	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Drained/managed organic soils	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Total	4.19	5.24	6.95	6.70	6.69	4.60	6.68

3D Indirect Emission from Managed Soils

2.2.14.25 Methodology

In addition to direct N_2O emissions from soils, N_2O can be emitted indirectly through volatilisation of N species and leaching/run-off:

- Volatilisation of N as NH3 and oxide of N (NOx) and then deposition of these gases and their products NH4+ and NO3- on to soils and water surfaces gives rise to further emissions.
- Leaching and run-off of N from farmed land into water courses can occur. The N in the soil comes from synthetic and organic nitrogen fertiliser application, crop residues, mineralisation of N, draining/management of organic soils, and urine and dung deposition from grazing animals. A portion of the N that is transported into the water courses can then be emitted as N_2O.

The 2006 IPCC guideline Tier 1 approach was used to obtain indirect N_2O emissions from soils, using 2006 IPCC guideline default emission factors and equations 11.9 and 11.10 for volatilisation and leaching/runoff respectively.

2.2.14.26 Category emissions

Indirect emissions of N_2O from soils are presented in the table below.

Table 0.14 Indirect Emissions from Managed Soils (Gg N_2O)

	2006	2007	2008	2009	2010	2011	2012
Atm. Deposition	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Leaching/runoff	0.97	1.28	1.80	1.74	1.74	1.13	1.74
Total	0.98	1.29	1.81	1.74	1.75	1.14	1.76

3F Biomass Burning
2.2.14.27 Methodology

Large amounts of crop residue is produce from farming activities. However, there are several methods being practiced to dispose of this crop residue in Jamaica. Some of these methods are: ploughing in soil, use in compost, used as trash barriers, animal feed and field burning.

Data was only available for sugar cane in respect to crop residue burning. Discussion with the Sugar Industry Research Institute indicates that approximately 60-70% of the total cane harvested is burn prior to harvest.

The 2006 IPCC guideline tier 1 methodology was used to obtain the emissions of CH_4 and N_2O from crop residue burning (and also emissions of indirect GHGs).

2.2.14.28 Category emissions

Emission estimates from the on-field burning of sugar cane crop residues are presented in Table 5.16.

Table 0.15. Emissions from crop burning (Gg)

	2006	2007	2008	2009	2010	2011	2012
CH_4 Emissions	0.3	0.3	0.3	0.2	0.2	0.2	0.2
N_2O Emissions	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOx Emissions	0.2	0.2	0.2	0.2	0.2	0.2	0.2
CO Emissions	8.6	8.8	8.6	7.5	7.9	8.0	8.1

3G Liming

2.2.14.29 Methodology

Lime is applied to soils in the form of limestone for soil management. However, a large amount of Jamaica's land consists of limestone; as a result the application of lime to soils is only typically done (according to MOAF-ALMD) based on detailed soil analysis. This application is used to reduce the acidity of the soil to ensure optimum plant growth. When lime is added to soils and dissolved, bicarbonate (2HCO3-) is released and evolves into the CO_2 and H2O.

The amount of limestone supplied to the fertiliser company (Fersan) was used as a basis to estimate the annual consumption over the inventory period. The 2006 IPCC Guidelines Tier 1 methodology was used to obtain the amount of CO_2 emitted from lime application. The emission factor used is 0.12 tonnes of C released per tonne of lime applied.

Discussion held with the MOAF-Agriculture Land Management Division (ALMD) indicates that little information is known as to how much lime is applied to soils in Jamaica. However information was obtain between the years 2009-2012 from the Lydford Mining Company, who supplies limestone to the fertiliser manufacturers. It is assumed that all the limestone supplied to the fertiliser manufacturers is consumed locally. The data for years 2006-2008 was extrapolated from those given in by Lydford Mining Company to give a complete time series.

The table below presents the annual application of lime to soils in Jamaica. There is a substantial increase in lime consumed between 2010 and 2012, this is assumed to be a result of the increase in the adaptation of protected agriculture practices (e.g. greenhouse technology) that require better nutrient formulation. However such a large increase across a short time period raises questions regarding the quality of the available data.

Table 0.16. Lime application to soils (Tonnes)

	2006	2007	2008	2009	2010	2011	2012
Lime application	15	18	20	23	74	1,060	790

2.2.14.30 Category Emissions

Emissions of CO_2 from the application of lime have been calculated by combining the lime consumption estimates with the Tier 1 default EF from the 2006 IPCC Guidance, and are presented in the table below.

Table 0.17. Emissions from lime application to soils (Gg CO_2)

	2006	2007	2008	2009	2010	2011	2012
Lime application	0.01	0.01	0.01	0.01	0.03	0.47	0.35

Over the inventory period there has being an increase of approximately 3400%. This increase can be assumed to be of a result from the increase in the use of greenhouse technology for crop production, which utilises a lot of special blend fertiliser containing lime, and as a result of more detailed soil analysis and amendment is being done. But until this can be confirmed with certainty, questions regarding the accuracy of the lime consumption data will remain.

3H Urea Application

2.2.14.31 Methodology

Urea fertiliser is widely used throughout Jamaica on farmed lands. When urea is added to soils the fixed CO_2 is lost as it is converted ammonium (NH4+), Hydroxyl ion (OH-), and bicarbonate (HCO3-) by the urease enzymes and water.

A Tier 1 methodology was used that combines the assumed urea consumption across the time series

With the 2006 IPCC Guidance default EF of 0.2 tonne of C per tonnes of urea applied.

2.2.14.32 Category Emissions

Emission estimates of CO_2 from urea application are presented in the table below.

Table 0.18. Emissions from urea application to soils (Gg CO_2)

	2006	2007	2008	2009	2010	2011	2012
Urea Fertiliser Application	1.06	2.09	1.60	0.73	1.07	0.84	2.15

Over the inventory period an increase of just over 100% was observed due to the increase in fertiliser used and crop production.

2.2.14.33 Indirect GHG Emissions: NOx and NMVOC

2.2.14.34 Methodology

NMVOC and NO are indirect GHGs that contribute to the formation of ozone (a GHG). Emission of these gases arises from livestock excreta in and around buildings and agriculture waste management systems. NO is formed in manure aerated to reduce odour or used in composting, and from the surface of stored manure. In addition, nitrification of manure in soils will lead to emissions of NO from soils. So emissions arise under both 3B Manure Management and 3D Agricultural Soils.

NMVOC is produced in the rumen of animals which is release through exhalation or flatus. Emission also takes place from manure managed as solid or slurry form, and from feed storage in silage.

The 2013 EMEP/EEA Guidebook was used to estimate the emissions. The tier 1 approach was used to estimate NMVOC emissions from housing, manure storage and application, and from soils. A tier 2 approach was used to estimate NMVOC from animal grazing. A tier 1 methodology was used to estimate emissions of NO. CO was estimated from field burning using the 2006 IPCC Guidance.

2.2.14.35 Category Emissions

Emission estimates of indirect GHGs from manure management and agricultural soils are presented in the table below.

Table 0.19. Indirect GHG emissions of NMVOC and NOx (Gg NMVOC, Gg NO2)

		2006	2007	2008	2009	2010	2011	2012
Cultivated Soils	NMVOC Emissions	0.06	0.06	0.06	0.06	0.06	0.06	0.07
Livestock Manure Management	NMVOC Emissions	1.01	1.28	1.68	1.63	1.61	1.13	1.61
NO from Managed Soils	NOx Emissions	5.62	7.33	10.18	9.82	9.85	6.47	9.87

2.2.14.36 Sectoral Uncertainty Analysis

3A Enteric Fermentation (CH_4) - The uncertainty associated with the emission factor for enteric fermentation is 30-50%. With respect to activity data, because of the mixture of data source, the estimated uncertainty was assumed to be 10-20%.

3B Manure Management (CH_4) - Due to the fact that the 2006 IPCC Guidelines Tier 1 approach was used because of lack of data to apply higher tier, the uncertainty associated with the emission factor is +/-30% as given in the 2006 IPCC Guidance. Also because of the varying data source for activity data (population count and manure management system), an uncertainty of 10-20% was estimated – taking into account the fact that the data was compiled from national sources.

3C Rice Cultivation (CH_4) - The uncertainty associated with the emission factor used is 0.8-2.2 and that associated with the activity data is assumed to be 10-20%, based on the fact that that most data was from national sources.

3G Lime Application and 3H Urea Application (CO_2) - The uncertainty associated with the emission factor used for both urea and lime is +/-50%, while that associated with the activity data is assumed to be 5%.

3B Manure Management (N_2O) - The uncertainty associated with the N excretion rates is +/-50% as the 2006 IPCC default factors were used. The uncertainty associated with the default emission factor for direct emission is -50% to 100%. Activity data uncertainty ranges from 5-10%. The uncertainty relating to the use of manure management system is assumed to be 10-20% as this is primarily based on expert judgement, rather than robust data.

3D Managed Soils (Direct N2O) - The uncertainty estimate associated with the emission factor used is 0.003-0.03. The uncertainty estimate for the activity data used is assumed to be 5% since data was obtain from local sources.

3D Managed Soils (Indirect N2O) - Like that for direct N emission from soils, the uncertainty associated with the activity data used is estimated at 5%. The uncertainty estimate for the fraction of N volatilization is 0.002-0.05. The uncertainty of the fraction of N leached is 0.1-0.8 while the uncertainty of the emission factor for N leached/runoff from managed soils is 0.0005-0.025.

3F Crop Residue Burning - The uncertainty associated with the emission factors used are: for CO - +/-84, and for NOx +/-1. The uncertainty associated with the activity data used is assumed to be 10%.

Indirect GHGs - The uncertainty associated with the emission factor used is considered to be highly uncertain, as little study has been done on the emissions of NMVOC and NOx. However, with uncertainty associated with the activity data is assumed to have a 10-20% uncertainty.

The 2006 IPCC Guidance was used to quantify the uncertainty of the complete emissions inventory, and results are presented in Section 9.

2.2.14.37 Quality Assurance and Quality Control

The general inventory quality control procedures as guided by the 2006 IPCC Guideline Table 6.1 were undertaken. Comparisons between the National crop production and livestock data and FAOSTAT data were undertaken. Also specific livestock data were compared with category specific surveys, for example the 2012 pig farmer's survey was compared with the slaughter data provided by the MOAF.

At all stages of the data handling a transparent system was used, and quality checks were incorporated at every stage to eliminate errors to the extent possible.

The emission estimates ere independently checked in detail. Several points were identified and discussed prior to finalising the data, as presented in this report.

The overall quality of emissions estimated in this inventory report is considered to be good.

2.2.14.38 Recommendations for Improvements

To ensure improvement for future inventories, the following suggestions are made:

- Livestock population data need to be improved, and in particular more complete and consistent data are required across the time series. The MOAF need to capture the data in a similar manner to which the crop production data is being collected i.e. complete and consistent. This will facilitate much easier data analysis and collection, thus making the process of calculating the emissions more efficient, and the data will be of considerably improved quality.
- A central data collection hub could be created to collect all the activity data needed for each year. This will be considered in more detail as part of the work being undertaken on the "national system".
- Scholarship opportunities can be put in place for university students to conduct local studies to obtain country specific emission factors. This will lead to a more accurate and detailed emissions inventory, as it would be possible to use methodologies from higher Tiers for most categories.
- An Excel file has been developed for this emissions inventory. Continued use and development of this in future versions of the inventory will lead to a faster turnaround time for the inventory reports.
- Future studies are needed that look at how to estimate emissions from liquid waste used as fertiliser (e.g. from sugar factory dunder and sewage effiuent). This is not included in the current version of the inventory because there is a lack of data. This will need specific EFs and measurements, such as percentage N involved.

2.2.15 LULUCF

2.2.15.1 Description of the Sector

There are six main land-use categories used in the IPCC Guidance:

Forest Land (FL)
Cropland (CL)
Grassland (GL)
Wetlands (WL)
Settlements (SL)
Other Land (OL)

To quantify the net emissions or update of CO_2 from land-use change, it is necessary to evaluate the area of land that remains in the same class, and that converted to/from different combinations of land cover types. A complete matrix therefore needs to be compiled that represents all of the different possible combinations of land use change (including land that remains in the same use category).

Once this matrix and land use changes has been established, the changes in the carbon pools in each can be determined, resulting in emissions and/or sinks.

In Jamaica, forestland accounts for more land cover area than any other class (nearly half of the total land cover in 2012), and grassland is the second largest component (accounting for more than a third of the total in 2012).

Data on the land use change is only available for selected years, and it has therefore been necessary to conduct interpolation, the result being that the year to year land use change is constant for combinations of land use in most years of the time series. The land uses changes are small compared to the totals, and the largest component of the emission arises not from a change in the forested area, but changes in the way that the forest land is managed. The increase in the biomass held in the forest land cover gives rise to a substantial CO_2 sink.

This source is somewhat offset by net emissions from grasslands, but this emissions term is an order of magnitude smaller than the forestland sink.

The source and sink terms show little variation across the time series, but this is a reflection of the limitations of the available input datasets, rather than representing accurate year to year variations.

2.2.15.2 Areas of Land Cover Types

A systematic data gathering process, started in the year 2000 after a critical analysis of the existing land use/cover and land classification systems in Jamaica, was done by the Forestry Department (Camirand and Evelyn, 2003). This analysis determined that none of the systems that had been developed had the characteristics or capability of classifying forests for forest management, conservation or the evaluation for forest development in the island. A standardised broad classification system was therefore developed for use with satellite imagery and aerial photograph interpretation. An aerial photo interpretation manual was also prepared which provides guidelines for interpretation of the various land use types on aerial photographs (Forestry Department, 2002) and by extension, satellite imagery.

Evelyn and Camirand (2003) used this classification system for reporting, among other things, details of deforestation and land use/cover changes in Jamaica between 1989 and 1998. They reported that the annual rate of loss in forest cover during that period was 0.1%. A land use conversion matrix showing the area changes from one land use/cover to another during that period was also reported (see Table 3). The IPCC land-use categories are not dissimilar to Jamaica's national land use classes. For the National Forest Inventory Report 2003 (Camirand and Evelyn, 2004), the island's land uses were determined using 1992 colour aerial photographs following the procedures outlined in the Forestry Department Aerial Interpretation Manual (Forestry Department, 2002). The "Forest" and the "Mixed" Land/Use Cover classes were then aggregated to ten (10) broad categories (compare Table 4 in Camirand and Evelyn, 2004 and Table 6.1 below). These categories can be aligned to the six key IPCC GHG land-use categories, as shown in Table 6.1.

The area of Forest land and Cropland for the year 2005 as reported in Jamaica's second National Greenhouse Gas (GHG) emissions by sources and removal by sinks inventory (Davis et al., 2008) was 498, 834 hectares and 84,880 hectares respectively. However, after a review, errors were found in the calculations of both of these figures. Therefore, the figures had to be adjusted to 499,604 hectares and 81,715 hectares respectively. These are the benchmark figures on which the 2006-2012 GHG Inventory are built.

All of the forested lands in Jamaica can be classified as managed forests. This is so because anthropogenic activities such as extraction of wood and non-wood forest products are continuously taking place in almost all the forests. About 34% of this forest area has been designated as Forest Reserves and other protected areas and are under continuous management as stipulated by the Forest Act, 1996 (Section 8, 1) and the Natural Resources Conservation Authority Act, 1991.

It is to be noted that the area of Forest Land on the island being reported in Table 2 will differ from those reported elsewhere. This is because of the low resolution of the LandsatTM imagery that was used for the 1998 land use/Cover study which did not allow for separation of the forested areas in the "mixed" categories. Estimates of these mixed forest areas were done for the 2000-2005 GHG Inventory (Davis et al., 2008) and are again being estimated for this compilation because they represent a significant amount of carbon.

A spatially explicit land use conversion matrix for land use change in Jamaica was reported in Evelyn and Camirand, 2003. A modified version of this matrix is reproduced in the table below.

Table 0.1 Areas of Each IPCC Category (hectares)

GHG Inventory Classes	2006	2007	2008	2009	2010	2011	2012
FL remaining FL (FF)	496,949	496,330	495,711	495,212	494,713	494,214	493,715
Land converted to FL (LF)	2,156	2,275	2,395	2,395	2,395	2,395	2,395
CL remaining CL (CC)	81,611	81,522	81,433	81,343	81,254	81,164	81,075
Land converted to CL (LC)	14	14	14	14	14	14	14
GL remaining GL (GG)	368,905	368,966	369,027	369,089	369,150	369,211	369,273
Land converted to GL (LG)	479	479	479	479	479	479	479
WL remaining WL (WW)	12,433	12,425	12,417	12,409	12,401	12,394	12,386
Land converted to WL (LW)	5	5	5	5	5	5	5
SL remaining SL (SS)	52,534	52,573	52,612	52,651	52,690	52,729	52,768
Land converted to SL (LS)	39	39	39	39	39	39	39
OL remaining OL (OO)	80,706	81,202	81,697	82,193	82,689	83,185	83,681
Land converted to OL (LO)	585	585	585	585	585	585	585
TOTAL	1,096,416	1,096,416	1,096,416	1,096,416	1,096,416	1,096,416	1,096,416

A detailed explanation on the areas is presented in Annex 3.

4A Forest Land

The methodology in IPCC 2006 has been followed for the estimates of FL remaining FL and Land converted to FL.

2.2.15.3 Methodology

For the calculation of estimates for Forest Land Remaining Forest Land (FF) and Land Converted to Forest Land (LF), the 2006 IPCC Guidelines for GHG Inventories advise that calculations should distinguish between intensive and extensive forestry practices. This distinction is evident in the Jamaican National Classes. The two forest plantation categories, Caribbean Pine and Other Species, fit the former management practice while all the other categories fit the latter.

For estimating the annual increase in carbon stocks due to biomass increment in land remaining in the same land-use category, Equation 2.9 and 2.10 from Volume 4: Chapter 2 of the 2006 IPCC Guidelines have been used.

2.2.15.4 Activity Data

Country specific data for mean annual increments are reported in Thompson et al. (1986) for Caribbean Pine, also an estimate of average annual above-ground biomass growth for one of the IPCC climatic zones, sub-category Tropical mountain system, is documented in Camirand and Evelyn (2004). However, for the calculation of the estimated annual increase in biomass carbon stocks due to biomass growth and loss of Forest Land, the IPCC default tier 1 figures were used because the country specific figures are no longer considered valid (there have been changes in the Caribbean Pine structure after several hurricanes hit the island after 1986).

Details of the calculations of annual increase in biomass carbon stocks due to biomass growth for Forest Land Remaining Forest Land (FF) and Land Converted to Forest Land (LF) by reporting years are shown in Appendix 3, using the IPCC Category Tables 3B1a and 3B1b. The area used in these estimates are outlined in the table below.

Table 13. Areas used for the calculation in 3B1a: Annual increase in carbon stocks in biomass

Land-use category		Subcategories for reporting year	Area of Forest Land Remaining Forest Land (ha)						
			Year						
Initial land use	Land use during reporting year		2006	2007	2008	2009	2010	2011	2012
FL	FL	Tropical rain forest - natural forest	74343	74265	74186	74118	74049	73980	73912
		Tropical rain forest - other species plantations	1003	1003	1003	1003	1003	1003	1003
		Tropical rain forest - pine plantations	3124	3061	2998	2936	2873	2810	2747
		Tropical moist deciduous forest	79108	79006	78904	78820	78736	78653	78569
		Tropical moist deciduous forest-other species plantations	1114	1114	1114	1114	1114	1114	1114
		Tropical moist deciduous forest - pine plantations	189	186	182	178	174	170	166
		Tropical dry forest	198552	198323	198095	197930	197765	197600	197435
		Tropical mountain systems	137355	137219	137083	136976	136868	136761	136653
		Tropical mountain systems - other species plantations	1783	1783	1783	1783	1783	1783	1783
		Tropical mountain systems - pine plantations	379	371	363	356	348	341	333
Total			**496949**	**496330**	**495711**	**495212**	**494713**	**494214**	**493715**

2.2.15.5 Parameters and Emission Factors

The following tables present the values used for the estimates of biomass changes in FL remaining FL and Land converted to FL (LF).

Table 0.3 Biomass Growth Parameters - Forestland

	Average annual above-ground biomass growth G_W	Ratio of below-ground biomass to above-ground biomass R
Tropical rain forest - natural forest	3.10	0.37
Tropical rain forest - other species plantations	15.00	0.37
Tropical rain forest - pine plantations	15.00	0.23
Tropical moist deciduous forest	2.00	0.24
Tropical moist deciduous forest- other species plantations	10.00	0.24
Tropical moist deciduous forest - pine plantations	10.00	0.23
Tropical dry forest	1.00	0.28
Tropical mountain systems	0.90	0.27
Tropical mountain systems - other species plantations	5.00	0.27
Tropical mountain systems - pine plantations	5.00	0.27

2.2.15.6 Category Emissions

The following table presents the CO_2 emissions and uptake from forestland.

Table 0.4 CO_2 Emissions from Forestland Remaining Forestland and Land Converted to Forestland (Gg CO_2)

	2006	2007	2008	2009	2010	2011	2012
FF	-1833.57	-1786.12	-1778.56	-1769.65	-1767.04	-1766.33	-1776.97
Increase in Biomass	-1777.08	-1773.14	-1769.19	-1765.59	-1761.99	-1758.39	-1754.79
Loss of carbon from wood removals	-17.08	-3.80	-2.80	-1.24	-0.97	-1.85	-5.03
Loss of carbon from fuelwood removals	-39.41	-9.19	-6.57	-2.83	-4.08	-6.09	-17.15
LF	-29.57	-31.21	-32.86	-32.86	-32.86	-32.86	-32.86
Increase in Biomass	-28.91	-30.51	-32.12	-32.12	-32.12	-32.12	-32.12
Loss of carbon from wood removals	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Loss of carbon from fuelwood removals	-0.66	-0.70	-0.74	-0.74	-0.74	-0.74	-0.74

4B Cropland

2.2.15.7 Methodology and Activity Data

Only the accounting for carbon stored or lost in the biomass of croplands that contain perennial woody vegetation is required by the IPCC guidelines. It is assumed that "for annual crops, increase in biomass stocks in a single year is equal to biomass losses from harvest and mortality in that same year thus, there is no net accumulation of biomass carbon stocks".

For Cropland remaining Cropland, the IPCC Guidelines advised that one of two approaches can be used in estimating the changes in carbon in cropland biomass. The first is by estimating the annual rates of biomass gain and loss (default tier 1 methodology). The second is by estimating the carbon stocks at two points in time (tier 2 or higher methodology).

If the area of perennial crops that was lost (harvested) in the inventory year equals the mean harvested area over the entire harvest cycle of the perennial crop, the annual change in carbon stocks in biomass can be taken to be zero. It is assumed that this is the case in Jamaica.

The biomass stocks before the conversion into cropland is 8.7 for grassland (table 6.4 of the 2006 IPCC Guidance) and 0 for wetland.

Table 0.5. Area of land converted to CL from GL and WL (Hectares)

Land use change	Annual area of Land Converted to Cropland
Total	14.0
GL to CL	13.67
WL to CL	0.33

2.2.15.8 Category Emissions

The following table presents the CO_2 emissions and uptake from cropland.

Table 0.6 CO_2 Emissions from Cropland Remaining Cropland and Land Converted to Cropland (Gg CO_2)

	2006	2007	2008	2009	2010	2011	2012
CC	NE	NE	NE	NE	NE	NE	NE
LC	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Annual change in carbon stocks in biomass	0.03	0.03	0.03	0.03	0.03	0.03	0.03

4C Grassland

2.2.15.9 Methodology and Activity Data

Only emissions/removals from land converted to grassland have been estimated, due to the lack of parameters needed for the estimates of changes in the different carbon pools for grassland that remains grassland.

For land converted to grassland, the biomass after the conversion is assumed to be 0 and no biomass accumulation is considered in grassland. The biomass in the cropland before the conversion is 3.6 tonnes dm ha^{-1}, considering an annual biomass accumulation rate of 1.8 tonnes C ha^{-1} (table 5.1 of the 2006 IPCC Guidance).

Table 0.7 Area of Land Converted to GL from CL and FL (Hectares)

Land use Change	Annual area of Land Converted to Grassland
Total	479.5
CL to GL	73.0
FL to GL	338.1
WL to GL	4.0
SL to GL	0.07
OL to GL	64.3

2.2.15.10 Category Emissions

The following table presents the CO_2 emissions and uptake from grassland.

Table 0.8 CO_2 Emissions from Grassland Remaining Grassland, Land Converted to Grassland (Gg CO_2)

	2006	2007	2008	2009	2010	2011	2012
GG	NE	NE	NE	NE	NE	NE	NE
LG	115.77	115.77	115.77	115.77	115.77	115.77	115.77
Annual change in carbon stocks in biomass	113.17	113.17	113.17	113.17	113.17	113.17	113.17
Annual change in carbon stocks in dead organic matter	2.60	2.60	2.60	2.60	2.60	2.60	2.60

4D Wetland

In Jamaica, no peatland is managed for peat extraction and there is no air-dry weight of extracted peatland. In addition, the available data do not indicate a conversion of other land uses to wetland. Therefore, no emissions in wetland have been estimated.

4E Settlements

2.2.15.11 Methodology and Activity Data

The Tier 1 approach in 2006 IPCC Guidelines has been followed for the estimates in the settlements category. It is assumed that there is no change in the carbon biomass in settlements remaining settlements, so the estimated emissions corresponds to lands converted to settlements.

The changes to settlements are take place in the zone Tropical dry forest, so the biomass in the land uses before the conversion is 8.7 and 110.4 tonnes dry matter for grassland and forestland respectively (table 6.4 of the 2006 IPCC Guidelines and country specific data). The biomass in the settlement after the conversion is assumed to be 0.

Table 0.9 Area of Land Converted to SL (Hectares)

Land use change	Annual area of Land Converted to settlements
total	39.2
FL to SL	28.9
GL to SL	9.0
OL to SL	1.3

2.2.15.12 Category Emissions

The following table presents the CO_2 emissions and uptake from settlements.

Table 0.10 CO_2 emissions Settlements Remaining Settlements and Land Converted to Settlements (Gg CO_2)

	2006	2007	2008	2009	2010	2011	2012
SS	NE	NE	NE	NE	NE	NE	NE
LS	5.87	5.87	5.87	5.87	5.87	5.87	5.87
Annual change in carbon stocks in biomass	5.64	5.64	5.64	5.64	5.64	5.64	5.64
Annual change in carbon stocks in dead organic matter	0.22	0.22	0.22	0.22	0.22	0.22	0.22

4F Other Land Cover

2.2.15.13 Methodology and Activity Data

In line with IPCC2006 Guidelines, no change of carbon stock has been estimated in Other Lands remaining Other lands. Therefore, emissions reported corresponds to the conversion of Other Land uses to Other land.

For the estimates of lands converted to Other land it is assumed that the biomass in Other land is 0 and all the biomass is lost in the year of transition, being the biomass of forestland 110.37 tonnes dry matter ha^{-1}, corresponding to tropical dry forest.

Table 0.11. Area of Land Converted to Other land (Hectares)

Land use change	Annual area of Land Converted to Other land
Total	585.4
FL to OL	251.9
GL to OL	332.2
WL to OL	1.2
SL to OL	0.02

2.2.15.14 Category Emissions

Table 0.12 CO_2 emissions from Other Land Remaining Other Land and Land Converted to Other Land (Gg CO_2)

	2006	2007	2008	2009	2010	2011	2012
OO	NE	NE	NE	NE	NE	NE	NE
LO	56.27	56.27	56.27	56.27	56.27	56.27	56.27
Annual change in carbon stocks in biomass	56.27	56.27	56.27	56.27	56.27	56.27	56.27

2.2.15.15 Sectoral Uncertainties

The uncertainty of the parameters that equate to an EF for this source has been based on expert judgement, and estimated to be 30%. In future, a propagation of errors calculation could be undertaken to determine this with more accuracy. However, extensive use of expert judgement would still be required.

The activity data for the emission estimates is the area of each category for lands remaining the same land use and the area of conversion to other land uses. The value of the uncertainty of the areas in line with the recommendation of IPCC2006 GLs (table 3.7, approach 2). Taking into account that the value for areas converted to other areas is maintained constant since the analysis of land use changes for the period 1989-1998, the value of the uncertainty could be higher than the current estimate of 20%.

An uncertainty assessment for all sources of the emissions inventory is presented in Section 9.

2.2.15.16 Quality Assurance and Quality Control

There are a number of sector specific QA/QC procedures that have been undertaken as part of the emissions inventory compilation:

- Handling activity data: At all stages of the compilation, a programme of QC checks have been included that are specific to the way the activity data are handled in the emissions inventory. The matrix of land use area data and changes between the different land use types is relatively easy to check, as the change to the total land area is zero.
- Assumptions: It has been necessary to use assumptions in estimating emissions from a number of different sources. Local knowledge and expertise has been used to the extent possible.
- Updated Dataset: The data used was rather outdated, but an updated dataset was considered to be unreliable. However, it was used to verify general trends in the original dataset.

The emissions estimates as originally compiled were independently reviewed. This identified a number of calculation errors, and assumptions that required correction. These were addressed before data were finalised and included in this report.

2.2.15.17 Recommendations for Improvement

The quality of the activity data, in most cases, is a mix of tier 1 and tier 2, and quality can be variable. For example, the land use dataset used is country-specific and could be regarded as tier 2, however it is rather outdated. There was an updated dataset available but it was determined to be unreliable after a review was undertaken. It was only used to verify that some of the trends which were evident in the old dataset were continuing.

Regarding the EFs (or more specifically, the underlying parameters used in the calculations), there were no country specific values available. Therefore, the default tier 1 values from the IPCC Guidelines were used.

Two aspects of the forestry sector which should be a priority for improvement are the land use and the biomass components. The land use change analysis for 1998-2013 which the Forestry Department attempted can decrease the uncertainty in the inventory if it is reviewed properly and the issues pointed out in this report addressed and corrected. Also, the system of permanent sample plots (PSPs) which the Trees for Tomorrow project started to establish in the forest land use classes should by now be providing important data on the biomass, especially the above ground biomass. Improvement in these components might reduce the uncertainty in these datasets to below 5%.

Information on the wood conversion (removals for various purposes e.g. fuel wood, timber, agricultural purposes) on privately owned lands was also lacking. As was pointed out in the 2000-2005 GHG inventory, the design of suitable and viable solutions to obtain such data is challenging, but options that should be considered include legislation and well designed, periodic surveys.

Collecting high quality input datasets was a challenge for this sector. Acquiring the needed datasets from the responsible agencies was rather time consuming. This led to delays and inconveniences which could, and should, be avoided in the future. Before the next inventory, it is recommended that a clear timetable to facilitate periodic data collection as well as an efficient delivery system be put in place so that delays can be minimised.

2.2.16 Waste

2.2.16.1 Description of the Sector

Waste management in Jamaica is currently a politically sensitive topic. There are general calls to improve the current solid waste management infrastructure, and recent landfill fires have given profile to some of the existing challenges associated with management of municipal solid waste (MWS).

Some waste material is sent to anaerobic digestion, but the vast majority is sent to landfill. There is increasing pressure on this waste management route due to predicted population growth, and increases in the waste generated per capita.

Emission estimates have been made for all of the known waste management routes:

- Solid waste disposal of MSW land, i.e. landfill and subsequent emissions from the anaerobic breakdown of the waste.
- Industrial waste: Some waste is sent to landfill, but much of the waste generated is inert material.
- Biological treatment of solid waste: Some waste is sent to anaerobic digestion.
- Incineration: An incinerator at the hospital is used to dispose of medical and some industrial waste.
- Open burning of waste: This occurs at the landfill as well as in back yards.
- Domestic and industrial wastewater: Emissions were calculated from the treatment plant.

Each waste stream is considered in detail in the following sections.

2.2.16.2 Solid Waste Disposal

2.2.16.3 Methodology

A Tier 2 methodology was used to calculate the CH_4 emissions from solid waste disposal sites in Jamaica. The default values were taken from the "Parameters" spreadsheet provided in the IPCC Spreadsheet for Estimating Methane Emissions from Solid Waste Disposal Sites (IPCC Waste Model) and country specific activity data on current and historical solid waste disposal were utilised in the other tables.

2.2.16.4 Activity Data

2.2.16.5 Population Data

Population data was obtained from STATIN website. Exact values were provided for the years 2006 to 2012.

2.2.16.6 Waste Generation Rate

Jamaica's per capita generation rate for Municipal Solid Waste (MSW) for the each year within the period 2006-2012 was estimated 1kg/capita/day. This is based on information provided by the National Solid Waste Management Authority (NSWMA).

2.2.16.7 Percentage of MSW to Solid Waste Disposal Sites (SWDS)

The fraction of municipal solid waste disposed to SWDS was estimated to be 75% according to the NSWMA. This percentage was used for all the years.

2.2.16.8 Quantity of Waste

The NSWMA has demarcated Jamaica into four regions known as wastesheds: The Riverton, Retirement, West Kirkvine (Southern) and North-eastern wastesheds. Data on the quantity of waste disposed of at the four wastesheds were provided by the NSWMA.

The quantity of waste disposed at all the SWDS was available for all the years except 2006 and 2012 for Riverton (the quantity of waste for 2006 was interpolated using the amount reported in 2005, collected from the previous inventory, and that of 2007. In addition, an average of 2011 and 2013 data was used for the year 2012 for the Riverton disposal site. The Church Corner waste disposal site situated in St. Thomas had its waste recorded in Riverton's data and as such it was assumed that 5% of Riverton's waste represents Church Corner. This assumption was made based on the ratio of the quantity of waste disposed at Riverton to that disposed at Church Corner; obtained from data in the 2000-2005 inventory.

The percentage of waste going to each SWDS was then calculated for 2006-2012. The average percentages were then calculated to be 58%, 23%, 8% and 11% for Riverton, Retirement, North-eastern and West Kirkvine respectively.

2.2.16.9 Composition of MSW Disposed to SWDS

The 2010 State of the Environment Report (SOE) and the NSWMA provided data on the composition of waste going to SWDS based on waste characterisation studies that were done at the four wastesheds.

The waste streams for plastics, metal/tin, glass, e-waste, hazardous waste and other were combined into the fraction "plastics and other inert materials." The cardboard waste stream was combined into the "paper" waste composition category.

Riverton Disposal Site

The composition of solid waste disposed to the Riverton disposal site for 2006 was provided in the 2010 SOE report while the NSWMA only provided Riverton's waste composition for 2013. As a result, for the period 2007-2012 the data was interpolated.

Retirement, West Kirkvine (Southern) and North-Eastern Wastesheds

The composition of the waste at each of these sites was provided by the NSWMA for the year 2009. No composition data was available for the rest of the years. As such, the composition data for 2006-2008 and 2010-2012 was assumed the same as that of 2009 for each of these wastesheds.

The weighted average composition data was then calculated using the average percentage of waste going to each site and their composition data.

2.2.16.10 Methane Correction Factor (MCF)

The NSWMA provided descriptions of the solid waste disposal sites that are currently in operation. This allowed for the categorisation of the waste management sites into managed, unmanaged deep, unmanaged shallow, managed semi-aerobic and uncategorised. The percentage of waste going to each category was calculated for 2006-2012 using the data provided by the NSWMA.

The MCF default values for each category were used from Table 3.1 of the 2006 IPCC Guidelines for National Gas Inventories: Chapter 3, Volume 5. This, along with the percentage of waste going to each waste site allowed for the calculation of the weighted average MCF for MSW.

2.2.16.11 Industrial Waste Disposal Sites

No data on the quantity of industrial waste disposed to the four municipal SWDS was provided by the NSWMA. In order to determine the emissions from the most established industrial waste landfills, data was collected from the Jamaica Bauxite Institute (JBI).

There are five bauxite /alumina plants in Jamaica: Noranda (bauxite mining only), Jamalco, Windalco Kirkvine, Windalco Ewarton and Alpart. The JBI provided data on the quantity of waste disposed to the industrial waste disposal sites used by the bauxite alumina plants for Windalco Kirkvine, Windalco Ewarton and Alpart. The data reflects that Windalco Kirkvine Works has not been in operation since 2009 and the operations at Alpart were significantly scaled back due to its closure, except for maintenance works since 2009.

Table 0.1. Bauxite Industry Waste (Tonnes)

Site	Type of Waste	2006	2007	2008	2009	2010	2011	2012
Alpart	Alpart Dump	63,294	70,138	82,646	18,587.3	7,664.5	5,374.85	1,059.94
Windalco Kirkvine works	Industrial Alkaline Waste	50,638	52,383	54,110	0	0	0	0
Windalco Ewarton Works	Industrial Alkaline Waste	49,845	33,932	43,945	50,109	39,566	51,117	27,679

The industrial waste deposited to landfills comprises of boiler scales, filter press cloth and other waste material from the bauxite alumina plants. It was assumed that 50% of the waste will degrade under anaerobic conditions resulting in methane emissions. Whilst this is relatively high in uncertainty, it represents the best expert judgement available at the time. It was also assumed that 100% industrial waste goes to the disposal sites.

Other industrial waste generated by bauxite alumina plants which are landfilled are red mud tailings and calcium oxalate. These were not included in the inventory as they do not comprise a biodegradable form of waste which releases greenhouse gases; in fact they function as carbon sinks, and are considered in Section 7.2.5 below.

2.2.16.12 Emission Factors

Default values were used from the “Parameters” spreadsheet provided in the IPCC FOD Model Spreadsheet under the category “waste by composition” for Degradable Organic Carbon (DOC), Fraction of Degradable Organic Carbon (DOC_f) and Fraction of CH_4 in generated landfill gas (F).

2.2.16.13 Category Emissions

CH_4 emissions from domestic and industrial solid waste disposal facilities were estimated as shown in the table below for the years 2006-2012.

Year	CH_4 (Gg)
2006	19.04
2007	19.64
2008	20.11
2009	21.71
2010	22.30
2011	22.29
2012	22.05

The results show that the emissions slightly increased from 2006 to 2010 but started to decrease thereafter reflecting the effects of the shutdown of the bauxite plants in 2009.

2.2.16.14 Red Mud as a Carbon Sink

Red mud, the industrial waste resulting from the extraction of alumina from the Bayer process is mineral waste containing iron in the form of hematite (Fe2O3), left-over aluminium oxide ($Al2O_3$), silica (SiO_2), some titanium dioxide (TiO_2), and other residual minerals.

The red mud will absorb atmospheric CO_2 to produce HCO_3^- in an alkaline environment and HCO_3^- will continue to produce CO_3^{2-} ions under alkaline conditions. Eventually, products like Na_2CO_3, $CaCO_3$ will be produced and so the red mud disposal sites are considered to be carbon sinks. Oxalate is also considered as a reliable sink for atmospheric CO_2 through calcium carbonate bio-mineralisation in ferralitic tropical soils.

There is no IPCC guidance or methodology on estimating the CO_2 uptake from red muds, but it was possible to make a quantifiable approximation using first principles and material from the literature. Bonenfant et al (2008) concluded that red mud adsorbs CO_2 from the air at a rate of 41.5 g CO_2/kg of red mud. This suggest that the CO_2 uptake in Jamaica is the order of approximately 20 Gg CO_2 in 2012.

This equates to approximately 0.1% of the total GHG emissions. The estimate is high in uncertainty, and considering the very small contribution to the CO_2 emissions inventory overall, it was decided not to include this sink in the emissions inventory at this time.

2.2.16.15 Biological Treatment of Solid Waste

2.2.16.16 Methodology

Tier 1 methodology was used to determine the CH_4 emissions from anaerobic digestion in biogas facilities. This means that a default emission factor (on a dry weight basis) was used from the 2006 IPCC Guidelines for National GHG Inventories: Volume 5 together with national data on the amount of CH_4 generated from bio-digesters.

2.2.16.17 Activity Data

2.2.16.18 CH4 Gas Flow Rate

Data for the methane gas flow rate (m^3/day) was provided by the Scientific Research Council (SRC) for the years 2000 to 2005 and recorded in the report "Estimated Greenhouse Gas Emissions from Waste Facilities" dated January 2008. Using the density of methane (0.717 kg/m^3) the methane generation rate was found (g/yr) then used to calculate the methane emissions for 2000-2005. For 2006-2012, data on the gas flow rate of bio-digesters was unavailable. Therefore, the methane emissions for 2006-2012 were extrapolated using the data from the previous inventory.

2.2.16.19 Default Value

Information from the Scientific Research Council indicated that about 75 % of methane generated from all biologically treated solid waste was used and the remainder was burnt off/flared. However, Chapter 4, Section 4.1 of the 2006 IPCC Guidelines for National GHG Inventories: Volume 5 suggests that unintentional leakages during process disturbances and other unexpected events during anaerobic digestion of organic waste should be accounted for by reducing the quantity of CH_4 generated by the bio-digesters by between 0 and 10 per cent. It was therefore assumed in this case that the leakages would be minimal and a value of 5 per cent was used.

2.2.16.20 Emission Factors

The emission factor (g CH_4/kg waste treated) for anaerobic digestion at biogas facilities on a dry weight basis used for the calculation of the methane emissions was taken from Table 4.1 in the 2006 IPCC Guidelines for National GHG Inventories: Volume 5. In addition, Table 4.1 indicates that the EF for N_2O from anaerobic digestion should be assumed to be negligible.

2.2.16.21 Category Emissions

The estimated CH_4 and N_2O emissions from bio-digesters for the years 2006-2012 are negligible as shown in the following table.

Table 0.3. Estimated Methane and Nitrous Oxide Emissions from Bio-digesters (Gg)

Year	CH_4 (Gg)	N_2O (Gg)[1]
2006	3.62E-05	NE
2007	3.85E-05	NE
2008	4.09E-05	NE
2009	4.32E-05	NE
2010	4.55E-05	NE
2011	4.79E-05	NE
2012	5.02E-05	NE

[1]NE: emissions of N_2O are considered to be negligible, so no estimate is presented.

2.2.16.22 Waste Incineration – Medical and Industrial Waste

2.2.16.23 Methodology

Tier 1 methodology was used to estimate CH_4 and N_2O emissions as well as indirect greenhouse gas emissions (NOx, SO_2, CO and NMVOC). Data on the quantity of waste incinerated were estimated in the case of medical waste and were based on data provided by some industries with incinerators for the period under review.

2.2.16.24 Activity Data

2.2.16.25 Quantity of Medical Waste Incinerated

There is very little documentation on the quantity of waste that is generated and incinerated by both public and private healthcare facilities. To determine the quantity of waste incinerated, data on the medical waste generation rate (kg/bed/day) and the number of beds in the hospitals categorised by region were collected. Hospitals are categorised into four regions as follows:

Table 0.4 Regional Categorisation of Hospitals

Region	Hospitals
North East Regional Hospitals	St. Ann's Bay, Annotto Bay, Port Antonio, Port Maria
South East Regional Hospitals	Spanish Town, Linstead, Princess Margaret, Bellevue, Bustamante Children, Hope Institute, Mona Rehabilitation, National Chest, Victoria Jubilee
Western Regional Hospitals	Cornwall Regional, Savannah la Mar, Falmouth, Noel Holmes
Southern Regional Hospitals	Mandeville, Black River, Lionel Town, May Pen, Percy Junior

The University Hospital of the West Indies (UHWI) was not included in any of the abovementioned categories and is located in the South East region of Jamaica.

An estimation of the quantity of waste incinerated at the St Ann's Bay hospital was provided by the Operations Manager for the years 2006-2012. The St Ann's Bay hospital incinerates medical waste from the hospitals and health centres located in the North East region. This medical waste is usually not sorted prior to treatment and has a composition of general healthcare waste (with similar characteristics to domestic waste), infectious waste, sharps, chemicals, pharmaceuticals, genotoxic waste (e.g. cytotoxic drugs, vomit, faeces, urine), radioactive matter and heavy metals.

Studies have indicated a generation rate of 0.24-1kg/bed/day for Jamaican public hospitals (Data obtained from the Management of Ship-Generated, Medical and Hazardous Wastes Report 7 regulated by Maritime Authority of Jamaica, NSWMA and NEPA). However, an average generation rate of 1.88kg waste/bed/day was calculated using the quantity of waste incinerated per day and the number of beds for St Ann's Bay hospital. This generation rate was considered to be generally representative of hospitals in Jamaica and was applied to the hospitals in the Southern and Western regions to determine the quantity of waste incinerated (in kg/yr), by calculating the product of the number of beds, their occupancy rates and the waste generation rate of 1.88 kg/bed/day.

Since late 2007, the Ministry of Health (MOH) opted to replace the incineration system used in the disposal of infectious medical waste in the public health sector with an autoclave and shredding technology which is considered more environmentally friendly. This information was obtained from the MOH as well as from the Jamaica Information Service website in a news report dated October 15, 2006 (http://jis.gov.jm/ministry-of-health-to-introduce-new-medical-waste-disposal-system/). The autoclave technology uses steam at a very high pressure and temperature to destroy all the infectious particles within the waste within an enclosed chamber. The waste becomes sterile and is then shredded. The sterile mass is buried in a landfill and has no infectious properties. There is no burning or emissions generated from this process. The autoclave is used to sterilise the medical waste of all the hospitals in the South East region including University Hospital of the West Indies (UHWI).

T

he Waste Management Unit at the MOH operates an incinerator since 2010 which burns non-infectious medical waste for all the hospitals in the South East region including UHWI. Data on the quantity of waste incinerated for 2011 and 2012 was provided by the MOH. Before 2010, the incinerator was operated by the Health Corporation Limited. The National Health Fund merged with the Health Corporation Limited in 2010 to reduce the financial burden of health care on the public and it was then that the Waste Management Unit at the MOH took over the operations of the incinerator. However, no records of the quantity of medical waste incinerated before 2010 were transferred over to the MOH therefore the MOH was unable to provide the data for 2006-2010.

2.2.16.26 Number of Beds and Occupancy Rates

The number of beds in all hospitals, categorised by region, was obtained from STATIN for only 2006-2008. The bed occupancy rates for the hospitals by region was used to determine the actual number of beds used (# of beds × occupancy rate).

Western Regional Hospitals

For the Cornwall Regional hospital, located in the western region, the number of beds in the year 2009 was obtained from the Western Regional Health Authority (WRHA) website (http://www.wrha.gov.jm/). Interpolation and extrapolation was used with these data, and 2008 STATIN data to generate the number of beds for the complete time series.

Southern Regional Hospitals

The Southern Regional Health Authority (SRHA) website (http://www.srha.gov.jm/) provided information on the number of beds and occupancy rates in the hospitals located in the Southern region for the year 2014. The number of beds for the years 2009-2012 was interpolated between the data collected from STATIN for 2008 and that from the website for 2014. An occupancy rate of 66.4% for 2006, collected from the Ministry of Health Annual Report 2006 was used for 2007-2008 while the occupancy rates for 2009-2012 were extrapolated.

North East Regional Hospitals

Since the number of beds was already given by STATIN, the numbers from the report were cross checked; the result with the larger number of beds was chosen. The number of beds for the year 2009-2012 was assumed to be the same as that of 2008.

South East Regional Hospitals & UHWI

The MOH provided the data on the quantity of waste incinerated for 2011-2012, this data was extrapolated to estimate the waste incinerated from 2006-2010.

The quantity of UHWI's waste that was incinerated in 2011-2012 was assumed to be 9.1% of the total waste incinerated by the MOH since UHWI was one of the eleven hospitals in the South East region. The medical waste recalculated for 2011-2012 to represent UHWI's medical waste was then used to extrapolate the waste incinerated for 2006-2010.

An average bed occupancy rate of 95% was assumed because the daily patient load is almost equal to the number of beds in the hospitals located in South East region including the UHWI hospital.

2.2.16.27 Quantity of Industrial Waste Incinerated

A list of permitted incinerators operating within the period 2006-2012 was provided by NEPA along with the average annual quantity of waste incinerated. This average value was used for all years in the time series, as no year specific data were available.

2.2.16.28 Emission Factors

The default values for the emission factors for CH_4 and N_2O were used:

- 60 kg CH_4/Gg waste for from Table 5.2 in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5 [batch type –stoker]
- 100 kg N_2O/Gg waste from Section 5.4.1.3 in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5

To calculate the CO_2 emissions, default values were obtained from Table 5.2, 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5 for the relevant waste streams as follows:

Table 0.5. Default Emission Values for CO_2 EFs for Incineration

Default Values	Medical waste (fraction)	Industrial waste (fraction)
Dry matter content	Not applicable	Not applicable
Fraction of carbon in dry matter	0.60	0.50
Fraction of fossil carbon in Total carbon	0.40	0.90
Oxidation factor	1	1
Conversion of C to CO_2 emitted	44/12	44/12

To estimate the indirect greenhouse gas emissions, the default values in the table below were taken from 2013 EMEP/EEA Guidebook, Chapter 5C1biii, Table 3.1:

Table 0.6. Emission factors for Indirect Greenhouse Gases. Waste incineration

NOx EF (kg/Mg)	SO_2 EF (kg/Mg)	NMVOC EF (kg/Mg)	CO EF (kg/Mg)
2.3	0.54	0.7	0.19

2.2.16.29 Category Emissions

The estimated CH_4, N_2O and fossil CO_2 emissions from incinerators for the years 2006 to 2012 are shown in the table below. A decrease in the emissions is observed which reflects the reduced used of incinerators due to the implementation and use of the autoclave technology. The CH_4 and N_2O emissions are negligible.

Table 0.7. Total emissions from Incineration of Medical and Industrial Waste (Gg)

Year	CH_4		N_2O	Fossil CO_2	NOx	SO_2	NMVOC	CO
2006	0.0002	0.0004	5.5276	0.0058	0.0010	0.0197	0.0005	0.0002
2007	0.0002	0.0004	5.2975	0.0052	0.0008	0.0196	0.0004	0.0002
2008	0.0002	0.0004	5.3369	0.0053	0.0008	0.0196	0.0004	0.0002
2009	0.0002	0.0004	5.3585	0.0053	0.0009	0.0196	0.0004	0.0002
2010	0.0002	0.0004	5.3682	0.0054	0.0009	0.0196	0.0004	0.0002
2011	0.0002	0.0004	5.3223	0.0052	0.0008	0.0196	0.0004	0.0002
2012	0.0002	0.0004	5.1851	0.0049	0.0007	0.0195	0.0004	0.0002

2.2.16.30 Open Burning of Waste

2.2.16.31 Methodology

Tier 2 methodology was used to estimate the CH_4 and N_2O emissions from open burning of waste at landfills and in the backyard. Country specific data on the quantity of open burned municipal solid waste was used together with default EFs from the 2006 IPCC Guidelines for National GHG Emissions Inventories: Volume 5.

Tier 2a methodology was used to estimate the CO_2 emissions from open burning of waste. Country specific data on the quantity of open burned municipal solid waste and the composition by waste stream were used together with default EFs from the 2006 IPCC Guidelines for National Greenhouse Gas Emissions Inventories: Volume 5.

2.2.16.32 Activity Data

Population Data

Population data (P) for the years 2006 to 2012 were obtained from STATIN website.

Per Capita Waste Generation

Per capita waste generation (MSW_p) for Jamaica is 1 kg/per person per day.

Fraction of Population Burning Waste, P_{frac}

The fraction of the population that reportedly burned their waste in the backyard in 2006 and 2010 were 38% and 32% respectively. In the absence of year specific data, the percentage obtained for 2006 was applied to 2007- 2009 while 32% was used for 2010-2012.

The fraction of municipal solid waste disposed to SWDS is reportedly 75% as discussed in section 7.2.2 above. It was therefore assumed that 50% of the amount disposed to the SWDS is burnt as not all of the waste is burnt when there are fires at landfills.

Fraction of Waste Burnt Relative to the Amount Treated, B_{frac}

The 2006 IPCC Guidelines for National Greenhouse Gas Emissions Inventories, Section 5.3.2 suggests that if all waste is burned without leaving a residue, the fraction of waste burned relative to the amount of waste treated (B_{frac}) waste should be 1.

For landfill fires, the fraction burned was estimated to be 0.6 as only this fraction of the waste is burnt with 40% of waste being residue. Backyard burning was estimated to be 0.9 as nearly all the waste is burned with a small amount of ash residue.

Number of Fires

It assumed that burning took place twice per week in backyards.

In 2008, there were two fires at the Riverton disposal site while there were reportedly one fire occurring in each of the other years in the inventory period. Each fire lasted for 14 days.

2.2.16.33 Emission Factors

A methane emission factor of 6500g/t MSW wet weight (or 6500 kg/Gg) as suggested in Section 5.4.2 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5 was used.

A N_2O emission factor of 150 g/t of MSW (or 150 kg/Gg) as indicated in Section 5.4.3, Table 5.6 was used to estimate the N_2O emissions.

The EFs used for the indirect emissions obtained from 2013 EMEP/EEA Guidebook, Chapter 5C2, Table 3.1 are as follows:

Table 0.8. EFs for Open burning of waste (indirect GHGs)

NOx EF (kg/Mg)	SO_2 EF (kg/Mg)	NMVOC EF (kg/Mg)	CO EF (kg/Mg)
3.18	0.11	1.23	55.83

2.2.16.34 Default Values

To calculate the CO_2 emissions, dry matter content (dm), fraction of carbon in dry matter and fraction of fossil carbon in total carbon were all obtained from Table 2.4, 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5 for the relevant waste streams.

The default value for oxidation factor of 58% for open burning of municipal solid waste was provided in Table 5.2, 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5.

2.2.16.35 Category Emissions

Table 0.9. Emissions from the Open Burning of Waste at Landfills (Gg of gas)

	OPEN BURNING OF WASTE (LANDFILLS). Gg							
Year	CH_4	N_2O	CO_2	CO	NMVOC	NOx	SO_2	CH_4
2006	0.091	0.002	5.004	0.779	0.017	0.044	0.002	0.091
2007	0.091	0.002	5.002	0.782	0.017	0.045	0.002	0.091
2008	0.183	0.004	10.001	1.569	0.035	0.089	0.003	0.183
2009	0.092	0.002	4.999	0.787	0.017	0.045	0.002	0.092
2010	0.092	0.002	4.997	0.790	0.017	0.045	0.002	0.092
2011	0.092	0.002	4.993	0.793	0.017	0.045	0.002	0.092
2012	0.093	0.002	4.987	0.795	0.018	0.045	0.002	0.093

Table 0.10. Emissions from the Open Burning of Waste in Backyards (Gg of gas)

	OPEN BURNING OF WASTE (BACKYARDS). Gg							
Year	CH_4	N_2O	CO_2	CO	NMVOC	NOx	SO_2	CH_4
2006	0.614	0.014	33.901	5.278	0.116	0.301	0.010	0.614
2007	0.617	0.014	33.890	5.296	0.117	0.302	0.010	0.617
2008	0.619	0.014	33.878	5.315	0.117	0.303	0.010	0.619
2009	0.621	0.014	33.865	5.334	0.118	0.304	0.011	0.621
2010	0.525	0.012	28.507	4.508	0.099	0.257	0.009	0.525
2011	0.526	0.012	28.485	4.522	0.100	0.258	0.009	0.526
2012	0.528	0.012	28.450	4.534	0.100	0.258	0.009	0.528

2.2.16.36 Domestic wastewater – CH_4

2.2.16.37 Methodology

Tier 2 methodology was used to calculate the CH_4 emissions from domestic wastewater treatment plants in Jamaica. Although the default EF was utilised, country specific activity data was used to calculate the average BOD_5 in g/capita/ year.

2.2.16.38 Activity Data

Population Data

The yearly population within the period 2006 to 2012 was obtained from STATIN website. The number of dwelling units in high-urban (Kingston, St. Andrew, St James and St Catherine), low-urban (other urban areas) and rural areas were obtained from the 2011 Census of Population & Housing-Jamaica.

The population in 2011 was divided by the total dwellings to determine the average number of persons per dwelling (3.17persons/dwelling). This enabled the population in each income group to be calculated as follows:

$$\textit{Total dwellings}_{(i)}\ \textit{average persons per dwelling} = \textit{population}_{(i)}$$

The population fractions that were calculated were used to determine the population of the high urban, low urban and rural areas for the other years (2006-2010 and 2012).

Table 0.11. Population Data for 2011

Year	Total dwellings	Population	Population fraction	Total dwellings
high urban (KMA)	341,560	1,081,947	0.400	341,560
low urban	118,959	376,822	0.139	118,959
rural	393,149	1,245,364	0.461	393,149
Total	853,668	2,704,133	1.000	853,668

2.2.16.39 BOD5 Generation Rate

The Biochemical Oxygen Demand (BOD) loading rate (g/yr) and the average population (capita) served by the wastewater treatment plants were used to determine the BOD generation rate (g/capita/day).

Loading Rate

To calculate the loading rate (g/yr), the capacities (L/yr) of the treatment plants and the BOD (mg/L) were collected from the National Water Commission (NWC) and the National Environment and Planning Agency (NEPA). The BOD for seventy six (76) sewage treatment plants was provided by NWC. However the capacities of only 66% of the plants were available.

The BOD for 189 sewage treatment plants were provided by NEPA, six of which were NWC plants, the other 183 were private sewage treatment plants. Data provided on the six NWC plants were cross checked with that provided by NWC and used to fill gaps of the missing data. NEPA only provided the capacities of 64% of the plants.

Average Population Served by each Plant

The average population served by 56 of the sewage treatment plants was found from research together with the data provided by NWC. NEPA did not provide any data on population served by each plant therefore the BOD generation rate of the 183 private sewage treatment plants could not be calculated.

In summary, the BOD generation rates of only 50 sewage treatment plants were calculated due to the fact that data on plant capacities and the average population served by each plant were unavailable.

The rates that were less than 0.1 g/capita/day and greater than 90 g/capita/day were not used in the calculation of methane emissions level are they are deemed outliers.

Degree of Utilisation

The sewage treatment facilities for Jamaica are predominantly aerobic systems. The data on the performance of the systems (degree of utilisation (Tij) in high-urban, low-urban and rural areas) for 2006, 2007, 2009 and 2010 were obtained from the Planning Institute of Jamaica (PIOJ) and STATIN (Jamaica Survey of Living Conditions 2006, 2007, 2009 & 2010, Table F3, F3, F3 and F7 respectively).

To find the degree of utilisation in 2008, an average of the values for 2007 and 2009 was used since no data was available. For 2011 and 2012, the degree of utilisation obtained for 2010 was used.

2.2.16.40 Emission Factors

Table 6.3 in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 5 provides values for the default Methane Correction Factor (MCF). The wastewater treatment plants in Jamaica fall into two main categories for which default MCF values were provided:

- for untreated systems with high organic loadings or
- for treated, not well managed systems.

Therefore, an average default MCF value of 0.2 was estimated. The default value of 0.6 kg CH_4/kg BOD was used for the maximum CH_4 producing capacity (B_0), from Table 6.2, 2006 IPCC Guidelines for National GHG Emissions Inventories, Volume 5.

The EF for domestic wastewater was calculated to be 0.12 kg CH_4/kg BOD (MCF x default value B_0) for the years 2006 to 2012. There were no values for sludge production, so the EF for domestic sludge is zero for all the years.

Sludge Removal and Methane Recovery

Neither NEPA nor NWC was able to provide any data on sludge removal and the amount of CH_4 recovered. For the purpose of this exercise these parameters were assumed to be zero.

2.2.16.41 Category Emissions

The estimated CH_4 emissions for domestic wastewater are presented in the table below.

Table 0.12. CH4 emissions from Domestic Wastewater Treatment Facilities (Gg)

Year	CH_4 (Gg)
2006	1.63
2007	1.73
2008	1.84
2009	1.94
2010	2.05
2011	2.15
2012	1.88

2.2.16.42 Industrial Wastewater

2.2.16.43 Methodology

The Tier 2 methodology was used to calculate the CH_4 emissions from industrial wastewater treatment plants in Jamaica.

Default wastewater generation and the corresponding Chemical Oxygen Demand (COD) values were used for most of the primary industries generating wastewater in Jamaica. Country specific data on total industrial product was used. In addition, country specific data on COD for the sugar industry and the wastewater generation rate for the alcohol industry were used.

2.2.16.44 Activity Data

The activity data for this source category is the amount of organically degradable material in the wastewater (TOW). This parameter is a function of industrial output (product) P (tonnes/yr), wastewater generation W (m^3/tonne of product) and degradable organics concentration in the wastewater COD (kg COD/m^3). The table below shows the activity data collected and used for the calculation of emissions from primary industries in Jamaica.

2.2.16.45 Total Industrial Product, P

Production data for 2006 to 2012 for the primary industries in Jamaica was obtained from the Planning Institute of Jamaica (Economic and Social Survey Jamaica 2006, 2011 and 2013).

Alcohol production data for 2006-2012 was provided by the Spirits Pool Association (SPA) and The Sugar Industry Association (SIA) provided data on the amount of sugar produced for 2006-2012.

The data obtained from the survey on alcohol and sugar industries was cross checked with the data from their respective industries. The data provided by the SPA and SIA was chosen as it was considered to be more representative.

2.2.16.46 Wastewater Generation Rate, W

The default wastewater generation rates in Table 6.9 in the 2006 IPCC Guidelines for National GHG Inventories: Volume 5 were used for all industries except for the alcohol and sugar industries. The wastewater generation rates for the other industries were not available. The alcohol production process generates wastewater at an approximate ratio of 18 litres of wastewater for every litre of rum produced. Using this ratio along with the production data obtained from the SPA, the wastewater generation rate was determined to be 22.5 m^3/tonne.

2.2.16.47 COD

COD data was provided for 2006-2009 by the SIA for all the sugar industries. Using this data, an average COD was calculated (2.87 kg/m^3) and used. The default COD values in Table 6.9 in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5 were used for the other industries as country specific data was unavailable.

Table 0.13. Annual Production, Wastewater Generation and COD values for Primary Industries in Jamaica

2006 IPCC GUIDELINE DEFAULT VALUES & COUNTRY SPECIFIC VALUES			TOTAL INDUSTRIAL PRODUCT (P) [t/yr]						
Industry Type	Wastewater Generation W [m^3/ton]	COD Generated [kg/m3]	2006	2007	2008	2009	2010	2011	2012
Alcohol Refining	22.5	11	23,218	21,737	23,266	22,020	19,050	20,019	23,500
Beer & Malt	6.3	2.9	86,955	68,117	85,985	69,204	65,516	58,343	50,226
Coffee & Cocoa		9	12,985	15,885	9,441	12,919	9,666	8,299	7,244
Dairy Products	7	2.7	4,877	5,704	4,525	3,868	4,386	3,864	3,648
Fish Processing	13	2.5	21,087	17,438	15,355	18,346	16,498	15,358	11,138
Meat & Poultry	13	4.1	118,113	120,695	122,556	119,770	114,822	115,596	118,583
Sugar Refining		2.87	146,882	164,387	140,872	125,818	121,806	139,594	131,589
Vegetables, Fruits & Juices	20	5	467,802	197,951	196,095	229,073	212,796	273,388	280,615
Petroleum Refineries	0.6	1	1,033,055	1,089,163	1,135,801	1,047,265	1,104,994	1,160,199	1,132,389
Detergent	2.5	0.85	1,609	2,194	2,457	1,568	392	367	387
Vegetable Oil	3.1	0.85	21,122	21,306	20,642	18,617	21,712	21,266	21,102
Total			1,937,705	1,724,577	1,756,995	1,668,468	1,691,638	1,816,293	1,780,421

2.2.16.48 Emission Factors

The industrial wastewater treatment facilities for Jamaica are predominantly aerobic systems. However there is no specific data on the performance of the systems, especially the fraction of wastewater treated.

The default value of 0.2 for the Methane Correction Factor (MCF) in Table 6.8 of the 2006 IPCC Guidelines for National GHG Inventories: Volume 5 was used. Section 6.2.3.2 of the 2006 IPCC Guidelines suggested the default value of 0.25 for the maximum methane producing capacity (B_0). The EF for industrial wastewater was therefore calculated to be 0.05 kg CH_4/kg COD (MCF x default value) and used for each of the years 2006 to 2012.

2.2.16.49 Category Emissions

The estimated CH_4 emissions from industrial wastewater facilities are presented in the table below.

Table 0.14 CH_4 Emissions from Industrial Wastewater Treatment Plants (Gg)

Year	CH_4 (Gg)
2006	2.80
2007	1.71
2008	1.74
2009	1.87
2010	1.73
2011	2.04
2012	2.11

2.2.16.50 Domestic Wastewater - N_2O

2.2.16.51 Methodology

The methodology used for this section is provided by Chapter 6 of the 2006 IPCC Guidelines for National Gas Inventories: Volume 5. It addresses indirect N_2O emissions from wastewater treatment effiuent that is discharged into aquatic environments.

2.2.16.52 Activity Data

The activity data that is needed for estimating N_2O emissions are nitrogen content in the wastewater effiuent, country population and average annual per capita protein generation (kg/person/yr).

2.2.16.53 Population Data

Population data for the years 2006 to 2012 was obtained from STATIN (website).

2.2.16.54 Per Capita Protein Consumption

Data on per capita protein available for consumption in 2006 to 2012 was obtained from the Food and Agriculture Organisation (FAOSTAT) website (http://faostat3.fao.org/download/D/FS/E). It was assumed that all protein available for consumption was actually consumed.

2.2.16.55 Nitrogen Content in the Wastewater

The following default values were used:

- fraction of Nitrogen in protein (FN_{PR}) - 0.16 kg N/kg protein
- the non-consumed protein ($FNON_{-}CON$) added to wastewater - 1.1
- for industrial and commercial co-discharged protein ($F_I N_{D-} CO_M$) - 1.25

The default values were obtained from Chapter 6, Table 6.11, in the 2006 IPCC Guidelines for National GHG Inventories: Volume 5.

2.2.16.56 Emission Factors

The default EF of the wastewater effiuent ($EF_{EFFLUE} N_T$) was obtained from Chapter 6, Table 6.11, in the 2006 IPCC Guidelines for National GHG Inventories: Volume 5; $EF_{EFFLUE} N_T$= 0.005 kg N_2O-N/kg sewage-N produced.

2.2.16.57 Category Emissions

The estimated N_2O emissions from wastewater for the years 2006 to 2012 are presented in the table below:

Table 0.15. N_2O Emissions from Wastewater treatment (Gg)

Year	N_2O (Gg)
2006	0.131
2007	0.131
2008	0.132
2009	0.130
2010	0.131
2011	0.131
2012	0.132

2.2.16.58 Sectoral Uncertainties

2.2.16.59 Solid Waste Disposal

Data for the quantity of waste disposed to different sites was complete for all the years for all disposal sites except Riverton. Data was missing for 2006 which was then interpolated between the data for 2005 and 2007. Therefore, calculations on the percentages of waste going to the disposal site and the Methane Correction Factors (MCF) may have been overestimated or underestimated.

Data for the composition of domestic waste was available for only 2006 for Retirement, North-eastern and West Kirkvine waste-sheds. The data for the rest of the years was assumed the same which may result in inaccuracy of the results.

Industrial waste going to landfills was only obtained for the bauxite industry therefore the emissions calculated in this regard do not include other industries that also dispose of their waste in landfills. Additionally, some industrial waste is disposed of at the municipal disposal sites but the quantity is unknown.

Estimates of uncertainties were calculated as shown in the Table below based on information provided in Chapter 3, Table 3.5 of the 2006 IPCC Guidelines for National Gas Inventories: Volume 5.

2.2.16.60 Biological Treatment of Solid Waste

Uncertainties for activity data related to biologically treated waste were calculated using information from Table 3.5 the 2006 IPCC Guidelines for National GHG Inventories: Volume 5. Uncertainties related to the EFs were calculated using the ranges provided in Table 4.1 of the 2006 IPCC Guidelines for National Gas Inventories: Volume 5.

The data from the Scientific Research Council on the CH_4 gas flow rate is expected to be reliable and a $\pm$10% error was assumed. The CH_4 recovery (R) uncertainty was obtained from Chapter 3, Table 3.5 of the 2006 IPCC Guidelines for National Gas Inventories: Volume 5 which suggested an uncertainty for metered CH_4 recovery or flaring systems of $\pm$10%. The uncertainty for the CH_4 EF (a value of 2 within a range of 0 to 20) was -100% to +900%. This information was obtained from Chapter 4, Table 4.1 of the 2006 IPCC Guidelines for National Gas Inventories: Volume 5 and is presented in table 7.16 below.

2.2.16.61 Incineration of Waste

Data on the quantity of medical waste incinerated was found by using the waste generation rate calculated for the St Ann's Bay hospital as this was the only hospital for which data was available. It is expected that the waste generation rates of hospitals located in different regions will vary and so the assumption that the generation rate is the same could lead to misrepresentations in the emissions calculations. In addition, interpolation/extrapolation was used to estimate the data for the years for which no data was available on the number of beds and occupancy rates.

Site-specific EFs were not available and default values obtained from the 2006 IPCC Guidelines for National GHG Inventories: Volume 5 and the 2013 EMEP/EEA Guidebook had to be used.

Data obtained from NEPA on the quantity of industrial waste incinerated was an average annual estimate as yearly values were not available. Some CH_4 emissions are unaccounted for as it was difficult to obtain information from some facilities which NEPA granted permits to operate incinerators.

There was insufficient information in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5 to calculate the percentage uncertainty for CO_2 emissions.

2.2.16.62 Open Burning of Waste

As indicated above, the default value for the fraction of waste burned relative to the amount of waste treated (B_{frac}) waste was used in the absence of country specific data. Data on the number of fires in the backyard was assumed and was not based on any studies carried out by the NSWMA.

There was insufficient information in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5 to calculate the percentage uncertainty for CO_2 emissions.

2.2.16.63 Domestic Wastewater – CH_4

To determine the BOD generation rate (g/capita/day), the average population served by each plant and the capacities of the plants were needed. However, the NWC and NEPA provided limited data and as such, BOD data for 26 of NWC plants as well as 183 private sewage plants were not included in the calculations.

The design capacities of the treatment plant had to be used rather than the actual annual average flow rate. This may result in inaccurate representation of the BOD generated from the plants.

The population fractions calculated for 2011 were used as the population fractions for the other years due to the absence of year specific data on the population of each income group. The change in population however is expected to be minimal.

Data for the degree of utilisation of type of treatment system (sewered, not sewered, pit latrines) were obtained for some of the years except 2008, 2011 and 2012 from the Jamaica Survey of Living Conditions. 2010 data was used for the years 2011-2012, even though there was a small increase in the use of sewered water closets and a corresponding decline in the use of pit latrines observed in the high urban time series.

Since no country-specific data was available for the emission factors for domestic wastewater, estimates were based on default EF values provided by Tables 6.2 and 6.3 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5.

Using the default values provided by Table 6.7 of the 2006 IPCC Guidelines for National GHG Inventories: Volume 5, together with expert judgment, the percentage uncertainty in the CH_4 emission estimations was calculated.

2.2.16.64 Industrial Wastewater – CH_4

Since data for wastewater generated (W) and the chemical oxygen demand (COD) were not available for most industries example values from Table 6.9 in the 2006 IPCC Guidelines for National GHG Inventories were used. For the coffee and cocoa industry, no IPCC example values or range on the rate of generation of wastewater for this critical sector was available which is known to produce significant quantities of wastewater. Country specific data on wastewater generation and COD was only available for the alcohol and sugar industry respectively.

Country specific information for the maximum CH_4 producing capacity (B_0) and CH_4 correction factor was not available and default values obtained from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories had to be used.

Using the default values provided by Table 6.10 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5, together with expert judgment, the percentage uncertainty in the CH_4 emission estimations was calculated.

2.2.16.65 Wastewater Treatment – N_2O

Using the default values provided by Table 6.10 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5, together with expert judgment, the percentage uncertainty in the N_2O emission estimations was calculated.

Table 0.16 Uncertainties in Emissions Estimates in Waste Sector

Activity data, Parameter or Emission factor	% Uncertainty	Remarks
Solid waste disposal		
Total municipal solid waste (MSW_T)	30	Waste generation data collected on a regular basis
Fraction of MSW_T sent to SWDS (MSW_F)	50	Periodic studies conducted to determine % of solid waste sent to municipal disposal sites
Total uncertainty of waste composition	50	Periodic studies conducted including sampling
Degradable Organic Carbon (DOC)	20	IPCC default values used
Fraction of Degradable Organic Carbon (DOC_f)	20	IPCC default values used
Methane Correction Factor (MCF)	20	IPCC default values used
Biological treatment - CH_4		
Emission factor	-100 to +900	
Methane recovery (R)	10	
Methane gas flow rate	10	
Incineration and open burning- CO_2		
Amount of solid waste incinerated	70	Some waste incineration data available
Amount of solid waste burnt	20	Some waste burning data available
Fraction of carbon in dry matter	?	IPCC default values used
Fraction of Fossil Carbon on Total Carbon	?	IPCC default values used
Oxidation factor	?	IPCC default values used
Conversion factor	?	IPCC default values used
Nitrous oxide emission factor	100	IPCC default values used
Methane Emission factor	100	IPCC default values used
Domestic and Industrial wastewater treatment - CH_4		
Maximum CH_4 producing capacity (B_0)	30	
Fraction treated anaerobically (MCF)	40	Mixture of untreated systems and latrines and lagoons, poorly managed treatment plants
Human Population (P)	5	
BOD per person	30	
Fraction of population income group (U)	15	
Degree of utilisation of treatment/discharge pathway or system for each income group (T_{ij})	30	

Activity data, Parameter or Emission factor	% Uncertainty	Remarks
Correction factor for additional industrial BOD discharged into sewers	20	
Industrial production (P)	10	
Wastewater/unit production (W)	35	
COD/unit wastewater		
Wastewater -N_2O		
$EF_{EFFLUE}N_T$ (kgN_2O-N/kg-N)	30	
$EF_{PLA}N_{TS}$ (gN_2O/person/year)	40	
Human Population (P)	5	
Protein	10	
Fraction of nitrogen in protein (FN_{PR}) (kgN/kg protein)	6	
Degree of utilisation of large WWT plants (T_{plant})	20	
Factor to adjust for non-consumed protein (FNON_CON)	30	

These data have been used in determining the uncertainties from the individual sources in the waste sector. Results of the uncertainty analysis conducted across the whole emissions inventory are presented in Section 9.

2.2.16.66 Quality Assurance and Quality Control

There are a number of sector specific QA/QC procedures that have been undertaken as part of the emissions inventory compilation:

- Handling activity data: At all stages of the compilation, a programme of QC checks have been included that are specific to the way the activity data are handled in the emissions inventory. The activity data that was obtained for use in the emissions calculations is generally high in detail level, although not always high in completeness.
- It was possible to compare the activity data with that from other countries by using simple metrics, such as waste generated per capita. This provided an important and useful quality check on the data.
- Interpolation/extrapolation: There are some occasions where it was necessary to extend available data to the whole time series by using interpolation or extrapolation. Gap filling in this way is typically straightforward, but there are occasions where there are options for the approach used to extrapolate data. Where there was the potential for choice to have a significant impact on the resulting emissions, the available approaches were discussed between experts to agree the most appropriate method. This also helped to ensure a consistent approach with other sectors of the emissions inventory.
- Assumptions: It has been necessary to use assumptions in estimating emissions from a number of different sources. The inventory compilers were able to bring excellent in-depth local knowledge and expertise in making assumptions, as well as consulting with an internationally experienced inventory compiler before finalising on assumptions.
- The IPCC model was used for estimating CH_4 emissions from landfilled domestic and industrial waste landfills. A number of QC routines were added to the model to ensure that data handling errors were eliminated.

The emissions estimates as originally compiled were independently reviewed. This identified a number of calculation errors, and assumptions that required correction. These were addressed before data were finalised and included in this report.

2.2.16.67 Recommendations for Improvement

2.2.16.68 Solid Waste Disposal

Improvements to data quality and availability would be achieved if industries operating industrial disposal sites established reliable systems to estimate/ measure the quantity and types of industrial wastes being disposed at dump sites. A requirement to submit this information annually to the National Solid Waste Management Authority (NSWMA) would help with accessibility. The NSWMA could then maintain a database with this information to enable easy data retrieval.

Similarly, if the NSWMA, the current operator of the municipal disposal sites, logged information on the source, quantities and types of industrial and municipal solid waste being delivered to its sites and maintained this information in a database, it would help with the availability of high quality datasets.

2.2.16.69 Biological Treatment of Solid Waste

Improvements to data quality and availability would be achieved if the SRC maintained a database of the quantity of waste that is treated by bio-digesters and made this information readily available.

2.2.16.70 Incineration of Waste

Improvements to data quality and availability would be achieved if the MOH maintained records of the quantity of medical waste generated from health care facilities and made this data readily accessible.

To improve data quality and availability, a number of changes are proposed. It is expected that the National Environment and Planning Agency (NEPA) could take the role of maintaining an up-to-date database of all existing incinerators. All major and significant facilities must be licenced under the Air Quality Regulations to discharge emissions. Through this regime, data could be provided by the facilities on their annual emissions. NEPA would need to ensure an effective system for monitoring facilities. While challenging, NEPA would also need to ensure that small facilities which do not fall within the licencing system still use the best available technology and /or best practices to operate their facilities.

2.2.16.71 Open Burning of Waste

It is suggested that the NSWMA carry out studies to determine country specific data for the fraction of waste burned relative to the amount of waste treated (B_{frac}). Regular analysis of the waste stream composition could be conducted by the NSWMA at each of the disposal sites so that the differences across the country can be assessed.

2.2.16.72 Domestic Wastewater – CH_4

It is necessary that flow meters are installed at the sewage treatment facilities to get actual flow-rates of the wastewater instead of estimating the BOD loading rates using the capacity of the plants. In addition, increasing the frequency of sampling would give better data for each plant on the BOD values throughout the year. The NEPA has the legal mandate to request information on domestic sewage flows and effiuent quality from the operators of sewage treatment plants and it would improve data availability if this information was regularly submitted.

It would bring significant efficiencies if STATIN and PIOJ collected and presented data in the same formats annually. Information required includes:

- Population according to income groups (KMA, Other towns and Rural Areas)
- Degree of utilisation of type of treatment system (sewered, not sewered, pit latrines) split between KMA, Other towns and Rural Areas.

2.2.16.73 Industrial wastewater – CH_4

Data on annual wastewater flows, COD and annual production were difficult to obtain for major industries in Jamaica. Improved input data could be made available if industries conducted more frequent BOD and COD analysis on wastewater. The NEPA has the legal mandate to request information on wastewater flows, production and effiuent quality from industries that are generators of large volumes of wastewater.

2.2.16.75 Uncertainty Analysis

2.2.16.76 Introduction

The IPCC Guidance provides information on the quantification of uncertainties associated with emission estimates, and uncertainty ranges are given for the EFs in the guidance. Methodologies are also presented that allow the combination of uncertainties to give an overall uncertainty value that can be applied to a pollutant total and also to a trend in the time series.

2.2.16.77 Methodology

The data available on uncertainties associated with the input data was very variable. Consideration has been given to uncertainties in each of the individual sector chapters of this report, and this provides an overview of the inputs used – both EFs and activity data.

In the vast majority of cases, EF uncertainties have been chosen after close consultation with the information provided in the IPCC 2006 guidance. Most of the approaches used in the inventory are Tier 1 methodologies, and hence uncertainties are generally larger than those for higher Tier methodologies.

Estimating uncertainties associated with activity data is often more challenging. Little quantified information was provided with input data, and hence it has been necessary to draw on expert opinion. Whilst expert opinions can be difficult to justify or explain, they typically provide a very good representation of the data, because the expert possesses a detailed understanding of the data.

Once an uncertainty value has been assigned to the activity data and EF (or in some cases parameters that are used in calculating the activity data or EF), then a "propagation of errors" methodology was used to estimate the emissions for each individual source, and ultimately the pollutant total. This follows best practise in the IPCC 2006 Guidance.

The overall uncertainties are summarised in Table 8.1:

Table 0.1 GHG Emission Uncertainties (Absolute and Trend)

Year	Uncertainty in the emission total	Uncertainty in the trend 2006-2012
CO_2 (including LULUCF)	2.8%	0.9%
CO_2 (including LULUCF)	10%	3.5%
CH_4	55%	62%
N_2O	111%	34%
HFC	317%	112%

These results reflect the fact that CO_2 emissions from fuel combustion are typically well characterised, as the amount of fuel is measured with higher accuracy than most other activity data in the inventory, and the carbon content of the fuels are also well known.

Emissions from LULUCF are very high in uncertainty, reflecting the challenges associated with accurately quantifying/representing changes to natural ecosystems. As a result, there is a significant increase in the CO_2 emissions uncertainty when LULUCF is included.

The largest CH_4 source is the emission from landfill, and this is one of the more uncertain sources, representing the challenges associated with accurately quantifying the generation of CH_4 from the breakdown of waste, which is dependent on many different factors. Emissions from agriculture also make a large contribution to the emissions total. These are also sources which are affected by a number of different parameters in complex relationships.

Emissions of N_2O are very much dominated by the agriculture sector. Emissions from manure management are relatively high, reflecting the complexity of the emissions mechanism. The generation and release of N_2O into the air is affected by weather and meteorological conditions, the details of the manure management system, as well the properties of the manure itself – all of which are challenging to determine or take into account in any detail.

Emissions from soils are even higher in uncertainty than those of manure management. This is because, in addition to the uncertainties associated with the detail of the manure or other sources of N applied to the soils, the release mechanism of N_2O from the soil is particularly dependent on factors such as the weather, soil moisture content, pH of the soil etc.

The uncertainty analysis for HFCs is relatively simple, and results in high uncertainties. This is primarily because there is little information on the emissions of HFC. Hence a relatively simple methodology has been used for estimating the emissions, and associated uncertainties are high. In addition to this, the nature of the emissions are challenging to quantify anyway (resulting from leakage and other unintentional sources). So even when detailed input data are available, it can still be challenging to estimate HFC emissions with any accuracy.

The uncertainty assessment that has been undertaken provides information to help direct improvement activities in the national emissions inventory improvements programme. However there are improvements that can be made to the uncertainty assessment itself. It has been necessary to rely on expert opinion for many of the inputs. Whilst this is relatively common, there is scope to obtain better information, and potentially quantified information, on the uncertainties associated with the emissions inventory input data. The detailed results of the uncertainty analysis (on a source specific basis) are shown in the next section in a table format.

2.2.16.78 CO_2 Uncertainty Analysis

Table 0.2 Uncertainties CO_2 Emissions Estimates

	IPCC Source Category	Fuel	Emissions 2006	Emissions 2012	Activity Data (AD) Uncertainty	Emission Factor (EF) Uncertainty	Combined Uncertainty	Combined Uncertainty as % of Emissions in 2012	Combined Emissions Uncertainty Squared	Type A Sensitivity	Type B Sensitivity	Uncertainty in Trend in Total Emissions due to AD	Uncertainty in Trend in Total Emissions due to EF	Combined Uncertainty in Trend in Total Emissions	Combined Trend Uncertainty Squared
	CO2		Gg CO_2eq	Gg CO_2eq	%	%	%	%		%	%	%	%	%	
1A1a	Public electricity and heat production	Fuel oil	2161	1982	1	7	7.07	2.43	5.92	0.07	0.21	0.29	0.49	0.58	0.33
1A1a	Public electricity and heat production	Diesel oil	729	700	1	7	7.07	0.86	0.74	0.03	0.07	0.10	0.19	0.22	0.05
1A1b	Petroleum refining	Fuel oil	114	143	1	2	2.24	0.06	0.00	0.01	0.02	0.02	0.02	0.03	0.00
1A1b	Petroleum refining	Diesel oil	0	0	1	2	2.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A2b	Mining/Bauxite	Fuel Oil	4600	1525	2	2	2.83	0.75	0.56	-0.13	0.16	0.45	-0.26	0.52	0.27
1A2e	Sugar	Fuel oil	12	2	2	2	2.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A2e	Sugar	Bagasse	0	0	5	5	7.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A2f	Cement	Fuel oil	7	12	2	2	2.83	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A2f	Cement	Coal	109	180	2	2	2.83	0.09	0.01	0.01	0.02	0.05	0.02	0.06	0.00
1A2gviii	Industry Other, Stationary	LPG	5	5	5	2	5.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A2gviii	Industry Other, Stationary	Fuel oil	91	20	5	2	5.39	0.02	0.00	0.00	0.00	0.01	-0.01	0.02	0.00
1A2gvii	Industry, Mobile machinery	Gasoline	27	20	5	2	5.39	0.02	0.00	0.00	0.00	0.02	0.00	0.02	0.00
1A2gvii	Industry, Mobile machinery	Diesel Oil	109	226	5	2	5.39	0.21	0.04	0.02	0.02	0.17	0.03	0.17	0.03
1A3aii(i)	Domestic aviation LTO (civil)	Turbo	4	2	5	1	5.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3aii(i)	Domestic aviation LTO (civil)	Avgas	2	1	5	1	5.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3aii(ii)	Domestic aviation, cruise	Turbo	0	0	5	1	5.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3aii(ii)	Domestic aviation, cruise	Avgas	0	0	5	1	5.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3b	Road Transport	Gasoline	1603	1276	1	2	2.24	0.50	0.25	0.03	0.13	0.19	0.06	0.20	0.04
1A3b	Road Transport	Diesel Oil	459	450	1	2	2.24	0.17	0.03	0.02	0.05	0.07	0.04	0.08	0.01
1A3c	Railways	Diesel oil	0	0	2	2	2.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3d	Domestic shipping/National Navigation	Diesel Oil	24	5	1	1	1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3d	Domestic shipping/National Navigation	Fuel Oil	19	9	1	1	1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4aii	Commercial/institutional: Mobile	Gasoline	0	0	10	2	10.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4aii	Commercial/institutional: Mobile	Diesel oil	14	15	10	2	10.20	0.03	0.00	0.00	0.00	0.02	0.00	0.02	0.00
1A4ai	Commercial/institutional: Stationary	Fuel Oil	41	0	5	2	5.39	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1A4ai	Commercial/institutional: Stationary	LPG	99	110	5	2	5.39	0.10	0.01	0.01	0.01	0.08	0.01	0.08	0.01
1A4ai	Commercial/institutional: Stationary	Kerosene	76	8	5	2	5.39	0.01	0.00	0.00	0.00	0.01	-0.01	0.01	0.00
1A4ai	Commercial/institutional: Stationary	Charcoal	0	0	20	5	20.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4bi	Residential: Stationary	Kerosene	100	9	10	2	10.20	0.02	0.00	-0.01	0.00	0.01	-0.01	0.02	0.00
1A4bi	Residential: Stationary	LPG	132	130	10	2	10.20	0.23	0.05	0.01	0.01	0.19	0.01	0.19	0.04
1A4bi	Residential: Stationary	Wood	0	0	20	5	20.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4cii	Agriculture/Forestry/Fishing: Mobile	Gasoline	28	27	10	2	10.20	0.05	0.00	0.00	0.00	0.04	0.00	0.04	0.00
1A4cii	Agriculture/Forestry/Fishing: Mobile	Diesel oil	49	52	10	2	10.20	0.09	0.01	0.00	0.01	0.08	0.00	0.08	0.01
1B2aiv	Refinery flaring	Flared gases and v	1	0	5	10	11.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2A1	Cement	Clinker Production	314	339	2	5	5.39	0.32	0.10	0.02	0.04	0.10	0.08	0.13	0.02
2A2	Lime	Lime Production	228	95	2	1	2.24	0.04	0.00	0.00	0.01	0.03	0.00	0.03	0.00
2D1	Non-Energy Products	Lubricating Oil	2	2	500	1	500.00	0.15	0.02	0.00	0.00	0.13	0.00	0.13	0.02
2D1	Non-Energy Products	Grease	0	0	500	1	500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3D	Urea Fertiliser Application	Urea Fertiliser App	1	2	5	50	50.25	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.00
3D	Lime Application	Lime Application	0	0	10	50	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4B1a	Forest Land Remaining Forest Land	LUCF	-1834	-1777	10	30	31.62	-9.75	95.14	-0.07	-0.19	-2.64	-2.11	3.38	11.41
4B1b	Land Converted to Forest Land	LUCF	-30	-33	20	30	36.06	-0.21	0.04	0.00	0.00	-0.10	-0.05	0.11	0.01
4B2a	Cropland Remaining Cropland	LUCF	0	0	10	30	31.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4B2b	Land Converted to Cropland	LUCF	0	0	20	30	36.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4B3a	Grassland Remaining Grassland	LUCF	0	0	10	30	31.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4B3b	Land converted to Grassland	LUCF	116	116	20	30	36.06	0.72	0.52	0.00	0.01	0.34	0.14	0.37	0.14
4B4ai	Wetlands Remaining Wetlands	LUCF	0	0	10	30	31.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4B4bi, ii	Land converted to Wetlands	LUCF	0	0	20	30	36.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4B5a	Settlement Remaining settlement	LUCF	0	0	10	30	31.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4B5b	Land converted to Settlement	LUCF	6	6	20	30	36.06	0.04	0.00	0.00	0.00	0.02	0.01	0.02	0.00
4B6a	Other land Remaining other land	LUCF	0	6	10	30	31.62	0.03	0.00	0.00	0.00	0.01	0.02	0.02	0.00
4B6b	Land converted to Other Land	LUCF	56	56	20	30	36.06	0.35	0.12	0.00	0.01	0.17	0.07	0.18	0.03
5A	Solid waste disposal on land	Waste	0	0	77	65	100.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5B	Biological treatment of waste (compostin	Waste	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C1	Waste incineration	Waste	6	5	70	40	80.62	0.07	0.01	0.00	0.00	0.05	0.01	0.05	0.00
5C2	Open burning of waste (backyards)	Waste	34	28	20	40	44.72	0.22	0.05	0.00	0.00	0.08	0.03	0.09	0.01
5C2	Open burning of waste (landfills)	Waste	5	5	20	40	44.72	0.04	0.00	0.00	0.00	0.01	0.01	0.02	0.00
5D1	Domestic wastewater handling	Waste	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5D2	Industrial wastewater handling	Waste	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
									103.63						**12.42**
TOTAL	**CO2 emissions (incl LULUCF)**		**9520**	**5761**			**% Uncertainty (abs)**		**10.18**				**% Trend Uncertainty**		**3.52**
TOTAL	**CO2 emissions (excl LULUCF)**		**11205**	**7387**			**% Uncertainty (abs)**		**2.79**				**% Trend Uncertainty**		**0.91**

CH_4 Uncertainty Analysis

Table 0.3 Uncertainties in CH_4 Emissions Estimates

		GWP	21												
CRF		Fuel	Emissions 2006	Emissions 2012	Activity Data (AD) Uncertainty	Emission Factor (EF) Uncertainty	Combined Uncertainty	Combined Uncertainty as % of Emissions in 2012	Combined Emissions Uncertainty Squared	Type A Sensitivity	Type B Sensitivity	Uncertainty in Trend in Total Emissions	Uncertainty in Trend in Total Emissions	Combined Uncertainty in Trend in Total	Combined Trend Uncertainty Squared
	CH4		Gg CO_2eq	Gg CO_2eq	%	%	%	%		%	%	%	%	%	
1A1a	Public electricity and heat production	Fuel oil	2	2	1	100	100.00	0.19	0.04	0.00	0.00	0.00	-0.03	0.03	0.00
1A1a	Public electricity and heat production	Diesel oil	1	1	1	100	100.00	0.07	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1A1b	Petroleum refining	Fuel oil	0	0	1	100	100.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A1b	Petroleum refining	Diesel oil	0	0	1	100	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A2b	Mining/Bauxite	Fuel Oil	4	1	2	100	100.02	0.15	0.02	0.00	0.00	0.00	-0.32	0.32	0.11
1A2e	Sugar	Fuel oil	0	0	2	100	100.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A2e	Sugar	Bagasse	2	2	5	100	100.12	0.25	0.06	0.00	0.00	0.02	-0.03	0.03	0.00
1A2f	Cement	Fuel oil	0	0	2	100	100.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A2f	Cement	Coal	0	0	2	100	100.02	0.05	0.00	0.00	0.00	0.00	0.02	0.02	0.00
1A2gviii	Industry Other, Stationary	LPG	0	0	5	100	100.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A2gviii	Industry Other, Stationary	Fuel oil	0	0	5	100	100.12	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1A2gvii	Industry, Mobile machinery	Gasoline	0	0	5	100	100.12	0.02	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1A2gvii	Industry, Mobile machinery	Diesel Oil	0	0	5	100	100.12	0.03	0.00	0.00	0.00	0.00	0.02	0.02	0.00
1A3aii(i)	Domestic aviation LTO (civil)	Turbo	0	0	5	100	100.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3aii(i)	Domestic aviation LTO (civil)	Avgas	0	0	5	100	100.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3aii(ii)	Domestic aviation, cruise	Turbo	0	0	5	100	100.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3aii(ii)	Domestic aviation, cruise	Avgas	0	0	5	100	100.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3b	Road Transport	Gasoline	12	10	1	49	49.01	0.56	0.31	0.00	0.01	0.02	-0.18	0.18	0.03
1A3b	Road Transport	Diesel Oil	1	0	1	49	49.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3c	Railways	Diesel oil	0	0	2	100	100.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3d	Domestic shipping/National Navigation	Diesel Oil	0	0	1	100	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3d	Domestic shipping/National Navigation	Fuel Oil	0	0	1	100	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4aii	Commercial/institutional: Mobile	Gasoline	0	0	10	100	100.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4aii	Commercial/institutional: Mobile	Diesel oil	0	0	10	100	100.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4ai	Commercial/institutional: Stationary	Fuel Oil	0	0	5	100	100.12	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1A4ai	Commercial/institutional: Stationary	LPG	0	0	5	100	100.12	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4ai	Commercial/institutional: Stationary	Kerosene	0	0	5	100	100.12	0.00	0.00	0.00	0.00	0.00	-0.03	0.03	0.00
1A4ai	Commercial/institutional: Stationary	Charcoal	3	3	20	100	101.98	0.41	0.17	0.00	0.00	0.12	0.00	0.12	0.01
1A4bi	Residential: Stationary	Kerosene	0	0	10	100	100.50	0.00	0.00	0.00	0.00	0.00	-0.03	0.03	0.00
1A4bi	Residential: Stationary	LPG	0	0	10	100	100.50	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4bi	Residential: Stationary	Wood	8	9	20	100	101.98	1.03	1.06	0.00	0.01	0.30	-0.02	0.30	0.09
1A4cii	Agriculture/Forestry/Fishing: Mobile	Gasoline	0	0	10	39	40.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4cii	Agriculture/Forestry/Fishing: Mobile	Diesel oil	0	0	10	39	40.26	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1B2aiv	Refinery flaring	Flared gases and v	0	0	5	100	100.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3A	Dairy Cattle	Dairy Cattle	22	24	10	40	41.23	1.18	1.40	0.00	0.03	0.42	0.08	0.43	0.18
3A	Other Cattle	Other Cattle	88	98	10	40	41.23	4.75	22.53	0.01	0.12	1.70	0.31	1.72	2.97
3A	Buffalo	Buffalo	0	0	10	40	41.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3A	Sheep	Sheep	1	2	10	40	41.23	0.09	0.01	0.00	0.00	0.03	0.05	0.06	0.00
3A	Goats	Goats	49	35	10	40	41.23	1.72	2.94	-0.02	0.04	0.61	-0.76	0.97	0.95
3A	Horses	Horses	7	8	10	40	41.23	0.39	0.15	0.00	0.01	0.14	0.01	0.14	0.02
3A	Mules/Asses	Mules/Asses	2	2	10	40	41.23	0.09	0.01	0.00	0.00	0.03	0.00	0.03	0.00
3A	Market Swine	Market Swine	4	3	10	40	41.23	0.13	0.02	0.00	0.00	0.05	-0.06	0.08	0.01
3A	Breeding Swine	Breeding Swine	0	0	10	40	41.23	0.01	0.00	0.00	0.00	0.01	-0.01	0.01	0.00
3B	Dairy Cattle	Dairy Cattle	16	18	10	30	31.62	0.67	0.45	0.00	0.02	0.31	0.04	0.32	0.10
3B	Other Cattle	Other Cattle	2	3	10	30	31.62	0.10	0.01	0.00	0.00	0.05	0.01	0.05	0.00
3B	Buffalo	Buffalo	0	0	10	30	31.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B	Sheep	Sheep	0	0	10	30	31.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B	Goats	Goats	2	2	10	30	31.62	0.06	0.00	0.00	0.00	0.03	-0.03	0.04	0.00
3B	Horses	Horses	1	1	10	30	31.62	0.04	0.00	0.00	0.00	0.02	0.00	0.02	0.00
3B	Mules/Asses	Mules/Asses	0	0	10	30	31.62	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B	Market Swine	Market Swine	46	32	10	30	31.62	1.20	1.44	-0.02	0.04	0.56	-0.56	0.79	0.62
3B	Breeding Swine	Breeding Swine	9	6	10	30	31.62	0.24	0.06	0.00	0.01	0.11	-0.11	0.16	0.02
3B	Poultry- Chickens (Layers)	Poultry- Chickens (	2	3	10	30	31.62	0.10	0.01	0.00	0.00	0.05	0.01	0.05	0.00
3B	Poultry- Chickens (Broilers)	Poultry- Chickens (	12	27	10	30	31.62	1.00	0.99	0.02	0.03	0.46	0.51	0.69	0.48
3B	Poultry- Turkeys	Poultry- Turkeys	0	0	10	30	31.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B	Poultry- Ducks&Geese	Poultry- Ducks&Ge	0	0	10	30	31.62	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
3B	Rabbit	Rabbit	0	0	10	30	31.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3C	Rice	TOTAL	0	0	5	76	76.50	0.03	0.00	0.00	0.00	0.00	0.03	0.03	0.00
3F	Field Burning	TOTAL	5	5	5	112	112.36	0.66	0.43	0.00	0.01	0.04	-0.08	0.09	0.01
5A	Solid waste disposal on land	Waste	400	463	77	65	100.62	54.69	2990.60	0.06	0.57	61.47	3.68	61.58	3792.58
5B	Biological treatment of waste (compostin	Waste	0.00	0.00	14	900	900.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C1	Waste incineration	Waste	0	0	70	100	122.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C2	Open burning of waste (backyards)	Waste	13	11	20	100	101.98	1.33	1.76	0.00	0.01	0.38	-0.29	0.48	0.23
5C2	Open burning of waste (landfills)	Waste	2	2	20	100	101.98	0.23	0.05	0.00	0.00	0.07	0.00	0.07	0.00
5D1	Domestic wastewater handling	Waste	40	32	49	50	70.36	2.63	6.90	-0.01	0.04	2.72	-0.57	2.78	7.73
5D2	Industrial wastewater handling	Waste	59	44	36	50	61.85	3.22	10.38	-0.02	0.05	2.79	-1.03	2.98	8.86
									3041.84						**3815.03**
Total	**CH4 emissions**		**818**	**852**			**% Uncertainty (abs)**		**55.15**				**% Trend Uncertainty**		**61.77**

N_2O Uncertainty Analysis

Table 0.4 Uncertainties in N_2O Emissions Estimates

		GWP	310												
CRF		Fuel	Emissions 2006	Emissions 2012	Activity Data (AD) Uncertainty	Emission Factor (EF) Uncertainty	Combined Uncertainty	Combined Uncertainty as % of Emissions in 2012	Combined Emissions Uncertainty Squared	Type A Sensitivity	Type B Sensitivity	Uncertainty in Trend in Total Emissions due to AD	Uncertainty in Trend in Total Emissions due to EF	Combined Uncertainty in Trend in Total Emissions	Combined Trend Uncertainty Squared
			Gg CO_2eq	Gg CO_2eq	%	%	%	%		%	%	%	%	%	
1 A1 a	Public electricity and heat production	Fuel oil	5	5	1	150	150.00	0.11	0.01	0.00	0.00	0.00	-0.16	0.16	0.03
1 A1 a	Public electricity and heat production	Diesel oil	2	2	1	150	150.00	0.04	0.00	0.00	0.00	0.00	-0.05	0.05	0.00
1 A1 b	Petroleum refining	Fuel oil	0	0	1	150	150.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A1 b	Petroleum refining	Diesel oil	0	0	1	150	150.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A2 b	Mining/Bauxite	Fuel Oil	11	4	2	150	150.01	0.08	0.01	0.00	0.00	0.00	-0.59	0.59	0.35
1 A2 e	Sugar	Fuel oil	0	0	2	150	150.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A2 e	Sugar	Bagasse	4	4	5	150	150.08	0.10	0.01	0.00	0.00	0.01	-0.13	0.13	0.02
1 A2 f	Cement	Fuel oil	0	0	2	150	150.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A2 f	Cement	Coal	1	1	2	150	150.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A2 gviii	Industry Other, Stationary	LPG	0	0	5	150	150.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A2 gviii	Industry Other, Stationary	Fuel oil	0	0	5	150	150.08	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1 A2 gvii	Industry, Mobile machinery	Gasoline	1	1	5	150	150.08	0.02	0.00	0.00	0.00	0.00	-0.04	0.04	0.00
1 A2 gvii	Industry, Mobile machinery	Diesel Oil	2	4	5	150	150.08	0.08	0.01	0.00	0.00	0.01	0.03	0.03	0.00
1 A3 aii(i)	Domestic aviation LTO (civil)	Turbo	0	0	5	150	150.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A3 aii(i)	Domestic aviation LTO (civil)	Avgas	0	0	5	150	150.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A3 aii(ii)	Domestic aviation, cruise	Turbo	0	0	5	150	150.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A3 aii(ii)	Domestic aviation, cruise	Avgas	0	0	5	150	150.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A3 b	Road Transport	Gasoline	57	46	1	39	39.01	0.27	0.07	-0.01	0.01	0.02	-0.52	0.52	0.28
1 A3 b	Road Transport	Diesel Oil	7	7	1	39	39.01	0.04	0.00	0.00	0.00	0.00	-0.05	0.05	0.00
1 A3 c	Railways	Diesel oil	0	0	2	150	150.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A3 d	Domestic shipping/National Navigation	Diesel Oil	0	0	1	150	150.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1 A3 d	Domestic shipping/National Navigation	Fuel Oil	0	0	1	150	150.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1 A4aii	Commercial/institutional: Mobile	Gasoline	0	0	10	150	150.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A4aii	Commercial/institutional: Mobile	Diesel oil	0	0	10	150	150.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A4ai	Commercial/institutional: Stationary	Fuel Oil	0	0	5	150	150.08	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1 A4ai	Commercial/institutional: Stationary	LPG	0	0	5	150	150.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A4ai	Commercial/institutional: Stationary	Kerosene	0	0	5	150	150.08	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1 A4ai	Commercial/institutional: Stationary	Charcoal	0	0	20	150	151.33	0.01	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1 A4bi	Residential: Stationary	Kerosene	0	0	10	150	150.33	0.00	0.00	0.00	0.00	0.00	-0.02	0.02	0.00
1 A4bi	Residential: Stationary	LPG	0	0	10	150	150.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A4bi	Residential: Stationary	Wood	2	2	20	150	151.33	0.04	0.00	0.00	0.00	0.01	-0.04	0.05	0.00
1 A4cii	Agriculture/Forestry/Fishing: Mobile	Gasoline	0	0	10	49	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 A4cii	Agriculture/Forestry/Fishing: Mobile	Diesel oil	0	0	10	49	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 B2 aiv	Refinery flaring	Flared gases and v	0	0	5	150	150.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3 B	Dairy Cattle	Dairy Cattle	4	5	10	100	100.50	0.07	0.01	0.00	0.00	0.02	-0.07	0.07	0.00
3 B	Other Cattle	Other Cattle	18	20	10	100	100.50	0.31	0.10	0.00	0.01	0.07	-0.28	0.29	0.08
3 B	Buffalo	Buffalo	0	0	10	100	100.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3 B	Market Swine	Market Swine	127	90	10	100	100.50	1.37	1.89	-0.03	0.02	0.33	-3.27	3.28	10.78
3 B	Breeding Swine	Breeding Swine	7	5	10	100	100.50	0.08	0.01	0.00	0.00	0.02	-0.19	0.19	0.04
3 B	Poultry- Chickens (Layers)	Poultry- Chickens (	35	39	10	100	100.50	0.60	0.36	-0.01	0.01	0.14	-0.54	0.56	0.31
3 B	Poultry- Chickens (Broilers)	Poultry- Chickens (	820	1794	10	100	100.50	27.34	747.67	0.10	0.46	6.56	10.22	12.14	147.39
3 B	Poultry- Turkeys	Poultry- Turkeys	0	1	10	100	100.50	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.00
3 B	Poultry- Ducks&Geese	Poultry- Ducks&Ge	2	3	10	100	100.50	0.05	0.00	0.00	0.00	0.01	0.02	0.02	0.00
3 B	Sheep	Sheep	2	4	10	100	100.50	0.06	0.00	0.00	0.00	0.02	0.04	0.04	0.00
3 B	Goats	Goats	114	82	10	100	100.50	1.26	1.58	-0.03	0.02	0.30	-2.88	2.90	8.39
3 B	Horses	Horses	5	5	10	100	100.50	0.08	0.01	0.00	0.00	0.02	-0.08	0.08	0.01
3 B	Mules/Asses	Mules/Asses	2	2	10	100	100.50	0.03	0.00	0.00	0.00	0.01	-0.04	0.04	0.00
3 B	Rabbit	Rabbit	92	65	10	100	100.50	1.00	0.99	-0.02	0.02	0.24	-2.37	2.38	5.66
3 D	Synthetic N fertilizer	Synthetic N fertiliz	28	56	5	300	300.04	2.55	6.48	0.00	0.01	0.10	0.67	0.67	0.45
3 D	Organic N fertilizer	Organic N fertilizer	855	1646	5	300	300.04	74.91	5611.33	0.05	0.43	3.01	14.67	14.97	224.22
3 D	Grazing animals	Grazing animals	342	295	5	300	300.04	13.41	179.88	-0.07	0.08	0.54	-22.32	22.33	498.47
3 D	Crop residues	Crop residues	6	8	5	300	300.04	0.35	0.12	0.00	0.00	0.01	-0.26	0.26	0.07
3 D	N mineralised from mineral soils as a resu	N mineralised from	0	0	5	300	300.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3 D	Drained/managed organic soils	Drained/managed	67	67	5	300	300.04	3.05	9.30	-0.01	0.02	0.12	-3.66	3.66	13.38
3 E	Soils- Atm. Deposition	Soils- Atm. Deposi	3	6	5	330	330.04	0.31	0.10	0.00	0.00	0.01	0.08	0.08	0.01
3 E	Soils- Leaching/runoff	Soils- Leaching/rur	319	569	5	330	330.04	28.47	810.29	0.01	0.15	1.04	2.10	2.34	5.48
3 E	Manure - Atm. Deposition	Manure - Atm. De	696	1353	5	330	330.04	67.73	4587.11	0.04	0.35	2.47	14.22	14.44	208.44
3 E	Manure - Leaching/runoff	Manure - Leaching	182	354	5	330	330.04	17.70	313.26	0.01	0.09	0.65	3.77	3.82	14.63
3 F	Field burning	Field burning	2	2	5	65	65.19	0.02	0.00	0.00	0.00	0.00	-0.03	0.03	0.00
5 A	Solid waste disposal on land	Waste	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 B	Biological treatment of waste (compostir	Waste	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 C1	Waste incineration	Waste	0	0	70	100	122.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 C2	Open burning of waste (backyards)	Waste	4	4	20	100	101.98	0.06	0.00	0.00	0.00	0.03	-0.10	0.10	0.01
5 C2	Open burning of waste (landfills)	Waste	1	1	20	100	101.98	0.01	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
5 D1	Domestic wastewater handling	Waste	41	41	43.14	50	66.04	0.41	0.17	-0.01	0.01	0.64	-0.36	0.74	0.55
5 D2	Industrial wastewater handling	Waste	0	0	36.40	50	61.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
									12270.77						**1139.04**
TOTAL	**N2O emissions**		**3870**	**6594**			**% Uncertainty (abs)**		**110.77**				**% Trend Uncertainty**		**33.75**

2.2.16.79 HFC Uncertainty Analysis

Table 0.5 Uncertainties in HFC Emissions Estimates

	CODE	Gas	Emissions 2006	Emissions 2012	Activity Data (AD) Uncertainty	Emission Factor (EF) Uncertainty	Combined Uncertainty	Combined Uncertainty as % of Emissions in 2012	Combined Emissions Uncertainty Squared	Type A Sensitivity	Type B Sensitivity	Uncertainty in Trend in Total Emissions due to AD	Uncertainty in Trend in Total Emissions due to EF	Combined Uncertainty in Trend in Total Emissions	Combined Trend Uncertainty Squared
	HFCs		Gg CO_2eq	Gg CO_2eq	%	%	%	%		%	%	%	%	%	
2F	HFC_consumption	HFC-32	4	11	100	500	509.90	60.47	3656.04	0.07	0.14	19.47	37.20	41.99	1763.27
2F	HFC_consumption	HFC-125	12	11	100	500	509.90	63.82	4072.61	-0.04	0.15	20.55	-18.55	27.68	766.42
2F	HFC_consumption	HFC-134a	44	52	100	500	509.90	290.94	84646.27	0.01	0.66	93.70	5.79	93.88	8813.30
2F	HFC_consumption	HFC-143a	16	16	100	500	509.90	90.55	8199.87	-0.03	0.21	29.16	-14.68	32.65	1065.89
2F	HFC_consumption	HFC-152a	0	0	100	500	509.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2F	HFC_consumption	HFC-227ea	2	1	100	500	509.90	3.53	12.46	-0.02	0.01	1.14	-8.35	8.43	71.08
2F	HFC_consumption	HFC-236fa	0	0	100	500	509.90	0.59	0.35	0.00	0.00	0.19	-1.41	1.42	2.01
									100587.61						**12481.97**
2F	**HFC_consumption**	**HFC**	**79**	**92**			**% Uncertainty (abs)**		**317.16**				**% Trend Uncertainty**		**111.72**

The results of the uncertainty analysis can be used to prioritise improvements that will have the greatest impact. This is considered in the section below which presents a Key Category Analysis on the inventory.

2.2.17 Key Category Analysis

2.2.17.1 Introduction

The IPCC Guidance provides a tool for assessing the sources that make the largest contribution to the emission totals, and hence should be prioritised in terms of using better than Tier 1 methodologies. This is known as a Key Category Analysis (KCA).

Emission sources are expressed as CO_2 equivalents, and then ranked in order of largest to smallest (all emissions are expressed as a magnitude, and hence any land use change sinks are expressed as an emission). A running total is included to identify the largest sources which contribute 95% of the total emission. These are labelled "key" sources, and best practice indicates that better than Tier 1 methodologies should be used for estimating emissions from these sources.

The output from a KCA is dependent on the level of source aggregation. For this analysis, sources have been aggregated across different activity data with a source category to give a single value (e.g. emissions from different fuels have been aggregated). The exceptions to this is the agriculture sector, where the emissions from different livestock types have been retained to provide detailed information.

It should also be noted that HFCs have been included in the analysis on an individual basis. The result is that the emissions of individual HFCs are small, and do not feature on the list of key categories. However, if the individual HFC emissions were summed, then the total HFC emission from 2F Refrigeration and Air Conditioning would appear on the list of key categories in position 21, making a contribution of 1% to the total emissions (see table 8.1 below).

2.2.17.2 KCA Results

The table below presents the results of the KCA analysis. Colour coding has been used or easy interpretation of the different sources and sectors which are the largest overall contributors.

The results are common with other countries in that CO_2 emissions from the energy sector (shown in red) typically make the largest contributions to the GHG emissions total. Electricity generation, road transport and the Mining/Bauxite industry all feature in the ten largest sources.

The agriculture sector (brown) also makes substantial contributions to the total emission. The largest source in the agriculture sector are associated with manure management, and its application to land as a fertiliser. The contribution from the agriculture sector to the total emission typically decreases across countries with increasingly developed economies – because there are higher levels of fuel consumption for: electricity generation, industry, transport and in the residential sector.

The importance of forested areas in the emissions inventory is evident, with forestland remaining forestland making the third largest contribution to the emission inventory total.

CH_4 emissions from landfill is also shown to be one of the larger sources in the inventory, although only making a 3% contribution to the total.

Table 0.1 Key Category Analysis

Rank	CRF	Source	Pollutant	Emission (Gg CO_2 EQ)	Emission (%)	Running Total%
1	1A1a	Public electricity & heat prodn	CO_2	2,682	16%	15.9%
2	4B	Manure Mgt - Chickens (Broilers)	N_2O	1,794	11%	26.5%
3	5A	Forest Land Remaining FL	CO_2	1,777	11%	37.0%
4	1A3b	Road Transport	CO_2	1,726	10%	47.2%
5	4D	Organic N fertiliser	N_2O	1,646	10%	56.9%
6	1A2b	Mining/Bauxite	CO_2	1,525	9%	65.9%
7	4G	Manure - Atm. Deposition	N_2O	1,353	8%	73.9%
8	4G	Soils- Leaching/runoff	N_2O	569	3%	77.3%
9	6A	Solid waste disposal on land	CH_4	463	3%	80.0%
10	4G	Manure - Leaching/runoff	N_2O	354	2%	82.1%
11	2A1	Cement	CO_2	339	2%	84.1%
12	4D	Grazing animals	N_2O	295	2%	85.8%
13	1A2gvii	Industry, Mobile machinery	CO_2	247	1%	87.3%
14	1A2f	Cement	CO_2	192	1%	88.4%
15	1A1b	Petroleum refining	CO_2	143	1%	89.3%
16	1A4bi	Residential: Stationary	CO_2	139	1%	90.1%
17	1A4ai	Commercial/Institnl: Stationary	CO_2	119	1%	90.8%
18	5B	Land converted to Grassland	CO_2	116	1%	91.5%
19	4A	Enteric - Other Cattle	CH_4	98	1%	92.1%
20	2A2	Lime	CO_2	95	1%	92.6%
21	4B	Manure Mgt - Market Swine	N_2O	90	1%	93.2%
22	4B	Manure Mgt - Goats	N_2O	82	0.5%	93.6%
23	1A4cii	Agricul/Forest/Fishing: Mobile	CO_2	79	0.5%	94.1%
24	4D	Drained/managed organic soils	N_2O	67	0.4%	94.5%
25	4B	Manure Mgt - Rabbit	N_2O	65	0.4%	94.9%
26	5E	Land converted to Other Land	CO_2	56	0.3%	95.2%

LEGEND 1 Energy 2 IPPU 3 Agricul. 4 LULUCF 5 Waste

2.2.17.3 Improvements

The results from the key category analysis can be used to help with the prioritisation of improvement activities. The IPCC Good Practice Guidance (2006) indicates that it is best practice for all key sources to use methodologies that are higher than Tier 1.

There are some improvements that could be made to the methodologies used for emissions from both the agriculture and energy sectors which would help to elevate the methodologies to Tier 2 or better. In general, the focus of this improvement would require the collation and use of country specific data more completely throughout the emission calculations.

This would be a particularly effective and efficient approach for improving the quality (and in particular the accuracy) of the emissions inventory. The results from the uncertainty analysis also help to steer the prioritisation of inventory improvements.

The ten largest sources (which account for more than 80% of the emissions) are considered below.

1A1a Public Electricity & Heat Production (CO_2), 1A2b Mining/Bauxite (CO_2)

The current methodology uses activity data from the national energy balance tables and default EFs from the 2006 IPCC Guidance. This is generally an accurate way of determining emissions of CO_2, but the use of country specific data at the individual plant level would allow both the activity data and EFs to be characterised in more detail. Furthermore, it is highly likely that these data exist, making this improvement an issue of data collection rather than data availability.

It would also help with the transparency of the emissions calculations for large point sources if improvements were made to the transparency of the activity data used.

4B Manure Management from Broiler Chickens (N2O), and 4D Organic N Fertiliser (N2O)

Uncertainties in EFs for the agriculture sector are typically higher than combustion sources, and for these sources result in an overall uncertainty of more than 100% and 300% for Broiler Chickens (N_2O) and Organic N Fertiliser (N_2O) respectively.

The methodology used for estimating emissions from the agriculture sector (both manure management and from soils) is very detailed, and is based on a full assessment of the N flows through the whole sector. It is thought that the activity data represents the best quality that is currently available. So whilst improvements could be made to some of the assumptions that underpin these emission estimates, it is likely that this would require new data collection, making any significant improvements challenging.

Nevertheless, there are key datasets which should be prioritised in terms of improving the quality. In particular a high quality dataset of livestock numbers across the time series was not readily available. These data were assembled from several different sources, and required extensive interpolation/extrapolation to obtain a reliable time series. Given the importance of these data, it is recommended that improvements are made to the quality and availability of livestock numbers data.

5A Forest Land Remaining Forest Land (CO2)

Uncertainties in emissions from land use and land use change are typically higher than other categories, because the input data is challenging to obtain at high quality levels, and the current uncertainty of 32% may represent an underestimate of the uncertainty.

Significant improvements could be made to the emission estimates in the Jamaican inventory by investing resources in improved data collection, and in particular more frequent assessment of land cover types and changes. This is likely to be resource intensive, but would be valuable in also helping to support the general management of forested areas, and not just for use in the emissions inventory.

1A3b Road Transport (CO2)

The activity data for road transport is taken from the energy balance tables. Local experts consider this to be of a good level of accuracy, and the overall uncertainty in CO_2 emissions is estimated to be approximately 2%.

However, it has not been possible to obtain bottom-up sales data. This means that a single dataset is used in both the reference approach and the sectoral approach. The use of two independent datasets for the reference and sectoral approaches allows an important quality check on the activity data, and sourcing data that allows this check should be a high priority.

4G Indirect Emissions (N2O)

Atmospheric deposition (and re-emission) and leaching/runoff from soils and manure management are all indirect emissions of N_2O. Indirect emissions of N_2O from the agriculture sector are particularly challenging to estimate with any accuracy, and this is reflected in the uncertainty assessment which calculates the uncertainties associated with the emissions from indirect sources as 330%.

The methodologies currently used in the inventory are detailed, using a full assessment of the N flows in the agriculture sector. It is therefore unlikely that improvements could be easily made to the underlying methodology. The high uncertainty is driven by uncertainties in the EFs, and obtaining country specific data would involve a detailed study of e.g. agricultural soils, runoff potential, fertiliser application rates to fields, topography etc. This would be a large undertaking and is expected to be beyond current resources.

6A Solid Waste Disposal on Land (CH4)

The uncertainty assessment in the waste sector has been undertaken in detail, considering the uncertainty associated with each of the underlying parameters. The uncertainty analysis indicates that the uncertainty in the emission is over 100%, and that this is significantly influenced by the uncertainty in both activity data and the EF.

The relatively high EFs for CH_4 from landfills reflects the uncertainties in characterising an emission source that is influenced by many different variables. It is therefore challenging to make significant improvements to the EF uncertainty by sourcing additional data, although this could be done by using more detailed country specific data in the modelling of CH4 generation and emissions from Jamaican landfills.

It is more straightforward to target improvement efforts at obtaining better quality activity data i.e. the amount and composition of waste going to landfill. Whilst it is thought that the data used in the emissions inventory is the best quality that is currently available, it may be that improvements are made in the coming years as part of a general improvement in solid waste management in Jamaica.

2.2.18.0 The National System

2.2.18.1 Introduction

The "National System" is a term used to describe the overarching framework for the emissions inventory compilation. It includes not just the emission calculations, but also all other activities associated with, and that support, the emissions calculations. So, for example the national system also includes the assessment and planning of: data provision/collection, roles and responsibilities of all inventory team members, the quality assurance and quality control processes throughout the inventory, management of the different inventory processes, the inventory improvement programme etc. etc.

The creation and development of a national system for Jamaica will be fully considered in a separate report. However, it is appropriate to include here some headline comments and recommendations that relate to the national system and cross-cutting issues.

Sections 3-7 of this report include a consideration of improvements that could be made to the emission estimates in the emissions inventory on a sector by sector basis, and Sections 8 and 9 (Uncertainty analysis and Key Category Analysis) consider how improvements to emission estimates might be prioritised. But this does not address cross-cutting or structural issues.

2.2.18.2 Previous Versions of the Emissions Inventory

Prior to starting the compilation of the current GHG inventory it was assumed that the detailed files would be available from the previous inventory, covering the period 2000-2005 (Davis et al, 2008). However this did not prove to be possible.

Best practice in emissions inventories requires the effective archiving and storage of previous versions of the inventory. This is important for a number of reasons. Firstly, it ensuring continued transparency of the emission inventory, allowing the detailed calculations to be checked long after compilation. Secondly, it provides a fundamentally important platform for subsequent inventories, because the generation of an inventory 'from scratch' requires considerably more resource than updating and improving an existing emissions inventory.

Substantial effort has been invested in ensuring that the calculation sheets that comprise the current emissions inventory are transparent, and can easily be extended to include emission estimates for future years. This is important in ensuring that they can be used as a platform for future versions of the inventory. However effective management of the files and technical experts will need to be in place to ensure that this is possible in the future.

Some key decisions will need to be made if the emissions inventory is to be developed into an on-going programme that can deliver an emissions inventory that continues to be improved each time it is compiled.

The 'home' of the emissions inventory first needs to be established. It is appreciated that there are likely to be challenges associated with securing resources to allow the inventory to be an on-going programme, but this is an issue which can be dealt with separately to the organisation and management of the emissions inventory.

It is recommended that management of an on-going emissions inventory programme be identified as a responsibility of the Ministry of Water, Land, Environment and Climate Change. This would allow the permanent appointment of a dedicated programme manager. The programme manager can then have the responsibility of building the framework that is required for the compilation of the emissions inventory. This framework, and in particular the activity levels in different areas, can be tailored to the available funding/resources.

The following is a brief consideration of several key parts of the national system, assuming that the emissions inventory is based within the Ministry. These will be considered in detail in the report that will be drafted on the National System.

2.2.18.4 Data Collection

The quality of input data is a fundamental parameter in determining the quality of the resulting emission estimates. The experience of compiling the emissions inventory presented in this report shows that the quality of existing data to be very variable across the different sectors. It has also shown that the availability of data from different organisations is very variable.

Planning is needed to identify and secure key datasets, as well as influencing the development of data collection in Jamaica. Experience indicates that it is often the emissions inventory team who are responsible for driving the improvements in data (both in terms of quality and coverage). A strong relationship between the emissions inventory team and data providers is always a key factor in being able to compile a high quality emissions inventory. Priority should be given to ensuring that good quality input data can be made available to the inventory team on a regular basis.

2.2.18.5 Technical Experts

Decisions will need to be made on whether technical expertise is drawn from Ministries and other Government departments or the private sector. There are advantages/disadvantages of using either option, and the decision needs to be taken on a sector by sector basis depending on the national circumstances. The experience of compiling the emissions inventory presented in this report shows that there is good expertise in both the public and private sectors.

The aim should be to secure individuals who are not just knowledgeable about a particular technical area, but are also well connected in terms of obtaining data, and are willing to invest time in learning about GHG emissions inventories and the underlying methodologies used for making emission estimates.

2.2.18.6 Quality Assurance/Quality Control

This is a function that should encompass all aspects of an emissions inventory programme, and typically needs an individual to oversee and manage the different aspects of this work.

The emissions inventory presented in this report has been compiled with rigorous QA/QC processes, and it is sensible that these are maintained and continued for the next version of the emissions inventory. Efforts have been made to ensure that as much of the QA/QC work undertaken is transparent, so that they can be easily reproduced in the next version of the emissions inventory (for example internal consistency checks in compilation spreadsheets).

CHAPTER 3
GENERAL DESCRIPTION OF STEPS TO FACILITATE ADAPTATION

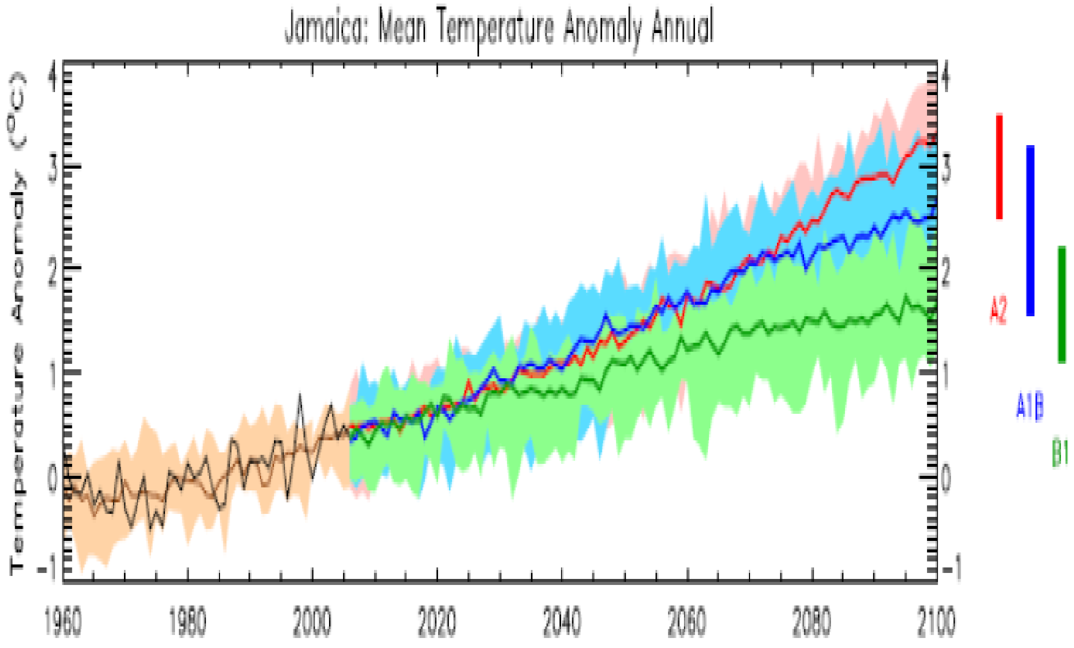
3.1 Agriculture sector

3.1.1 Background

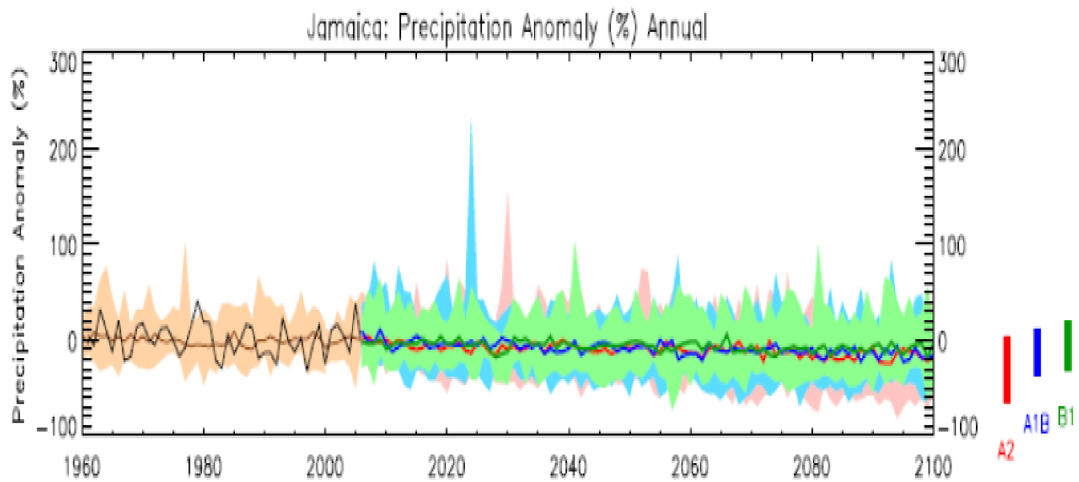
3.1.1.1Climate projections, downscaled scenarios, and policy responses

Food production systems such as agriculture and fisheries are highly susceptible to climate change impacts. The State of Climate Jamaica 2012 provides a rich historical overview of climate variability and climate impact trends from mid-century to recent decades (CSGM, 2012). The report concludes that mean temperatures show an increasing linear trend at a rate of 0.16oC/decade and is consistent with regional and global trends. Similarly, there is an increasing amount and intensity of rainfall patterns from the 1940s to 2010s with some wet and dry anomalies and inter-annual variability due to El Niño Southern Oscillation events. This will affect food production systems as well as related socioeconomic activities and economic development. For instance, projected positive trend for rainfall indices in the mountainous regions will receive excess rainfall of 1700 mm annually, which will affect domesticated local food systems and export revenues.

Figure 1: Historical and projected trends in temperature and rainfall



Source: McSweeney et al. 2008; CSGM, 2011



Source: CSGM, 2011

Climate projections from both Global Climate Models (GCM) and downscaled Regional Climate Models (RCM) predict an increase in temperatures year round with variations between coastal and non-coastal regions (UWI, 2016). Future predictions emphasise mean temperatures increase from about 0.42-0.46ºC by the 2020s and from 0.87-1.74ºC by the 2050s. On the other hand, rainfall patterns will show decreasing trends with dryer conditions according to GCMs ranging from 2% by 2020 to 10% by 2050. RCM projections also indicate a drying trend from the mid-2030s to the end of the century with similar spatial variability across coastal and interior regions (UWI, 2016). Regionally, the Caribbean region tends to be hotter and drier during El Niño and El Niña events, which occurs every 3-5 years and have been severe since the 1970s especially during the late wet seasons. This affects the duration of the growing season and regional economic development.

Owing to the cross-cutting nature of the impact of climate change, the Government of Jamaica has developed a Climate Change Policy Framework and Action Plan through the Ministry of Water, Land, Environment and Climate Change. The policy framework offers an institutional platform to facilitate the development, coordination and implementation of adaptation and mitigation policies and sectoral plans including agricultural and fisheries. Community level initiatives and national adaptation planning are delegated through a Climate Change Division (CCD) in partnership with non-state actors and stakeholder groups. Attention has been given towards sectoral approaches especially for natural resource, which includes the following:

- Sustainable use of natural resources;
- Multi-sectoral approach to climate change;
- Public Participation and Collaboration;
- The Precautionary Approach;
- Transparency and accountability, and
- Best available science.

Jamaica being a party to the UNFCCC has committed to climate change assessments as well as adaptation and mitigation plans in the agriculture and coastal sectors, as detailed in the Second National Communication.

Box 1: Anticipated climate impact natural resource sectors

Summary of Climate Change Impacts
Fluctuation in water resources due to episodic flooding and drought events;
Water abstraction and saline intrusion into ground water sources;
Prevalence of pests and diseases due to increasing temperature;
Land use change due to soil erosion and deforestation;
Poor soil quality due to lack of soil carbon and salinization;
Variations in agro-climatic conditions causing storms and hurricanes;
Habitat destruction especially spawning grounds caused by the occurrence of severe weather events;
Loss and damage to essential infrastructure and disruption along commodity production chains;
Livelihood concerns and loss in socioeconomic opportunities;
Poor return on investment and loss of revenue due to reduction in export markets;
Increased in processed food imports affecting household expenditures and non-communicable disease.

3.1.2 Climate change and the natural resource sectors

Jamaica is a Small Island Developing State and highly dependent on natural resources. Its geographical location and biophysical landscape make it highly vulnerable to climate change impacts especially along coastal sectors and livelihood activities. Food production from the agricultural sector currently contributes about 7% to the country' GDP and employs close to 18% of the labour workforce (World Bank 2013). Major export commodities include sugar, banana, coffee, and cocoa. Other local produce are important for the domestic food market, primarily vegetables, cassava, poultry, and livestock. Similarly, the fisheries sector also contributes to local seafood security, has been an important protein source, and is well integrated with tourism livelihoods in some regions. Fisheries also contribute tremendously to foreign earnings. For example, total seafood export was estimated at $11 million USD in 2013, up from US$8.93 million in 2012 (ref).

Both fisheries and agriculture account for the majority of rural livelihoods. Compared to the 1940s when the agriculture sector contributed significantly to labor markets (about 45%) with GDP amounting to 28% in 1943, the 2000s have seen a gradual decrease in both employment and GDP, with GDP inputs amounting to only 7% in 2012 (Planning Institute if Jamaica, 2013; Government of Jamaica, 2013). Agriculture's contribution to GDP has fluctuated in the past few decades from 6.7% in 1991 to 5.8% in 2010 and reaching its nadir in 2008 (at 4.8%). However, recent production increase in the sector was observed through government interventions in the agricultural industry from 2009 to 2011 but was cut short by extreme events and climate disasters as shown in Figure 2.

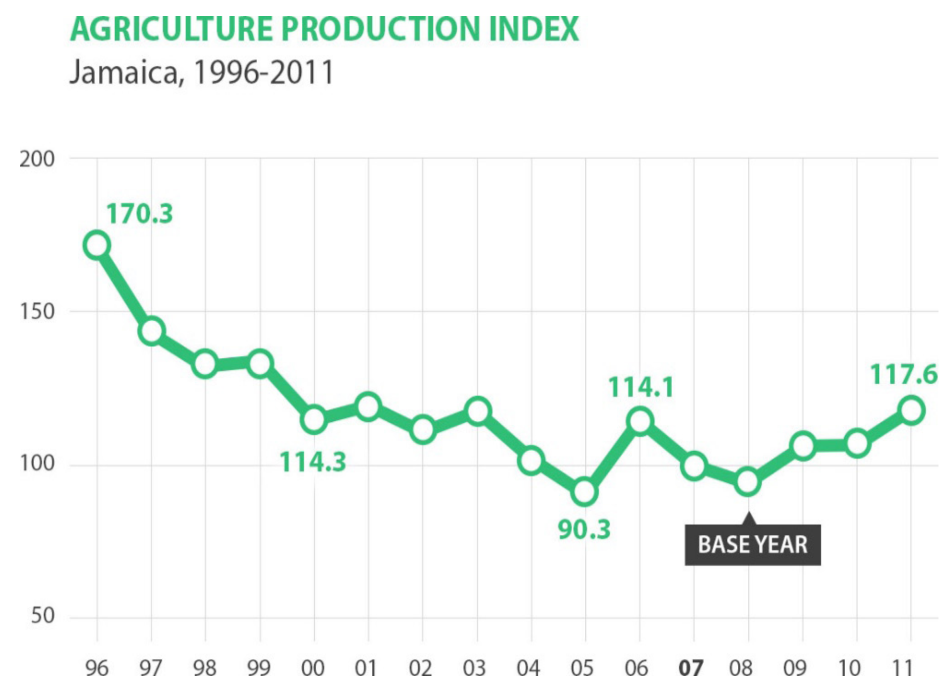


Figure 2: Agricultural production index from 1996 to 2014

Jamaica has experienced several storms and hurricanes in the past decade with severe flooding damage, loss of lives, and destruction of goods and services to the amount of $ 129 billion USD (State of the Climate 2012 Report). The impacts of increasing climatic events such as tropical hurricanes and associated peaks of strong winds have profound consequences on agricultural production, food security, and local livelihoods. It has been recognised that there is a strong interaction between climatic episodes such as increasing sea surface temperatures and hurricane intensities (Peterson et al. 2002), which has implications for natural resource sectors such as fisheries. For instance, El Niño events do influence hurricane activities and impacts both agriculture and fisheries sectors (Tataglione et al. 2003).

Warmer temperatures increase the rate of evapotranspiration and do affect water availability causing drought and strife in food production systems particularly for smallholder farmers in the southwest. Extreme aridity stunts vegetative growth and crop yields leading to economic stress and livelihood vulnerability. This is further compounded by unplanned land-use practices and urbanisation that erodes soil carbon and stifles food production particularly in the northeastern region of Jamaica around the parishes of St. Ann, Trelawney and Portland (Ganpat and Isaac, 2015).

Flooding also affects soil cover and loss of nutrients thereby reducing on production volume and supply. The cumulative impact of global economic change with regional climate impacts, i.e., double exposure, has been known to exacerbate community vulnerability in the "breadbasket of Jamaica" (Gamble et al. 2010).

Various climatic 'shocks' and 'stresses' affect food production through access and availability that impacts food price and livelihood activities. The cumulative impact of shocks and stress exacerbates community vulnerability and often lead to food security (Campbell and Beckford, 2009). Food security is understood within the context of four defining criteria, notably availability, access, stability and utilisation (FAO, 2008). These linkages with climate stressors are often explained through poor yield resulting to lower production, pest and diseases, damage to essential infrastructure affecting supply, and increasing demand that might lead to price hikes (Ganpat and Isaac, 2015). Two major exports, coffee, and banana have been highly devastated due to hurricanes and storms that have stifle productivity and the livelihoods that depend on it.

For fisheries, the impact of climate change affects the entire fish production chain from oceans to plate, i.e., from the pre-harvest stage to the harvesting and post-harvest stage. Within marine ecosystems, ENSO events do impact the biophysical environment through ocean acidification and calcification, the abundance of fish stocks and impedes nursery and spawning habitats. Within the harvesting stage, climate change impacts through sea level rise damage essential coastal infrastructure such as wharves as well as compromise catch quotas and access rights. These impacts are also felt in inland fisheries and aquaculture operations around Bowden Bay, St. Catherine and Clarendon.

Shortages in food production due to climate hazards have led to higher food imports and a diet change that has spur concerns about non-communicable chronic disease (obesity and diabetes). A drastic increase in food imports in the two decades has put local farmers out of business due to competitive pricing thereby affecting livelihoods and community health. Obesity, for instance, has increased from 10 to 25% from 2000 to 2008 due to lifestyle and dietary changes resulting from poor food choices, local inaccessibility, and unavailability (Labonte et al. 2010). The National Food and Nutrition Security Policy aims at filling in this gap by providing strategies and action plans that can address food security and nutritional well-being (Government of Jamaica, 2013b). The policy framework consists of an inter-agency collaborative program spearheaded by the Ministry of Agriculture and Fisheries, and the Ministry of Health. The goal is to a) manage food production and consumption, b) coordinate an inter-agency and stakeholder network in addressing emerging issues, c) explore private sector participation and market-based instruments, and d) determine suitable best practices and activities that are sustainable in the long term. Mainstreaming of adaptation plans and policy integration of sectoral plans for community development could boost agricultural investments and local resilience through infrastructure protection, new market access, and new leadership (Table 1).

3.2 Methodological Framework

Owing to the cross-cutting nature of climate change, a holistic and integrated approach is necessary for dealing with multiple economic sectors and agencies. Sectoral adaptation to climate change accordingly calls for an assessment of the current state of knowledge on the risks and challenges posed by climate change as well as adaptive decision-making frameworks to cope and be resilient. Knowing that there are data availability and reliability concerns, in addition to temporal and spatial scale mismatches, various approaches have been suggested depending on specific contexts (Box 2).

Irrespective of the approach or framework, certain steps are imperative in designing and conducting adaptation assessments. Generically, this includes a particular context and scope, clear objectives and outcomes, assessment options and scenarios, practical plans, and implementation strategies, and monitoring and evaluation guidelines.

In the natural resource sectors, adaptation can be redefined to reflect on current or future actions (i.e. autonomous versus proactive measures), as well as incremental or transformative adaptation measures. Take for example coastal fisheries; adaptation assessment will entail not only the pros and cons of institutional frameworks and policy instrument choices but also building capacity at the local level, technological needs assessment, soft versus hard measures, funding options, social and community capital, to name a few.

Table 1: Short-term priorities and action plan for a competitive industry

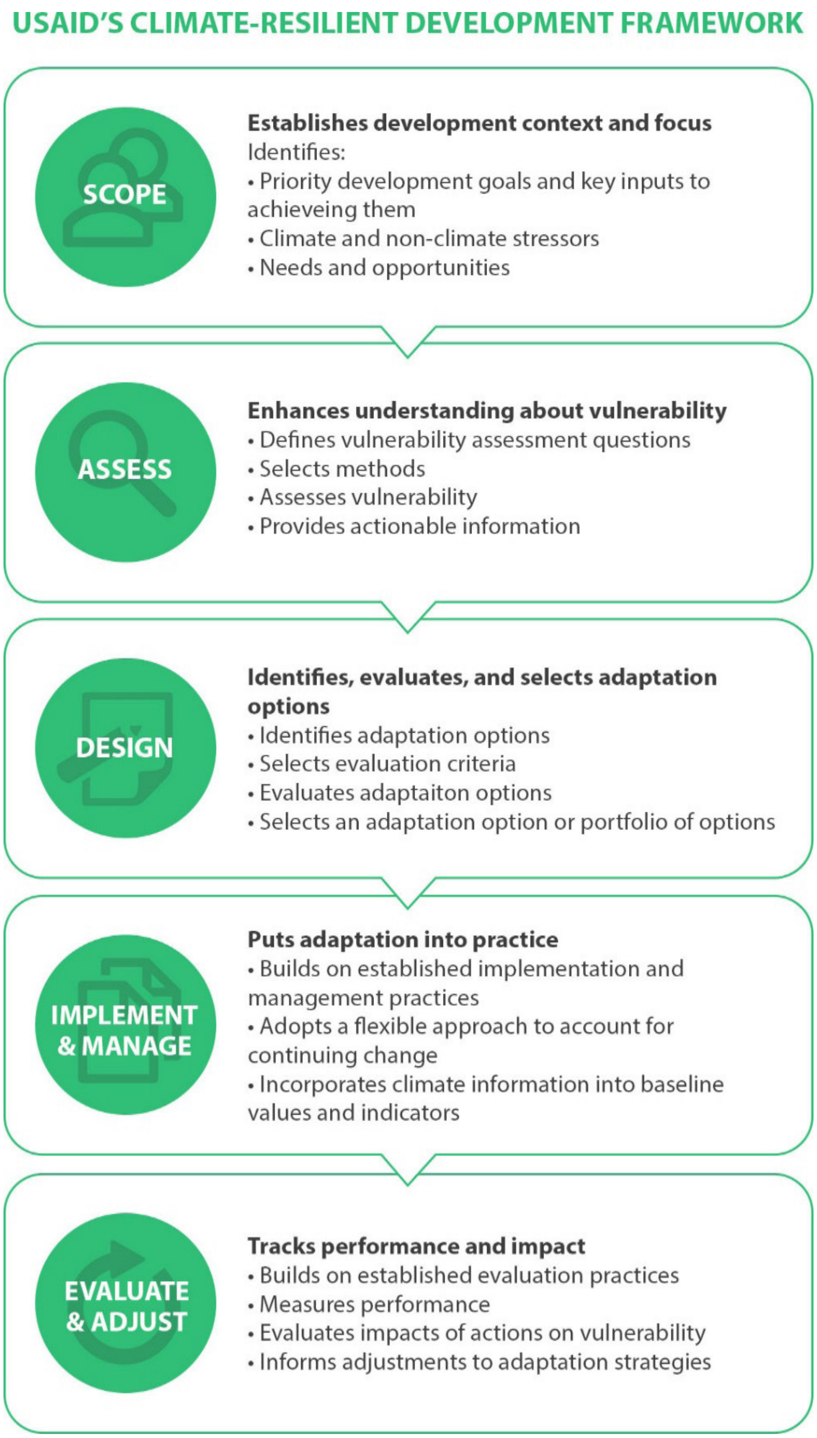
Internationally Competitive Industry Structures: Agriculture			
	PRIORITY STRATEGIES AND ACTIONS FOR FY2012/2013 - FY2014/2015	TIMEFRAME	RESPONSIBLE AGENCIES
SECTOR STRATEGY: IMPROVE AND RATIONALIZE ROAD NETWORK INCLUDING FARM ROADS NETWORK			
1	Improve agricultural feeder roads	172.5km of farm road improved in FY2013/2014 - FY2014/2015	NWA, MOAF
SECTOR STRATEGY: STRENGTHEN AGRICULTURAL RESEARCH INSTITUTIONS AND PROGRAMMES			
2	Rehabilitate Government agricultural research stations	FY2012/2013 - FY2014/2015	MOAF, R&D Division
3	Strengthen conservation, research and export of genetic material and germplasm of select animal and plant species	FY2012/2013 - FY2014/2015 -	MOAF, R&D Division
SECTOR STRATEGY: DEVELOP A DIVERSIFIED RANGE OF AGRICULTURAL PRODUCTION INCLUDING HIGHER VALUE-ADDED PRODUCTION			
4	Implement agro-parks to strengthen the agricultural value chain	8 agro parks developed in FY2013/2014 - FY2014/2015	MOAF, AIC, private sector
5	Construct modern abattoirs	Architectural designs and financial plans completed in FY2013/2014 - FY2014/2015	MOAF, AIC, private sector
6	Promote increase in local content of animal feed	FY2013/2014 - FY2014/2015	MOAF, BSJ, private sector
SECTOR STRATEGY: IMPLEMENT DEVELOPMENT PLANS FOR KEY AGRICULTURAL SUB-SECTORS			

Box 2: Key approaches and frameworks in sectoral adaptation assessments

Impact assessments	IPCC Technical Guidelines
Community-based vulnerability assessment	UK Climate Impact Program
Vulnerability and capacity assessment	USAID Adapting to Climate Change
Vulnerability and adaptation assessment	UNDP CC Adaptation Initiative Toolkit
Adaptation assessment	UNEP PROVIA Framework
Risk-based assessment	GIZ Vulnerability Guide

Recognising that vulnerability assessments have evolved over the past few decades, integrated assessments that offer planning and governance consideration have been deem to be robust, legitimate and inclusive especially amongst diverse actors and interest groups. Thus, the focus has shifted from impact and vulnerability assessments to vulnerability and adaptation (V&A) assessment, in addition to vulnerability and capacity assessment especially in developing countries with limited scientific and technical competencies. This is the context under which various governments and NGOs have developed tools and bilateral cooperation under the Cancun Adaptation Framework to assist countries in need to develop and finalised their National Adaptation Plans and their National Communications.

Figure 3: Climate-resilient development framework

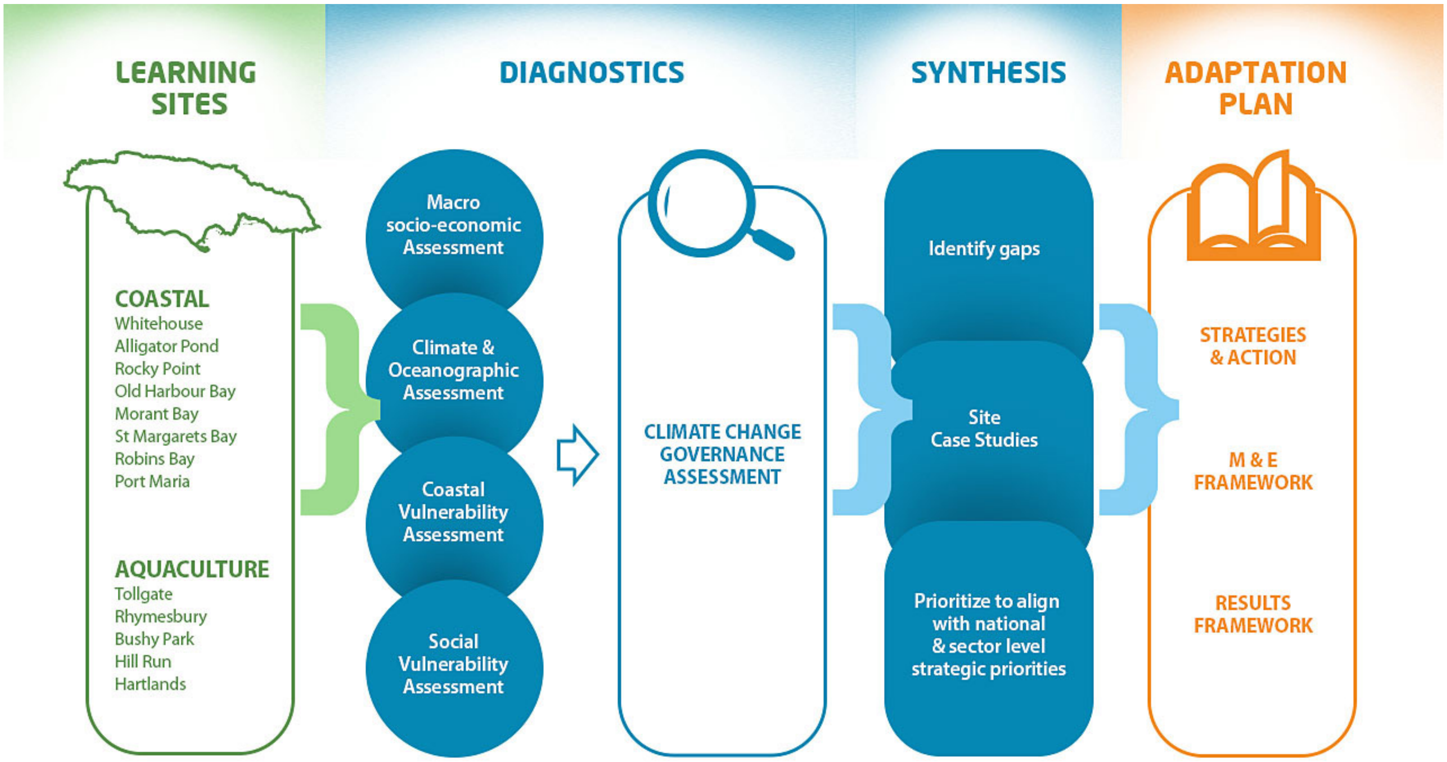


3.2.1 Vulnerability and Capacity Assessments

In Jamaica, multiple vulnerability assessments have been undertaken. Specifically V&A in the agriculture and VCA in the fisheries sectors; owing to the scope of climate change drivers and the nature of such the problem-driven research challenges. Both the UNDP adaptation policy and the USAID resilient development frameworks were useful in assessing vulnerability and identifying intervention nodes for natural resource sectors. The V&A framework is critical for the human dimension aspect of climate change especially in meeting stakeholder expectations and engaging the public on cost and benefits of interventions. Various field approaches were carried out in addition to community workshops to incorporate technical inputs into local visioning and development plans. A landscape and livelihood approach was useful in identifying leverage points for community resilience through an asset framework that considers five capital assets including the natural, social, physical, human and financial capital. Using participatory learning, household surveys, and focus groups; both quantitative and qualitative information were synthesised to reflect on the interactions amongst farming systems, household characteristics, and livelihood strategies. Qualitative data entailed document analysis, interpretation of narratives, creating seasonal calendars, ranking hazard impacts, developing vulnerability matrixes, and profiling community assets. The analyses offer insights on good practices for dealing with climate hazards and identifying adaptation interventions and options.

For coastal and marine fisheries, the VCA framework is not only analytical in design but also provides a decision support tool for adaptation planning and climate change governance. An integrated assessment was conducted drawing on several methodologies from both the natural and social sciences comprising of coastal vulnerability mapping and assessment, meteorological and oceanographic assessments, and social vulnerability assessments at several learning sites (Figure 4).

Figure 4: Integrated assessment of vulnerability and adaptation in a fisheries context



For the coastal vulnerability and mapping, multiple tools were used to assess biophysical landforms and critical habitats for sea level rise and its implication for essential infrastructure. Fishing landing sites and shoreline characteristics were surveyed using geo-mapping tools in addition to beach profiling and coastal flood scenarios using digital elevation models (Forbes et al. 2013; van Prosdij and Perrott, 2013). Analysis of meteorological and oceanic data for fisheries and aquaculture entailed a nuanced understanding of local variability and potential episodic events. This is based on satellite imageries and weather station data on rainfall anomalies, evapotranspiration rates, normalised difference vegetation index, standardised precipitation index, in addition to sea surface temperature (SST). Relationships and patterns were developed especially using evapotranspiration rates, SST, and rainfall for early warning signals for storms as well as for El Niño and El Niña. Furthermore, GCM and downscaled regional climate models are analysed to gain insights into projected SST anomalies and changes in salinity that affects ocean acidification and the general health of the oceans and marine resources such as fisheries.

3.3 Case Studies On Adaptation Planning And Implementation

Recognising the importance of the resource-based industries to Jamaican economy and society, the government has prioritised climate change adaptation interventions and resilience development as central to its policy framework and action plans. Climate communication and knowledge mobilisation initiatives are now parts and parcels of extension services provided by the Rural Agricultural Development Authority that meet the needs of local farmers about climate variability, drought resistant crops, and the use of adaptation technology for rain harvesting and drip irrigation (Government of Jamaica, 2013).

Table 2: Recent meteorological hazards on fisheries and agriculture (GoJ, 2011)

Event	Year	Estimate of Damage and Loss (J$ Million)	Select Social Impact
Tropical Storm Nicole	2010	**576.5**	40% of banana production affected; 26 greenhouses damaged; 3,740 ha of crops destroyed
Hurricane Dean	2007	**7960.5**	Some 3,523 fisherfolk impacted; 80% of greenhouses islandwide destroyed; 5,453 ha of arable produce lost
Hurricanes Dennis and Emily	2005	**379.9**	8,399 farmers affected; almost 1,300 ha crops lost
Hurricane Ivan	2004	**8550.1**	117,700 farmers impacted; 11,100 ha of agricultural ponds, coastal resources and fishery fleet and equipment suffered damage; reduced fish catch due to reduced fleet and migration of fish species

SOURCE: PIOJ

Three case studies are presented to illustrate local level vulnerabilities as well as adaptation planning and implementation to date. The examples underscore how small-scale communities are grappling with climate change across three key products namely coffee, vegetables and seafood; and the planning and implementation of challenges from government agencies.

3.3.1 Adaptation planning and capacity interventions

Due to its unique geography and geological history, Jamaica is vulnerable to climatic hazards exacerbated by episodic events such as hurricanes, drought, and flooding. These climatic hazards have impacted coffee production in the Cedar Valley for the past decade affecting export volumes, revenues, and local livelihoods. It has been predicted that coffee producers will incur more cost due to factors of production and make it economically unviable. This is particularly so in the case of Cedar Valley farmers as environmental change has led to livelihood vulnerability. Hence the need for a livelihood approaches to climate variability in understanding community assets and how to nurture the adaptive capacity and build community resilience. The Environment Health Foundation undertook a pilot project with funds from USAID on “The Climate Change Adaptation to Secure Rural Livelihoods”. Using participatory livelihood assessments and well-being indicators, farmers were asked to rank and evaluate various hazards, seasonality and production conditions, and potential coping and adaptation strategies (Table 3).

Table 3: Livelihood assessment and vulnerability indicators

Vulnerability	Adaptive Capacity	Livelihood strategies and flexibility	Livelihood Diversification
			Dependence on livelihood activity
		Social network / organization	Support within livelihood activity/or community
			Support outside of community
			Participation in community group or organization
			Government support services (access)
		Assets	Community support services
			Access to livelihood resource
			Ownership of house
			Ownership of land
			Loan/credit
			Insurance
			Saving
			Livelihood assets
		Knowledge, awareness & learning	Disaster risk communication
			Information on market price and condition
			Use of technology
			Disaster mitigation strategies
		Biophysical	Natural hazard induced production failures
			Condition of natural resource

Farmers agreed there have been many environmental and socioeconomic changes to impact their livelihoods especially climatic variability and community spirit. There are also rapid changes in demographics, household structure, and farming units to influence coping strategies. These interactions impact adaptation options and local capacity to be resilient. Farmers identified various seasonal patterns of stress and therefore developed an agro-climatic calendar underscores grace periods and bumper harvests. They also rely on local knowledge to monitor early warning signals for episodic events especially regarding changes in temperature and rainfall as shown in Table 5.

Since climate variability affects livelihood in Cedar Valley, a focus on sustainable livelihoods and asset framework provides leverage points to build community resilience and adaptive capacity through various entry points as shown in Figure 8.

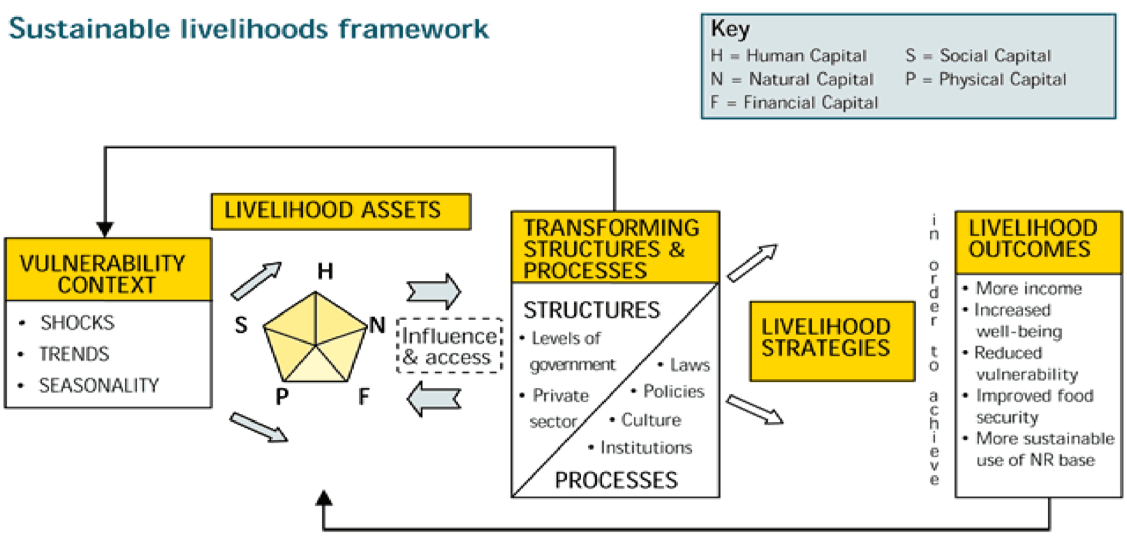
Five assets are provided as entry points, including i) human capital (skills development, training and knowledge mobilisation), ii) social capital (community spirit through networks, kinships, reciprocity, and trust), iii) natural capital (sustainable use of ecosystem goods and services), iv) physical capital (essential infrastructure both at the household level as well as community in terms of roads and farm level in terms), and v) financial capital (savings, loans, micro-credits, and insurance).

Table 4: Seasonal calendar and farmers' perception of favourable growing seasons

Events	Months											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Planting Coffee	Highland								Highland	Highland	Highland	Highland
Harvesting Coffee	Lowland			Highland	Highland	Highland	Highland	Lowland	Lowland	Lowland	Lowland	Lowland
Planting Gungo	Highland	Highland	Highland	Highland	Highland	Highland						
Reaping Gungo												
Rainy Months					Highland	Highland						
Dry Months	Highland	Highland	Highland	Highland								
Worst Months	Highland		Highland	Highland	Highland	Highland						
Best Months									Highland	Highland	Highland	Highland

HIGHLAND COFFEE LOWLAND COFFEE

Figure 8: Sustainable livelihood approach and community resilience model (DFID, 1999)



Farmers identified ownership of livestock as capital assets to access formal credits and usually assist with off- farm income sources and the household economy. According to (Hatfield & Davis, 2006), the significance of livestock in agrarian communities has been known to "give increased economic stability to farm households, acting as a cash buffer (small stock), a capital reserve (large animals) and as a hedge against inflation." Although most farmers in Cedar Valley have access to formal loans and about 50% have obtained formal credit; some are ambivalent about loan repayment conditions. In the past, unfavorable loans and crop failure due to hurricanes and extreme weather have made it impossible to service formal loans and provide extra hardship on farmers. For farmers who can access insurance, there is an insurance scheme for climatic disasters for coffee crops after berries have sprouted, and could assist in the event of major loss and damage. During Hurricane Ivan in 2004, insurance was set at $20 USD per box for Blue Mountain Coffee and $12 USD per box for lowland coffee. However, most crops were not insured as the premiums are very high and led to major loss except for the few who insured their crops.

Human capital regarding training and skills development is a key component to integrated livelihood strategies and community development. On the farm training and off-farm skills are necessary to deal with farm production and household earnings. Only a small fraction (13%) of farmers and their household in a survey conducted in Cedar Valley have alternative livelihood skills besides farming, with women and youth mostly marginalised in daily agrarian activities. There are opportunities for farmers and their household members for retraining and capacity in business operations, catering, management, retail, transportation, and teaching. This focus can also strengthen social capital through trade unions and associations, community programs as it builds trust and networks amongst community members.

Farmers are also part of several social groups from unions and associations to various labor programs where folks are assisted through 'lending a day' during bottleneck farming periods. The Jamaica Agricultural Society (JAS) and the Producer Marketing Organisations are key examples. Marketing initiatives have been a topic of community engagement and seminars by the JAS. The St. Thomas Coffee Growers have also been instrumental in advocating the rights and welfare of local farmers especially against powerful societies such as the Myall Coffee Cooperative in 1997. This reciprocated farming program, historically important in agrarian communities, is slowly dying out as farmers prefer to be paid for daily services and as farming becomes more modernised and mechanised. Remittances from social ties and kinships have also been a significant aspect of household earnings, especially during lean months and disasters. Farmers also indicated that there is a strong bond to help each other during disasters and years of bad harvest.

Environmental stewardship and the landscape approach to ecosystem-based adaptation has been a challenge in Jamaica, especially in Cedar Valley due to historical land tenure systems and land use patterns that lead to degradation and land use change. There is surely an issue of vulnerability with farming systems on steep slopes, where flooding and landslides can be catastrophic and exacerbated by access rights. Landslides are not only hazardous from a natural capital standpoint, but it also affects essential infrastructure (physical capital) such as roads and bridges. Access to good quality farm lands is a concern that farmers raised as a potential issue to address for future adaptation strategies. Due to the rain-fed nature of farming, variability in rainfall can cause droughts and raise issues about water availability as well as potential irrigation measures as adaptation options. Irrigation systems and other technological innovation in farming such as drought resistant species, processing machinery, and farm roads can be instrumental towards crop production and local adaptive capacity. For example in early 2001, the Blue Mountain Coffee Co-op received three new machines valued at $ 12 million USD for processing operations for the St. Thomas region.

It is well established that farming systems such as slash and burn agriculture on hilly slopes also affects watershed health as it increases run-off and sedimentation as well as leaching of nutrients affecting crop yield in the long term. Furthermore, good yields and multiple income streams can contribute to reinforcing housing development for flooding and hurricanes as they provide an important pillar regarding human security and protection. Most farmers in Cedar Valley own their homes and are willing to upgrade it in the event of disasters.

In summary, climate variability has ramifications on coffee production in Cedar Valley communities. These impacts will be pronounced in the future as temperature projections increase with a new normal of frequent storms and droughts. Thus, community engagement on adaptation planning and intervention is necessary and overdue in addressing these vulnerabilities. Livelihood security provides an entry point to understanding these interactions amongst climate and non-climatic factors as well as socioeconomic and policy overlays. A community-based adaptation approach that draws upon local farmers knowledge and historical context can be instrumental in nurturing the building blocks for resiliency taking into account issues of power, class, gender and equitable access to resources.

Understanding ideal growing seasons and potential water stress periods are local knowledge and experiential skills that farmers have relied on in the past. An early growing season has been identified from April through June before the onset of the rains in August to November – the most ideal time to cultivate vegetables (Figure 10). Early season droughts have been recorded in the past decades through increased temperatures, low rainfall, and strong winds. Farmers who observed this phenomenon mostly agree that they are experiencing drought episodes or water stress periods. In the absence of irrigation techniques and farm site relocation, this could lead to low yields and food security concerns. This has adaptation implications for farm locations along a topographic gradient, soil nourishment measures, and irrigation techniques.

Figure 10: The two growing seasons in southern St. Elizabeth (Gamble et al. 2016)

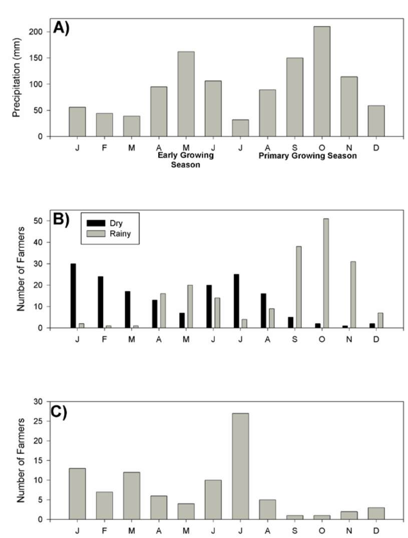


Table 4: climatic stressors and its implication on St. Elizabeth (Campbell et al. 2010)

Some of the stresses on farmers in southern St. Elizabeth (2006-2008)			
STRESS	**MAIN PROBLEMS**	**BRIEF EXPLANATION**	**SOME IMPACTS**
Water	Lack of irrigation water Poor water supply system High cost of water	Lack of reliable supply of irrigation water. Water is brought from a government agency (Rapid Response). However, it is expensive (US$114 and $US285 for 4000 and 8000 gl respectively) and unreliable.	Reduction in the number of crops produced per year Crop failure Forced to buy water from private vendors who sell at a higher price
Guinea grass	High cost of guinea grass	The importance of Guinea grass (used for mulching) to farmers in southern St. Elizabeth has led to its comodofication. The grass is expensive and costs approximately $US114 per acre.	Use other grasses that are generally less effective Chage cash crop - grow crops that are more resilient to drought Cultivate on a smaller scale
Market	Lack of reliable market for produce Erratic and unreliable 'higglers' (market purveyors)	The lack of reliable marketing facilities has relegated farmers to a dependence on 'higglers' (market purveyors) as the main outlet for their produce. These 'higglers' are often unreliable and deceptive, farmers complain.	Spoilage of produce Reduced profits Left to the mercy of higglers
Farm inputs	High price of fertilizer, seeds and chemicals	The price of fertilizer increased in less than 1 year from $US28.5 per bag in June 2007 to $US71 in April 2008. This increase has occured alongside other farm inputs such as hybrid seed, pesticides and equipment.	Decreased output per crop Use of alternative methods that are sometimes less effective Cultivate 'lower' varieties that require less external input Reduction in area under cultivation
Food imports	Increased competition from imported food	The importation ofcheap produce (e.g.onions, tomato, carrot and cabbage) in the farming communities is a major stress to farmers. For example, onion farmers of Flagaman were virtually wiped out over a period of 3 years as total acreage fell from a high of 800 acres in 1996 to an almost negligible value in 1999.	Lower price for produce Change of cash crop - cultivate non-imported crops Loss of buyers ('higglers') to importers
Environmental conditions	Rain shadow effect - very low rainfall	Even though farmers have adapted well to the marginal environmental conditions in their area, the cost of adaptation is a major stress to farmers. The dry conditions demand the use of Guinea grass and more water than the typical farming region in Jamaica.	General added expense of adapting to dry conditions (e.g. buying Guinea grass) Limited capacity for livestock production (e.g. cattle, sheep, goat) Higher than usual demand for irrigation water

In a recent study by Gamble et al. (2016), they identified seven of the double exposure factors in St. Elizabeth. They include: i) water variability especially during the first rainy season; ii) price volatility of harvested crops; iii) prevalence of pest and disease; iv) marketing produce; v) high cost of inputs such as seeds and fertiliser; vi) local competition with imported food; and vii) poor soil quality.

Responses in addressing these drivers and stressors fall within a broad spectrum of tools, capacity, approaches by individual farmers, as well as community initiatives and policy interventions.

Adaptation in this context includes the wise use of water such as water harvesting and pumps, irrigation techniques, adjusting the growing season of certain crops based on local knowledge, kinship and social networks, government support through infrastructure such as greenhouse, local marketing and value addition, as well as micro-credits and insurance programs. In another study, various planting methods were identified by farmers to be effective in addressing drought episodes and various climatic stresses (Campbell et al. 2010). These include selecting crops that are drought resistance (e.g. tubers), using irrigation techniques such as drip irrigation and mulching to address loss of moisture, water sharing mechanisms, and scale down by working on smaller farm plots and looking into livestock or alternative livelihood activities till after the episodic event. Coping and adaptation strategies from previous episodic events underline the importance of place specific or farm level decision as well as local leadership to accommodate and bounced back through relocation, farm restoration and managing post-disaster production (Campbell and Beckford, 2009). Before Hurricane Dean, for instance, specific pre- disaster planning included sheltering nurseries, harvesting matured crops and safe storage, transplanting to safer areas, bracing branches, spraying and the cutting of trenches. For post- disaster responses, government interventions through relief and recovery assistance, when well planned, can contribute to farmers' morale and resilience. For examples, the assistance by the Rural Agricultural Development Agency has the potential if well executed to alleviate the initial distress that farmers undergo after these episodic events.

These strategies are however dependent on several factors such as disaster relief and farming policies, terrain and elevation, stages of growth and maturity of the crops, scale of production, and human labour including the capacity of the farming and the farming community to assist each other.

3.3.2 Wild Capture Fisheries Production

3.3.2.1 Vulnerability context

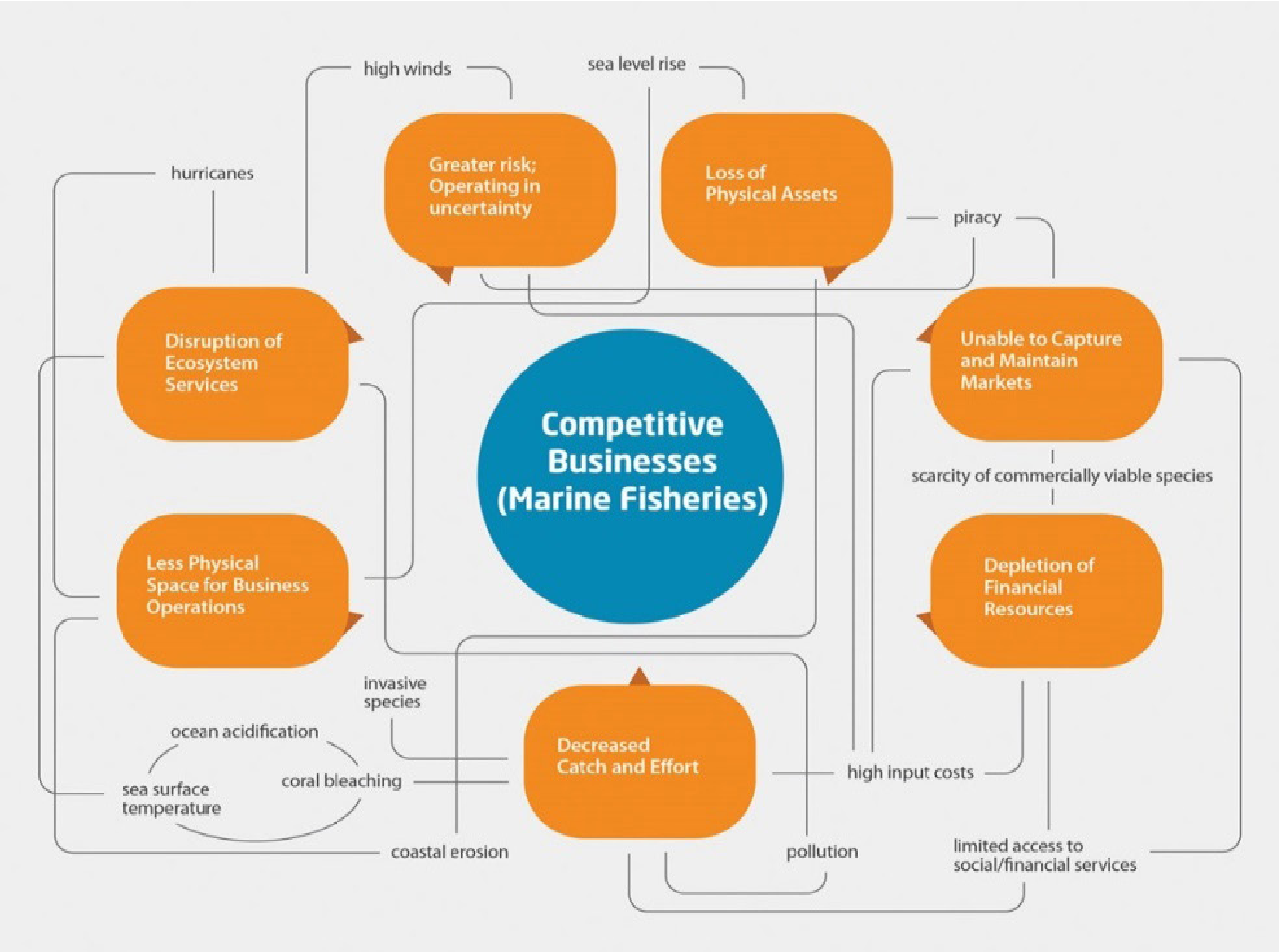
Marine capture fisheries offer many benefits at multiple scales from local food security and employment opportunities to regional livelihoods in the processing and marketing of seafood products. In many coastal communities in Jamaica, fishing is part of the fabric of society and is a cultural identity and way of life. Moreover, seafood is also an important export commodity contributing to GDP and foreign exchange earnings. Due to these multiple contributions, the Jamaican government has realigned its priorities within Vision 2030 (for both the National Development Plan and Agriculture Sector Plan) to focus on six national and local level domains (CCCCC, 2015). These include a) appropriate institutional, policy, legislative and regulatory environment; b) effective climate change adaptation and disaster risk reduction; c) sufficient domestic food production and food security; d) effective environmental sustainability; e) efficient and developed fisheries as part of agriculture sector; and f) sustainable natural environment and healthy ecosystems.

Despite these potential contributions, fisheries are highly vulnerable to climate change impacts. Whether the impacts arise out of sea level rise and coastal flooding or increasing sea surface temperature and ocean acidification, wind patterns and storms all, affect resource abundance and fishing practices as shown in Figure 11.

In fact, future projections indicate that the annual SST is expected to increase by 2°C, which will affect salinity ranges of 2-3% thereby affecting chlorophyll formation and marine ecosystem health as shown in Figure 14a-c (average SSTs, PH, and chlorophyll formation).

Figure 11: Climatic stressors and shocks to the fisheries production (CCCCC, 2015)

Figure 12a, b, and c: Average annual values for SST, PH, and chlorophyll and projected end of century anomalies, respectively



(CCCCC, 2015).

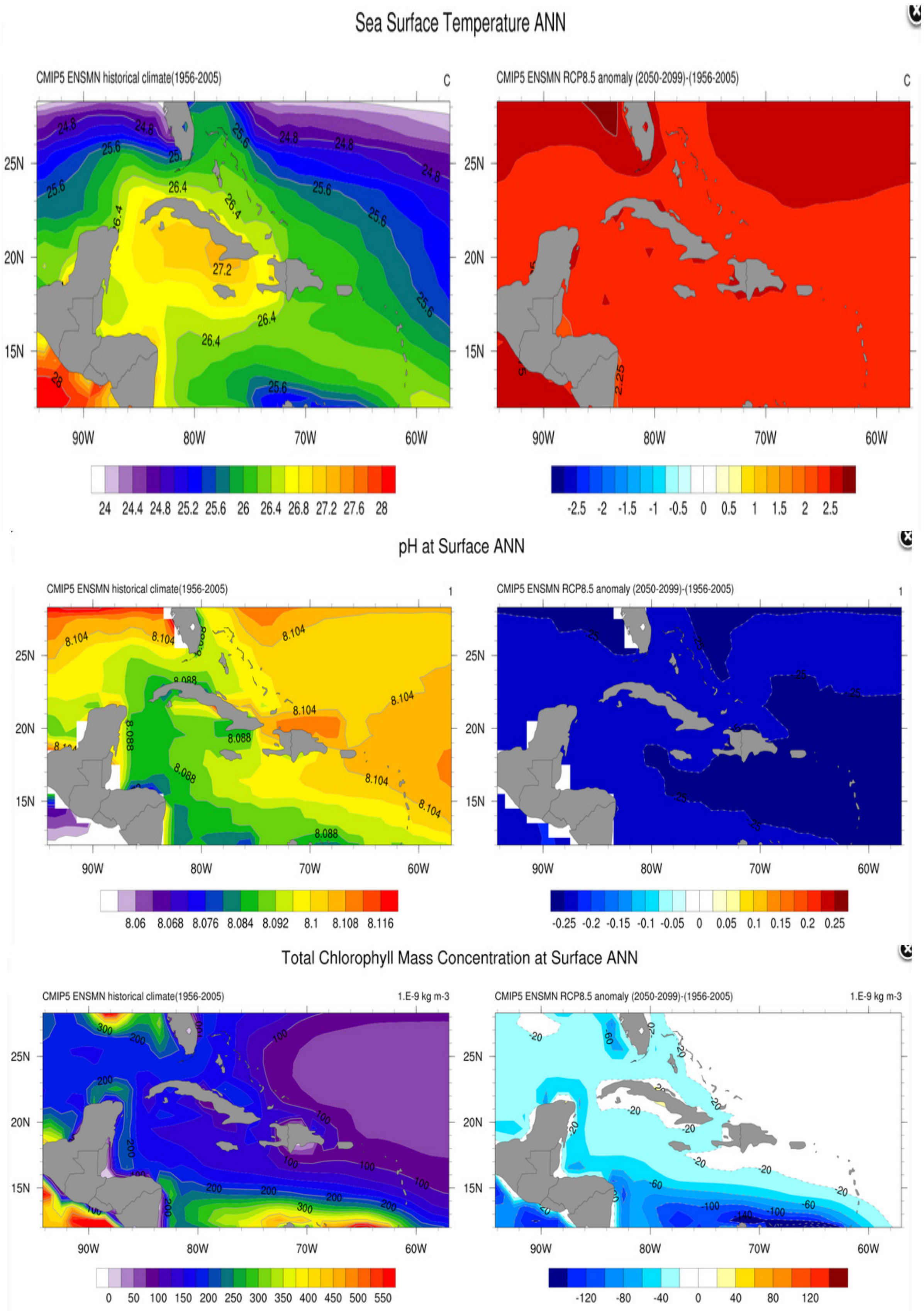

Sea Surface Temperature ANN
CMIP5 ENSMN historical climate(1956-2005)
C
CMIP5 ENSMN RCP8.5 anomaly (2050-2099)-(1956-2005)
C
25N
20N
15N
90W
80W
70W
60W
24 24.4 24.8 25.2 25.6 26 26.4 26.8 27.2 27.6 28
-2.5 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2 2.5
pH at Surface ANN
CMIP5 ENSMN historical climate(1956-2005)
1
CMIP5 ENSMN RCP8.5 anomaly (2050-2099)-(1956-2005)
1
8.06 8.068 8.076 8.084 8.092 8.1 8.108 8.116
-0.25 -0.2 -0.15 -0.1 -0.05 0 0.05 0.1 0.15 0.2 0.25
Total Chlorophyll Mass Concentration at Surface ANN
CMIP5 ENSMN historical climate(1956-2005)
1.E-9 kg m-3
CMIP5 ENSMN RCP8.5 anomaly (2050-2099)-(1956-2005)
1.E-9 kg m-3
0 50 100 150 200 250 300 350 400 450 500 550
-120 -80 -40 0 40 80 120

Figure 13: Field backshore characterisation conducted in July 2015 and assessment of shore stability. 'Failing, damaged, intact' refer to anthropogenic structures and the remainder associated with the stability of a natural feature.

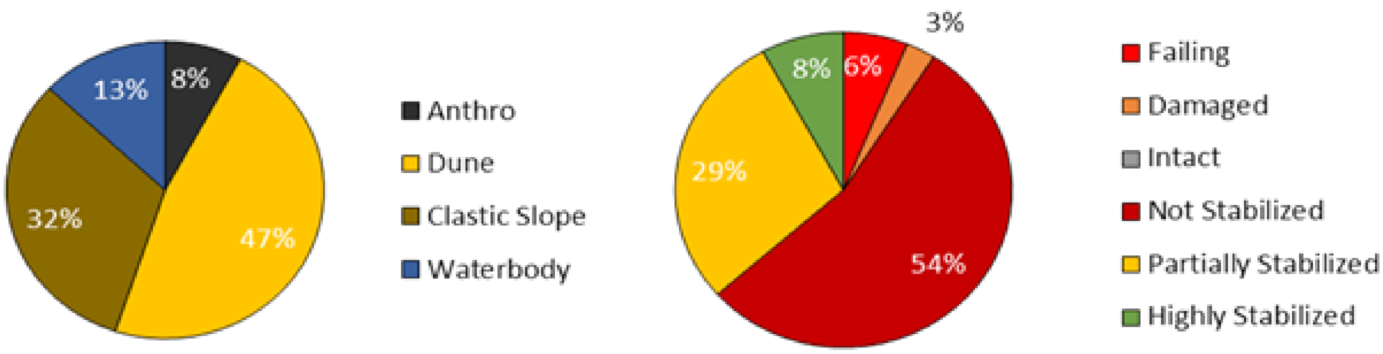
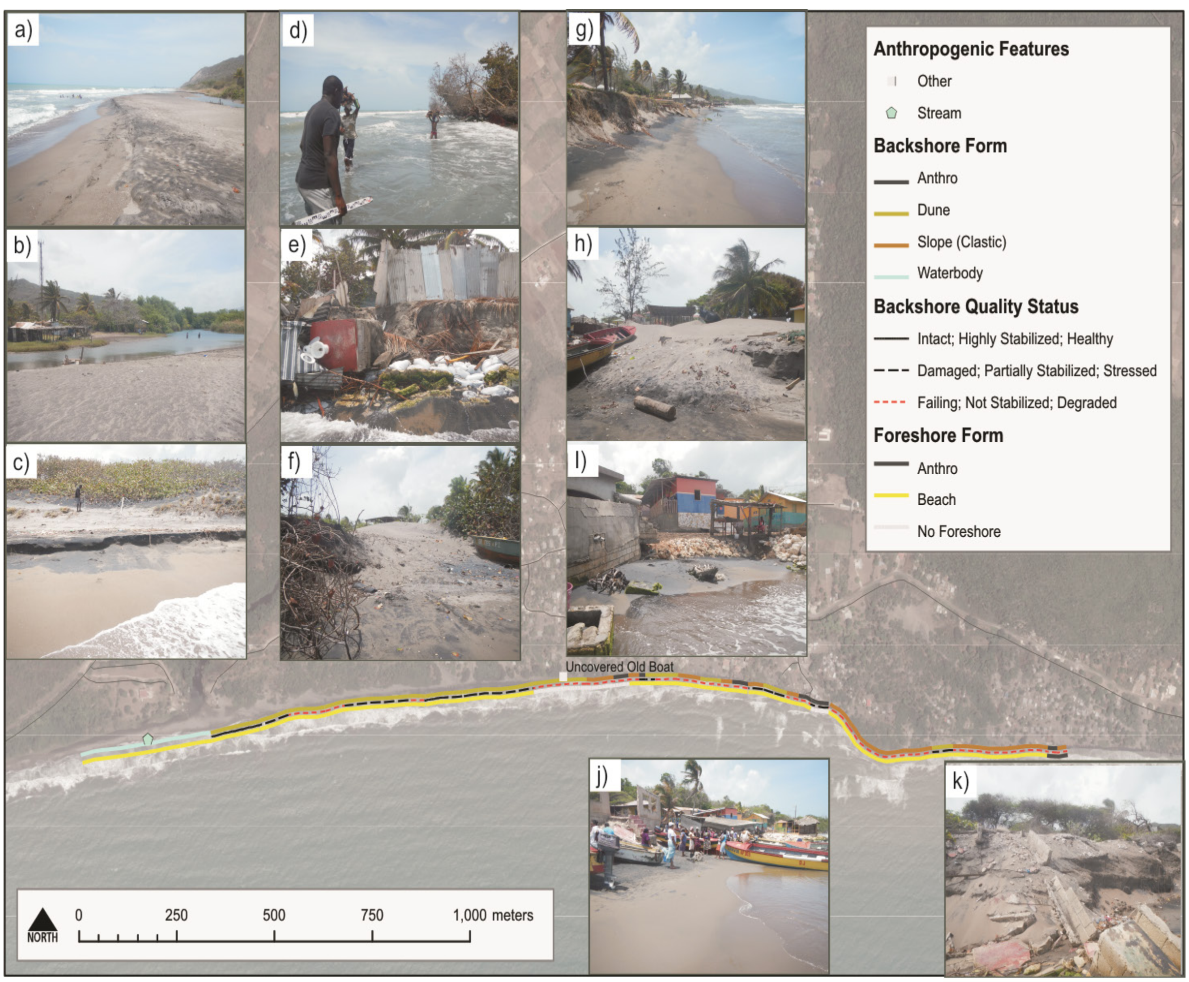


Plate: Shoreline characterisation based on site assessment in July 2015. Examples are provided for backshore and foreshore types such as a) sand bar with seasonal erosion; b) freshwater river at western edge; c) reversible eroding scarp at top of swash zone; d) no foreshore at either low or high tide; e) significant erosion of backshore including toilet; f) dune blowout; g) eroding backshore clastic slope; h) sand transport into interior at former blowout; i) house that collapsed in June 2015; j) fishing beach east of main town and k) old eroded foundations.



Satellite imagery: Worldview-2, 2014-06-18.

3.4 Adaptation Needs in Agriculture and Fisheries

Communities have been adapting to global change since millennia. However, what is unique about current adaptation intervention is the severity and cost of inaction owing to the increasing level of climate hazards and natural disasters. Hence short-term coping strategies are not enough to meet such challenges but rather a continuous set of decision-making processes and outcomes that meet stakeholder needs (Campbell and Beckford, 2009).

Agriculture and fisheries are two of the most resilient food production and natural resource sectors grappling with climate change. The sectors have evolved from traditional small-scale subsistence and artisanal sectors to medium and large scale production systems based on an export-oriented market economy. This type of farming system gained momentum during colonial expansion and involved export crops such as sugarcane, banana, and coffee using slave labour. Unlike the export crops and large-scale plantation agricultural systems, the subsistence sector focuses on domestic needs and food items for household consumption such as yam, potato, cassava, peas, beans, and a variety of fruits and vegetables. The prioritisation of food production for export markets, unlike for local consumption, also encourage the import of staples and exacerbates food security. An approach that links vulnerabilities in the context of land use change and access rights could provide a platform to leverage sustainable fisheries and agricultural practices.

3.4.1 Agriculture

Despite a decrease in agricultural production in the 1980s and 1990s and the global recession in 2008, recent statistics indicate an average growth rate of about 8% with a positive impact on GDP. The Agricultural Production Index increased recently from 106 in 2009 to 118 in 2011. This success can be attributed to a couple of industry initiatives including a boost in government capacity to address marketing and supply chain concerns, establishment of a Food Safety Policy framework that has improved post-harvest spoilage and export standards, a new Fisheries Act and designation of fish sanctuaries, the creation of a Agro-Investment Corporation to stimulate private sector involved and improvement of food production infrastructure for transportation, processing and value addition.

Although there has been substantial progress towards food production and community well-being with the enactment of the 1978 Food and Nutritional Policy, the country still faces meager food production and malnutrition. In addition to rising food prices and high unemployment, Jamaica has also been experiencing high inflation which affects food imports and dietary needs. The food import bill has been escalating in the past few decades due to the need for raw and semi-processed foods for local consumption. The total cost ranged from $153 million USD in 1991 to about $819 million USD in 2010. Seafood accounted for 12% of the total food import bill in 2012, valued at $110 million USD in 2012. Most of Jamaican household income is spent on imported food as opposed to local food, which is not sufficient to meet national needs. According to data from the Ministry of Health, it takes close to $5,195 USD to feed a family of five for a week, which is two-thirds the minimum wage. For most rural agrarian communities, with lower wages, remittances have supplemented their income in meeting their daily food needs (Government of Jamaica, 2013).

Access to land and land use policies has also been decisive factors in food production. This is further aggravated by episodic events such as drought and floods. Flooding erodes soil nutrients and natural vegetation especially in watersheds as a greater proportion of land is hilly with very slopes greater than 20 degrees. Other land use activities such as deforestation, charcoal production, and unplanned urban development have led to the loss of topsoil and watershed degradation (ref). Topography also affects land tenure and ownership, as seen in the historical development of large-scale mono-cropping on coastal plains and interior valleys, in contrast to small-scale upland mixed farming systems as seen in the central parishes and hilly mountains. These two major types of farming systems have evolved with colonial settlement patterns as priority was given to first settlers who had a plantation style farming system on coastal plains using slave labour. Most of the small-scale farming systems ensured when freed slaves left the bigger plantation farms and estates and resorted to farming their plots in the hilly interior for subsistence, where land was accessible. Thus, this paved the way for such small-scale and mixed farming systems to date. About 80% of the fertile land is privately owned, next to lease plots (9%), with the rest a mixture of rent, rent-free, and squatting system common amongst small-scale farmers. The proportion of ownership increases with large farm size of 5-200 hectares with about majority privately owned. In contrasts, small-scale farmers utilise only about 10% of the land yet make up about 80% of the farming population with farm plots of 2 hectares and less. This uneven distribution skews production as most of the active labour force have limited access to land and close to half of the cultivable land is owned by less than 1% of the population. Despite agrarian reforms in the 1960s and 1970s and recent land access policies, the inequitable distribution of land resources and land tenure system has profound impacts on community vulnerability and livelihoods of farmers who solely depend on agriculture. Recently, however, land fragmentation has resulted in an increase in the sizes of smallholder farmlands with an increase to farmers who are landless – defined as those who do not hold the minimum criteria for land acreage but meets the herding and pastoral criteria).

Farm acreage has also decreased based on transformation of historic agricultural practices of small upland mixed farming techniques. As stated in the Second National Communication, records from the Provincial Farmers Registry from the Ministry of Agriculture indicated 603,126 hectares in 1968 as compared to 2007 estimates of 325,810 acres. Local production has also decreased as reflected in agriculture's contribution to GDP over the past few decades. In fact, local production including both fisheries and agriculture for export markets and household consumption has decreased considerably in addition to related post-harvest activities (Government of Jamaica, 2013). In fact, post-harvest losses have been estimated at lower values of 10% for legumes and cereals, 20% for cassava and other tubers and as high as 40% for fruits and vegetables. Similarly, losses are also evident in the seafood production, which affects overall food security as well as regional economic development.

Furthermore, food production sector is plagued by technical and human resource constraints. These include an aging workforce and labour market concerns, capacity for R&D, essential investments in technological innovation especially in irrigation and food processing, and innovative strategies to be competitive entrepreneurs. The government has improved its institutional framework to address these food production challenges through various ministries (the focal one being the Ministry of Agriculture and Fisheries) as well as through various Directorates, Units and Divisions focusing on the following key domains: technical services, policy coordination, planning, data and information management, marketing and credit, and land use policy. Various commodity boards (for major export crops) and loan allocation schemes have been promoted to meet the investment needs of the sectors through cooperative banks. Farmers are given local loans at a very low rate although most of the investment goes to the export crops. There are also directives towards micro-insurance to meet the growing needs of poor households vulnerable to climate change.

Owing to the nature of rain-fed farming systems in Jamaica, a National Irrigation Development Plan has been put in place to support small-scale farming through sprinkler and micro-irrigation techniques, drip irrigation and other common systems for land nourishment, and manual irrigation of steep slope, especially for hillside farmers. Developing early warning systems is an important component of addressing potential vulnerabilities through planning tools for building local capacity for water management as well as flood control and other risk reduction measures.

3.4.2 Fisheries

Similar to declining agricultural production, the status of fish stocks and aquatic ecosystems has also been dismal with concerns about overfishing, degrading marine ecosystems, coral bleaching, and flooding of coastal fishing communities. Fisheries are one of the most vulnerable sectors to climate change due to high coupling between socio-ecological systems and its implication on food security and international trade (Smith et al. 2010). From ocean acidification to stock migration pole-ward due to warming waters (Cheung et al. 2010); fisheries are highly vulnerable to climate change impacts and exacerbate economic development. Knowing that seafood is the most traded commodity globally, this provides an imperative for adaptation planning and intervention portfolios across the entire fish chain. According to recent statistics, global seafood imports have exceeded $120 billion dollars according to the Food and Agricultural Organisation of the United Nations (FAO 2015). In Jamaica, seafood exports exceeded half a million Jamaican dollars in the late 1990s regarding landed value and reached 2 million in 1999 (CRFM, 2005). Seafood also feeds more than a billion of the world population and employs more than half a billion in coastal communities. Domestically, seafood contributes approximately 20% of the overall supply of fish and fish products from both marine and culture species with low-priced imported fish dominating local markets. Jamaica, like most countries, is a net importer of seafood with total value estimated at US$109.85 million in 2012 (Government of Jamaica, 2015).

Fishery resources are managed under the Fisheries Directorate with various institutional and legal arrangements. Notable ones include the Maritime Areas and Exclusive Economic Zone Acts of 1996 and 1991, respectively; which stems from the 1982 United Nations Convention on the Law of the Sea. Other fisheries management instruments include the Fisheries Industry Act of 1975, the Beach Control Act of 1956, the Inspection, Licensing, and Export Act; Wildlife Protection Act of 1945 and the 1991 National Resources Conservation Authority Act. The newly revised Fisheries Act caters to the management of both capture fisheries as well as aquaculture development. This is in collaboration with Coast Guard for monitoring and surveillance and the National Environment and Protection Agency for conservation planning. A top-down management directive is often used employing input and output control measures that restrict total allowable catch (TAC), days at sea, fish gear restrictions, habitat protection, as well as providing incentives for processing and value addition. According to the National Fisheries and Aquaculture Policy, the vision of the sector is to "ensure the optimal contribution of the fisheries and aquaculture sector to Jamaica's economy, food and nutrition security, poverty alleviation and sustainable livelihoods through the sustainable management and development of capture fisheries and aquaculture." The industry is divided into a pre-harvest (marine ecosystems), harvesting (production sector) and processing (and marketing sectors) as shown in Figure 6. Both the harvest and post-harvest stages involve capture and culture species (aquaculture) that ranges from saltwater (marine), brackish (estuarine) and freshwater (riverine) species.

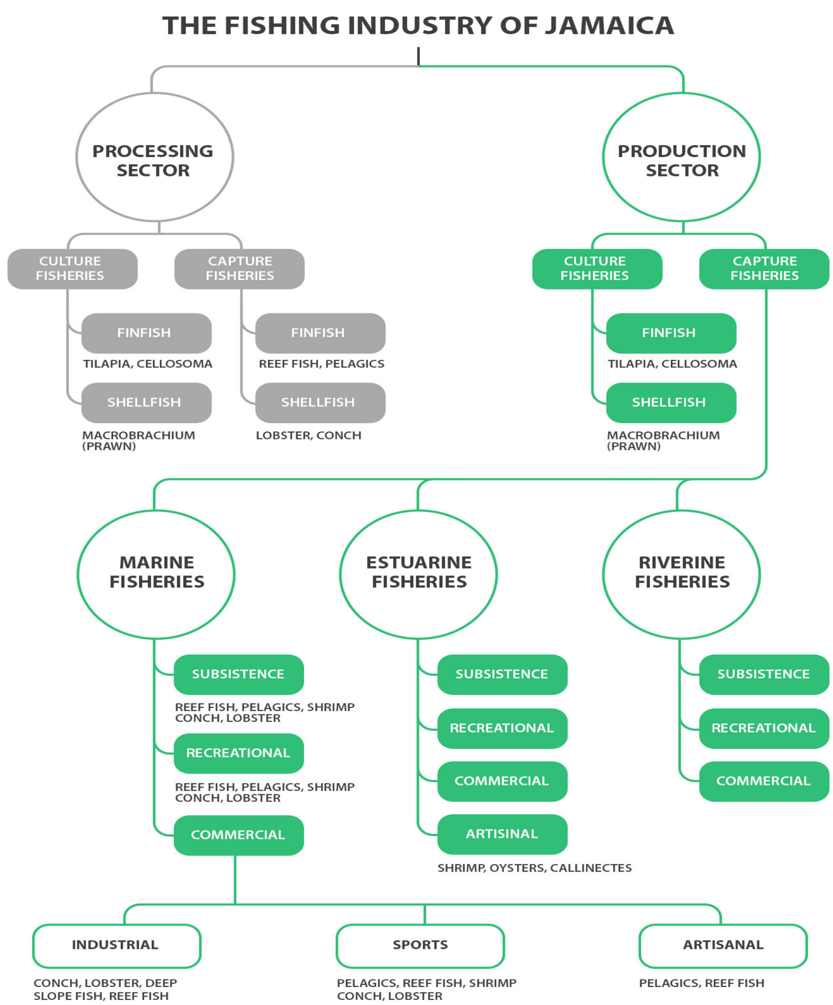
Total production fluctuated around 10,000 metric tonnes in the late 1990s and early 2000 including high value captured species (conch, lobsters, etc.) and low-value cultured species (tilapia). The Agricultural Production Index shows that between 2009 and 2013, fisheries production increased by 4.1% and was at its lowest in 2012 for the previous five-year period. Production drastically declined from 18,346 metric tonnes in 2009 to 11,138 metric tonnes in 2012, due mostly to a reduction in TACs. Total seafood exports were estimated at US$11 million in 2013, up from US$8.93 million in 2012, including major exports such as lobster tails, conch, finfish species and ornamentals (ref).

The industry is composed of an artisanal small scale sector for local consumption, a large-scale export-oriented sector targeting mostly shellfisheries around Pedro Bank, and a recreational eco-tourism sector mostly for sports fishing and on charter boats. The fishery is mostly open access except for the shellfish industry subsector on Pedro Bank where limited entry and TACs are instituted. Major fishing areas include the inshore coastal fishery notably on the North and South coasts, the Pedro and Moral Banks especially for shellfish and finfish, deep sea fishing inside and outside of the exclusive economic zone, inland fisheries along the Black River, and joint Jamaica-Columbia region near Alice Shoal.

With 7000 registered boats, the fishing fleet consists of small canoes of about 3-9m long made of wood and fiberglass using oars and outboard engines in the artisanal sector; in addition to deck vessels (about 15-30m) made of steel in the large-scale sector. A total number of fishers is estimated close to 50,000 in 2013, who are actively involved in various beach landing sites (about 187) and supporting coastal communities with a processing and marketing livelihoods estimated to be close to 300,000 (Government of Jamaica, 2015).

The fishery sector has evolved from top-down management to an ecosystem-based management where stakeholder involvement (industry, NGOs, and civil society) is valued as well as adopting a large marine ecosystem and regional governance scope (Fanning et al. 2010). Co-management has been very popular with a binding agreement between managers and resource users especially with the conch fishery, the establishment of the Portland Blight Fisheries Management Council, and the CARICOM Fisheries Resource Assessment and Management Project. Since 2010, there have been joint initiatives to establish and managed special fishery conservation areas or sanctuaries to help with habitat protection (Alexander et al. 2016).

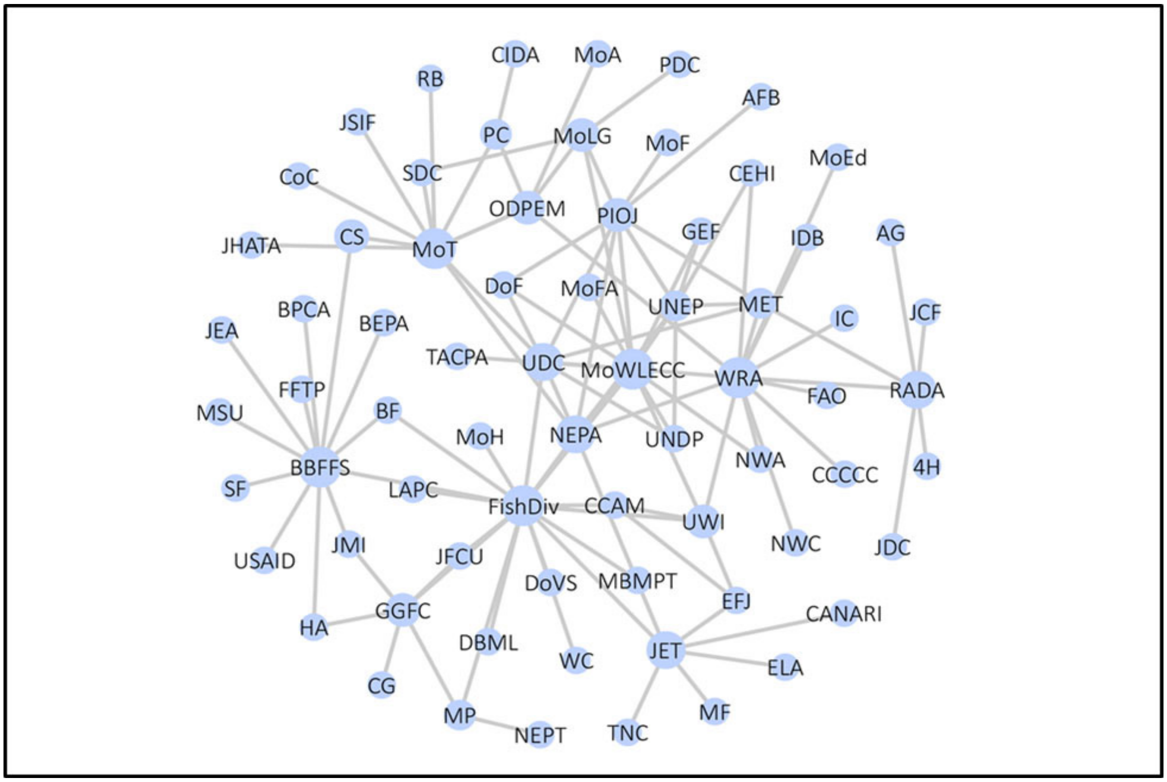
Figure 18: Diversity of the fisheries sector in Jamaica (Modified from CRFM, 2005)



3.4.3 Adaptation planning and capacity interventions

Adaptation readiness and capacity assessment are often multi-scale involving a wide range of stakeholders and institutions, especially in fisheries. In Jamaican, the focus is currently placed on governance effectiveness and institutional adaptive capacity with a special emphasis on policy and social networks, analytical deliberation and institutional diversity (Pittman et al. 2015). Various actors contribute uniquely to the planning process such as bridging organisations (mostly NGOs) or policy entrepreneurs (e.g. researchers) in meeting multiple livelihoods, ecosystem, and resource sustainability benefits as shown in Figure 17. Cross-sector initiatives and interagency programs often assist in addressing the multiple aspects of climate change impacts particularly with coastal hazards and essential infrastructure.

Figure 19: Network analysis of state and non-state actors in meeting multiple fisheries benefits under global and economic changes CCCCC, 2015).



Also, both formal and informal institutions and local level organisations contribute to the capacity building (i.e., learning, deciding and acting capacities). For instance, the Rocky Point Fisherman's Co-operative Society and the Rocky Point Fisheries Association are instrumental in community business development and stewardship initiatives. At the local level, both hard and soft measures are necessary for community resilience. For instance, maintenance of coastal infrastructure especially the old groyne can contribute to coastal protection from both lagoon processes as well as seal level rise impacts. Also, improving educational opportunities and training can promote capacity for alternative and integrated livelihoods considering the seasonal aspect of coastal sectors such as fisheries and tourism.

3.5 Case Studies on Adaptation Planning and Implementation

Three case studies are presented to illustrate local level vulnerabilities as well as adaptation planning and implementation to date. The examples underscore how small-scale communities are grappling with climate change across three key products namely coffee, vegetables and seafood; and the planning and implementation of challenges from government agencies.

3.5.1 Blue Mountain Coffee Production in Cedar Valley

Like most rural communities in Jamaica, livelihood systems in Cedar Valley are primarily centred on agriculture. In the last three decades or so, socio-economic and environmental challenges have occurred in concert to pressure the sustainability of this livelihood systems. Despite this, the residents has shown tremendous resilience when confronted by shocks and stresses. Farmers in the area are often plagued with many interrelated and complex problems that they have to negotiate on a daily basis in order to survive. This knowledge of dealing with livelihood challenges, is a critical component of the resilience of the community. Coffee, one of Jamaica's major export crops and contributes to foreign earnings as well as local livelihoods especially in the Cedar Valley and the surrounding communities in St. Thomas Parish (Figure 2).

Unlike banana and sugar cane that are mostly large scale plantation-oriented, coffee is sometimes grown by small-scale farmers in Cedar Valley at altitudes of 3,000 to 5,000 feet. Coffee is very sensitive to climatic variability, and environmental change especially wind, rainfall, and temperatures. An increase in temperature, for instance, affect the cropping treeline and limits the suitability for cultivation downhill.

Both climatic and non-climatic factors interact from the farm level unit to the community and household levels in creating a multi-level tier of coupled risks and vulnerability. These include crops and their susceptibility to disease and episodic events, securing livestock and other capital assets, maintaining household structure, and upgrading communication infrastructure (see Figure 3).

Figure 2: Topographic map of Cedar Valley, St. Thomas.

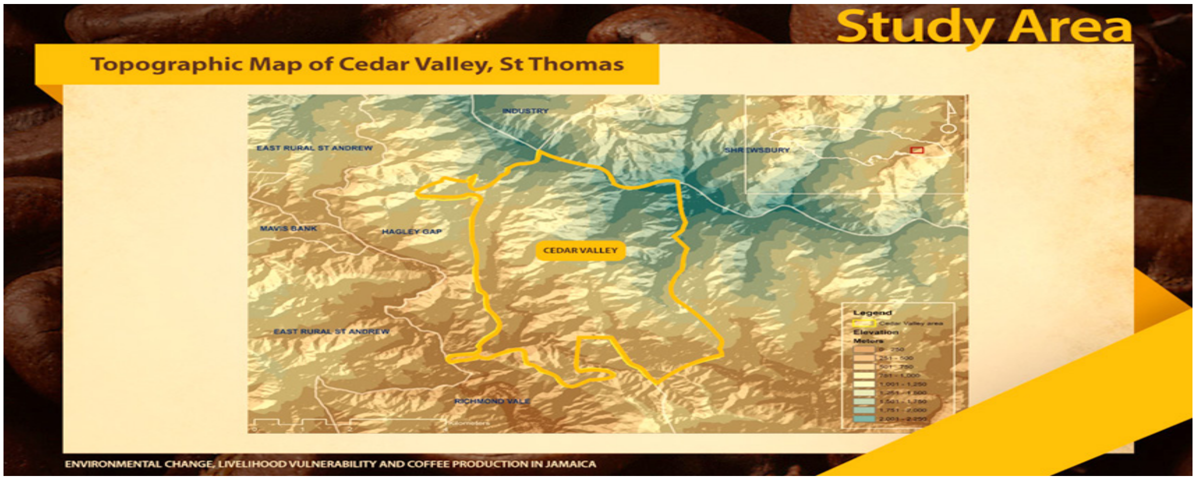
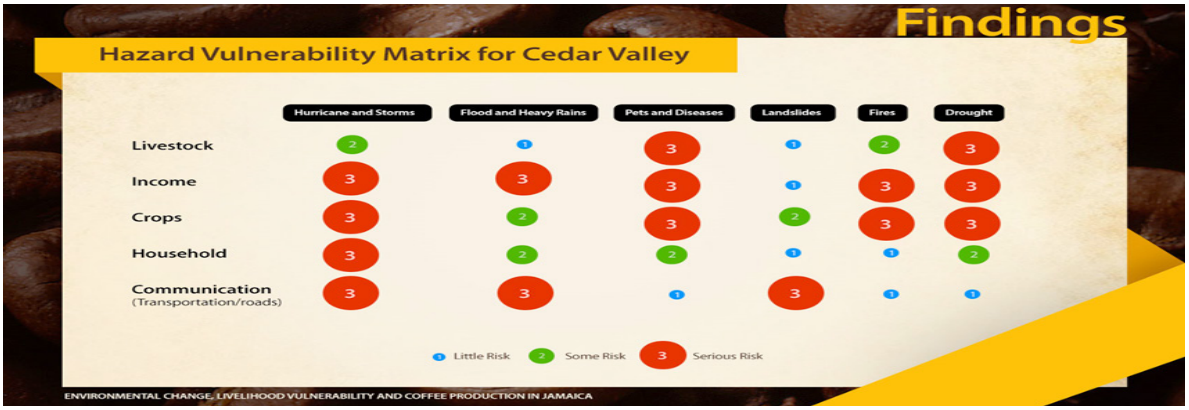


Figure 3: Hazard vulnerability matrix and risk ranking for Cedar Valley farmers



- Farmers agreed there have been many environmental and socioeconomic changes to impact their livelihoods especially climatic variability and community spirit. There are also rapid changes in demographics, household structure, and farming units to influence coping strategies. These interactions impact adaptation options and local capacity to be resilient. Farmers identified various seasonal patterns of stress and therefore developed an agro-climatic calendar underscores grace periods and bumper harvests. They also rely on local knowledge to monitor early warning signals for episodic events especially regarding changes in temperature and rainfall as shown in Table 1.
- Farmers identified ownership of livestock as capital assets to access formal credits and usually assist with off- farm income sources and the household economy. Although most farmers in Cedar Valley have access to formal loans and about 50% have obtained formal credit; some are ambivalent about loan repayment conditions. In the past, unfavorable loans and crop failure due to hurricanes and extreme weather have made it impossible to service formal loans and provide extra hardship on farmers.
- Human capital regarding training and skills development is a key component to integrated livelihood strategies and community development. On the farm training and off-farm skills are necessary to deal with farm production and household earnings. Only a small fraction (13%) of farmers and their household in a survey conducted in Cedar Valley have alternative livelihood skills besides farming, with women and youth mostly marginalised in daily agrarian activities.
- Farmers are also part of several social groups from unions and associations to various labor programs where folks are assisted through 'lending a day' during bottleneck farming periods. The Jamaica Agricultural Society (JAS) and the Producer Marketing Organisations are key examples. Marketing initiatives have been a topic of community engagement and seminars by the JAS. The St. Thomas Coffee Growers have also been instrumental in advocating the rights and welfare of local farmers especially against powerful societies such as the Myall Coffee Cooperative in 1997.
- Environmental stewardship and the landscape approach to ecosystem-based adaptation has been a challenge in Jamaica, especially in Cedar Valley due to historical land tenure systems and land use patterns that lead to degradation and land use change. There is surely an issue of vulnerability with farming systems on steep slopes, where flooding and landslides can be catastrophic and exacerbated by access rights. Landslides are not only hazardous from a natural capital standpoint, but it also affects essential infrastructure (physical capital) such as roads and bridges.

Table 1: Seasonal calendar and farmers' perception of favourable growing seasons

Events	Months											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Planting Coffee	Highland								Highland	Highland	Highland	Highland
Harvesting Coffee	Lowland			Highland	Highland	Highland	Highland	Lowland	Lowland	Lowland	Lowland	Lowland
Planting Gungo	Highland	Highland	Highland	Highland	Highland	Highland						
Reaping Gungo												
Rainy Months					Highland	Highland						
Dry Months	Highland	Highland	Highland	Highland								
Worst Months	Highland		Highland	Highland	Highland	Highland						
Best Months									Highland	Highland	Highland	Highland

HIGHLAND COFFEE LOWLAND COFFEE

- It is well established that farming systems such as slash and burn agriculture on hilly slopes also affects watershed health as it increases run-off and sedimentation as well as leaching of nutrients affecting crop yield in the long term. Furthermore, good yields and multiple income streams can contribute to reinforcing housing development for flooding and hurricanes as they provide an important pillar regarding human security and protection.

3.5.1.1 Summary

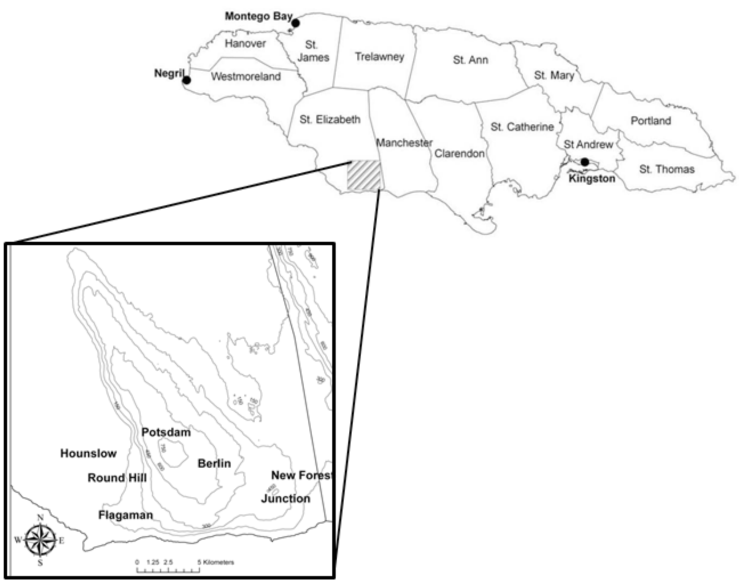
Climate variability has ramifications on coffee production in Cedar Valley communities. These impacts will be pronounced in the future as temperature projections increase with a new normal of frequent storms and droughts. Thus, community engagement on adaptation planning and intervention is necessary and overdue in addressing these vulnerabilities. Livelihood security provides an entry point to understanding these interactions amongst climate and non-climatic factors as well as socioeconomic and policy overlays. A community-based adaptation approach that draws upon local farmers knowledge and historical context can be instrumental in nurturing the building blocks for resiliency taking into account issues of power, class, gender and equitable access to resources.

3.5.2 Vegetable Farming in the "Bread Basket" of St. Elizabeth

Farming in St. Elizabeth is crucial to Jamaican nutritional well-being and food security. It is the leading Parish with the highest production of domestic crops often termed the "breadbasket of Jamaica", located in the southwestern part of the island (Figure 4). In 2008, the Parish accounted for 22% of Jamaica's total domestic food production (400,105 tonnes) in comparison to Trelawney, Manchester, Clarendon, and Westmoreland; despite a drop in production due to Hurricane Dean in 2007 and tropical storm Gustav.

Figure 4: Map of St. Elizabeth showing vulnerable communities to droughts

Rainfall is a key driver for vegetable production in the region in addition to the price of inputs such as fertilizers. This 'double exposure' vulnerability due to global environmental and economic changes affects local production and nutritional well-being (Gamble et al. 2010). This is in addition to declining state support



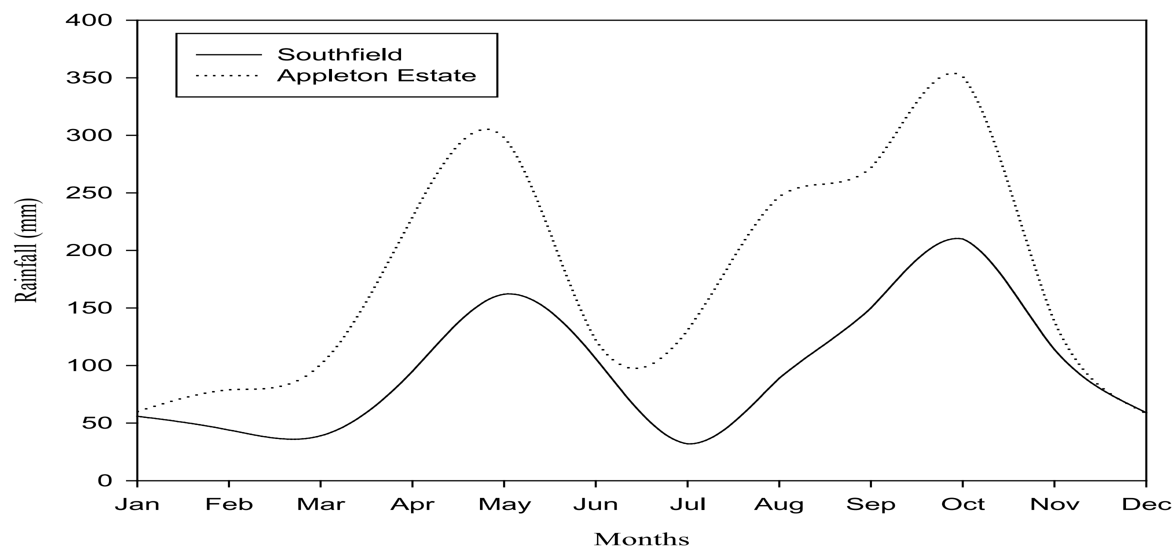
especially towards farming inputs and increased competition from imported food (Weis, 2004).

- Tropical Rainfall Measuring Mission (TRMM) for the period May 1998- May 2010. Figure 3.3b highlights the spatial variability in rainfall across the parish and illustrates the gradual decrease in totals from north to south. The Santa Cruz Mountain is perhaps responsible for the 'V-shape' pattern of rainfall distribution.
- The south of the Parish is much drier compared to the north with average annual rainfalls of 2000mm and 1000mm, respectively (Gamble et al. 2010). Rainfall patterns and trends are highly dynamic, influenced by a combination of factors notably topography, maritime influences from the nearby coast, which creates a rain shadow effect and variability in precipitation. Early season droughts and infrequent rainfall during the growing season (August to November) have led to water stress conditions and the need to adapt in meeting national nutritional needs.
- Understanding ideal growing seasons and potential water stress periods are local knowledge and experiential skills that farmers have relied on in the

past. An early growing season has been identified from April through June before the onset of the rains in August to November – the most ideal time to cultivate vegetables.

- Early season droughts have been recorded in the past decades through increased temperatures, low rainfall, and strong winds. Farmers who observed this phenomenon mostly agree that they are experiencing drought episodes or water stress periods. In the absence of irrigation techniques and farm site relocation, this could lead to low yields and food security concerns. This has adaptation implications for farm locations along a topographic gradient, soil nourishment measures, and irrigation techniques.
- Vegetation monitoring can be done through satellite based remote sensing analysis. The NASA MODIS sensor measures spectral reflectance from the earth's surface to derive vegetation indices that estimate the amount of chlorophyll in vegetation. The effects of the 2014 and 2015 summer drought can be seen in changes in mid-summer NDVI compared to average mid-summer NDVI conditions. The southern region of the island tends to respond more to early summer rainfall deficits compared to the northern areas.
- Farmers operating in marginal environmental conditions are especially sensitive to changes in rainfall patterns. Of the sampled farmers, 78 per cent indicated that they have observed some change in the rainfall patterns in the area. Of this total, 80 per cent stated that they have observed an overall decline in rainfall for the area. More specifically, farmers claim that the rainy season is increasingly characterised by unpredictable shorter periods of torrential rainfall. For a rain-fed farming system that is entirely dependent on the quality of the rainy season, these changes are obvious setbacks to crop production, and increase risk.
- Two-thirds of the farmers interviewed stated that they have noticed changes in the overall weather patterns in the area. Of these, 40 per cent believe that this change has involved an increase in the frequency and magnitude of extreme rainfall events (flood rains) locally called "pond rains", and a significant decrease in lower-intensity (but longer-lasting) "garden rains". However, not all the farmers who perceive these changes are responding to them.

Figure 5: 30-year mean rainfall recorded at the Appleton Estate and Southfield meteorological stations



- When asked if they did anything on their farm or within their household to adjust to these changes, 57 per cent answered affirmatively. The most common coping strategies includes scaling-down production during the early growing season (which has been described by farmers as being the most unpredictable in recent times) and planting more during the primary growing season; the cultivation of crops that are more resistant to extreme weather conditions (more common among younger farmers); soil management techniques specifically geared towards reducing increased moisture loss during the dry seasons and rates of soil erosion during the rainy seasons; and crop management techniques involving adjustments in the timing and application of water, fertiliser and other farm chemicals.
- While most farmers (74 per cent) indicated that they use guinea grass as mulch, a notable 25 per cent uses other types such as Baccarie, Pongola and Seymour-grass. Most farmers learnt the mulching technique from their parents and apart from combining different types of grass, they rarely modify the technique. When asked specifically if they had modified any aspect of the mulching technique taught to them, 88 per cent of the sample said no. Farmers who claimed that they have modified aspects of the mulching technique identified change in the type and amount of grass used as the main adjustments. Guinea grass is the most widely used grass for mulching and is the only one sold in the area for this purpose. Table 2 shows an estimate of the total cost for guinea grass to mulch 3 acres of farmland.

The main argument here is that empowerment among small farmers can be achieved by helping them to build up their asset portfolios. As far as livelihoods strategies are concerned, 'those with more assets tend to have a greater range of options and the ability to switch between multiple strategies to secure their livelihoods' (DFID, 1999: 6). In addition, the ability of individuals to escape from poverty (a major livelihood outcome) is been linked to their access to assets (DFID, 1999).

FIGURE 6: NDVI maps showing the regional distribution of drought during July 2014 and July 2015

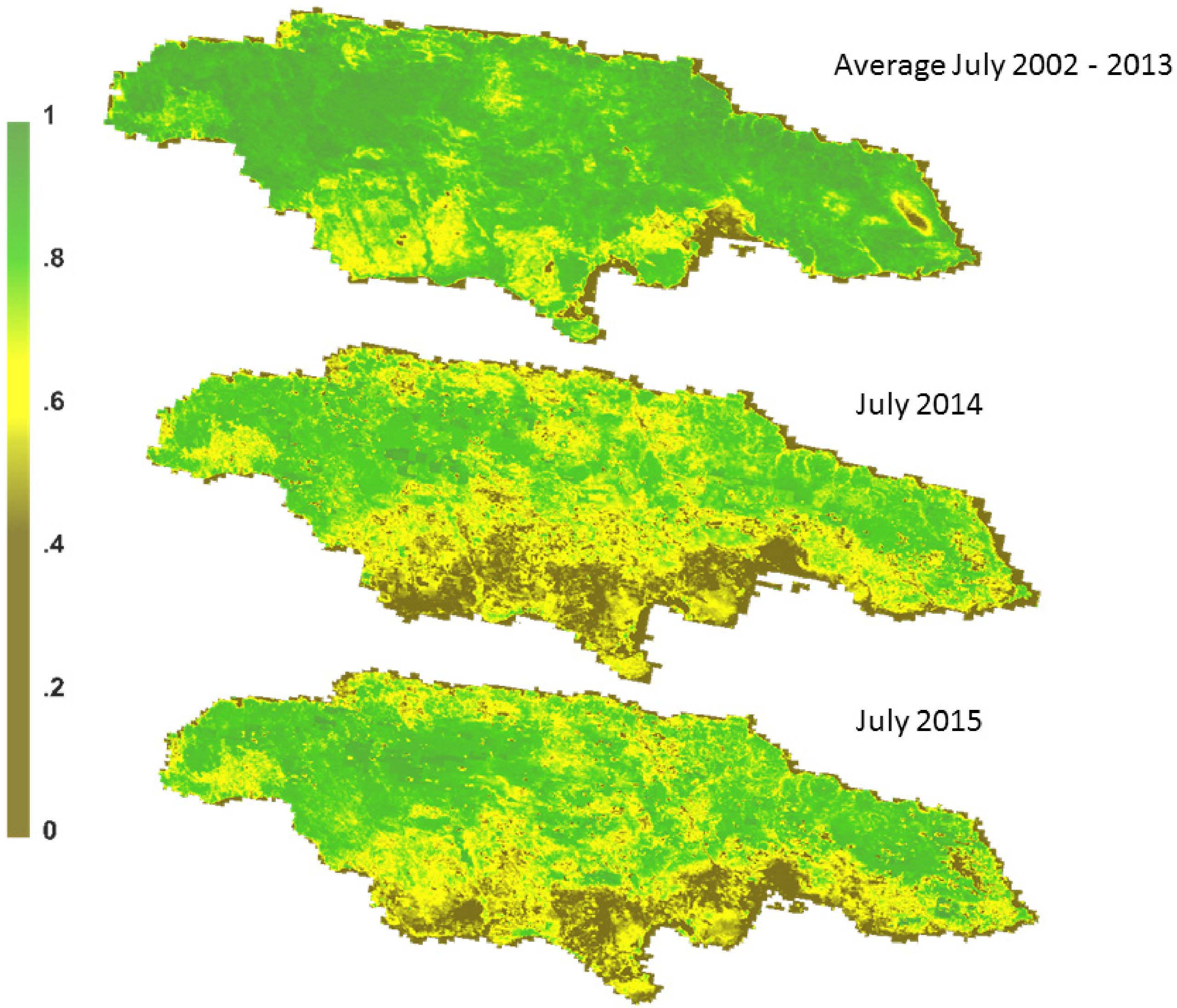


Plate 1: Truck transporting guinea grass

Figure 7: Livelihood assets pentagon for communities within the study area

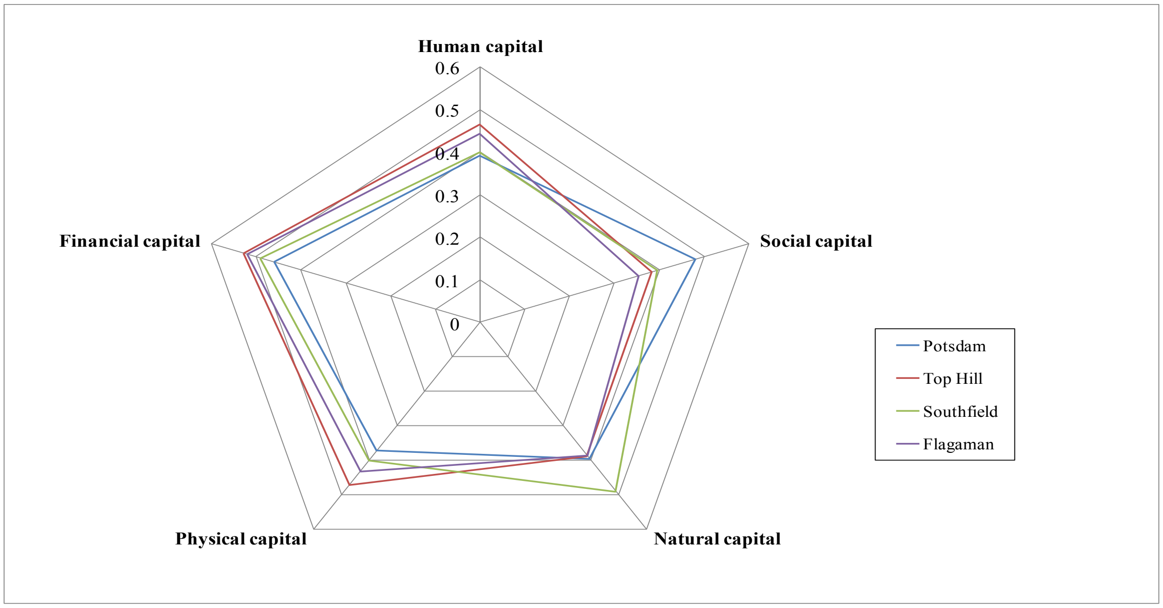


Table 2: typology of the sources of multiple stresses affecting farming systems in southern St. Elizabeth

Stress	Main problems	Brief explanation	Some impacts
Water	• Lack of irrigation water • Poor water supply system • High cost of water	Lack of reliable supply of irrigation water. Water is bought from a government agency (Rapid Response). However, it is expensive ($US114 and $US285 for 4000 and 8000 galleons respectively) and unreliable.	• Reduction in the number of crops produced per year • Crop failure • Forced to buy water from private vendors who sell at a higher price
Guinea grass	• High cost of guinea grass	The importance of Guinea grass (used for mulching) to farmers in southern St. Elizabeth has led to its commodification. The grass is expensive and cost approximately $US114 per acre.	• Use other grass that are generally less effective • Change cash crop- grow crops that are more resilient to drought • Cultivate on a smaller scale
Market	• Lack of reliable market for produce • Erratic and unreliable ‘ higglers’ (market purveyors)	The lack of reliable marketing facilities has relegated farmers to a dependence on ‘ higglers’ (market purveyors) as the main outlet for their produce. These ‘ higglers’ are often unreliable and deceptive, farmers complain.	• Spoilage of produce • Reduced profits • Left to the mercy of higglers
Farm inputs	• High price of fertiliser, seeds and chemicals	The price of fertiliser has increased by 60 per cent in less than one year- from $US28.5 in June 2007 to $US71 in April 2008. This increase has occurred alongside other farm inputs such as hybrid seed, pesticides and equipment.	• Decreased output per crop • Use of alternative methods that are sometimes less effective • Cultivate ‘ lower’ varieties that require less external input • Reduction in area under cultivation
Food imports	• Increased competition from imported food	The importation of cheap produce (e.g. onions, tomato, carrot and cabbage) in the farming communities is a major stress to farmers. For example, onion farmers of Flagaman were virtually wiped out over a period of 3 years as total acreage fell from a high of 800 acres in 1996 to an almost negligible value in 1999	• Lower price for produce • Change of cash crop -cultivate non-imported crops • Loss of buyers (‘ higglers’) to importers
Environmental conditions	Rain shadow effect- very low rainfall	Even though farmers have adapted well to the marginal environmental conditions in their area, the cost of adaptation is a major stress to farmers. The dry conditions demand the use of Guinea grass and more water than the typical farming region in Jamaica.	• General added expense of adapting to dry conditions (e.g. buying Guinea grass) • Limited capacity for livestock production (e.g. cattle, sheep, goat) • Higher than usual demand for irrigation water

3.5.2.1 Summary

- Farmers in southern St. Elizabeth have demonstrated considerable fortitude in coping with a series of droughts in recent years. They have employed a number of damage-reducing coping strategies to lessen their exposure to drought hazard. Principal among these are: proactively introducing a variety of planting methods; proactively employing a range of moisture loss reduction techniques; varied responses to stress during the drought itself, including sacrificing a part of the growing crop in order to enhance survival of the remainder; and a variety of strategies to aid recovery, ranging from cutting back on the area farmed, seeking off-farm employment and a temporary exit from farming.
- Insights gathered from a study of the rationality of farmers, through their unique perceptions of reality, livelihood objectives, and expectations are critical to any understanding of why some farmers are more vulnerable than others. Top-down agricultural policies tend to assume uniformity in the behaviour and rationality of farmers, which has often led to the development of inappropriate policies. The rationality of actions taken by farmers to protect as well as improve their livelihoods can help development practitioners to increase the efficiency and chance of success of intervention programmes.
- In light of the importance of agriculture to rural livelihood and the Jamaican economy, considerable attention should be given to the sector in order to reduce its vulnerability to natural hazards. There is also a need to set vulnerability response capacity and policies and to support the sector in light of both the long-term incapacitation of state support for agriculture through processes of debt and adjustment and the recurring effects of extreme natural events. These farmers are dependent on a sector that is extremely vulnerable to natural hazards and this has serious implications for food security at all levels within the country.
- Small farmers need help to adapt to changes in rainfall patterns brought on by climate change. They are doing their best to cope with the changes by utilising the rich body of local knowledge available to them. However, the implementation of future policies and programmes that complement these existing traditional coping mechanisms will be essential in alleviating stresses as well as preventing further degradation of the local knowledge base that supports the survival of these farming communities. Since most farm incomes are either stagnant or in decline, the impacts of droughts are presumed to be profound and far-reaching.

3.5.3 Vulnerability of capture fisheries to climate change: The Case of Alligator Pond

In Jamaica, fisheries plays an important economic and cultural role. Fisheries provide multiple socio-economic contributions, such as income generation, food security, and livelihood diversification opportunities. It forms the backbone of the local economy in many coastal communities across the island. Additionally, fisheries form part of the cultural identity in these communities. Participation in fisheries has become a tradition, and the knowledge, practice and way of life associated with fisheries has transcended many generations. The Jamaican fisheries resources are already vulnerable, and further unsustainable exploitation could have grave consequences in light of projected changes in climate (MOAF 2015).

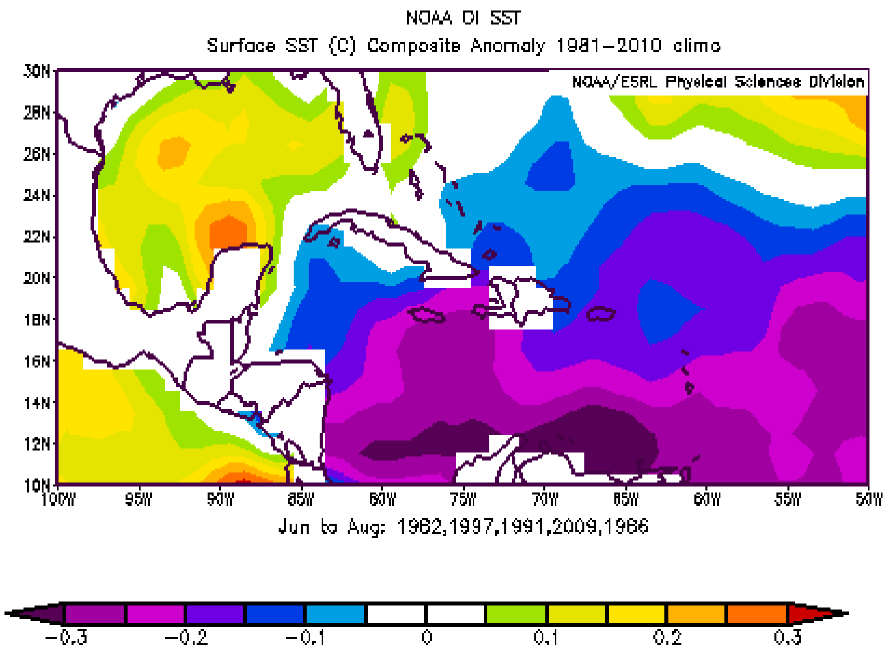
The majority of these fishers are considered 'small-scale' or 'artisanal', often fishing from small, open canoes power by outboard motors. They target demersal and pelagic fish, lobster, shrimp and conch within a significant portion of Jamaica's maritime waters. In addition to the artisanal fishers, industrial operations also target Queen Conch and Caribbean Spiny Lobster around the Pedro Bank. Fisheries exports were valued at approximately $US 11 million in 2013. Almost 80% of local fish consumed was imported in 2012, and which was valued at $US 109.85 million. Imports are driven by decreasing production, which results in part from serious fisheries governance challenges associated with overfishing, habitat degradation, and illegal fishing (MOAF 2015).

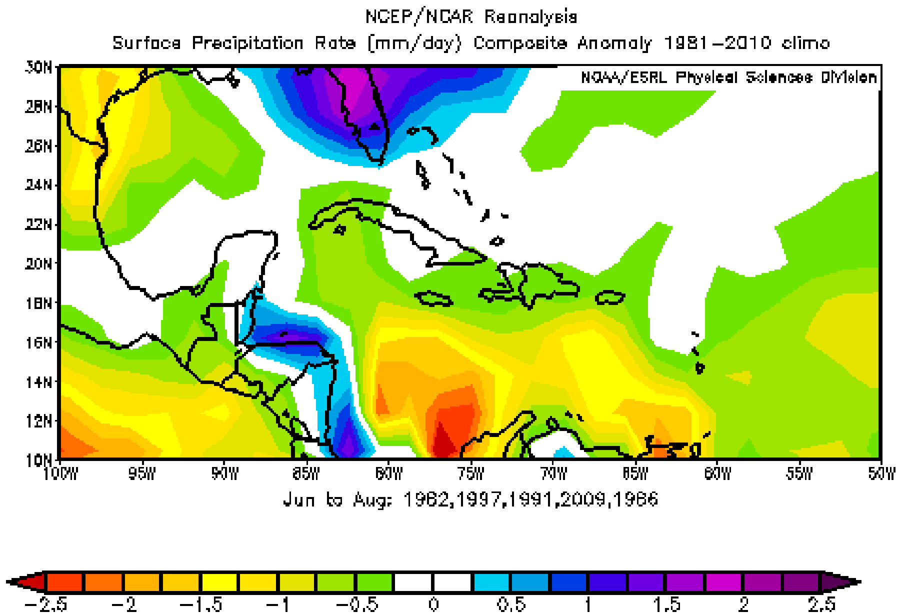
3.5.4 Current and Future Climate Changes

- **Local Sea Surface Temperature:** Patterns of sea surface temperatures in Jamaica exhibit a clear seasonal SST cycle. Around the island, the maximum SST is experienced in the late summer months and the minimum SST is experienced during the cooler winter. SST follows the solar declination angle and increases as the sun becomes more overhead during the summer. There is a statistically significant annual trend of +0.15C/decade from 1980 to 2015. The seasonal trends offer a better indication of the degree to which the waters surrounding Jamaica are warming. The seasonal trends in SST show that warming is occurring at rate of +0.09C/decade for January SST and +0.17C/decade for August SST. It is believed that more extreme weather will occur with increased SST. The annual sea surface temperature (SST) is expected to increase locally by 2C, which would warm the waters surrounding Jamaica to an annual average of +28C with summer averages exceeding 29C.

There is a relationship between SST and El Niño and La Niña Phases. Though the relationships are not as pronounced as the relationships between SST and El Niño and La Niña Phases that are experienced in the tropical East Pacific Ocean, it is observed that SST cools with reduced rainfall and that the opposite is true during La Niña phases when Caribbean SST is increases while accumulated summer rainfall increases (Figure 4).

Figure 8: SST anomaly composite with respect to El Niño (above) and La Niña (below).

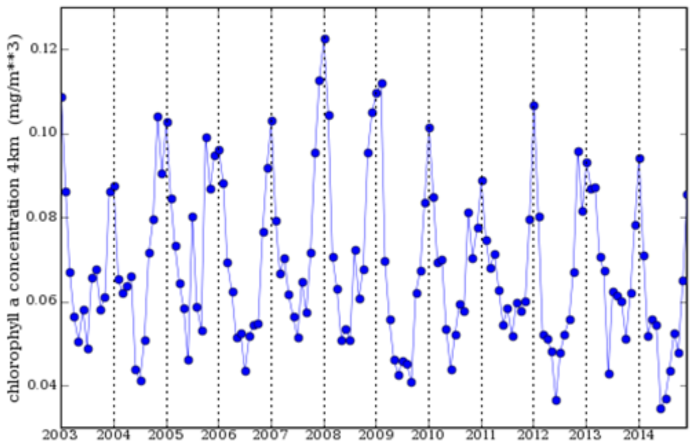


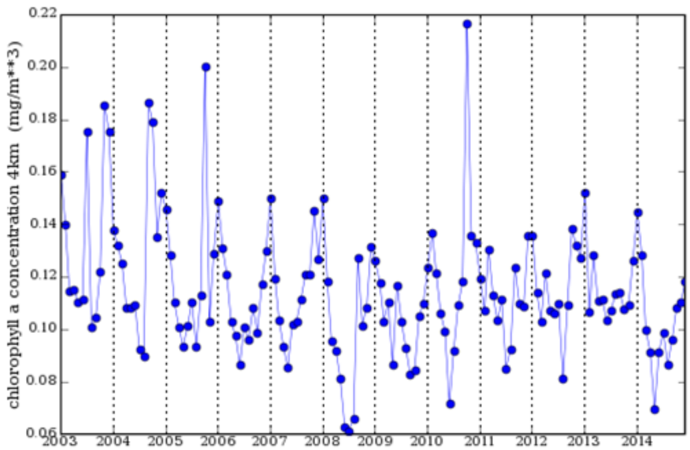


- **Variation in Chlorophyll Concentration:** Chlorophyll is an important indicator for the state of conditions for marine life. Areas of high primary productivity attract species that are higher in the food chain. The analysis of Chlorophyll-a for Jamaica reveals the following:

  Chlorophyll-concentrations are higher during the winter period when the water is cooler and the winds remain high. Chlorophyll-a is not equally distributed between the northern and southern coasts of Jamaica. The variations are seasonal. The seasonal range in chlorophyll-a is higher along the northern coastline. The southern coastline experiences much higher in summertime chlorophyll-a than the northern coastline. The variations are site-specific. Chlorophyll-a concentrations increase dramatically from the open ocean east of Jamaica towards the west along the Jamaican coast

Figure 9: Monthly observations of satellite derived chlorophyll-a concentrations along the north (top) and south (bottom) coasts of Jamaica.



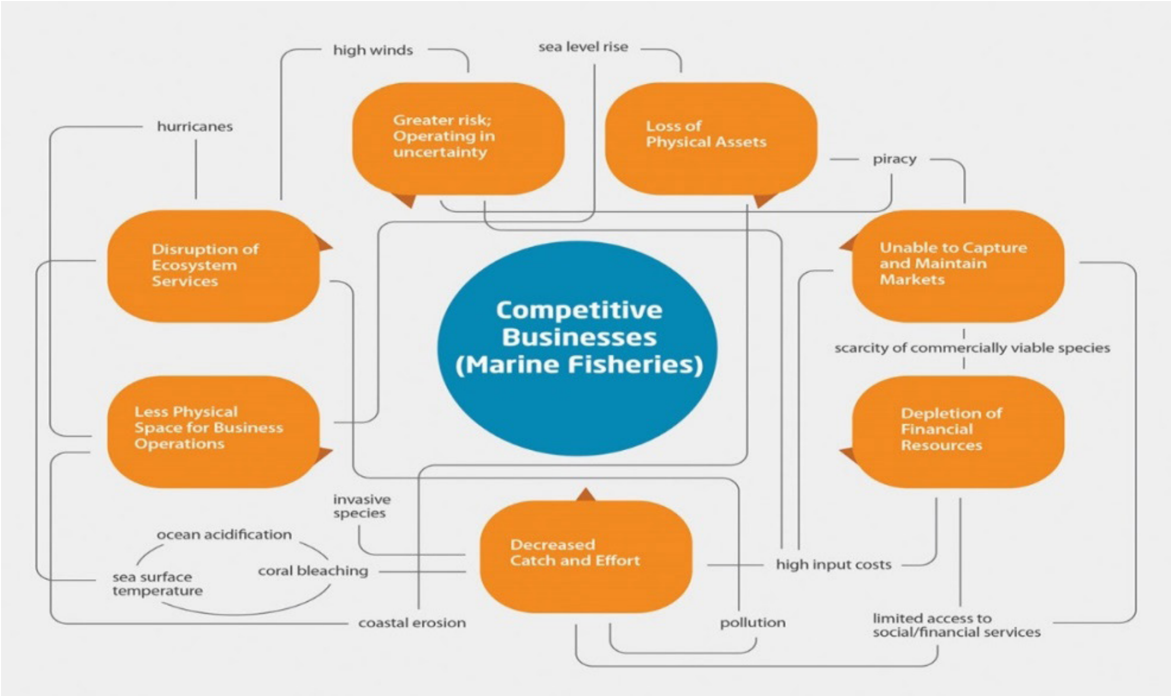


- **Seasonal changes:** Projections indicate that the summers will be particularly dry. The General Circulation Models show that the majority of the drying is expected to occur during the summer months, which is characteristically wet. This observation is also seen using Downscaled Regional Climate Models for Jamaica which predicted end of century drying, with most intense drying in the summer. Not only are higher temperatures expected, but there will also be very little seasonal deviation. It is project that there will be only about a 0.5C difference between a warmer summer versus winter. The range in seasonal surface temperature projections is not as large as the seasonal ranges in projected rainfall for Jamaica (Downscaled regional climate model). The PRECIS model output does suggest however, a stronger rate of projected warming along the southern portion of Jamaica relative to the northern section.

- **Changes in temperature and salinity:** The Caribbean as a whole is projected to warm by almost an additional 3C by the end of this century. Strong surface heating combined with warmer surface waters will result in higher surface evaporation rates thus resulting in higher surface salinity values.

- **Annual pH level projections:** pH levels are expected to increase along Jamaica by 2-3% by the end of this century. This is not surprising since the CMIP5 models show an increasing rate of acidification for Jamaica's shorelines and for the Caribbean in general. In addition to an increase in ocean acidity and decreasing chlorophyll levels, it is expected that primary productivity levels will fall by the end of the 21st century. Overall, a warming environment with increasing CO2 content will pose a greater risk to an already fragile marine ecosystem.
- Despite these potential contributions, fisheries are highly vulnerable to climate change impacts. Whether the impacts arise out of sea level rise and coastal flooding or increasing sea surface temperature and ocean acidification, wind patterns and storms all, affect resource abundance and fishing practices as shown in Figure 10.

Figure 10: Climatic stressors and shocks to the fisheries production (CCCCC, 2015)



3.5.5 The Case of Alligator Pond

Fishing is central to the economy of Alligator Pond and helps to support a population of 190,800 (Statistical Institute of Jamaica, 2013). During the focus group discussion, community members estimated that between 75 to 80 per cent of local businesses are dependent fishing. This includes a mix of near-shore and offshore pelagic fishing. The fishing methods most commonly used are hook and line, pots and diving/spear shooting. Participants in the focus group discussions also noted that the fishing population in the community has increased in recent times. This has resulted in increased competition and greater levels of investment in fishing operations to remain viable. Fishers in Alligator Pond also indicated that beach erosion and strong winds are major factors currently affecting their operations. The rate of beach erosion has increased significantly since 2006.

Tourism and fishing activities have been affected due to flooding that occurs from higher elevations during heavy rainfall. The government is working to mitigate the severity of the erosion by redesigning engineered infrastructure to act as a buffer (Jamaica Information Service, 2010). As of the 2015 field survey, however, there was limited evidence of this having been installed although riprap armouring has been placed on some business establishments at risk. Some of these responses may be considered as maladaptive as they have exacerbated erosion immediately in front of the rip rap and at either end.

While climate change was listed as a factor, there was no comprehensive scientific study of the erosion situation and anthropogenic factors were labelled as the main reasons for the erosion (mainly dumping in the ravines and denudation of elevated areas) (Office of Disaster Preparedness and Emergency Management, 2011). The 2008 Jamaica Economic and Social Survey indicated that 19 out of 34 beach sites monitored showed erosion and 15 showed signs of accretion (Myers, 2010).

So much of the fishing beach has been lost to erosion that fishers have resorted to ad hoc measures to secure their boats ashore, while fish vendors have been relegated to operating from the road side. Some fishers are of the view that the customer being able to buy the freshly caught fish boat or beach side was part the Alligator Pond experience. They believe that the customers have stayed away, and that has impacted their earnings. The intensity of winds in recent times has also made it increasingly difficult for some fishers to venture to sea. Some of the fishers explained that due to strong winds they had not been able to go out for up to six months in recent times.

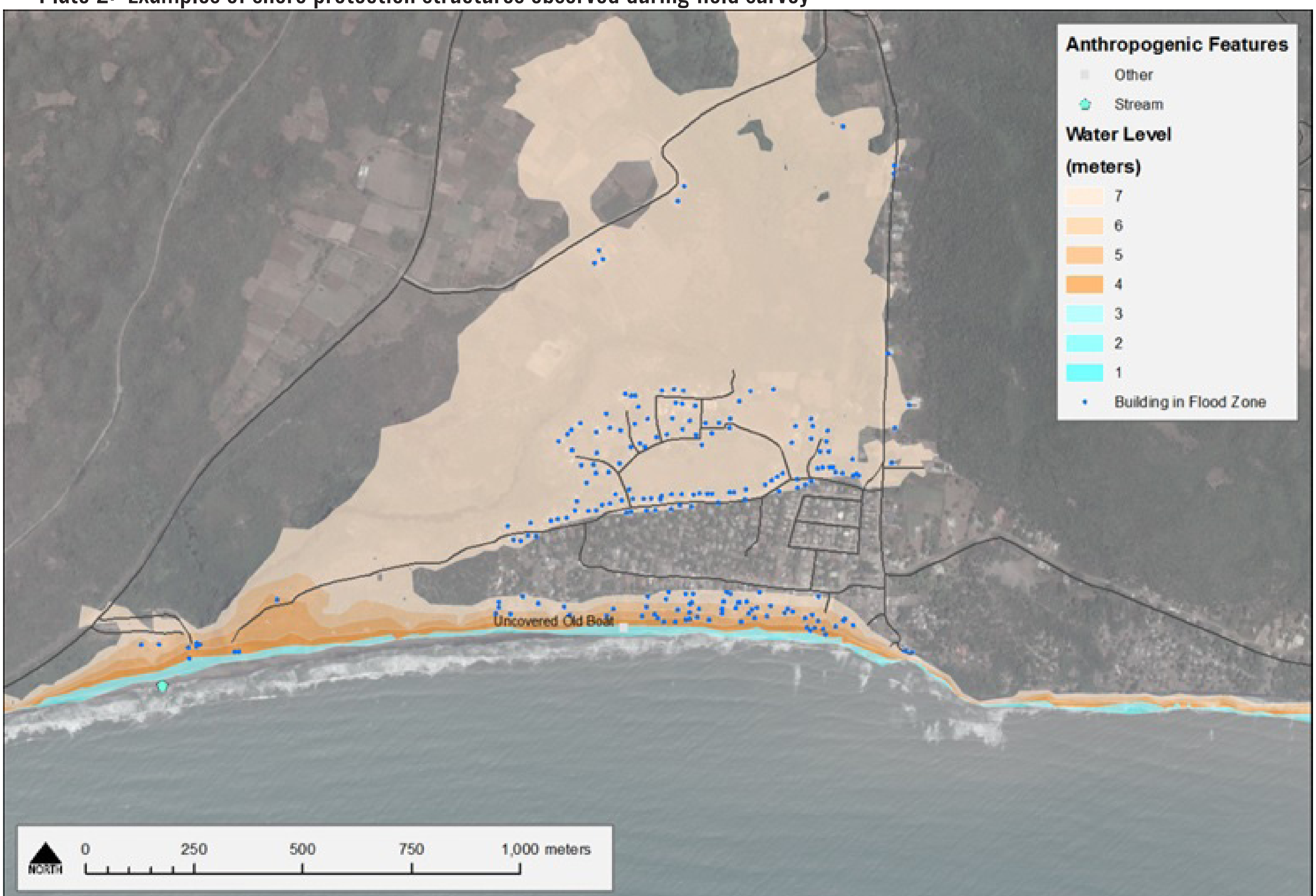
Over the period of 2009-2010, the beach located within the Alligator Pond fishing village is estimated to have eroded by approximately 12.2 meters (40 feet) (Myers, 2010). Tourism (especially at Little Ochi, a prominent restaurant/retreat spot) and fishing activities have been affected due to flooding that occurs from higher elevations during heavy rainfall. During the Atlantic Hurricane Season of 2014, property and business owners in the Alligator Pond area were asked to contact the National Planning and Environmental Agency (NEPA) to discuss strategies to minimise property.

There are signs of sand accumulation backed by dunes with evidence of active sand transport and partial stabilisation by trees and grasses. Large alternating beach cusps were observed with alternating steep and shallow swash berms. Large blowouts are evident in addition to a 'loss' of sand into the interior (outside of the coastal zone) that occurs at a rapid rate as inland transport of sand is perpetuated. The backshore is classified primarily as dune and clastic slope, the latter of which is likely part of the large historical dune complex referred to in Khan and Robinson (2011).

Attempts at shore protection using sand bags and rocks have been largely unsuccessful. More systematic use of armour stone has been used near Little Ochi and the main village where the beach used to extend beyond the restaurant. This use, however, can be seen as short term solution to the problem and is exacerbating erosion at either end. While the use of tires does reduce wave energy reaching the toe of the slope, it could be better stabilised with paired plantings of vegetation. Further east, erosion rate decreases initially as a nearshore platform protects beach; on the other hand, backshore rates increase significantly, exposing layers of garbage and debris within the old dune field.

Figure 11: Flooding scenarios based on contiguous flood models for 1 m flood intervals at Alligator Pond. Floods less than 3 m represent combined contemporary sea level rise and storm surge

Plate 2: Examples of shore protection structures observed during field survey



d from NextMap5 Digital Terrain Model, InterMap Technologies, November 1998. Vertical Datum: EGM96. Satellite imagery: Worldview-2, 2014-06-18.

Figure 12: Comparison of the position of shorelines digitised from historical aerial photography from 1953 and satellite imagery from 2001 and 2014. 2015 shoreline based on GPS points collected in the field.

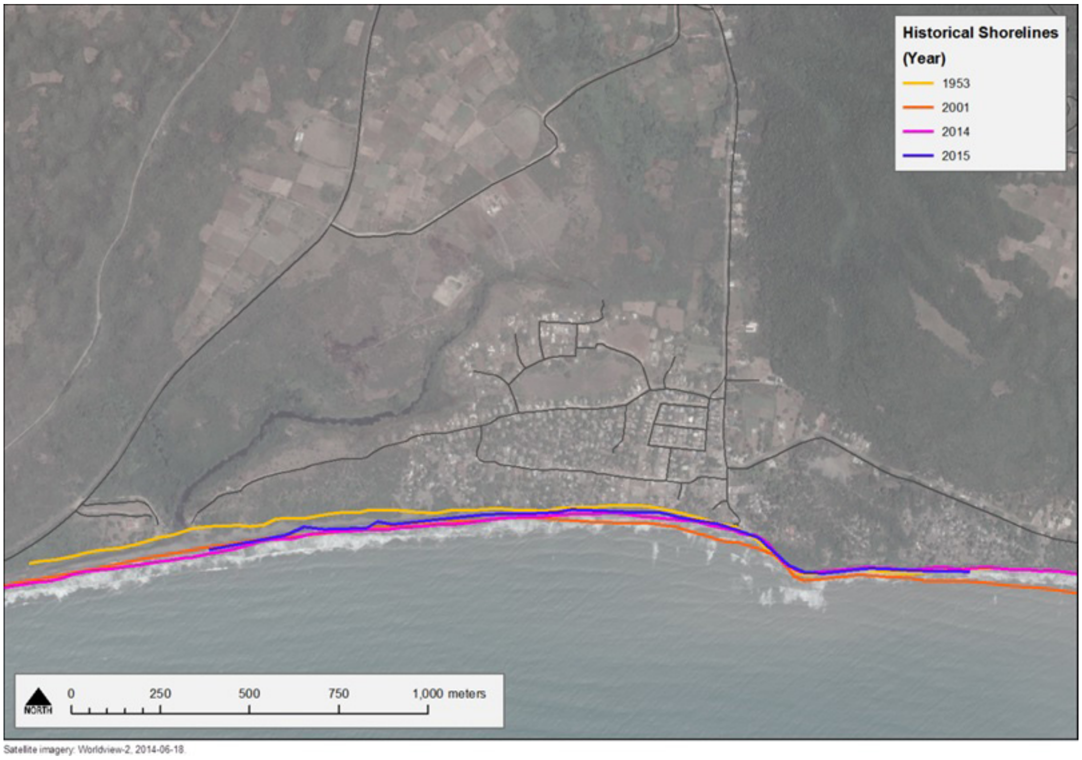


Figure 13: Comparison of 1953 aerial photo with 2014 satellite image. Location of profiles indicated on 2014 image

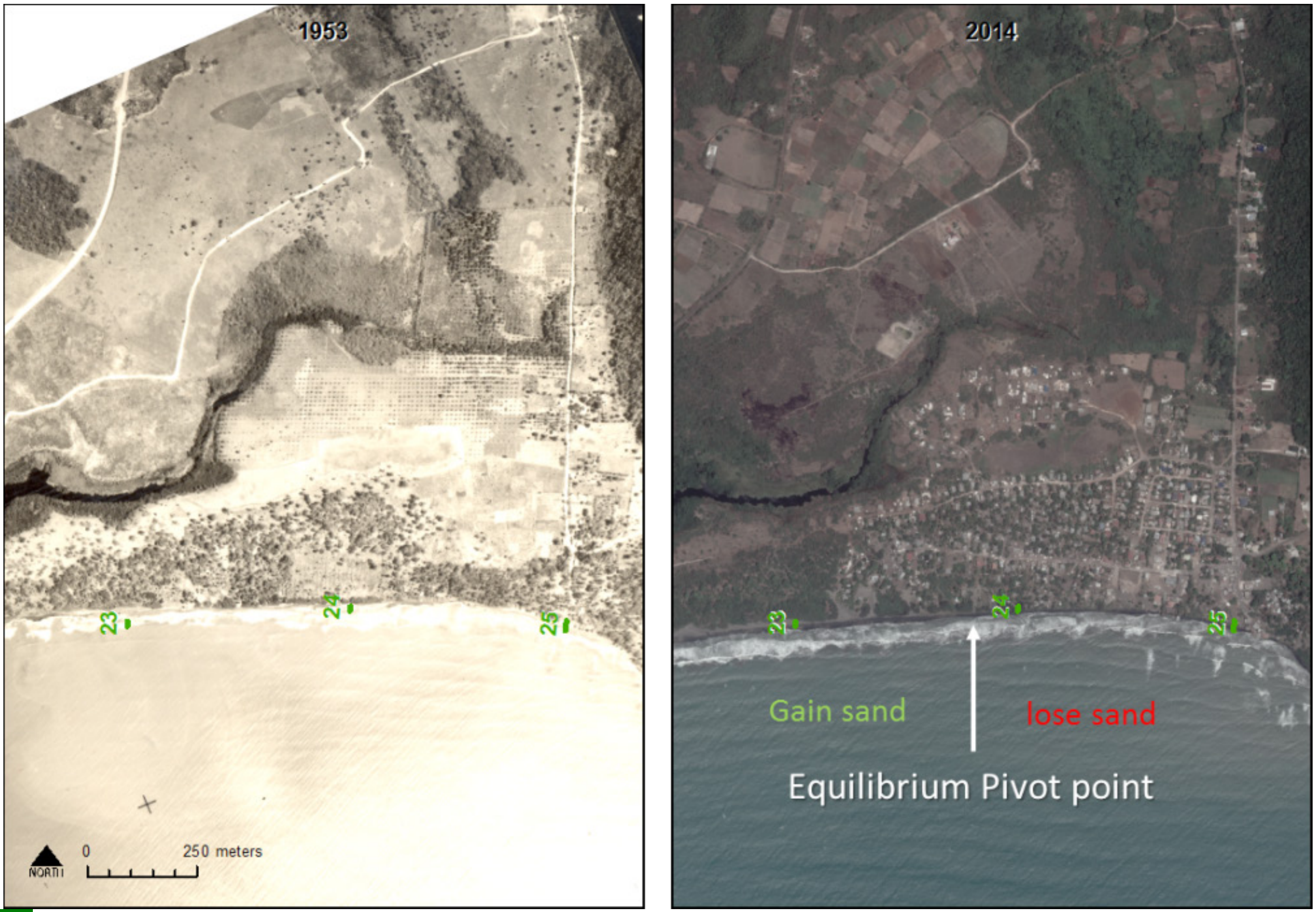
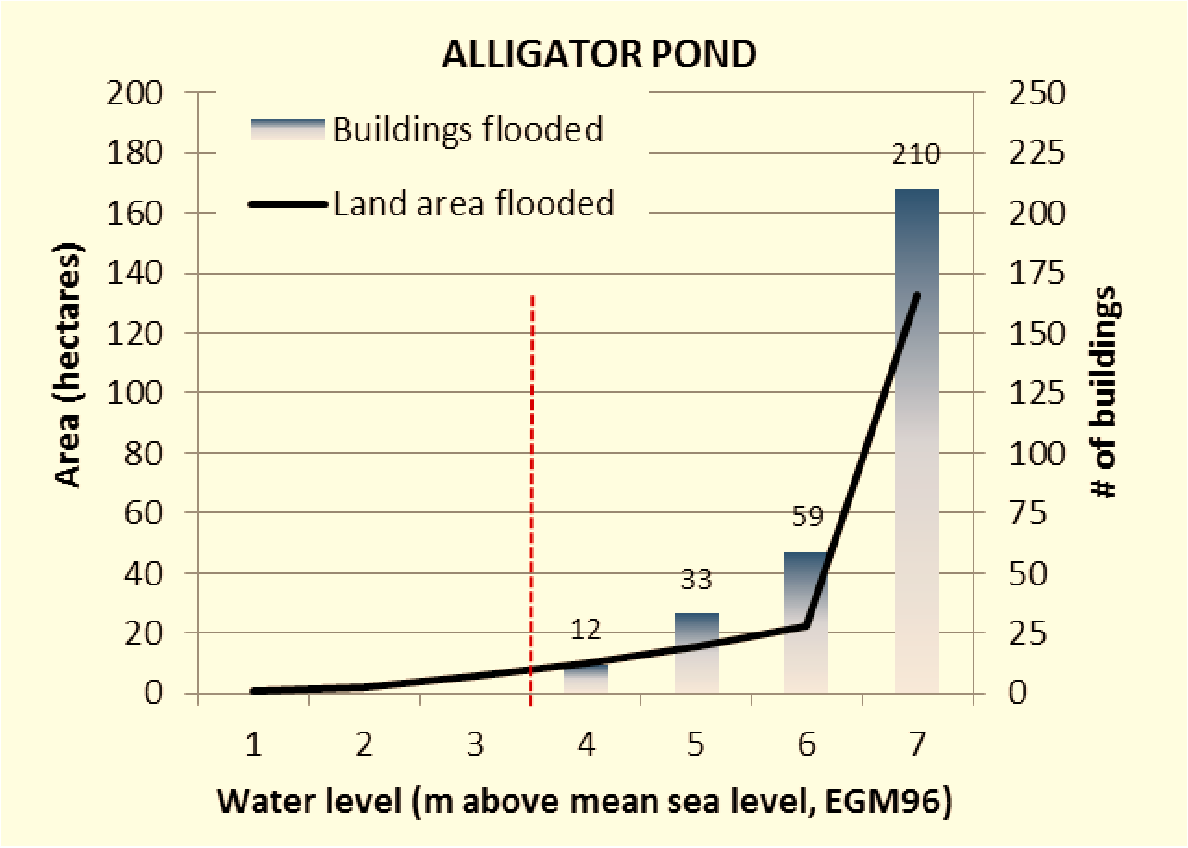


Table 3: Historical (1953-2001) and contemporary (2001-2015) change in shoreline position (in meters) at intersection for field profiles. Location of profiles indicated in Figure 18. Measurement accuracy ± 5 m. Erosion indicated by negative values.

Profile #	1953-2001	2001-2014
22	+58	+20
23	+50	+5
24	+24	-7
25	+45	-35
26	+13	-24

The primary hazard affecting Alligator Pond is coastal erosion along portions of the study area that have changed over time. During the 1953 to 2001 period, the system was in a net progradation phase, with 54m of beach added at a rate of 1.23 $m \cdot yr^{-1}$ on the western end and 0.28 $m \cdot yr^{-1}$ on the eastern end.

Figure 14: GIS analysis of land area flooded and number of buildings directly impacted relative to modelled water levels.



Red dotted line indicates boundary of likelihood of scenarios.

Locals report that there seems to be an acceleration of change (erosion), but it does not appear to be associated with a significant single storm event. The passage of two major hurricanes in 2007 likely did not allow for sufficient relaxation time for recovery and beach is still in disequilibrium. Hurricanes, however, are also important mobilisers of sediment. After large storms, sediment is brought down the Rio Minho into the coastal zone.

3.5.6 Recommendations for Reducing Vulnerability

- **Improve ecosystem resilience:** efforts need to be put in place to improve ecosystems' ability to adapt or recover from climate change impacts such as ocean acidification, disease outbreaks, and more frequent storm damage. It will be necessary for increased assessment and reduction of vulnerability of ecosystems, which are not limited to coastal ecosystems, but also forest and watershed ecosystems that impact aquaculture. This can be done through:
    - Ecosystem restoration
    - Maintaining a 'brood stock'
    - Reducing anthropogenic stresses such as habitat destruction, pollution, destructive fishing practices etc.
    - Reducing carbon footprint through more efficient gear, equipment and practices, and improve ability of ecosystems such as wetlands to act as carbon sink (Blue Carbon). Special emphasis should be placed for example on increasing the area and health of seagrass beds at the Pedro Cays, which is key conch fishing ground
- **Protect fish landing sites (beaches) and fishing communities:** from sea level rise, storm surge damage and other climate change impacts using engineered, ecosystem-based or hybrid approaches. Increase disaster warning systems and forecasting, whilst providing increased accesses to safe zones for fishers and equipment, insurance and post-disaster support. Infrastructure provision and management of 'coastal squeeze' and/or realignment options are important considerations
- **Promote competitive fisheries businesses:** through small and medium-scale enterprises (SMEs) development. This can serve as an important strategy for improving livelihood security, while simultaneously reducing pressures on the marine resources. Possible areas for SME development include renewable energy, cold storage, value added operations, marketing and financing for environmentally-friendly fishing gear.
- **Identification and protection of key species and areas:** e.g. nursery grounds, parrotfish, fish sanctuaries
- **Mainstream fisheries, aquaculture and climate change into policies and other sectors:** e.g. tourism, developments (especially coastal), waste disposal, agriculture and health. Increase policies, legal frameworks, laws for sustainable fishing methods and so on.
- **Improve knowledge base and information sharing**: through strategic data collection and monitoring:
    - A pilot monitoring protocol for Ocean Acidification (OA) is established for shell fishery (e.g. conch) and habitats (coral reefs).
    - Coral Reef: using existing data, to extrapolate climate change and OA impacts. Develop and action plan from same as well as improve the existing data collection by adding site specific carbon chemisrty parameters such as Dissolved Inorganic Carbon and Total Alkalinity as well as Net Ecosystem Calcification (NEC) rate
    - addressing gaps in science knowledge about local coastal areas (e.g., beach profiles, mapping shoreline trends over time)
- **Identification of new opportunities:** in types of fisheries (e.g. pelagic, aquaculture), market (e.g. export), products (fish oil), species or livelihoods (sport fishing, ecotourism, algal farming). Financial mechanisms must be in place to support these opportunities.
- **Improvements to aquaculture technology:** e.g. feed, water usage and recycling, investment in climate resilient species; improved spatial planning for aquaculture sites (further inland, area with reduced impacts)
- **Promote climate-smart fishing practices:** through more efficient gear, equipment and fishing methods, increased regulation for sustainable fisheries; tackle over-exploitation of species to meet quotas) that can have negative long term impacts.
- **Improve cooperative management and effectiveness:** Greater training on how to run cooperatives effectively and awareness of the role and value added that allowing women members into the group could enhance its operations. Increase awareness amongst non-members about the role and functions of the cooperative and criteria for membership. This type of support could strengthen structural arrangement of fisher's communities and improve livelihood conditions.
- **Access and use of technology:** Incorporate GPS training in local fisheries management strategies to increase awareness of its capabilities. This should be combined with improving the availability of GPS devices to locally. Promote the use of improved fish pots with biodegradable panels to prevent ghost fishing; greater involvement of fishers in the management of the new protected area; coral restoration program as a strategy to enhance fish stock

- **Sector-specific approach to gender mainstreaming:** female fishers own and manage a lot of the assets in the community and their losses to climate change impacts can often be underestimated. This could be partly achieved through greater involvement of female fishers in disaster risk management and community development planning at the community-level. Across the study sites, female fisherfolks are struggling with the dual burden of managing their business and domestic labour.

3.6 Water Resources

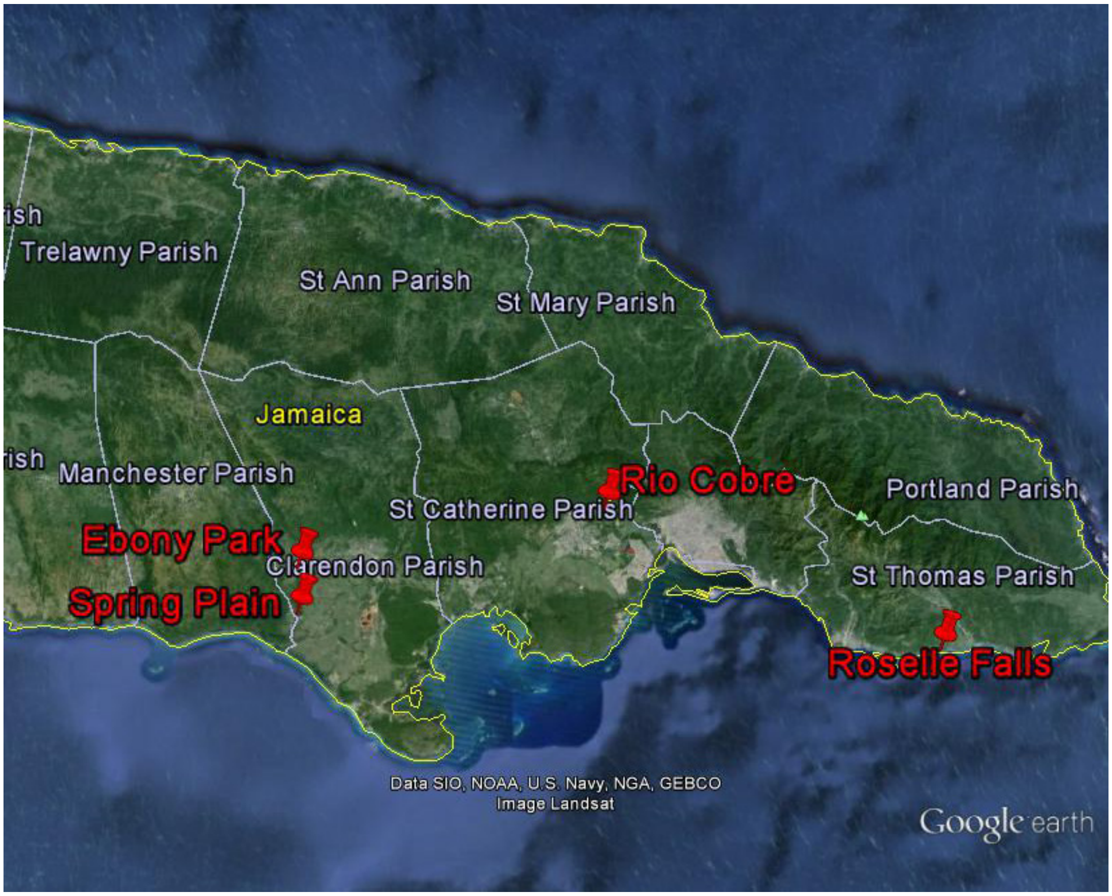
3.6.1 Origin

The cases studied for the Water Sector Resources were as follows:

1. Drought Induced Reduced Stream Flow, St. Toolis Spring, Manchester – A Source of Irrigation Water Supply to Mid-Clarendon District
2. Reduced Aquifer Recharge: Spring Plain Well, Clarendon
3. Cessation in the flow at Roselle Falls located in St. Thomas

The locations studied are shown in Figure 1.

Figure 1: Relative Locations for Case Studies (locations captioned in red)



3.6.2 Findings

3.6.3 General Findings

Jamaica's water sector, in general, and in particular its South Coast, has been severely impacted by climate change. In addition to the three (3) case studies mentioned above, for example, the lowest reduced stream flow was observed for the Rio Cobre which is vitally important in supplying the water demand for residential, agricultural, industrial, commercial and the health care services in the Kingston Metropolitan Region (KMR) and parts of St. Catherine outside of the KMR. Summary of Water Sector Resources. It should also be noted that rivers and streams which flowed steadily over several decades have dried up completely through changes in the hydrological regime. This has caused significant negative impacts on various economic and social activities.

These cases show significant impacts on the water sector, especially on Jamaica's southern coast at present. Among the highly vulnerable impact receptors from climate change in water sector resources are:

- Lack of availability of water for:
    - agricultural,
    - industrial,
    - commercial,
    - health care,
    - sanitation & hygiene,
    - domestic and
    - environmental purposes.
- Decreased stream flow (surface water availability)
- Reduced rate of aquifer recharge
- Decrease in aquifer level
- Change in water quality such as increased salinity
- Social and economic impacts inclusive of threats to livelihoods and concomitant social stability

Jamaica's water sector is undergoing major changes. This may put the traditional performance of the water sector at risk. Water storage and distribution systems are likely to underperform in relation to their design functions. There is major and likely increasing scope for water sector adaptation projects to address these changes. Several initiatives have been taken to develop policies, plans, programmes and actions to adapt to these changes and build resilience. These are at various stages of implementation.

3.6.4 Findings of Case Studies

3.6.4.1 Case 1: Drought Induced Reduced Stream Flow, St. Toolis Spring, and Manchester – A Source of Irrigation Water Supply to Mid-Clarendon District

In conducting the assessment of the vulnerability of the farmers within the mid-Clarendon Irrigation District, which was served from the St. Toolis Spring source, consultations were held with the National Irrigation Commission (NIC), the farmers and other stakeholders in the area. Summary of Water Sector Resources.

There are 660 active NIC customers, consisting mainly of farmers in the mid-Clarendon Irrigation District. These customers are dependent on the water supplied from the spring fed irrigation system for the production of agricultural produce and crops as well as for livestock farming. Without water from the St Toolis system, the limited available water was initially rationed among the farmers within the District. This affected production and productivity and negatively impacted on income to the farmers.

The severe drought and lack of irrigation water impacted various agricultural produce and livestock. Consequently, the value added chain associated with agro processing, food processing and food security were impacted. For example, at one point the severity of the drought coupled with the unavailability of irrigation water led to consideration being given to significantly reduce the size of a beef cattle herd through its slaughter. The thinking was that without alleviation of the problem, there would be unsustainable pasture lands. Hence, the locally grown beef cattle would have to be substituted with imported beef. 80% of the feed for beef cattle is based on grass grown in the pastures.

In order to sustain agricultural production in the area and maintain the livelihoods of the farmers while avoiding social and economic dislocation in the area, the NIC had to expend significant capital to rehabilitate and re-commission the St. Toolis wells. The wells were inactive for the 12 year period during which there was flow of water from the spring.

Case 2: Reduced Aquifer Recharge: Spring Plain Well, Clarendon

The vulnerability of this project to the impacts of climate change was assessed through various consultations with the farmers and the senior management of the NIC, the Ministry of Agriculture & Fisheries, the Agricultural Competitiveness Programme (ACP) and senior management of the Water Resources Authority (WRA).

The Spring Plain Well is one of the water sources being equipped to provide irrigation water to farmers in the Spring Plain – Ebony Park Agro Parks, which are 645 hectares and 567 hectares respectively (1212 hectares in total). This project represents an investment of approximately JM$290 million for infrastructure plus the payment of additional duties of approximately JM$10 million. The agro-park is expected to provide employment for about 300 farmers.

Prior to commissioning of the well, there was at least one instance of the well "breaking suction" during installation tests. Further investigation determined that the loss of suction occurred because the hydrological regime had changed over the project implementation period because of the protracted drought. This resulted in the static water level declining from 27.95 meters below ground level (mbgl) in October 2013 to 30.48 mbgl in October 2015.

In order to adapt to the changes in the aquifer level the pump setting was lowered by 10ft (3.00m) and pump at the licensed rate (USGPM).

An artificial aquifer recharge programme is also at an advanced stage of implementation to recharge ground water resources.

3.6.5 Case 3: Cessation in the flow at Roselle Falls located in St. Thomas

The vulnerability of the Roselles Falls community to the impacts of climate change was assessed through consultations with the stakeholders at and around the vicinity of the falls. These included the users of the falls and the beach, fisherfolks and fish vendors as well as residents within the nearby communities. An investigation was also carried out on a peak holiday period in which the users of the falls and the beach would normally been at its maximum. In addition, a historical review was carried out and compared with the existing situation.

The flow of the Roselle Falls has been significantly reduced to a mere trickle. The major impacts are as follows:

1. The use of the beach was significantly reduced because the falls was no longer available for bathing after swimming in the sea.
2. There was loss of income by the vendors of food, beverage and craft items consequent on the reduced use of the beach.

3. The aesthetics of the location has changed significantly.

The market for sale of the fish catch of the fishermen has been reduced. This has negatively impacted on their income and livelihoods.

A photo story of the falls was developed in which archival information was retrieved from the Daily Gleaner.

These were compared with photographs taken at the site in recent times, (See Figure 2 to Figure 4 below Figure 3). This shows the significant contrast in stream flow between earlier years and the present time.

Figure 2: Roselle Falls in Full Flow (Source: Daily Gleaner, 2010)

Figure 3: Decreased Flow of Roselle Spring (Source: Daily Gleaner, 2015)

Figure 4: Reduced flow of Roselle Falls (Source: CD&A, 2016)

3.6.6 Policies, Plans, Programmes and Actions

The situation in Jamaica, which is in part, supported by the cases in this water sector resources, clearly indicates that various policies, plans, programmes and projects must be developed and implemented with great urgency in order to adapt and make the country resilient to climate change.

3.6.7 Recommendations for Policy Decision Making

Several initiatives have already been undertaken and projects are at various stages of implementation in the water resources sector. The following are included among them and should be continued with the objective of informing policy decision making and integrating/mainstreaming outcomes into the national planning process:

1. A water sector strategy has been developed and is being further upgraded.
2. Watershed Management projects are being implemented. Among them are the Hope, Yallahs and Rio Minho watershed projects.
3. A major artificial aquifer recharge project is now under construction in St. Catherine
4. Discussions are underway concerning the damning of the Bog Walk Gorge, through which the Rio Cobre River flows. The objective is to provide more water for health care, residential, agricultural, industrial and commercial uses, while continuing to service eco-systems functions.
5. Water harvesting has been accepted as an alternative water conservation and adaptation strategy. This must be aggressively pursued.
6. Various recommendations are being made to develop water harvesting policies for guiding the development of residential and agricultural projects. Consideration is being given to include water conservation and harvesting in Jamaica's Building Code.
7. Water infiltration for aquifer recharge and water storage are moving rapidly to become integral parts of development projects.
8. Consideration is being given to include major pipeline projects as integral components of highway projects. This is aimed at distributing water from the northern coast of the island to parts of the southern coast, particularly in St. Catherine, St. Andrew and Kingston (KMR), in which the water balance show that water availability is exceeded by demand. The KMR is extremely vulnerable to the impacts of drought. These impacts have proven to be severe in recent years and have affected agricultural production, livelihoods, productivity and sanitation & hygiene.
9. A national water loss reduction project has been undertaken by the National Irrigation Commission (NIC) and this is now being implemented with marked positive results. There is significant stakeholder participation in the programme, especially among farmers in the Agro Parks.
10. The NIC is also implementing training programme throughout various irrigation districts in Jamaica. These programmes have water conservation and best practices as critical components of the programmes. Included among them is the use of tensiometers to monitor soil moisture in order to provide information on the level of irrigation needed.
11. Renewable energy, solar and wind projects have been implemented at the pilot and research stage in an effort to reduce the cost of irrigation water to farmers and thereby boost agricultural activity and production.
12. Consideration has also been given to introducing desalination plants on the southern coast using renewable energy. Ocean Thermal Energy Conversion (OTEC) is included among the renewable energy sources under consideration.
13. Completion of the Essex Valley Irrigation Project, St. Elizabeth is now being accelerated. This would result in consistently providing irrigation water to this area, which forms a significant part of Jamaica's major agricultural production system.
14. Conveying irrigation water in pipelines rather than in open canals is being evaluated for implementation. Using open canals for the conveyance of water is subject to evapo-transpiration and hence greater water loss. Evapo-transpiration will increase with increasing temperatures.
15. Rehabilitation and re-commissioning of decommissioned water storage and distribution facilities in the most vulnerable agricultural production districts such as Bluntas in St. Elizabeth has been carried out and significantly alleviated the water deficit caused by the protracted drought. This has resulted in the protection of the livelihoods of several farmers.
16. Modification of infrastructure such as ramps and additional pumping capacity to increase the volume and rate of delivery of water to drought stricken areas in St. Elizabeth has been done. This should be extended to other Irrigation Districts.
17. Rehabilitation and retrofitting of facilities, which have been placed at risk has also been carried out.
18. Extraction of water from the Black River in St. Elizabeth using solar energy is also under consideration.
19. Rehabilitation and retrofitting of the St. Toolis wells and irrigation systems have been done.

20. It is essential that a Water Supply Plan to complement the Water Resources Master Plan be developed with urgency.
21. Spatial planning using cutting edge, state-of-the-art technology would allow for more accurate determination of water demand and ensure this is met from available resources
22. Project development for the utilisation of treated wastewater for irrigation and industrial purposes is being pursued. Treated effiuent from all waste water treatment plant for agricultural and industrial purposes from the Bogue treatment system to the JPSCo power plant is under consideration.

3.7 TOURISM SECTOR

3.7.1 INTRODUCTION

Tourism is one of the most important sectors of the Jamaican economy. It provides much needed foreign revenue and is linked to many coastal livelihood activities such as fisheries, agriculture, and cultural preservation. In 2014, the Jamaica tourism sector attracted 3.5 million visitors and generated foreign exchange earnings of more than US$2.2 billion (MTE, 2014). Natural disasters and human-induced climate change impacts have been disastrous in the past few decades with loss and damage in billions of dollars. The proximity of the hotel industry and recreational infrastructure by the shoreline also poses a high level of vulnerability to beach erosion, storm surge and SLR. The cumulative impacts of 11 storm events, five hurricanes, and several flooding events from 2001 to 2012 resulted in loss and damage close to $129 billion USD. Historical and current trends in climate variability, change and extremes have already resulted in significant biophysical and socioeconomic impacts to coastal communities and livelihoods in Jamaica.

Detailed climate modelling projections for Jamaica predict:

- Increase in average atmospheric temperature
- Decrease in average annual rainfall
- Increased Sea Surface Temperatures (SST)
- Potential for increased intensity of tropical storms and storm surge
- Increases in regional sea-level rise commensurate with global average sea-level rise
- Increasing storm surges and beach erosion threats from SLR

TABLE 1: Sensitivities of Tourism to Climate Impacts

Climate Drivers: sea-level rise, storm surge, beach erosion, hurricanes, and storms, weather variability	
Physical Impacts	Socioeconomic Impacts
Damage to and destruction of tourism infrastructure and facilities located in coastal areas susceptible to storm surges, beach erosion and sea-level rise.	Warmer temperatures will lead to altered seasonality (i.e. shorter peak seasons), heat stress for Jamaicans and tourists and higher cooling costs for tourism operators.
Extensive coastal erosion caused by sea-level rise, storm surges, and hurricanes, resulting in the loss of beach areas.	Loss of archaeological, cultural and heritage attraction sites due to sea-level rise, flooding and hurricanes.
Warmer temperatures will affect natural systems and species, i.e. changes in phenology patterns and distribution ranges for plants, wildlife and insect populations, and the spatial distribution of infectious diseases.	Increased cost to protect coastline through the implementation and maintenance of beach stabilisation and sea defence systems.
Increased coral bleaching and degradation of marine resources due to increases in sea surface temperature.	Increases in insurance costs, or loss of insurability, and business interruption costs caused by increasing frequency and intensity of extreme storm events.
Changes in and loss of terrestrial and marine biodiversity.	Loss of tourism income due to the possible changes in, or loss of coral reefs, beaches, wetlands and other natural resources and attractions.
Acidification of the oceans.	Reduced visitor arrivals as a result of a higher frequency of extreme weather events (e.g. hurricanes), as well as reduced preference for sun and sand holidays as a result of higher temperatures.

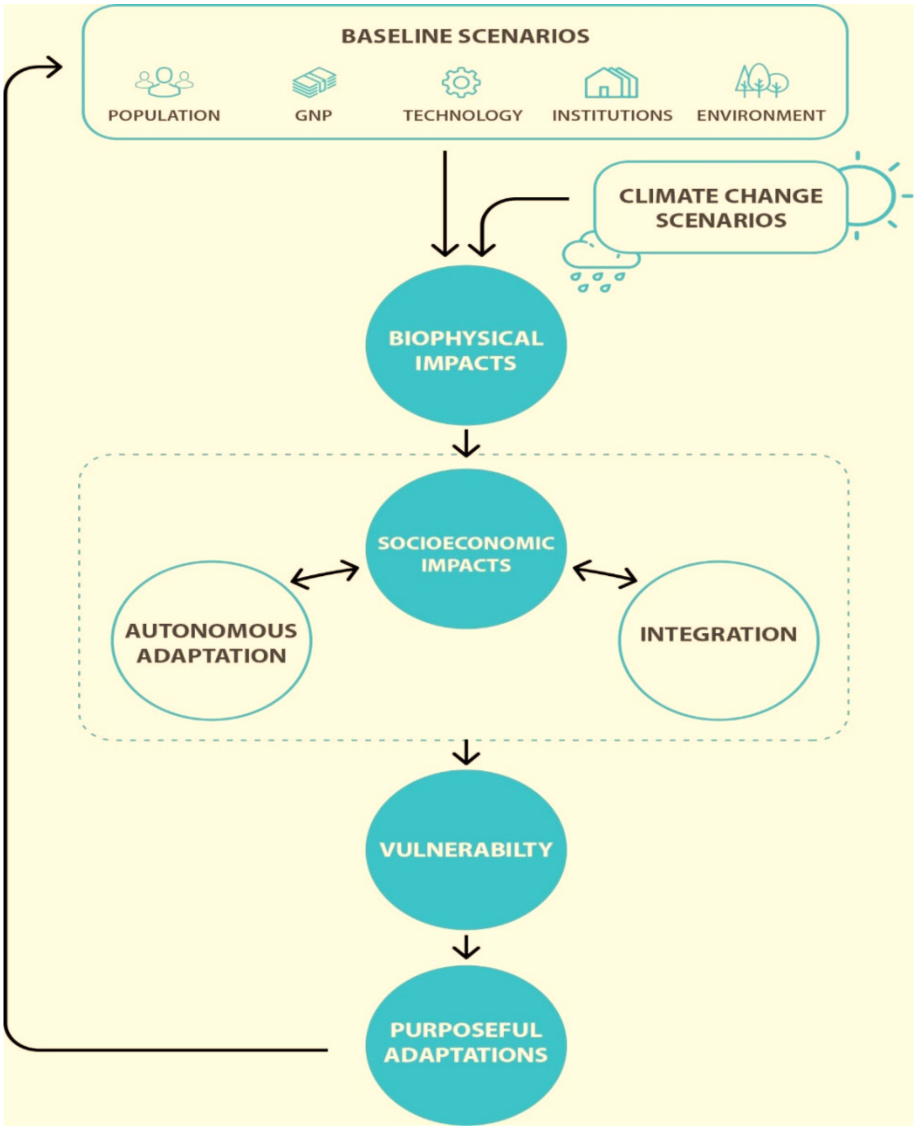
Source: (MWLECC, 2013)

In this report, case studies from two of Jamaica's most important tourism destinations are used to highlight vulnerability and adaptations challenges facing the sector.

3.7.2 METHODOLOGICAL FRAMEWORK

The methodological approach employed to understand climate change impacts and adaptation in the tourism sector befits the vulnerability and assessment (V&A) framework. The V&A framework employs multiple tools and interdisciplinary data collection techniques focusing on both top-down assessments as well as local adaptation needs (Figure 1) and underpins the Community-Based Vulnerability Assessment (CBVA) approach used here. The CBVA framework provides a conceptual and methodological tool for actively engaging community and institutional stakeholders in participatory vulnerability and adaptation-oriented assessment approaches at the local level (Smit & Wandel, 2006). This involves conducting semi-structured interviews with community stakeholders to understand existing exposures, sensitivities and adaptive capacities and strategies. The situated experiences and specialised knowledge that local communities and stakeholders have is particularly valuable to assessing nuanced and context-specific relationships and processes.

FIGURE 1: Modified V&A analytical framework with the top down and local adaptation focused assessments (PROVIA, 2013).



The core objectives of the CBVA framework are to i) determine current exposure sensitivities experienced by local stakeholders and their current adaptive capacity, and ii) determine anticipated exposure sensitivities by local stakeholders, and their capacity to adapt to future changes and risks. The CBVA uses a complex systems approach to analyse climate change vulnerability in a more comprehensive way. Therefore, the information collected is not exclusive of climatic stresses, but also looks at existing social, economic and governance challenges experienced at the community level.

The case study on Negril presents the results of both a detailed community-based vulnerability assessment (CBVA) and a review of secondary sources that analyse community perceptions and experiences of the multiple vulnerability and adaptation challenges affecting tourism in Negril. The assessment incorporates local knowledge, livelihood strategies and adaptive capacities to identify where adaptation interventions may be needed to reduce vulnerability and strengthen resilience at the community level. Community members working in tourism include hotel managers and employees, craft vendors, fisher people, and fish vendors. The CBVA team conducted a total number of 137 community-based interviews involving fishing (26%) and tourism (74%) sectors, and 17 governance interviews with relevant agencies and governance bodies.

The case study on the Greater Treasure Beach Area presents the results of both a detailed community-based vulnerability assessment (CBVA) and a review of secondary sources that analyse community perceptions and experiences of the multiple vulnerability and adaptation challenges affecting tourism in the GTBA. The assessment incorporates local perceptions of change and an analysis of adaptive capacity to identify where adaptation interventions may be needed to reduce vulnerability and strengthen resilience at the community level. The research team surveyed 36 tourism MSMEs in the GTBA to determine their vulnerability to environmental, climatic and socioeconomic stresses. Hotel owners and managers, craft vendors, tour operators and restaurant/bar managers were the main focus of the survey.

3.7.3 CASE STUDY 1: VULNERABILITY AND ADAPTATION IN NEGRIL

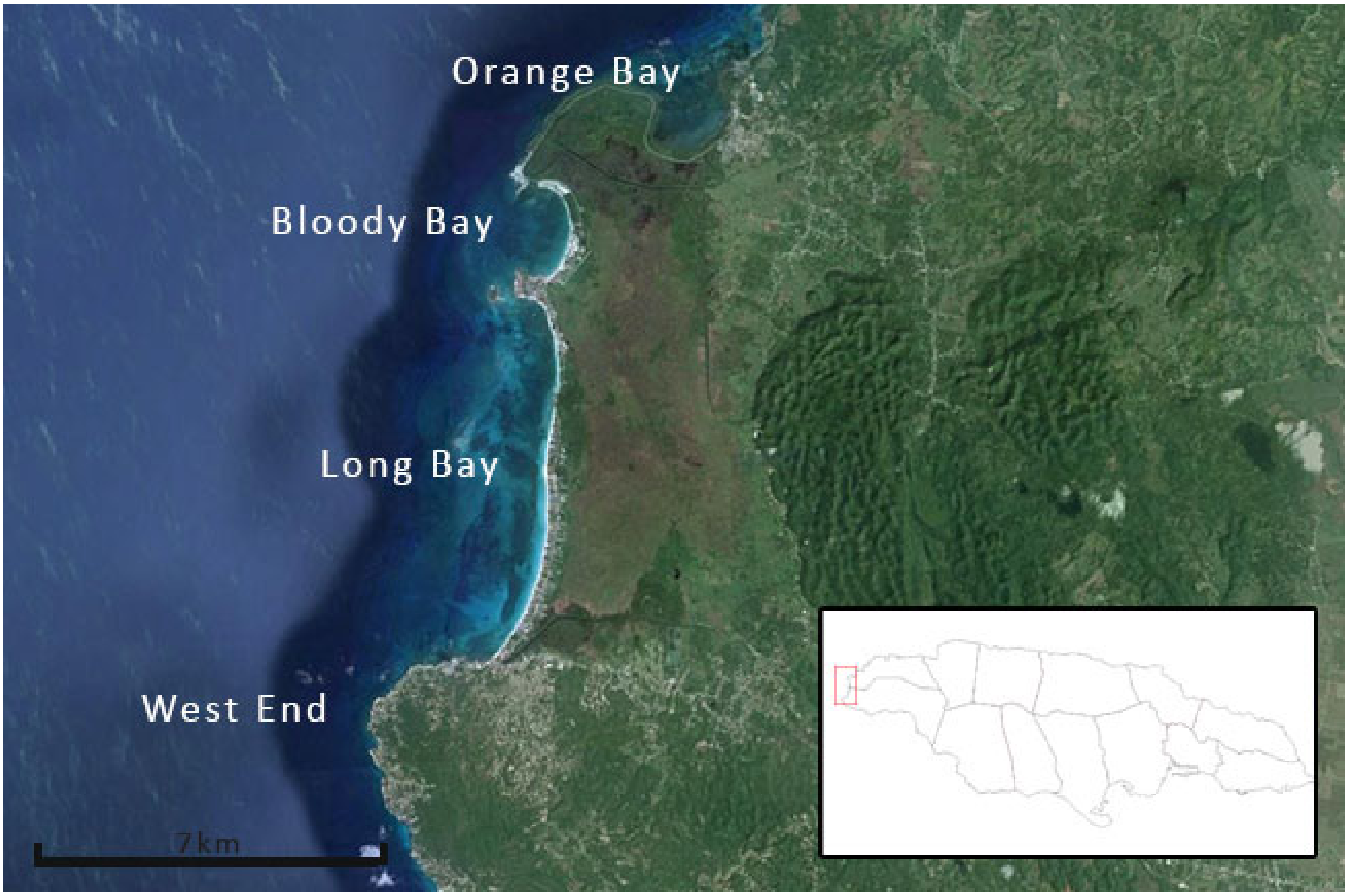
3.7.3.1 Vulnerability Context

Climate change poses a wide range of risks to the productivity and sustainability of tourism-based livelihoods in Negril, including impacts related to environmental and socioeconomic changes and extreme climate events. The resort area is situated at the western tip of the island of Jamaica and includes four geographically separated communities: West End, Long Bay, Bloody Bay and Orange Bay (Figure 2). The study site is 22km in length and falls into both Westmoreland and Hanover parishes. There are approximately 7,832 residents in the Negril area which is a 15 per cent increase in population from the 2001 census (STATIN, 2011). The four coastal communities are mainly dependent on tourism for income and, as such, have seasonally fluctuating incomes.

Negril's society is deeply connected with the changing ecology and climate of the island, and the development of livelihoods and cultural traditions reflect the adaptations to ongoing environmental change. Historically, ecosystems and populations were often resilient enough to adapt to and recover from gradual changes in weather conditions and natural variability. Strategies for reducing exposure and vulnerability to climate hazards such as tropical storms, extreme temperatures, flood events, erosion, and drought have shaped environmental and human health, livelihoods, settlement patterns, economies and cultures on the island.

Negril's coastal ecosystems (coral reefs, seagrass meadows, beaches, wetlands/peatlands and mangroves) provide important services that support tourism, economic development, local livelihoods and hazard mitigation. In particular, when these ecosystems are healthy, integral and functioning, they provide protective (i.e. reduce the risk of disasters) services to coastal areas such as natural buffers that dissipate wave surge, flood abatement, slope stabilisation and coastal protection against storm surge.

FIGURE 2: The four coastal communities of Negril include West End (cliffs), Long Bay (beach), Bloody Bay (beach) and Orange Bay (beach)



3.7.3.2 Key Findings

Participants in the CBVA identified beach erosion, hurricanes (and tropical storms), storm surges, and heat stress as the most critical climate-related hazards to the sector in recent times. Due to the complex nature of the tourism sector's vulnerability to climate-related risks and impacts, there are a variety of sensitivities that are experienced by coastal ecosystems, communities and visitors to Negril.

- Beach erosion is one of the most serious concerns of tourism stakeholders in Negril. Studies show that over a 40-year period, the beach at Long Bay has undergone a cyclic pattern of severe erosion and slow accretion whereby many locations along the beach have eroded approximately 40 meters and in others, the beach has gained over 10 meters (Robinson, Khan, Coutou, & Johnson, 2012).
- Coastal erosion and beach loss in Negril is attributed not only to accelerating SLR and storm surge but also to the dramatic decline of Jamaica's coral reefs over the past 30 years. Beach erosion, especially along Long Bay, has increased the negative impacts felt by storm surges over the years.
- Sea surface temperatures (SST) in Negril have increased 0.07°C per decade between the period of 1960 and 2006. GCM projections indicate further increases of between 0.9°C and 2.7°C by the 2080s (Simpson, et al., 2012).
- Tropical storms are also associated with dramatic coastal erosion and severe flooding events as seen in table 3 below. The cost to restore beach in Long Bay and Bloody Bay after Hurricane Ivan (2004) was estimated to be JMD$600 million.
- From a geological perspective, Negril could be modified by isostatic/ tectonic movements as the Long Bay beach and Great Morass areas are situated on a recently down-faulted block (Robinson, Khan, Coutou, & Johnson, 2012). When sea-level rise data is combined with rates of beach erosion at Long Bay, an average of 42 meters of shoreline recession is expected by 2100 (Robinson, Khan, Coutou, & Johnson, 2012). Thus, in the long-term, beach erosion, and sea-level rise are projected to have a very large impact on Negril.
- It is predicted that sea-level rise by 2100 would increase the height of storm surge during a 10-yr return event from approximately 0.880m to 1.25m – a 42 per cent increase in Negril. Similarly, it is predicted that sea-level rise by 2100 would increase the height of storm surge during a 100-yr return event from approximately 1.27m to 1.64m – a 29 per cent increase (table 4).

FIGURE 3: Historical shoreline for a section of Long Bay, Negril 1968-2013 (ODPEM, 2015).

TABLE 2: Maximum and minimum losses under several scenarios of sea-level rise and a combination of causes (ASLR, storm surge and tidal effects). The minimum and maximum beach losses correspond to the minimum and maximum retreats predicted above. The beach sections refer to the 74 beach profiles used in the SWI (SWI, Preliminary engineering report. Beach restoration works at Negril, 2007) study (UNEP, 2010)		
Scenario	Minimum losses	Maximum losses
0.52m above MSL + Tidal effects +Lowest predicted MSL rise in 2060	7 sections lose >50% of original width	63 sections lose >50% of original width + 26 sections lose 100%
1.05m above MSL + tidal effects + highest predicted MSL rise in 2060	31 sections to lose >50% of original width + 4 sections to lose 100%	All (74) sections to lose 50% of original width + 53 sections entirely lose
0.65m above MSL + tidal effects + lowest predicted ASLR rise in 2020 and coastal storm surge 0.3m	9 sections to lose >50% of original width	67 sections to lose>50% of original width + 33 sections lose 100%
0.75m above MSL, tidal effects + highest predicted ASLR rise in 2020 and coastal storm surge 0.3m-10year return storm	14 sections to lose >50% of their original width + 1 section to lose 100%	71 sections to lose >50% of original width + 36 sections to lose 100%
2.02m above MSL + tidal effects + lowest predicted ASLR rise in 2060 + coastal storm surge of 1.5m- 50 year return storm	64 sections to lose ?50% of original width + 27 sections to lose 100%	All (74) sections to lose 100%
2.55m above MSL + tidal effects + highest predicted ASLR rise in 2060 + coastal storm surge of 1.5m	69 sections to lose >50% of original width + 36 sections to lose 100%	All (74) sections to lose 100%

TABLE 3: Impact of tropical storm events in Negril

Major Events	Impact on Negril
Hurricane Gilbert, 1988	West End - light poles, electrical wires, buildings and popular tourist venues such as Rick's Café sustained damage. Destruction of vegetation and limestone forest. Tensing Pen Hotel lost almost all its trees. Houses of seven families were destroyed. Negril Primary School lost its entire roof.
Flood, 1990	Flood rains caused millions of dollars in damage to roads, houses, and other properties. Blocked drains caused water to accumulate. Floods were so high that it negatively affected entertainment events in Negril.
Flood, 1997	Rains caused damage to pipelines. Heavy water flows dislodged lateral sewer line across Sheffield Road from its 2m depth.
Hurricane Mitch, 1998	West End and Long Bay Beach was affected by storm surge. The height of the storm surge was between 13-17m. Loss of coral reef and reef-dwelling organisms, beach migration (10m^3 of sand) & damage to shoreline structures, JMD$6.2m in damage to hotels.
Hurricane Michelle, 2001	1. Beach eroded 14m 2. Beach accreted 14m
Tropical Storm Isidore, 2002	Caused major flooding in Negril leading to flood waters creating deep trenches across both major and minor roadways.
Hurricane Ivan, 2004	1. Average beach erosion of 16m 2. Average beach accretion of 12m Net change: Loss of 4m of beach West End damage to several hotels and attractions. Complete destruction of facilities in Mariner's Inn and Rick's Café by waves. 318mm of rainfall in was recorded in Negril point. Several large trees were uprooted in several sections of the town, down power lines was also observed in several sections as well.
Hurricane Wilma, 2005	1. Average beach erosion of 19m 2. Average beach accretion of 18m Net change: Loss of 1m Large mats of seagrass beds were uprooted.
Hurricane Dean, 2007	1. Average beach erosion of 11m 2. Average beach accretion not available
Tropical Storm Nicole, 2010	Negril hit by storm surge and brutal waves. Surges reaching up to 30ft high were recorded in West End accompanied by crashing waves. Many businesses and resorts suffered damage by wind and storm surge.

Source: ODPEM (2015)

TABLE 4: Predicted storm surge heights for Negril under a variety of scenarios.

Return Period	Storm surge predictions (m) (current)	Storm surge height predictions with SLR (m)						
		2024[1]	2025[2]	2039[1]	2050[2]	2064[1]	2100[2]	2114[1]
10	0.880[1,2]	0.917	0.98	0.973	1.07	1.065	1.25	1.25
25	1.046[1,2]	1.083	1.14	1.139	1.23	1.231	1.42	1.416
50	1.153[2]-1.159[1]	1.196	1.25	1.252	1.34	1.344	1.53	1.529
100	1.270[1,2]	1.307	1.36	1.363	1.46	1.455	1.64	1.64

[1] (CEAC, 2014) - SLR value of 0.185m used (based on the IPCC sea-level rise projection of 3.7 mm per year for the 2000 to 2100 period

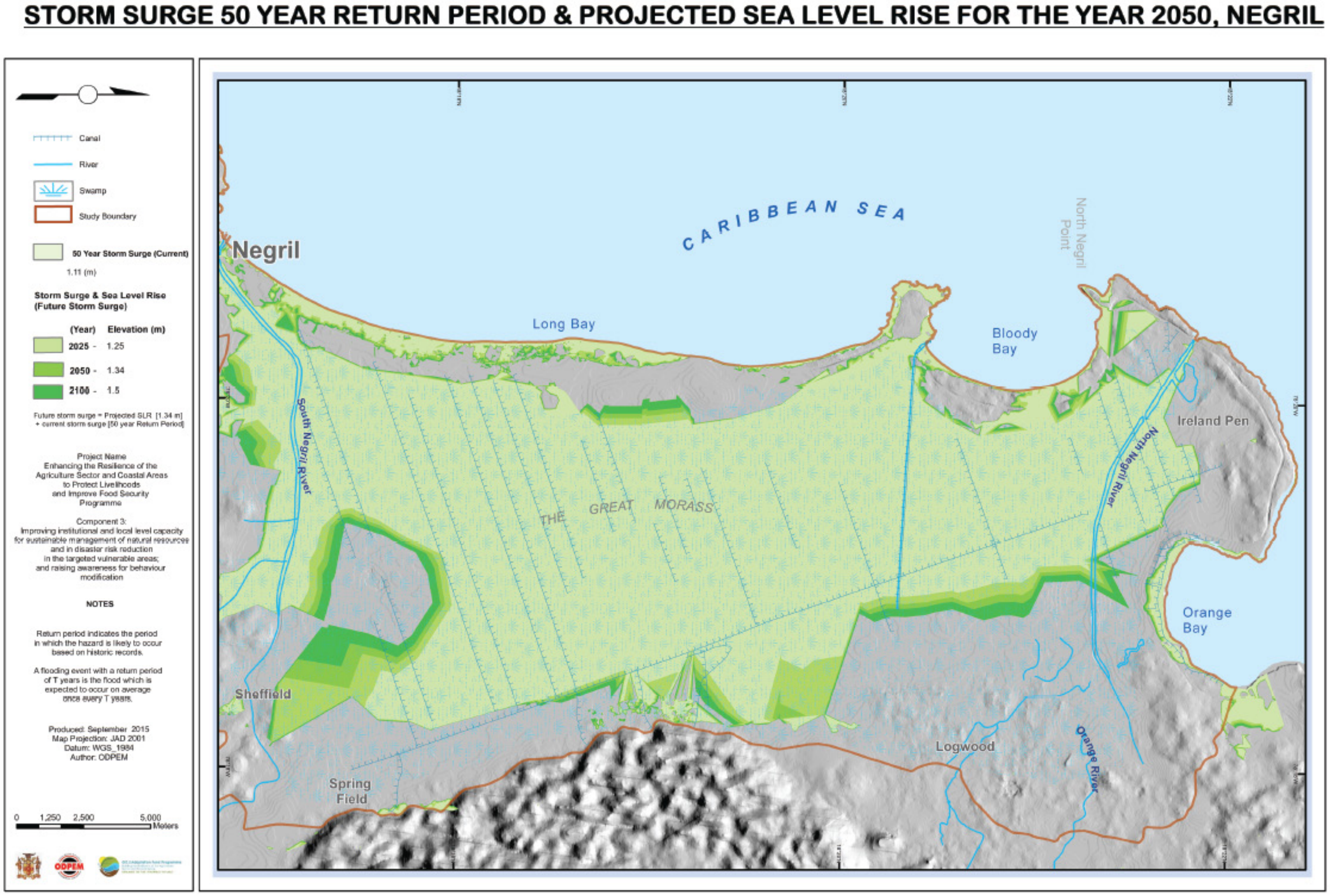
[2] (ODPEM, 2015) - The SLR values for 2025 and 2050 were calculated using IPCC's average rate of sea-level rise per year of 0.0037m/yr and for 2100 IPCC's projection for average SLR of 0.37m

- Using more relatable indicators, a 50-year storm event (with a projected surge of 1.5m, in year 2100) could cause flooding past the shoreline and into the Great Morass and New Savannah River areas, and has the potential to impact 2,500 persons (through storm surge and subsequent flooding), mainly along Long Bay coastline and the Great Morass environment (SWI, Preliminary engineering report. Beach restoration works at Negril, 2007)
- Higher temperatures and exposure to heat stress will affect multiple aspects of Negril's tourism sector, as the island's idyllic temperature is cited as a main attraction for tourists. However, with projected increases in maximum hot days during existing peak tourism seasons, visitors have the capacity to shift travel times or change destinations to options that are more comfortable.

TABLE 5: Exposure to flooding Negril for 10- and 50-yr return periods. Exposure was calculated for residing populations as tourist fluctuations were unable to be accounted for (UNEP, 2010).

	10-year return period storm	50-year return period storm
Assets	2 hotels (cliff) 1 market (beach) 1 NWC priority facility (beach) 2 wastewater facilities (cliff) 1 well (beach)	63 hotels (61 beaches, two cliffs) 1 market (beach) 2 NWC priority facilities (beach) 8 wastewater facilities (6 beaches, 2 cliffs) 9 wells (beach) 1 emergency shelter (cliff) 3 health centres (beach) 1 public school (cliff) 3 tourist facilities (beach) 1 licj airport (beach)
Population	478 (102 on beach, 376 on cliff)	2,487 (2,016 on beach, 471 on cliff)

FIGURE 4: Exposure to flooding Negril for 10- and 50-yr return periods



3.7.3.3 Proposed Adaptation Strategies

- Promote Ecosystem-based Adaptation strategies. Protecting coastal ecosystems such as mangroves and coral reefs from further degradation, and implementing restoration activities to improve the conditions of tourism-dependent ecosystem services.
- Diversify and expand local tourism product in Negril. In light of projections for an accelerated rate of beach erosion and the marine ecosystem services in general, it would be useful to develop and promote natural and cultural assets such as the cliffs, Great Morass, waterfalls, creative arts, and historical sites.
- Foster collaboration and effective communication with local tourism stakeholders. The introduction of adaptation solutions should benefit from co-design and co-implementation processes involving all relevant tourism stakeholders. This would enhance community cohesion and facilitate a greater sense of ownership for community-based adaptation initiatives.
- Improve governance of regulatory issues such as operating the recycling plant and enforcing MPA zoning. This should be accompanied by measures to promote compliance with and effective enforcement of existing regulations for environmental protection.
- Strengthen the adaptive capacity of local tourism and community organisations to facilitate adaptation initiatives (i.e. development of EMPs, record keeping of businesses and fish catches). Many communities have probably developed their traditional strategies to adapt to changes, hazards or disasters.
- Standardised beach stabilisation efforts through the planting of living shoreline structures such as deep-rooted native vegetation (e.g. coconut palm, sea grape, seashore dropseed, and panic grass) could reduce the rate of beach erosion along Seven Mile Beach.
- Support energy efficiency and conservation particularly among tourism MSMEs. This is a win-win that would help to reduce the carbon footprint of Negril's tourism while reducing operating costs and strengthening climate resilience.

- Improve the communication of climate change risk among tourism stakeholders in the industry. This could include information on climate change projections, good practices, cost-benefits of interventions, opportunities, and incentives.
- Improve the monitoring of climate change adaptation initiatives in the tourism sector to safeguard the success of local initiatives.

3.7.4 CASE STUDY 2: VULNERABILITY AND ADAPTATION IN GREATER TREASURE BEACH AREA

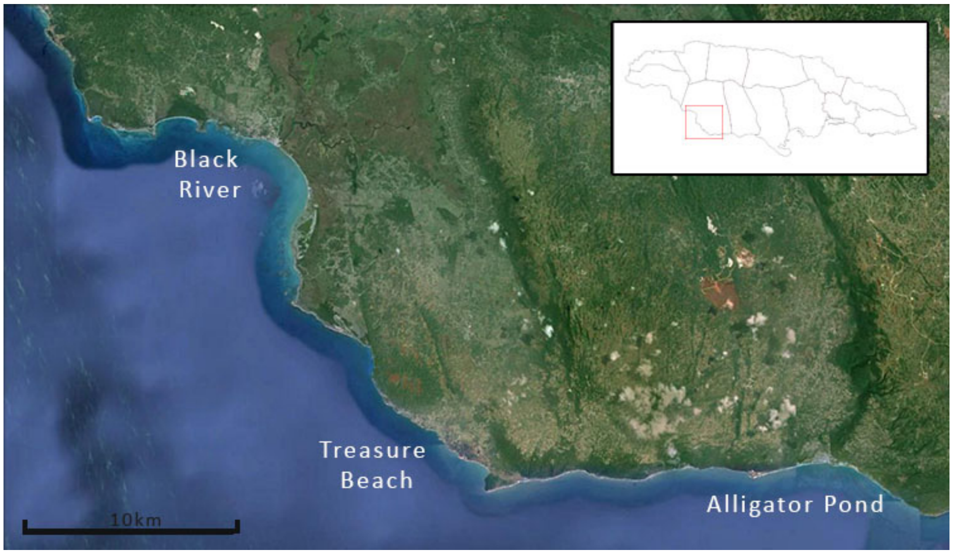
3.7.4.1 Vulnerability Context

The Greater Treasure Beach Area (GTBA) is a diverse ecological area comprised of coastal, wetland and grassland areas. It also has deep historical significance and cultural heritage, and an economy based on tourism, agriculture and fishing livelihoods. The GTBA's cultural and natural capital has made it a key driver in tourism development along the south coast of Jamaica. While the coastline is central to area's community-based tourism, GTBA's topography provides a very different option for tourists than the conventional sun, sea and sand focus. The varied coastline of limestone cliffs, caves, narrow beaches and a natural harbour; Lower Morass wetland; and historical attractions are the settings for GTBA's unique ecotourism, sports tourism, and cultural tourism products.

The environment within the GTBA is, however, becoming increasingly vulnerable to the impacts of changes to environmental and climate systems, as well as improperly planned and managed structural developments that may result in significant damage to fragile coastal and wetland ecosystems (GTBSDP, 2013). The exposure of climate-sensitive local livelihoods and coastal and wetland systems to storm surge, hurricanes, earthquakes, floods, coastal erosion, variable weather, and drought pose complex challenges for tourism, agriculture, and fisheries. Alongside ongoing environmental and development challenges, the impacts of climate change and natural hazards threaten the productivity and sustainability of tourism-based livelihoods in the GTBA.

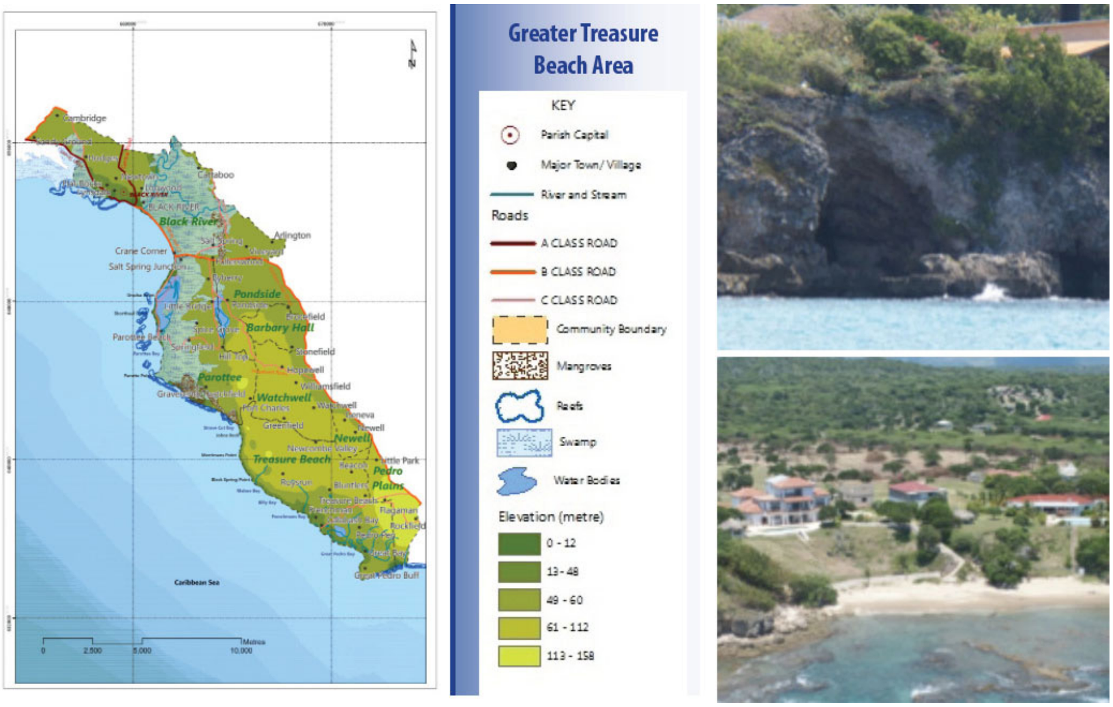
Tourism in the GTBA can be characterised as place-based and community oriented, developed through small and medium-sized enterprises in modest style accommodation and complemented by nature and heritage tours, and local food and beverage in small restaurants and bars. The sector departs from the iconic features such as beach and sea and relies more on ecological and cultural attributes. Eco-tourism and heritage tourism is most prominent in the community of Black River, where the town's rich history and unique natural environment allow for the development and marketing of a tourism product that is tailored to these particular geographical features. Current eco-tours explore the coastal, wetland and mangrove ecosystems, and allow visitors to interact with crocodiles and other rare and endemic species in their natural habitats.

FIGURE 5: The Greater Treasure Beach Area spans (mainly) coastal areas along the south coast of Jamaica comprising of eight communities - with Black River and Treasure Beach being the largest ones.



Tourism in the GTBA is heavily reliant on a coastal environment that is particularly under threat from both climate stress, and the unregulated building development occurring on the coast of Treasure Beach. The lack of development control has led to some coastal properties being located too close to the high water mark and therefore vulnerable to storm surges and coastal erosion (GTBSDP, 2013). Hence, future tourism development plans have been identified by the GTBA Sustainable Development Plan for more careful assessment by the local land use and planning agency regarding restrictions on setback limits, size, setting and design.

FIGURE 6: The GTBA region showing diverse landscape and coastal features (modified from SEPCC et al. 2013).



3.7.4.2 Key Findings

The CBVA focuses on the nature of exposure - sensitivity and adaptive capacity of local communities and livelihoods in the GBTA communities of Alligator Pond, Treasure Beach, and Black River on Jamaica's south coast. These communities are dependent on climate-sensitive sectors coastal and wetland systems (i.e. beaches, coral reefs, rivers and ponds), and ecosystem services. In particular, assessment participants identified the following climate-related events as overarching threats to their tourism businesses:

- Increased magnitude and frequency of hurricanes (75%)
- Increased level of sea rise (47%) and intensity of storm surge events (22%)
- Increased frequency of droughts (42%)
- Increased beach erosion (39%)
- Increased frequency of flooding events (25%)

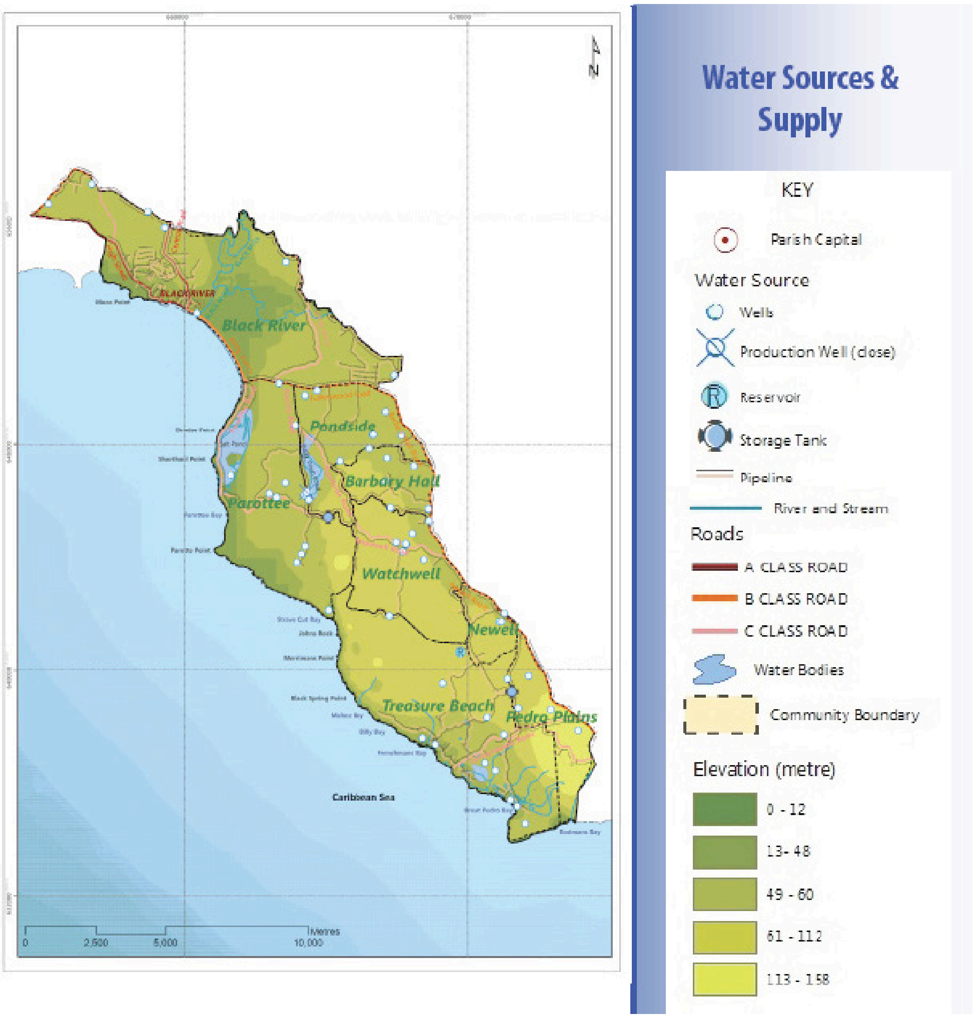
Storm surges are one of the greatest threats to the low-lying coastal areas within the GTBA, with some areas such as Crane Road in Black River being shown to be under serious threat (SWI, 2011). Many of the coastal properties (e.g. High Street) are unprotected from storm surges and high waves and have suffered historical damage from loose debris during storm events. Some sections are being further threatened by a weakening of infrastructure from wave action.

Flooding is particularly prevalent in low-lying areas that are close to watersheds such as the Black River or the Great Pond and smaller pond. Inadequate water infrastructure constrains the GTBA, saltwater intrusion in coastal aquifers, prolonged dry periods and variable levels of rainfall (SEPCC, Council, Institute, & Trust, 2013). The frequency and duration of rainfall have also been an issue in recent times. The GTBA receives approximate 200 to 400mm of rainfall/year with seasonal droughts and episodic floods.

PLATE 1 & 2: Treasure Beach's Great Pond, which was reduced to a dust bowl during the drought of early 2013 (SEPCC, Council, Institute, & Trust, 2013).

Typically, 'drought conditions' in the GTBA start between January and March and continue through summer until September. This period overlaps with the traditional 'peak' tourist season in Jamaica (which runs from December to April). This irregular supply of potable water to the area has forced communities to choose independent methods of purchasing and storing and water thereby increasing their expenses.

FIGURE 7: Alternative water sources and supplies in the GBTA during drought (SEPCC et al. 2013)



Flooding, arising from either coastal or riverine activities is considered to be a serious threat particularly around Black River, Parottee, and Treasure Beach. Flooding is prevalent in low-lying areas that are close to watersheds such as the Black River or the Great Pond and smaller pond. Intense rainfall, especially from Hurricane's Ivan in 2004 and Hurricane Dean in 2007 led to an overflow to the watershed banks which impacted nearby communities.

About three-quarters of participants from the CBVA experienced adverse climate-related impacts to their tourism ventures over the past decade. Instances of impacts range from damage to buildings to sea-level rise, flooding, and beach erosion, loss of customers, a decline of shoreline and coral reefs, drought-induced local food shortages, and effects on water quality. Seventy-five per cent of the respondents confirmed between 1 and 3 occurrences of damage to their tourism properties by climate impacts, and 47% reported between 1 and 3 occurrences of damage to or losses of physical assets. At times, climate-related threats were reported to have been severe enough to affect tourism revenues and livelihood security negatively.

The impact of storms and hurricanes also affect tourism flow and disrupts holiday vacations. Stakeholders are concerned about how their businesses are negatively affected by climate-related vacation interruptions such as airport closures, flight cancellations, and road closures. In particular, the majority of tourism operators stated that the frequent and continuous impact of these interruptions led to the closure of their businesses and loss of customers and revenue.

According to participants of the CBVA study, the main features of the GTBA that attract tourists are cultural experiences and food (50%); beach and ocean views (33%); tours and attractions (28%). The study reports that 39% of tourism stakeholders have more than 300 customers annually, and 58% reported having between 51 and 300 customers annually.

TABLE 2: List of cultural assets in the GTBA and overall status

Types of Cultural Assets	Asset Class	Site Location	No of Sites	Site Condition
Heritage buildings (19th-century sites)	Protected National heritage district	Black River	Over 50	Ranges from good to poor
Taino Artefacts	Caves, Wells, middens (pottery shards)	Treasure Beach – Great Pedro Bluff and Fort Charles, Black River Hospital	6	Under threat Hospital occupies site, the development of Black River Spa destroyed the site
Marine Archaeological Heritage		Port of Black River Treasure Beach		Under threat
Natural sites		Black River Spa	1	Under threat
Spanish Sites		Wallywash Pond Parottee		Destroyed

From the CBVA study, more than half (58%) of the tourism stakeholders said that the sea and beach are features of the services they provide. Other ecosystems that are important natural assets for stakeholders include agricultural lands (42%), coral reefs (17%), mangroves (17%) and watershed areas such as the Black River (14%). With respect to observed changes to these ecosystems since the participants had started their tourism operations, 53% of stakeholders perceived changes to the beach and coastal environment. Other notable changes to natural assets had been observed by stakeholders with regard to agricultural lands (39%), coral reefs (17%) and mangroves (11%).

The GBTA communities are highly reputed for their community spirit and social networks among residents, family and friends, and community-based organisations. Strong social cohesion and reciprocal relationships indicate a higher level of adaptive capacity among local stakeholders and the potential to reduce climate vulnerability at individual, household and community levels.

The GBTA vulnerability study showed that the vast majority of participants (92%) had a general level of knowledge about climate change and its implications for their tourism operations. 47% of participants described climate phenomena as changes in weather patterns relating to temperature, rainfall, and wind.

At a business level, 33% of the participants responded that they collaborate with other tourism-related businesses and groups such as the Treasure Beach Cluster, as compared to 67% who function independently. The Cluster strategy enables community stakeholders and businesses to develop tourism potential in the GTBA through improved marketing, employment and income-earning opportunities, diversification of services, access to specialised labour markets and suppliers, knowledge-sharing, training and learning opportunities, and access to funding.

3.7.4.3 Proposed Adaptation Strategies

Integrated capacity building and adaptation responses to these multiple and overlapping challenges have ranged from enhanced public awareness and education to stringent land use and coastal development policies, to the stabilisation of beaches and restoration of mangroves and coral reefs. The move towards ecologically and culturally-focused tourism have the potential to balance sustainable public use of fragile ecosystems by visitors and locals alike, with a commitment to protecting these natural systems.

TABLE 6: Adaptation options proposed by community stakeholders in the GBTA

Proposed Adaptation		Percentage response
Building Capacity	Business insurance (53%)	
	Strengthen national research (36%)	
Ecological Protection and restoration	Promote reforestation (33%)	
	Restore mangroves or coral reefs (25%)	
	Rainwater harvesting or irrigation (25%)	
Awareness and Education	Increase public awareness (89%)	
Energy Efficiency	Promote energy efficiency (86%)	
	Develop alternative sources of energy (47%)	
Land Use and Planning	Discourage construction in coastal zones (17%)	
Infrastructural Development	Upgrade tourism business infrastructure (69%)	
	Construct seawalls (31%)	

Other strategies are focused on emergency preparedness, and disaster management necessary for tourism businesses to be prepared for and able to adapt to climate-related threats. Of the CBVA survey participants, 25% responded that they had a disaster management plan; whereas 75% said that they did not have a plan in place. Forty-four of participants proposed development or enhancement of a disaster preparedness plan a key adaptation strategy. Many participants (14%) also chose relocation from vulnerable settlements as an important adaptation consideration. Specific strategies include:

- **Develop an early warning system** to alert the public of suddenly emerging threats in heavily populated tourist areas.
- **Improve water supply** through initiatives such as rebates, placing tariffs on water distributed to other parishes, water recycling, and conservation strategies, etc.
- **Enhance community cohesion** through actively organising and promoting community events; fostering collaboration and effective communication.
- **Diversifying the local tourism product** in the GTBA includes development of heritage tourism and the incorporation of agricultural activities such as farm tours.
- **Strengthen community partnerships to reduce vulnerability**. Increase collaborative working with local community organisations, build management and administrative capacity within these groups as well as improve their ability to work on climate change issues.
- **Strengthen the adaptive capacity of local tourism and community organisations** to facilitate adaptation initiatives (i.e. development of EMPs, record keeping of businesses and fish catches). Many communities have developed traditional strategies to adapt to changes, hazards or disasters.
- **Improve climate-friendly infrastructure**. Guide strategic new developments that protect against impacts such as flooding, erosion, storms, water shortages and subsidence by improved location or building designs such as sustainable drainage, or increased flood storage capacities.
- **Invest in Ecosystem-based Adaptation methods.** Protecting coastal ecosystems such as mangroves and coral reefs from further degradation, and implementing restoration activities can help to improve the ecosystem services that are provided by each including coastal stabilisation, protection from events, and provision of livelihoods.
- **Improve tourism product currently available**. This includes investing in making local food production more adequate or reliable enough to supply hotels, or improving craft industry through reduced flow of imported products or increased skill and value of local ones.
- **Reduce anthropogenic threats** that exacerbate impacts of climate change. Activities could include reducing solid waste through public recycling facilities, implementing beach or sand removal regulations, or promoting conservation of energy and water by tourists.

3.8 COASTAL RESOURCES

3.8.1 Background & Introduction

3.8.1.1Background

Jamaica's coastal resources including human settlements were developed using the improved methodologies and tools for conducting Vulnerability and Adaptation Assessments for Jamaica's Coastal Resources Sector including human settlements. Using advanced vulnerability assessment (VA) tools, among a suite of other approaches and methodologies, the context and perspective of the present and potential impact of climate change on Jamaica's coastline in general with special reference to its southern coast has been carried out.

It represents the assessment for the Coastal Resources by focusing on three (3) cases (locations) that have integrally related components for a total of five (5) cases. The communities and natural resources in the coastal resources sector are highly integrated because of the interdependency of members of the community on the natural resources for their livelihoods. They do not readily lend themselves to resolution into distinct components. Consequently, there are significant interrelationships (natural resources coastal settlements-physical infrastructure) between these bio-physical and socio-cultural features of the coastal resources and settlements in Jamaica.

These case studies involved assessing the effect of sea level rise and the projected changes in rainfall frequency, distribution and intensity, as well as more recent experiences in hurricanes, storms and storm surges on Jamaica's coastal resources and settlements. The case studies for the coastal resources sector and settlements are as follows:

1. Potential loss of energy supply resulting from sea level rise at the Hunts Bay Power Station located in Kingston
2. Potential impacts of sea level rise on fisheries resources on the Greenwich Town Fishing Village located in the western side of the Kingston Harbour, St. Andrew.
3. The impact of sea level rise on the coastline of the Hellshire coastal community and its implications for its sustainability as a human settlement.
4. Potential impacts on fisheries resources and its effect on the livelihoods for the Hellshire coastal community located in St. Catherine
5. Potential impact on fisheries resources and its effect on the livelihoods for the Rocky Point Fishing Village located in Clarendon

The locations studied are shown in the figure on the next page:

3.8.1.2 Context and Historical Perspective

In a report done by the Natural Resources Conservation Authority in 2000 (NRCA, 2000), over fifty national legislation, regulations and guidelines pertaining to the terrestrial environment, watersheds, the coastal zone, and the open sea have been identified. Of these, the overarching legislation pertaining to the coastal resources sector is the NRCA Act of 1991. The Beach Control Act of 1956 specifically addresses coastal resources along with other national and international legislations.

Figure 1: Study Locations: (1) Hunts Bay Power Station, (2) Greenwich Farm Fishing Village, (3) Hellshire Fishing Village, (4) Rocky Point Fishing Village

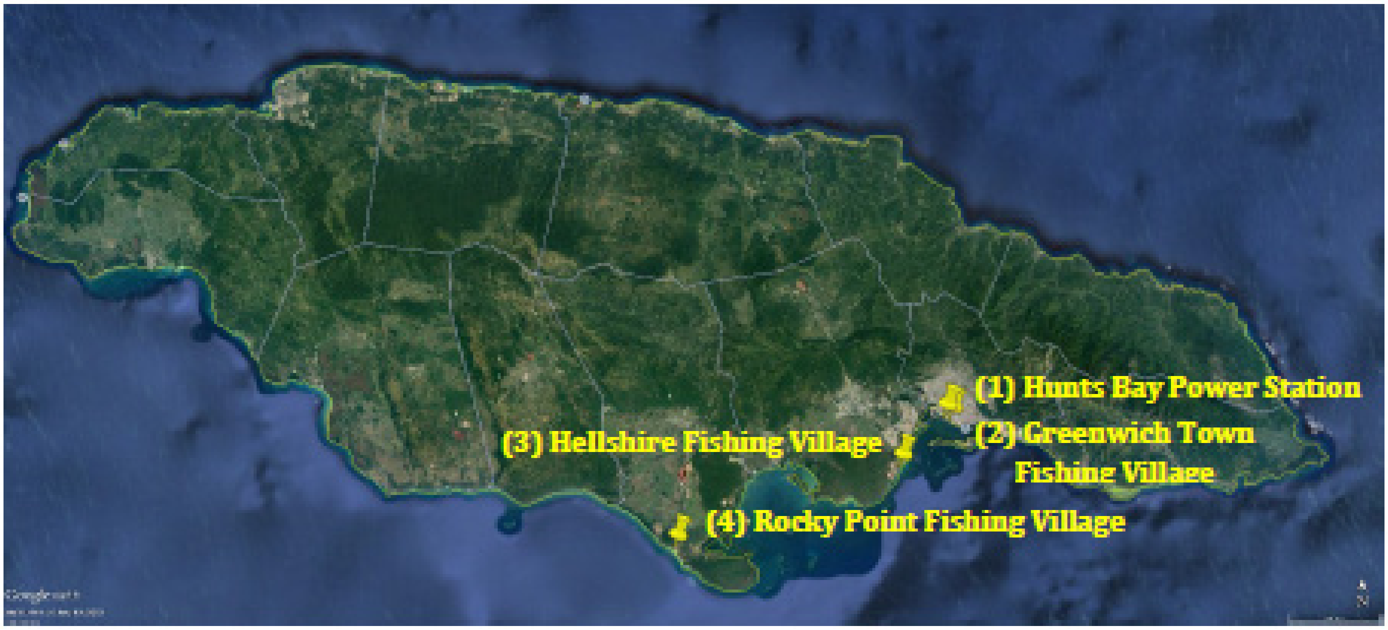


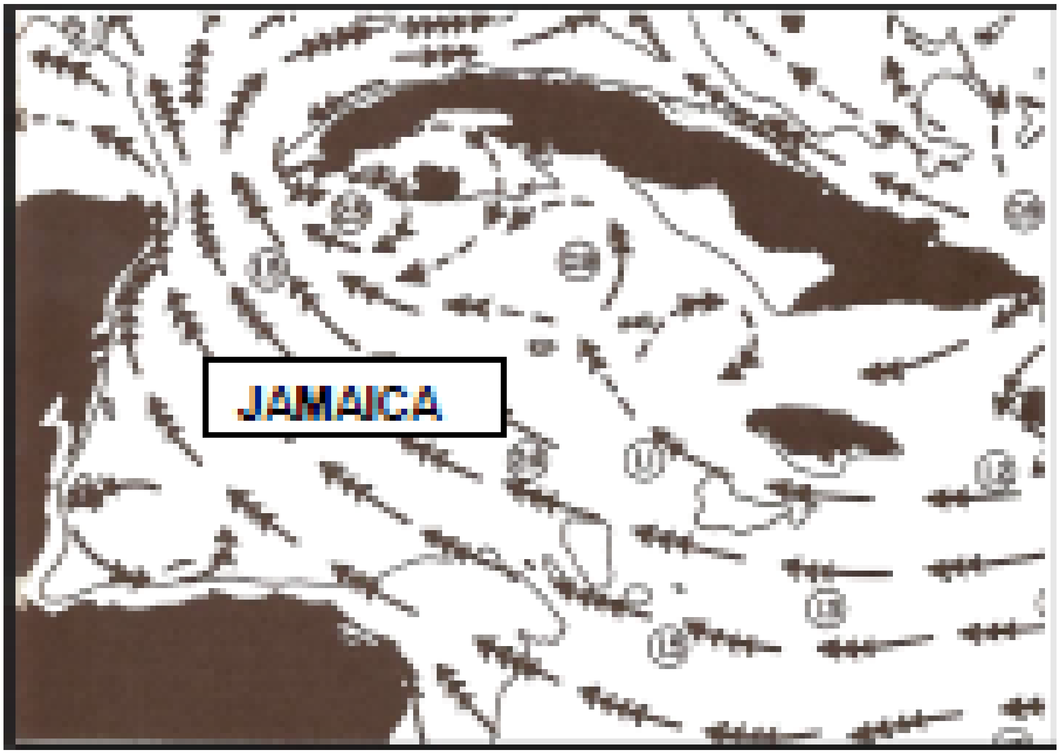
Figure 2: Study Locations: (1) Hunts Bay Power Station, (2) Greenwich Farm Fishing Village, (3) Hellshire Fishing Village, (4) Rocky Point Fishing Village

The National Environment & Planning Agency (NEPA) is responsible for the management of Jamaica's coastal resources. The Fisheries Division, Ministry of Industry, Commerce, Agriculture & Fisheries has responsibility for Jamaica's fisheries up to and including the Exclusive Economic Zone (EEZ). These agencies are responsible for administering the NRCA Act, the Beach Control Act and the Fisheries Act, respectively.

Jamaica's coastline is 631 miles (1,022 kilometres) and varies significantly in its biological, physical and social characteristics. There are also distinct differences between Jamaica's north coast and south coasts. This is observed, for example, in the very sharp near deep fall off on the north coast. This sudden fall off is characterised by depths ranging from 1,500 up to 9,000 metres. Conversely, the southern coast is characterised by a shallow continental shelf of less than 120 meters deep. This extends over a distance of 160 km from east to west and up to 32 km from the coastline.

The waves arriving in Jamaica are governed by the North East Trade Winds, which carries wind in a westerly direction around the island (Government of Jamaica, 2011). Depending on the season, the Trade Winds form waves at varying heights with tides ranging up to about 45 cm during spring tide (Figure 3). Figure 3 illustrates ocean current regime near Jamaica for the Month of July.

Figure 3: Ocean Current Regime near Jamaica for the Month of July Source: Wust, in Emilsson, 1971



According to the National Coastal Atlas of Jamaica (Natural Resources Conservation Authority, 2000) the coastal zones in Jamaica are shown in the figure below. The classification is also described below.

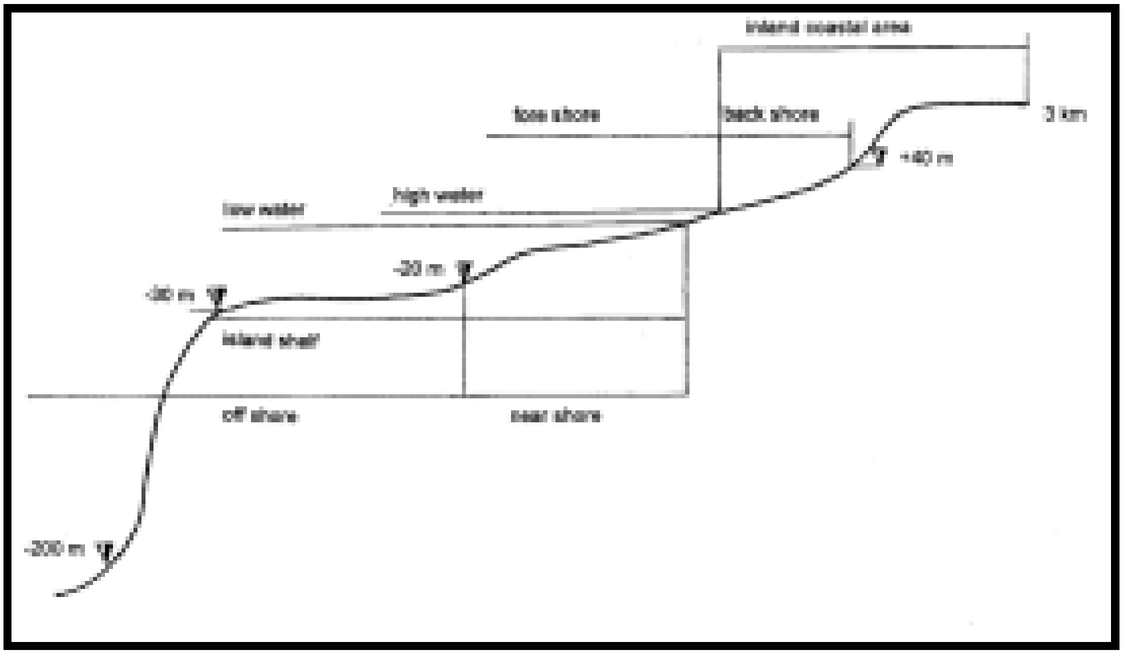
- The Inland Coastal Area should, in an early planning stage, be defined as an area being within three kilometres from the sea shore. After further analysis of resources, needs and potentials as well as functional linkages to the surrounding areas, the boundaries could be adjusted accordingly.
- The Backshore Area extending from the shoreline and inland to the 40m contour is likely to embrace much of the obvious coastal characteristics on land. However also this boundary – the 40m contour – could be subject to changes due to local conditions.
- The Foreshore Area is that part of the beach between low and high tide marks equivalent to much of the upper shore-face. It has – with the very limited tidal variations in Jamaica – an average width of approximately 1.5-2 m, depending on the topography of the shoreline.
- The Near-shore Area reaching from the shoreline to the 20m depth contour or to adjacent coral reefs. Outside this contour is likely to embrace most of the benthic (i.e., ocean bottom) area.
- The Island Shelf Area ranges outside the shoreline to the 30m depth contour, where the sea bottom almost immediately drops to 200m and deeper. (Government of Jamaica, 2011).

There are 187 fishing villages along the coastline and 18,000 fisher folks involved in fisheries from these locations. More than 60 cays are located within Jamaica's coastal zone. The shallow shelf along the south coast is mainly where the fishers make their catch. The Pedro Cays, Lime Cay and Morant Cays are also bases for fishers. The value of the fisheries industry is about US$3 billion per annum. The fish catch includes both shell-fish and finfish, with shell-fish accounted for primarily by conch and lobster.

Fish (finfish and shellfish), like all other organisms, are found in habitats that are conducive to their flourishing. Their survival depends on the sustainability of their environment within certain parameters covering the life cycles of the specific organism.

Adaptation and anthropogenic intervention have the possibility to conserve and enhance natural conditions to facilitate sustainability through intervention in bio-physical changes aimed at influencing the population dynamics of both shellfish and fin-fish.

Figure 4: Physical Features that Characterise a Coastal Zone



Among the major impacts to Jamaica's coastline resulting from climate change are:

- Sea level rise (erosion, deposition, inundation, changes in coastal and economic activities and saltwater intrusion)
- Increased temperatures (coral bleaching)
- Increased frequency and intensity of hurricanes and storm surges (loss of physical infrastructure, natural coastal resources and flooding)
- Severe prolonged droughts and flooding

3.8.1.3 Sea Level Rise

Sea level rise must be viewed in the context of fluid mechanics and the associated changes in coastal dynamics, in particular. As the sea level rises, the bathymetry also changes resulting in changes in wave, tidal and current dynamics and consequently their erosive action and transport and deposition of sediments. There are also impacts as a result of inland activities, such as transport of sediments from natural and artificial drainage and rain run-off water to the sea.

Sea level rise is measured based on the change in the sea level in relation to the surface of the dry land. It is mainly contributed by ocean thermal expansion and mass loss from glaciers (IPCC, 2014).

"Although the rate of sea level rise varies between different ocean basins, historically, the rate of sea-level rise in the Caribbean has been close to the global average rate and is expected to continue close to the global rate (IPCC, 2007, chapter 11 p. 915 and figure 10.32).

Since the IPCC published these findings, several peer-reviewed publications suggest that sea-level rise by the year 2100 could be more than twice the amount projected by the IPCC, perhaps as much as 1.6m (See Table 1 below) (Rahmstorf, 2007; Rignot et al., 2008; Rohling et al., 2008).

Further evidence for possible sea-level rise up to three times that projected by the IPCC was presented by Svetlana Jevrejeva and others to the European Geosciences Union conference in April 2008 (Reuter's news report, April 15, 2008; review by Ananthaswamy, 2009)". Source: (Government of Jamaica, 2011)

Table 1: Projected Global Average Surface Warming and Sea-Level Rise by 2100

Scenario		Temperature Change (degrees C)				Sea-level Rise (m)
		Best Estimate		Likely range		Model-based range
B1		1.8		1.1-2.9		0.18-0.38
A1T		2.4		1.4-3.8		0.20-0.45
B2		2.4		1.4-3.8		0.20-0.43
A1B		2.8		1.7-4.4		0.21-0.48
A2		3.4		2.0-5.4		0.23-0.51
A1F1		4.0		2.4-6.4		0.26-0.59

Extracted from: (Government of Jamaica, 2011) Source: Adapted from IPCC 2007, Table TS.6

These changes in sea level rise have the potential to and are impacting on Jamaica's natural and man-made coastal resources. This includes beaches, coral reefs, seabed grasses, mangroves, coastal ecosystems. In addition, there is the potential change to coastal settlements, recreational facilities and social and economic activities on which Jamaica is highly dependent. Approximately ninety per cent (90%) of Jamaica's GDP is generated in its coastal zone (The Planning Institute of Jamaica, 2013).

The maximum sea level rise projected for Jamaica's North and South coasts are 0.43m – 0.67m and 1.05m respectively by the end of the 21st century (Climate Studies Group, Mona, 2016). These changes have already started to impact on Jamaica's coastal zone and its entire Exclusive Economic Zone (EEZ). There is significant evidence to support this in several places. For example, among the Pedro Cays, the South Cay, which was an important staging ground for fishers, is now completely submerged.

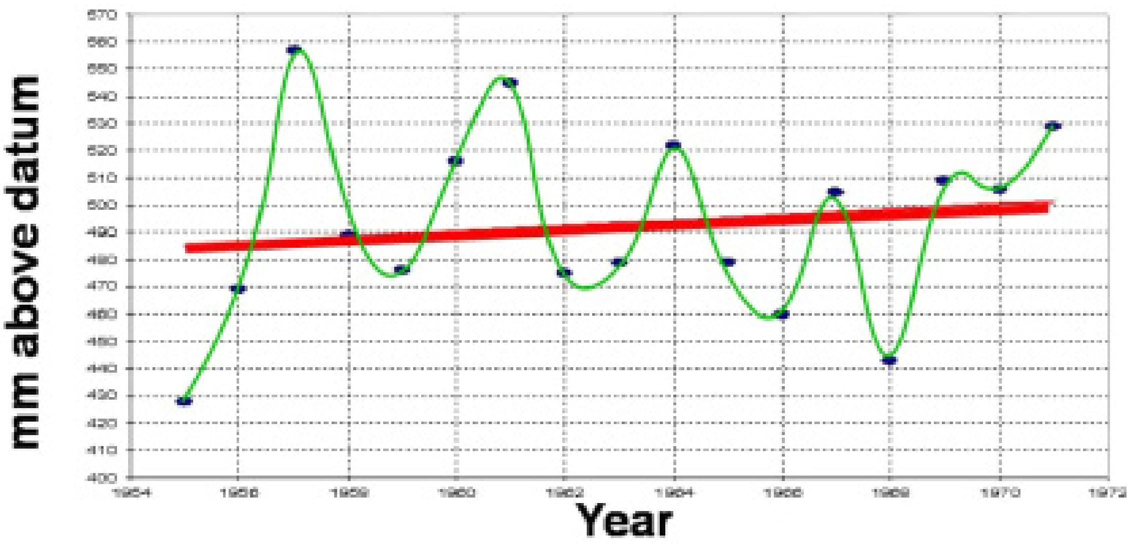
Figure 5 and Figure 6 below show the daily tidal gauge data during the period January 1965 to December 1971 off the coast of Port Royal. The data shows a steady increase in the mean sea level over the period with a total rise of 15mm.

Sea surface height anomalies averaged over Jamaica between 1950 and 2008 are shown in Figure 6 below. The linear trend (red line) indicates a rate of increase of 0.23 mm/year.

The Economic and Social Survey Jamaica, 2013 reports the status of the coastal and marine ecosystems as remaining poor with over 36 beach sites observing a net erosion of 20.8m (The Planning Institute of Jamaica, 2013).

The south-eastern coastline of Jamaica, along St. Thomas, appears to be one of the locations with the most severe impacts. For example, tombs have now been submerged in the sea and there is loss of formerly active commercial areas located along the coast. The Harbour View Drive-Inn Theatre and the community of Caribbean Terrace, both in St. Andrew have been severely impacted. The Harbour View drive-in theatre site is now filled with sand dunes, while the White Horses, Roselle's Area in St. Thomas has experienced severe coastal erosion and destruction of commercial buildings.

Figure 5: Mean Annual Sea-Levels at Port Royal (1955-71) Source: Modified from Horsfield, 1973 (Government of Jamaica, 2011)



The formation and stability of the sandbars at the Yallahs Ponds have also been disrupted in recent years with the immediate communities and Kingston, downwind of the location being impacted by unpleasant odours, consequent on disruption of the ecological balance of the ponds.

As one proceeds westward, the impact becomes more and more discernible. For example, Hellshire Beach, which is an important recreational location for the Kingston Metropolitan Area, and Portmore, and an important fishing community is now severely eroded to the extent that the beach has been completely lost in some areas. The sea is now right up against the structures, which are used by various vendors and users of the beach.

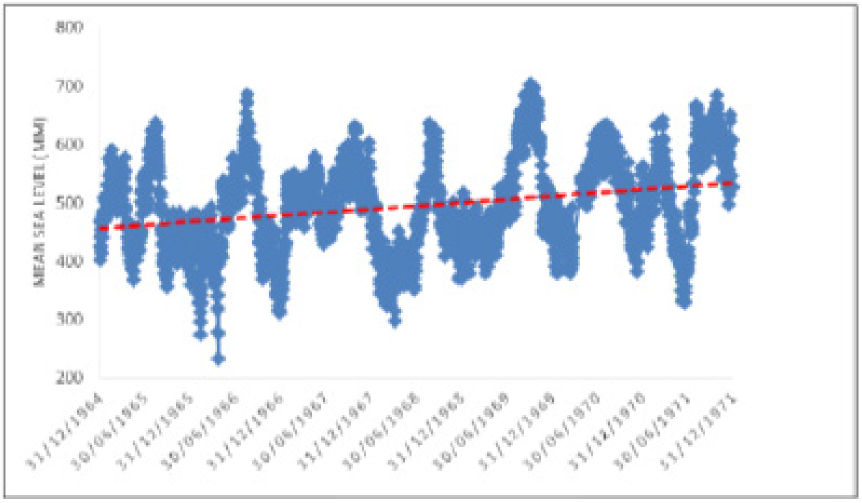
In proximity to this area, the Portmore Municipality has also experienced property losses resulting from coastal erosion. In this particular instance, the Municipality owned 10 acres of land, which has now been reduced to 6 acres as a result of sea level rise and coastal erosion.

Robinson & Khan et al have demonstrated that the Negril coastline is being eroded. Although we recognize that there is evidence of beach erosion, there is evidence of beach formation through deposition for example at Rocky point, Clarendon. This is possibly caused by the littoral drift (longshore drift). As waves are formed by the trade winds, sediments are transported along the coast within the littoral zone and being deposited along the Rocky Point coastline.

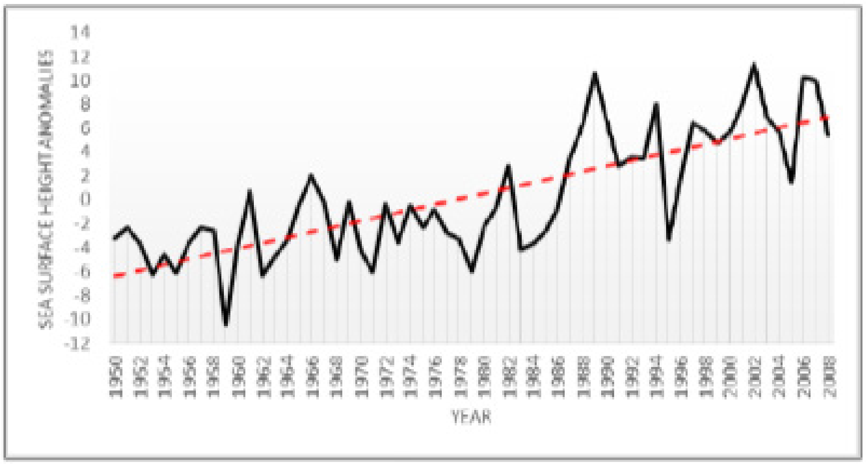
Halcrow and Robinson have stated that “along the central part of the south coast, currents have generated dunes on much of the south coast shelf, and a strong, persistent longshore current moves large quantities of sand at intervals in a westerly direction (Halcrow, 1998; Robinson, 2004)”.

Figure 6: (a) Daily tidal gauge data off the coast of Port Royal, Jamaica from January 1965 to December 1971. Source: University of Hawaii Sea Level Centre. The linear trend in the above plot indicates a steady increase in mean sea level. (b) Sea surface height anomalies averaged over Jamaica between 1950 and 2008. The linear trend (red line) indicates a rate of increase of 0.23 mm/year (Source: Climate Studies Group, Mona, 2016)

(a)



(b)



3.8.1.4 Increased Temperature

Global mean surface temperatures have increased by 0.85 °C ± 0.20°C when a linear trend is used to estimate the change from 1880-2012 (IPCC, 2013). Average annual temperatures for Caribbean islands have similarly increased by just over 0.5 °C for the period 1900 – 1995 (Extracted from Climate Studies Group, Mona, 2016. Source: IPCC, 2007)

The Jamaica: Future Climate Changes Report prepared by the Climate Studies Group states that for both Global Climate Model (GCM) and Regional Climate Model (RCM) derived projections:

- Mean annual temperatures are projected to increase irrespective of scenario through the end of the century.
- The GCMs suggest that mean temperature increase (oC) will be 0.42-0.46 by the 2020s; 0.75-1.04 by the 2030s, 0.87-1.74 by the 2050s and 0.82-3.09 for 2081-2100 overall four RCPs.
- Increases will be of the same approximate magnitude for maximum and minimum temperatures.
- The RCMs suggest increases of up to 4.0oC for the A1B scenario for the sub-island regions by the end of the century. This is in general higher than the values projected by the GCMs (including for RCP4.5). This is expected since the GCM average results across the entire country.

Given the vulnerability of fisheries resources to habitat conditions, climate change is projected to impact on the fisheries because of the anticipated effect on the natural equilibrium of the physical and chemical characteristics of the marine environment. The sea is not only a sink for heat from solar radiation, but is also a sink for acid anhydrides, including greenhouse gases, which result from the burning of fossil fuels.

These greenhouse gas emissions are leading to global increase in the surface temperature of the sea, as well as an increase in the acidity of the sea. These parameters affect population size and dynamics of fisheries resources and major habitats for marine life such as coral reefs. Invariably food security and livelihoods are also threatened.

Projections of sea-surface temperatures have been made for the Caribbean by Sheppard & Rioja-Nieto (2005) (See Figure 7 below). Vertical bars in the figure indicate the years 2015, 2030, and 2050 respectively.

"The current rate of acidification of the oceans is unprecedented. Reductions of average global surface ocean pH of between 0.14 and 0.35 units are projected over the 21st century, adding to the present decrease of 0.1 units since pre-industrial times (the range is very roughly 8.13 decreased to 8.09 over 1985-05, or 0.04 units over the past 20 years (IPCC, 2007, Chapter 5, p. 404). If this projected reduction is realised, ocean acidity will reach a level probably not seen for the past 20 million years (Feely et al. 2004; Guinotte & Fabry, 2008).The main effect of increased acidity will be to reduce calcification rates of many organisms that generate biogenic calcium carbonate skeletons. No measurements of ocean pH values are known to have been made around Jamaica (pers. comm., Marcia Creary)." Source: Government of Jamaica, 2011.

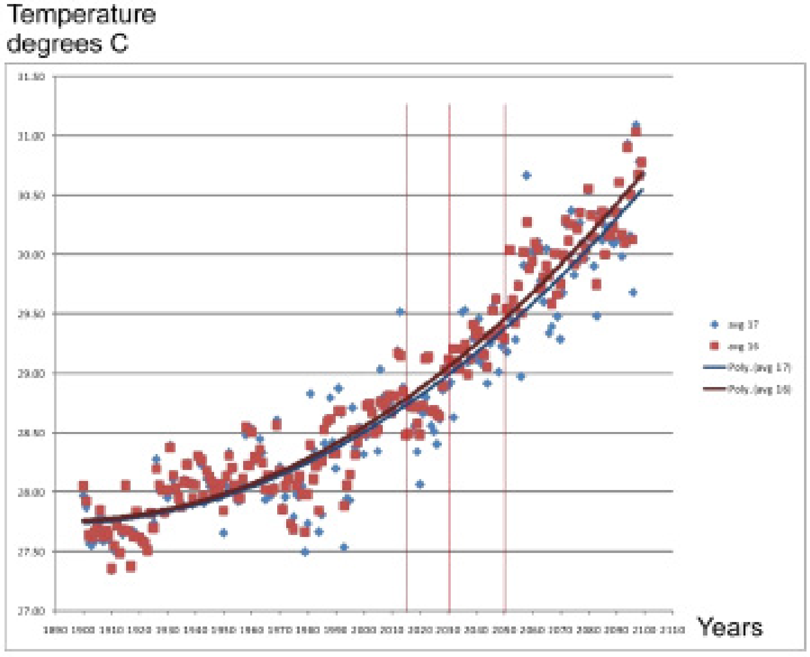
There will also be the tendency for acid attack on the calcareous exoskeleton of shellfish, such as lobster and conch. Furthermore, coral reefs, which are largely made of carbonates of calcium and magnesium will be impacted through dissolution/scarification.

3.8.1.5 Hurricane/Storm Surge

Jamaica's geographic location in the Caribbean makes its vulnerable to tropical storms, depressions and hurricanes. As a result, Jamaica has been impacted by hurricanes of up to category 5, which has caused major damage to physical infrastructure, natural resources and agriculture. In several instances, this has caused severe disruptions and devastating losses. For example, in 2004 Hurricane Ivan caused an estimated loss of $36.9 billion dollars or 8% of Jamaica's GDP (PIOJ).

Projections are that with warmer seas, the frequency and intensity of hurricanes and storms will increase. High winds, heavy rainfall and storm surges are major characteristics of hurricanes. In 2007, Hurricane Dean caused storm surges of up to 13 metres in height along the south coast.

Figure 7: Graph of Sea-Surface Temperatures for the Jamaican Region Compiled from data downloaded from Sheppard & Rioja-Nieto, 2005. (Source: Government of Jamaica, 2011)



3.8.1.6 Severe prolonged droughts to Flooding

The severe weather events, such as tropical storms, depressions and hurricanes also carry with them storm surges and increased rainfall. The loss of beach and changes in coastal features may result in the inundation of low lying areas close to the coast. It should also be noted that with sea level rise, the distance between the shoreline and the land will be decreased. Consequently, the inland reach and impact of tsunamis are likely to be greater.

3.8.1 The Case Studies

3.8.1.2 Case 1.1: Potential Loss of Energy Supply in Jamaica resulting from Sea Level Rise at the Hunt's Bay Power Station and the nearby Greenwich Town Fishing Village

During the implementation of this project, it was observed that there are locations with multiple cases, which require an integral approach to vulnerability and adaptation assessment of the impacts of climate change. The cases selected are concerned with the effect of sea level rise on:

1. The Potential Loss of Energy Supply in Jamaica at the Hunt's Bay Power Station and the nearby
2. Greenwich Town Fishing Village (coastal settlement)

The locations studied for the cases are shown in the Figure 8 below:

Figure 8: Location Map of Project Sites - Hunts Bay Power Station and Greenwich Farm Fishing Village

A vulnerability and adaptation assessment was carried out at these locations. They are described in two (2) cases below.

3.8.1.3 Potential Loss of Energy Supply resulting from sea level rise at the Hunts Bay Power Station

Jamaica has an installed electricity-generating capacity of 994 MW. The peak demand for electricity is 620 MW during the hours of 6am-9pm, mainly from base load. Going from east to west, the major power plants on the coast are:

- Jamaica Private Power Company;
- Jamaica Energy Partner (JEP) barges;
- Hunts Bay;
- Old Harbour Bay; and
- Bogue (Montego Bay).

There are also several other private power-generating plants mainly in the bauxite-alumina, cement and sugar industries and other production facilities. Some of the alumina plants are connected to the national grid. One major exception is the 60-cycle Alumina Partners of Jamaica Power Plant, which is not connected to the 50-cycle national grid.

The Hunts Bay Power Plant is fired with Bunker C Oil (No. 6 fuel oil), which is supplied by the Petrojam refinery. The Petrojam refinery is also located adjacent to the Hunts Bay Power Station and the Greenwich Town Fishing Village along the coast in Kingston Harbour. With increasing physical development, the demand for electricity will increase.

Hunts Bay Power station is located on Marcus Garvey Drive in the Kingston Harbour, along Jamaica's south coast. For the purpose of this case, it is noteworthy that Marcus Garvey Drive was previously known as Foreshore Road. The Hunts Bay Power Plant is at an estimated elevation of about 3.6m above sea level. It is an oil-fired power plant with a generating capacity of 188MW accounting for ~19% of Jamaica's generating capacity on the national grid.

Figure 9: Hunts Bay Power Station

The vulnerability of Hunts Bay Power Plant to sea level rise has been assessed. This has been done in the context of the various projections for sea level rise at the end of the century (2100) in relation to the elevation of the plant. Historical storm surge events have also been taken into account in assessing the vulnerability of the power plant. It should be noted that the Kingston Harbour is the seventh largest sheltered natural harbour in the world. Sheltering reduces vulnerability to wind and wave actions.

The projection for sea level rise for up to 2100 is given below in Table 2. This shows that there is a projected increase in sea level by 0.69m up to 2100 along the south coast of Jamaica. It is important to note that, ***"Since the IPCC published these findings, several peer-reviewed publications suggest that sea-level rise by the year 2100 could be more than twice the amount projected by the IPCC, perhaps as much as 1.6m (Rahmstorf, 2007; Rignot et al., 2008; Rohling et al., 2008). Further evidence for possible sea-level rise up to three times that projected by the IPCC was presented by Svetlana Jevrejeva and others to the European Geosciences Union conference in April 2008 (Reuter's news report, April 15, 2008; review by Ananthaswamy, 2009)"*** Source: (Government of Jamaica, 2011).

Table 2: Projected increases in mean sea level rise (m) for the north and south coasts of Jamaica. Range is the lowest projection under low-sensitivity conditions to the highest annual projection under high sensitivity during the period. Projections relative to 1986-2005.

	Sea Level Rise (m) North Coast (-77.076W, 18.8605N)							
Centered on	2025		2035		2055		End of century	
Averaged over	2016-2035		2026-2045		2046-2065		2081-2100	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
RCP2.6	0.11	0.05 - 0.20	0.16	0.09 – 0.27	0.26	0.15 – 0.41	0.43	0.26 – 0.65
RCP4.5	0.11	0.05 - 0.20	0.16	0.09 – 0.27	0.28	0.25 – 0.43	0.51	0.31 – 0.76
RCP6.0	0.11	0.05 – 0.19	0.16	0.08 – 0.26	0.26	0.15 – 0.42	0.51	0.31 – 0.78
RCP8.5	0.12	0.05 – 0.21	0.17	0.09 – 0.30	0.32	0.18 – 0.51	0.67	0.41 – 1.05
	Sea Level Rise (m) South Coast (-77.157W, 17.142N)							
Centered on	2025		2035		2055		End of century	
Averaged over	2016-2035		2026-2045		2046-2065		2081-2100	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
RCP2.6	0.12	0.05 - 0.17	0.16	0.09 – 0.28	0.27	0.15 – 0.42	0.44	0.26 – 0.67
RCP4.5	0.12	0.06 - 0.21	0.17	0.09 – 0.28	0.29	0.17 – 0.44	0.52	0.32 – 0.78
RCP6.0	0.11	0.06 – 0.20	0.16	0.09 – 0.26	0.27	0.15 – 0.43	0.52	0.32 – 0.80
RCP8.5	0.12	0.06 – 0.22	0.18	0.09 – 0.31	0.33	0.19 – 0.53	0.69	0.42 – 1.08

(Source: Climate Studies Group, Mona, 2016)

Therefore, in the worst case scenario it is projected that the mean sea level rise could be as high as 2.07m.

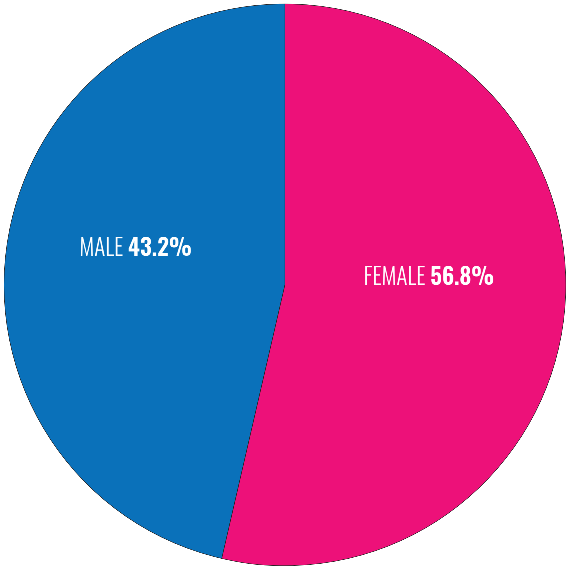
Without taking the projected climate change into consideration, the coastline could experience storm surges of up to 1.4m (Richards, 2008). Based on the elevation (3.6m) of the Hunts Bay Power Station under present conditions, the power plant would not be vulnerable to inundation. However, taking into consideration the maximum projections for sea level rise of 2.07m to 2100, the Hunts Bay Power Station would be at a new reduced elevation of 1.53m above sea level. Storm surges of 1.4m would be marginally below the level required to inundate the 188 MW Hunts Bay Power Station.

It should be noted that under Hurricane scenarios, the conditions of the sea would be very turbulent and it is possible that under these conditions, storm surges could result in flooding of the power plant.

3.8.2 Case 1.2: Greenwich Town Fishing Village

- Greenwich Town has a total population of 4,460 persons and is located in the Three Miles
- Development Area of St. Andrew. The gender distribution is illustrated in Figure 10 below.
- Greenwich Town has an average household size of 4 persons (SDC, 2009).

Figure 10: Gender Distribution at Greenwich Town at Greenwich Town (SDC, 2009)



The town comprises the following four districts:

- Top Farm,
- Bottom Farm,
- Boat Island and
- Fishing Village.

The Greenwich Fishing Village is in proximity to the Hunts Bay Power Station (Figure 11) and the physical conditions prevailing in the marine environment, such as increasing temperature and sea level rise could adversely impact the fishing village and its occupants.

Figure 11: Greenwich Farm Fishing Village

Among, the major environmental concerns (SDC, 2009) of the residents of Greenwich Town are:

- Air pollution (20.7%);
- Noise pollution (13.1%); and
- Flooding (9%).

In recent times the community has also been affected by major hurricanes, namely Hurricane Dean in 2007. The hurricane resulted in $23.8 billion in losses in Jamaica and 2.8% of the island's total Gross Domestic Product (GDP).

An interactive focal group consultation was carried out among members of the Greenwich Fishing Village. The objective was primarily to obtain current anecdotal information on the vulnerability of the settlement in respect of climate change with special emphasis on the sources of livelihoods of members of the community. Their awareness of climate change and changes that they have observed in the coastal zone over the past two (2) decades were also assessed.

The participants of the focal group session at Greenwich Town Fishing Village were aware of climate change. The major impacts of climate change to the occupants of Greenwich Town Fishing Village are changes in:

- Fish quantity, population, fish size and size of the catch (80%);
- the height of the sea (68%); and
- fish quality

The responses to proposed adaptation methods to climate change were:

- Install rock revetments (68%);
- Breakwaters (65%);
- groynes (48.4%); and
- To stop global warming through the reduction of atmospheric pollutants.

The Greenwich Town Fishing Village is at sea level and therefore the increase in sea level rise projected to the end of the century is most likely to submerge the fishing village to varying degrees. In the worst case, the fishing village will be completely submerged.

3.8.3 Potential impacts on the Hellshire Coastal Community

Hellshire is a major recreational and commercial area, which is dependent on the beach and other coastal natural resources for its support and sustainability. It is the largest recreational beach serving the parishes of St. Thomas, St. Andrew, Kingston and St. Catherine. Hellshire is a very popular beach and several thousand persons visit it weekly. A number of fishers and vendors also operate in the area. In recent years, the shoreline of Hellshire has receded significantly as a result of sea level rise and changes in coastal dynamics. This has caused severe erosion. The impacts of sea level rise have resulted in:

- Reduction in the comfortable use, aesthetics and possible safe use of this major recreational facility.
- Negative impacts on livelihoods (e.g. horse riding is no longer offered and incomes are decreasing)

The case study at the Hellshire Coastal Community is concerned with:

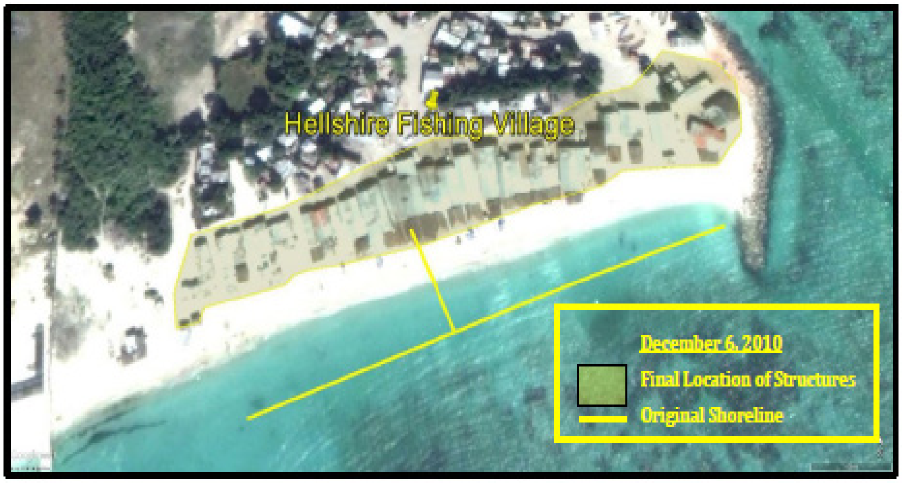
- The impact of sea level rise on the geomorphology of the Hellshire coastal community
- Potential impacts on fisheries resources and its effect on the livelihoods for the Hellshire coastal community located in St. Catherine

3.8.3.1 The impact of sea level rise on the geo-morphology of the Hellshire coastal Community.

A review was done of the coastline of Hellshire using time series satellite imagery over the period March 3, 2002 to March 6, 2016. This was followed by ground truthing in 2016. Archival photograph of the area from 2009 (Daily Gleaner) was compared with photographs taken on Easter Monday, March 28, 2016.

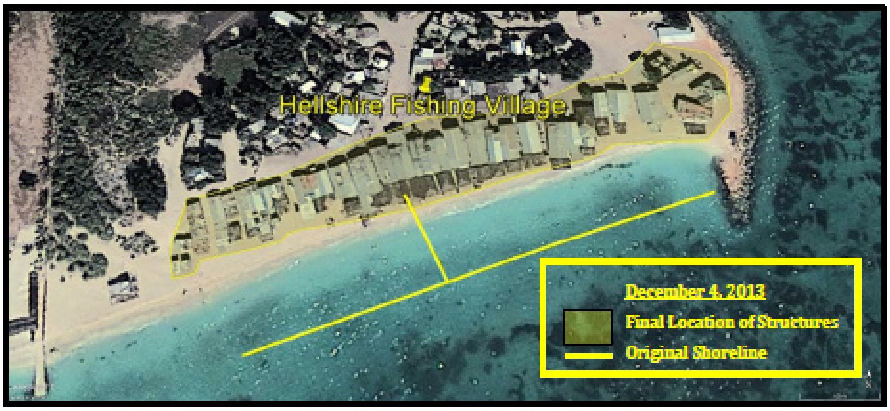
The comparative analyses show that the coastline has been progressively eroded over the fourteen-year period (2002-2016). The satellite imagery, time series photographs below show the relatively large beach (2002) and the severe erosion that has taken place in recent years (up to 2016). This correlates strongly with the photographs taken during the ground truthing activity. The backshore has now been eroded and evolved with significant geo-morphological changes to the foreshore.

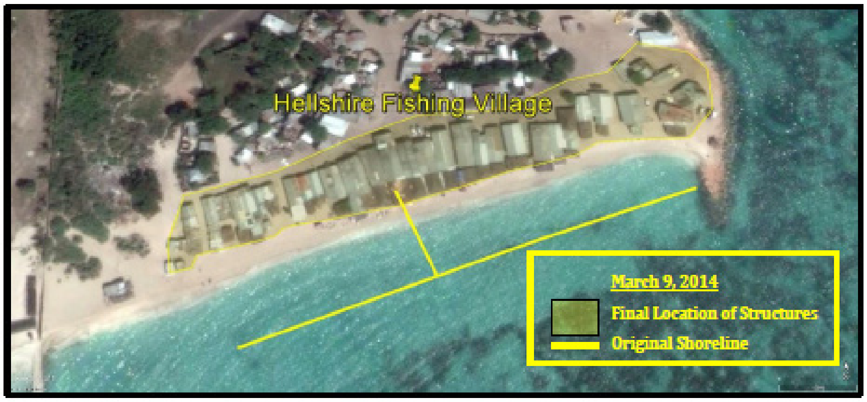
Satellite Imagery Time Series of Erosion/Sea Level Rise at Hellshire Beach March 3, 2002 – March 6, 2016 (The images for the period show progressive erosion of the shoreline)

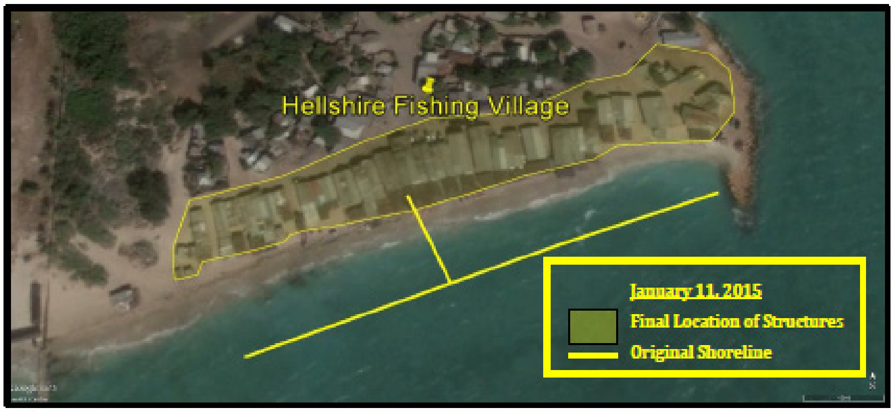

Hellshire Fishing Village
December 6, 2010
Final Location of Structures
Original Shoreline

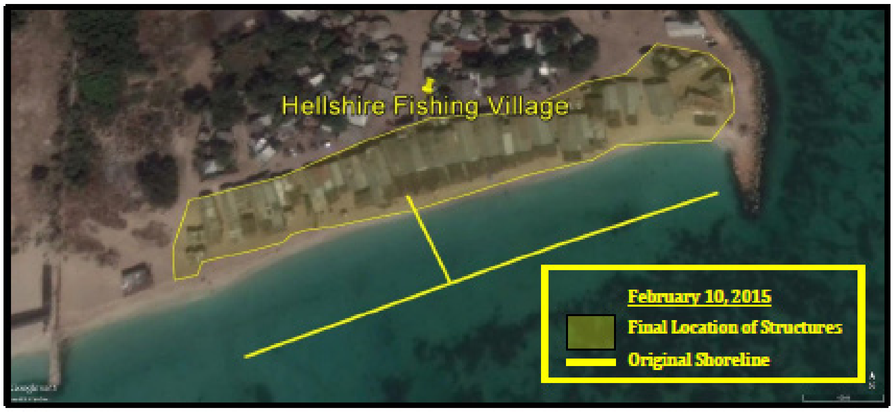

Hellshire Fishing Village
January 27, 2006
Final Location of Structures
Original Shoreline

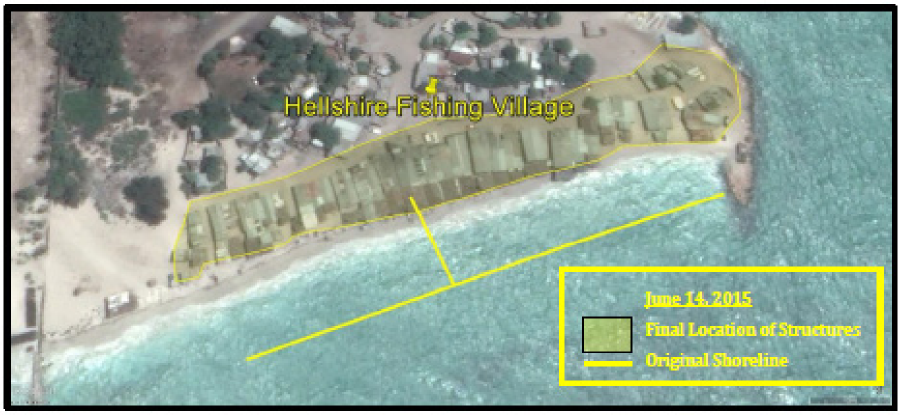

Hellshire Fishing Village
December 18, 2012
Final Location of Structures
Original Shoreline


Hellshire Fishing Village
December 4, 2013
Final Location of Structures
Original Shoreline


Hellshire Fishing Village
March 9, 2014
Final Location of Structures
Original Shoreline


Hellshire Fishing Village
January 11, 2015
Final Location of Structures
Original Shoreline


Hellshire Fishing Village
February 10, 2015
Final Location of Structures
Original Shoreline


Hellshire Fishing Village
June 14, 2015
Final Location of Structures
Original Shoreline

Archival image of Hellshire Beach, 2009 (Image No. 1) was compared with photographs taken on Easter Monday, March 28, 2016 (Images Nos. 2-10). These show significant erosion of the beach over the period and are illustrated below. In 2009, there was a wide sandy beach. In 2016, the beach has been eroded and the sea is now up to the structures on the shore

Figure 12: Hellshire Beach, January 2009, taken by Kamilah Taylor.

Series of images of Hellshire Beach showing thousands of patrons on Easter Monday, March 28, 2016.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Patrons in queue waiting to gain entry to the Hellshire Beach.

3.8.3.2 Potential impacts on fisheries resources and its effect on the livelihoods for the Hellshire coastal community located in St. Catherine

This case study reports on the importance of fisheries to Hellshire and the risk that climate change poses to the location. This case study also assesses the potential impact on the livelihoods of the stakeholders in the fishing industry at Hellshire.

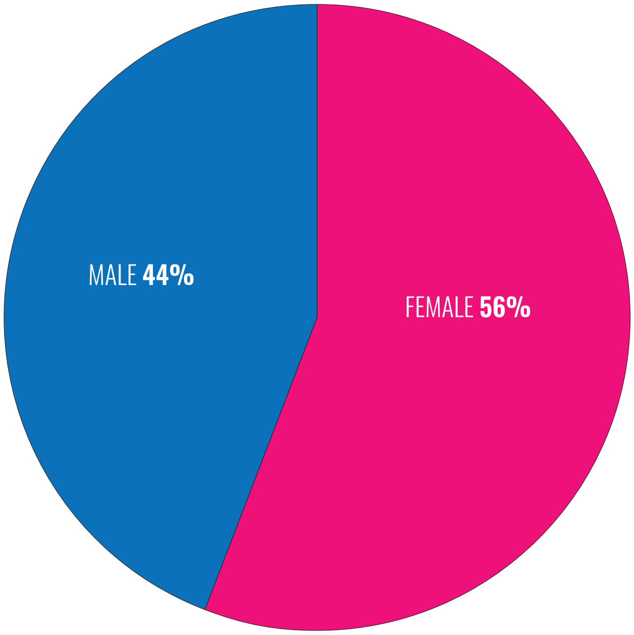
In the preparation of the case study, the following were taken into account:

- coral bleaching;
- acidification of the sea;
- changes in sea temperatures;
- potential for migration of fish to colder waters;
- impacts on breeding areas and nurseries such as mangroves, sea grass beds and coral reefs; and
- Marine pollution and illegal fishing practices.

Increasing sea surface temperature has resulted in coral bleaching and loss of coral reef. The fish population depending on them will further decrease. It is also expected that fish will migrate to the colder waters in the north.

According to the SDC Socio Economic Survey (SDC, 2010), the estimated total population of the Hellshire community is 4,116. The population is distributed across 1,205 households with a mean household size of 3.4 persons. The gender distribution is shown in Figure 13 below.

Figure 13: Gender Distribution at Hellshire community (SDC, 2010)



A focal group interactive consultation was carried out with the Hellshire coastal community to obtain anecdotal information on the awareness of the community members on climate change. The impacts observed and adaptation methods that could be employed were also obtained.

The focus group comprises fishermen, fish vendors and boat mechanics. Seventy-four per cent (74%) of the respondents have been operating in the area for more than 20 years. The respondents (90%) stated that their income has been affected as a result of climate change. The major impacts of climate change stated by the respondents were:

- beach erosion;
- the tide getting higher;
- loss of coral reef; and
- Loss of fishing grounds.

The major adaptation methods recommended by the respondents were installation of:

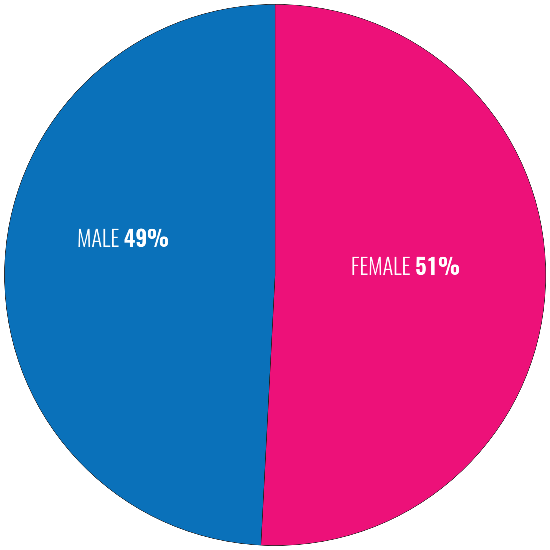
- rock revetments;
- breakwater; and
- Groynes.

One respondent also recommended the use of geo-textile tubing.

3.8.4 Case 3: Impact on Fisheries Resources at Rocky Point, Clarendon

The community of Rocky Point is located along Jamaica's southern coastline in the Vere Plains Development Area of south-east Clarendon. It has a total population of 4,240. Rocky Point has 1,060 dwellings with an average household size of 4 persons (SDC, 2009). The percentage distribution of households by gender is shown in Figure 14 below.

Figure 14: Percentage Distribution of Household Heads by Gender at Rocky Point (SDC, 2009)



The area's main economic activity is fishing. Rocky Point is considered to be the second largest fishing village in Jamaica.

Figure 15: Rocky Point Fishing Village

The main environmental issues identified in the Rocky Point area are (SDC, 2009):

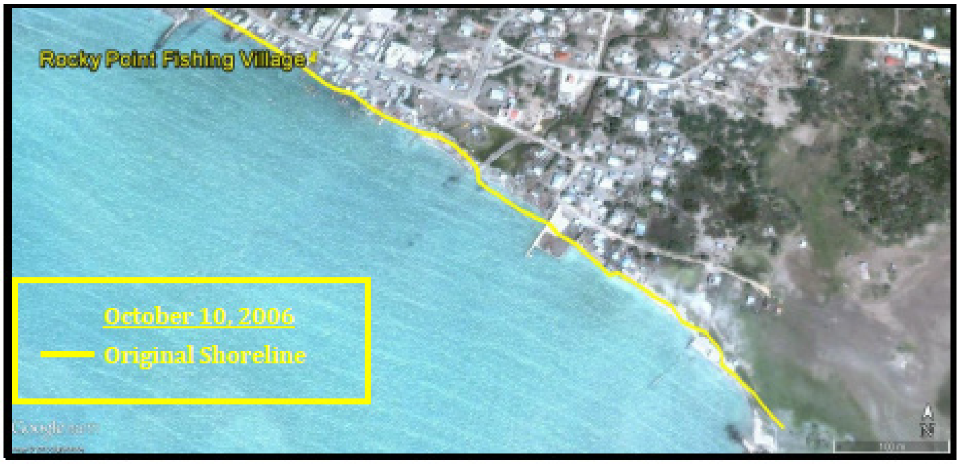
- Flooding (53.7%);
- Blocked drains (34.9%);
- air pollution (28.3%); and
- Garbage (22.6%).

In recent times, Rocky Point has experienced significant beach formation (see satellite, time series images below). A large foreshore white sand fishing and bathing beach has now been formed from recent sediment transport and deposition. The geo-morphological changes of the shoreline at Rocky Point is shown below and is most likely caused by littoral drift (longshore drift) and sediment transport influenced by changes in coastal dynamics as a result of climate change. As waves are formed by the trade winds, sediments are transported along the coast within the littoral zone and are deposited along the coastline.

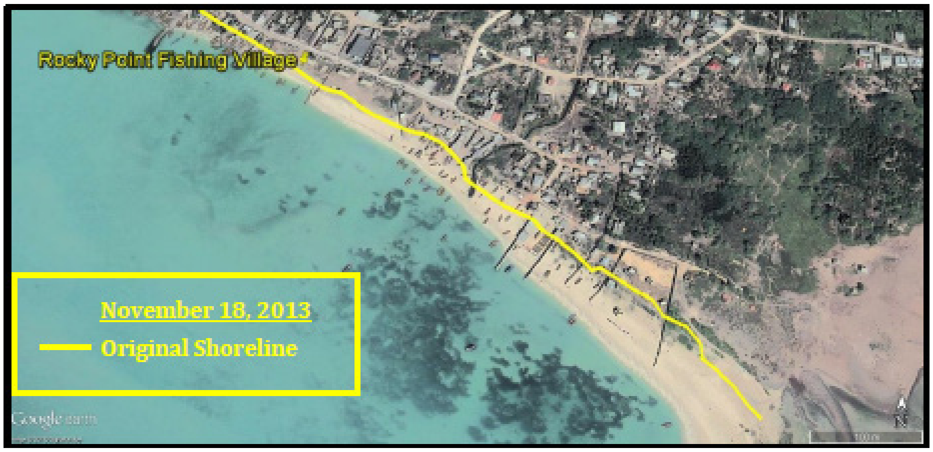
This was confirmed through ground truthing and a focus group consultation with the occupants of the Rocky Point Fishing Village. The respondents of the focus group stated that there have been changes to the white sand beaches in the area. Loss of coral reef was also stated as a climate change-related problem.

Photographic Time Series of Littoral Drift at Rocky Point, April 13, 2002 – July 21, 2015


Rocky Point Fishing Village
December 31, 2005
Original Shoreline
Google earth
N


Rocky Point Fishing Village
October 10, 2006
Original Shoreline
Google earth
N


Rocky Point Fishing Village
September 6, 2012
Original Shoreline
Google earth
N


Rocky Point Fishing Village
November 18, 2013
Original Shoreline
Google earth


Rocky Point Fishing Village
March 9, 2014
Original Shoreline
Google earth


Rocky Point Fishing Village
December 18, 2014
Original Shoreline
Google earth


Rocky Point Fishing Village
June 22, 2015
Original Shoreline
Google earth

Plate 1: Artisanal Canoes on Recently Formed Large White Sand Beach at Rocky Point (August 2016)

3.8.5 Policies, Plans, Programmes, and Actions

Projects aimed at adaptation to make Jamaica's coastal resources resilient to climate change are underway. Some are involved with assessing the changes in coastal dynamics with the view to adapting to the impacts of climate change. Some of the policies, plans, programmes and actions underway include the following:

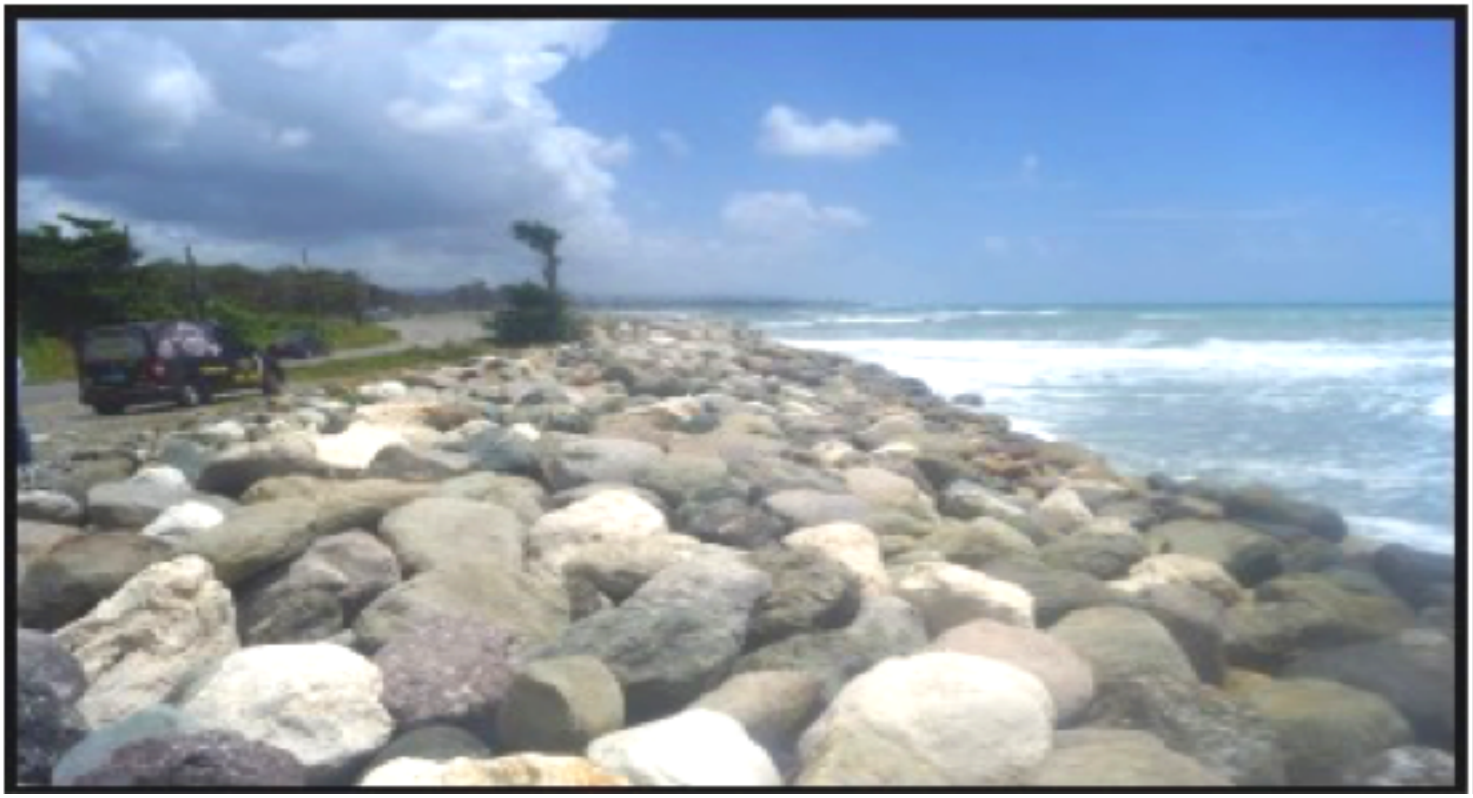
1. **Setbacks**

Consideration is underway to develop policies and regulations which would require increased setback for construction near the shoreline beyond that which is prescribed by the Beach Control Act of 1956.

2. **Shoreline revetment**

Shoreline revetment projects are being carried out on a number of locations on Jamaica's southern coast. These include, for example, revetment work that was done in the Roselle's White horses area, St. Thomas (See Figure 16 below), the windward side of the Palisadoes Peninsula, Gordon Cay, Kingston Harbour, and Bluefields, Westmoreland.

Figure 16: Extensive rock revetment along the St. Thomas coastline opposite Roselle Falls



3. Groynes

The placement of groynes along the seashore is an ongoing protective measure that is being carried out at various locations, in order to dissipate wave energy and the impact of currents and protect the shoreline from erosion. For example, a groyne has been installed at Hellshire Beach (See Figure 17 below).

Figure 17: Groyne installed at Hellshire Beach

4. Artificial coral reef

A project to install artificial coral reefs at Bluefields Bay, Westmoreland has been carried out.

Figure 18: Artificial Coral Reef placed at Bluefields Bay site for installation (Source: https://www.ecoreefs.com/)

Figure 19: Installation of artificial coral reef at Bluefields Bay, Westmoreland (https://www.ecoreefs.com/)

5. Geo-textile tubing

A project has been proposed for the installation of geo-textile tubing at Portmore to prevent erosion.

6. Installation of breakwaters

Breakwaters have been installed at various locations on the south coast. A controversial multimillion-dollar breakwater project, which was approved for installation at Negril to prevent coastal erosion was recently rejected by the Negril Chamber of Commerce and other members of the Negril community.

The project as originally proposed involved the combination use of breakwater and beach nourishment. The objective of the project was to control beach erosion.

7. Replanting of mangroves

A mangrove replanting project sponsored by the European Union has been carried out at Portland Cottage, Clarendon. The project was supervised by the National Environment & Planning Agency.

8. Declaration of fish sanctuaries

Nine (9) fish sanctuaries have been declared on Jamaica's north and southern coasts. These are being monitored and evaluated. Some of these sanctuaries are showing outstanding performance in terms of increased fish population, species type and the size of fish.

9. Early warning systems

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

10. Improved HydroMet Stations

A programme to improve hydromet stations nationally is being implemented by the Water Resources Authority and the Meteorological Service.

3.8.6 Conclusion

In concluding, a statement from 'Why Climate Demands Change' by Prof. Michael A. Taylor, at "The GraceKennedy Foundation Lecture 2015" eloquently describes the story of what has happened, is happening and is likely to continue in the future:

- *"It would also be true to suggest that under the new climate regime, new vulnerable groupings are emerging as a result of an expanded exposure to the climate threat. As sea levels rise, new areas become vulnerable to storm surge and higher wave heights. The eye of Hurricane Dean passed within 80 km south of Kingston and caused storm surges reaching up to 13 m in height along the eastern and southern coasts...*
- *Sea level rise is also resulting in beach erosion. Robinson et. Al (2012) reported the net average shoreline recession for the Long Bay area in Portland, Jamaica, between 1971 and 2008 as 8.4 m or about 23 cm per year.*
- *CARSEA (2007) noted that 70 per cent of Caribbean beaches are eroding at rates of between 0.25 and 9 m per year. Sea level rise and continued coastal erosion are placing previously distant infrastructure directly under threat, even in the absence of a severe storm event."*

The climate change-induced changes along the coastline of Roselle, Hellshire, Little Ochi, Bluefields and several other areas on Jamaica's southern coast support this statement.

It must be noted, however, that while beaches are being lost in some areas, significant beach formation is also taking place in other areas.

There is great urgency to develop integrated programmes of adaptation for making Jamaica's coastal resources more resilient to climate change. The issues being experienced are highly interdependent. While major coastal recreational facilities are being lost through erosion, recreational space is being diminished, which could lead to psycho-social stress and problems. This is especially in light of the limited number of green and open spaces, which are available generally in Jamaica.

In addition, the habitats and populations of fish and the size and quality of the fish catch, which is already under pressure from various anthropogenic practices is further exacerbated through rise in sea surface temperature which cause coral bleaching and negatively impact the health of Jamaica's coral reef systems. The consequence of this is a decrease in the size and quality of the fish catch and, therefore, the income of fishers. This can ultimately lead to a decrease in the quality of life, increased poverty and various social problems. The urgency and critical importance of maintaining global temperatures to the end of the century at 1.5 degrees Celsius cannot be over-emphasised.

3.9 HEALTH SECTOR

3.9.1 Introduction

Climate change is adversely affecting the health of populations around the world, with the greatest impacts in low-income countries (Confalonieri et al., 2007; McMichael A et al., 2003a). Impacts can arise from the following:

- The effects of climate change on natural and physical systems, which, in turn, alter the number of people at risk of malnutrition, the geographical range and incidence of vector-borne, zoonotic and food and water-borne diseases, and the prevalence of diseases associated with air pollutants and aeroallergens. Additionally, climate change in the coming decades is projected to significantly increase the number of people at risk of these major causes of ill health (Confalonieri U et al., 2007).
- Each year, extreme weather events (e.g. heat waves, floods, droughts and windstorms) affect millions of people, damage critical public health infrastructure, and cause billions of dollars of economic losses. The frequency and intensity of some types of extreme weather events are expected to increase over coming decades as a consequence of climate change (IPCC, 2007b), suggesting that the associated health impacts could increase without additional preventive actions.
- Climate change can affect population health through climate-induced economic dislocation and environmental decline, and through development setbacks incurred by damage to critical public health infrastructure and to livelihoods by extreme weather events.

Public health has experience in coping with climate-sensitive health outcomes. The current state of population health reflects (among many other factors) the degree of success or failure of the policies and measures designed to reduce climate-related risks. Climate change will make it more difficult to control a wide range of climate-sensitive health outcomes. Therefore, to maintain and improve current levels of population health, it will be necessary not only to continue to strengthen core functions of health systems, but also to explicitly consider the risks posed by a changing climate and to modify current health risk management activities to respond.

Policies and programmes will need to go beyond addressing current vulnerabilities, to protect against health risks from future and possibly more severe climate change. Because of the inherent inertia in the climate system and the length of time required for carbon dioxide to come to equilibrium in the atmosphere, the world is committed to three to five decades of climate change, no matter how quickly greenhouse gas emissions are reduced (IPCC, 2007b).

The future health impacts of climate change will vary over spatial and temporal scales, and will depend on changing socio-economic and environmental conditions, with possibilities for diseases to increase in incidence or change their geographical range. Therefore, capacity needs to be built within and outside the health sector to identify increased risks and prepare and manage them by evaluating the effectiveness of current and proposed programmes. These evaluations should consider both rapid climate change over the next few decades and longer-term changes in the averages of meteorological variables. Policies and programmes to address the health risks from climate change should explicitly consider how to avoid severe health impacts from cumulative or catastrophic events.

Reducing current and projected health risks attributable to climate change is a risk management issue. The primary responses to managing the health risks of climate change are mitigation or reduction of human influence on the climate system, and adaptation or policies and programmes designed to prevent avoidable impacts and minimise resulting health burdens (prevention). Mitigation and adaptation policies are not mutually exclusive; for example, co-benefits to human health can result from actions to reduce greenhouse gas emissions, and adaptation measures can lead to reduced emissions (Haines et al., 2009).

As the context for adaptation continues to change with changing demographics, technologies, socio-economic development and climate conditions, an iterative risk management approach is likely to be most effective. At the same time, because climate change is one of many factors associated with the geographical range and incidence of many adverse health outcomes, policies and measures designed to address the health risks of climate change need to be incorporated into existing programmes designed to address these risks and strengthen health systems.

Although there are uncertainties about the rate and magnitude of future climate change, failure to invest in adaptation and mitigation may leave communities and nations poorly prepared, thus increasing the probability of severe adverse consequences (WHO, 2009). Decision-makers need to understand the potential health impacts of climate change, the effectiveness of current adaptation and mitigation policies, and the range of choices available for enhanced or new policies and programmes.

3.9.2 The Jamaican Situation

3.9.2.1 Climate Trends and Projections for Jamaica at a Glance

The Climate Studies Group, Mona (Climate Studies Group, 2016) has projected the expected temperatures, rainfall, sea levels and occurrence of hurricanes. Table 1 presents the Climate Trends and Projections for Jamaica at a Glance.

Regarding temperatures, temperature increases across all seasons of the year is expected. A temperature rise in the order of 0.82-3.09°C by 2081-2100 is projected.

For rainfall, by the end of the century, the entire country may be up to 21% drier for the most severe RCP scenario (RCP8.5).

Sea level for the north coast is projected to be 0.43-0.67 m by the end of the century. Maximum rise is 1.05 m. Sea level rise (SLR) rates are similar for the south coast.

Finally, for hurricanes, no change or a slight decrease in frequency of hurricanes and a shift toward stronger storms by the end of the century as measured by maximum wind speed increases of +2 to +11%.

3.9.2.2 Previous Health Impacts Predicted

The Second Communication of Jamaica to the United Nations Framework Convention on Climate Change (Government of Jamaica, 2011) predicted the following:

- With global warming, human well-being will be affected by droughts and higher temperatures, either directly or indirectly.
- Pathogen loading of streams and poor sanitation could possibly result from lack of potable water.
- Storage of water during droughts in drums provides suitable habitats for mosquitoes and so augments the transmission of vector-borne diseases, like dengue fever and malaria, which are likely to increase with predicted higher temperatures. A two to three degree-Celsius rise in temperatures can lead to a three-fold increase in dengue fever transmission. Based on a simple proportion, an estimated figure of approximately 600 disability adjusted life years would be lost in Jamaica. The chances of dengue haemorrhagic fever will be increased. Since Jamaica has had all four sero-types, this could have a very serious impact on the tourist industry.
- Increased temperatures are also associated with increased episodes of diarrhoeal diseases, sea food poisoning and increases in dangerous pollutants. Threats from higher temperatures may cause greater contact between food and pest species. Warmer seas contribute to toxic algae bloom and increased cases of human shellfish and reef-fish poisoning. Such cases have been reported in French Polynesia.
- Incidents of high temperature morbidity and mortality are projected to increase.
- Due to water shortages, the impact expected on Jamaica would be loss of food production and the necessity to import and/or experience food shortages. This may lead to hunger and malnutrition.
- The leading causes of death in Jamaica are non-communicable diseases – respiratory and lifestyle diseases. Cerebrovascular (stroke) that is susceptible to heat stress is among the leading causes of deaths. The problem could be exacerbated by the design and type of construction materials used in housing. Attention must be given to the design of buildings in order to reduce heat stress.
- Asthma is active among young children and this is an increasing cause for concern. There is an ongoing study to determine the actual incidence of asthma. There are also two climate-related factors that are causing concern. The first is the fact that rising carbon dioxide levels could increase allergenic plant pollen. The second is the correlation between the outbreak of asthma affecting children and the concentration of the Saharan dust in Sahel Africa that could lead to increase of asthma in the Caribbean. This correlation has been established in Trinidad and Tobago: as the dust concentration rises, admissions to hospitals increase.
- The water and sanitation sectors of the population are dependent on water. Sources that are compromised have implications in the spread of diseases. Break‐out of typhoid after Hurricane Gilbert was associated with infrastructural damage to a treatment plant and the destruction of pit latrines.
- Epidemiological surveillance, including entomological surveillance behaviours that promote the proliferation of larval habitats and the promotion of behavioural change are considered priorities. If the health system is efficient, the country can adapt. The reorganisation of the health system has to be rethought.

3.9.2.3 The Impacts of Natural Events Related to Climate Change in Jamaica

Every year, Jamaica is affected by natural events, such as storms, hurricanes and droughts. The next paragraphs are a summary of the impacts of different natural events.

3.9.2.4 Summary of documents obtained from ODPEM

Over the years, several natural disasters have affected Jamaica, the Office of Disaster Preparedness and Emergency Management (ODPEM) has prepared damage assessment documents that speak to all the damage incurred by the island.

In 1995, flood rains affected the island. The total damage incurred by agriculture were J$3,500, 000, damage incurred by NWC were J$65,000, damage to infrastructure J$42,000,000 at the parish level while at the ministry level, the total was J$4,350,000.

In 1998, Portland was severely affected by flood. Total agricultural loss was J$201,324,250, loss within the public utilities and transportation sector totalled J$14.6 million, total loss incurred by NWC was J$11,221,178 (Table2).

Table 1. Climate Trends and Projections for Jamaica at a Glance

Historical Trend	Projection
Temperatures	
• Maximum and mean, minimum temperatures show upward (linear) trend. • Minimum temperatures are increasing faster (~0.27ºC/decade) than maximum temperatures (~0.56ºC/decade). Mean temperatures increasing at a rate of 0.16ºC/decade. • Increases consistent with global rates. • Daily temperature range has decreased.	• Min, max and mean temperatures increase irrespective of scenario through the end of the century. • The mean temperature increase (in ºC) from the GCMs will be 0.42-0.46ºC by the 2020s; 0.75-1.04ºC by the 2030s, 0.87-1.74ºC by the2050s and 0.82-3.09ºC for 2081-2100 over all four RCPs. • RCMs suggest higher magnitude increases for the downscaled grid boxes – up to 4ºC by end of century. • Temperature increases across all seasons of the year. • Coastal regions show slightly smaller increases than interior regions. • Mean daily maximum temperature each month at the Norman Manley International Airport station is expected to increase by 0.8-1.3°C (1-2-2.0°C) across all RCPs by early (mid) century. • The annual frequency of warm days in any given month at the Norman Manley International Airport station may increase by 2-12 (4-19) days across all RCPs by early (mid) century.

Rainfall	
• Significant year-to-year variability due to the influence of phenomenon like the El Niño Southern Oscillation (ENSO). • Insignificant upward trend • Strong decadal signal. With wet anomalies in the 1960s, early 1980s, late 1990s and mid to late 2000s. Dry anomalies in the late1970s, mid and late 1980s and post 2010. • Four rainfall zones. • Interior (1), West (3) and Coasts (4) co-vary on decadal time scale. East least well correlated. • Intensity and occurrence of extreme rainfall events increasing between 1940 -2010.	• GCMs suggest that mid 2020s will see 0 to 2 % less rainfall in the annual mean. The 2030s will be up to 4% drier, the 2050s up to 10% drier, while by the end of the century the country as a whole may be up to 21% drier for the most severe RCP scenario (RCP8.5). • The GCMs suggest that change in summer rainfall is the primary driver of the drying trend • Dry season rainfall generally shows small increases or no change. • RCM projections reflect the onset of a drying trend from the mid-2030s which continues through to the end of the century. • There is some spatial variation (across the country and even within Blocks) with the south and east showing greater decreases than the north and west. • The decreases are higher for the grid boxes in the RCM than for the GCM projections for the entire country.
Sea Levels	
• A regional rate of increase of 0.18 ± 0.01 mm/year between 1950 and 2010. • Higher rate of increase in later years: up to3.2 mm/year between 1993 and 2010. • Caribbean Sea level changes are near the global mean. • SLR at Port Royal, Jamaica ~ 1.66 mm/year.	• For the Caribbean, the combined range for projected SLR spans0.26-0.82m by 2100 relative to 1986-2005 levels. The range is 0.17-0.38 for 2046 – 2065. Other recent studies suggest an upper limit for the Caribbean of up to 1.5 m under RCP8.5 • For Jamaica, projected SLR over all RCPs for the north coast is 0.43-0.67m by the end of the century. Maximum rise is 1.05m. SLR rates are similar for the south coast.
Hurricanes	
• Dramatic increase in frequency and duration of Atlantic hurricanes since 1995. • Increase in category 4 and 5 hurricanes; rainfall intensity, associated peak wind intensities, mean rainfall for same period. • South more susceptible to hurricane influence.	• No change or slight decrease in frequency of hurricanes. • Shift toward stronger storms by the end of the century as measured by maximum wind speed increases of +2 to +11%. • +20% to +30% increases in rainfall rates for the model hurricane's inner core. Smaller increase (~10%) at radii of 200 km or larger. • An 80% increase in the frequency of Saffir-Simpson category 4 and 5 Atlantic hurricanes over the next 80 years using the A1B scenario.

Table 2. Summary of damage losses January 3-4, Portland flood events

Sector		Cost in Jamaican Dollars $
Agriculture		201,324,250
• Domestic Crops	174,280,000	
• Livestock	5,530,000	
• Fisheries	6,214,000	
• Soil Conservation Structures	2,500,000	
• Farm Building	3,500,000	
• Land Settlement, Farm roads	6,000,000	
Utilities		14,621,178
• Water	11,221,178	
• PC Water Supply	1,400,000	
• Electricity	2,000,000	
• Telephone (no damage)	-	
Physical Infrastructure		88,450,000
• PC Roads and Drains	20,450,000	
• Public Works Department	52,000,000	
• Roads, Bridges and Drains		
• Housing	16,000,000	
Social Infrastructure		39,010,095
• Welfare and Relief	18,000,000	
• Health	18,510,095	
• Pit Latrines	2,500,000	
Commerce and Tourism		5,824,500
Grand total		339,230,323

In 1999, it rained for four days, the total damage incurred was J$123.1 million distributed between road pavement and surface, drainage, and structure. There were three (3) reported deaths.

In 2002, Jamaica was affected by heavy rains resulting in nine (9) deaths and 1,310,550 persons (50% of the population) affected by the floods. Approximately 1,402 housing units were affected, the total monetary costs were $56,816,000, the total damage incurred by the educational sector was $2,520,000, damage to the health sector totalled $ 42,842,697, damage incurred by the agriculture, livestock and fisheries sector totalled J$99,895,000, the tourism sector also incurred damage amounting to J$425,000, water and sanitation a total of J$1,170,000.

In 2005, Hurricane Wilma affected Jamaica. A total of $45.2 million damage was incurred by the health sector, there was minimal damage to educational institutions, and there were 12 reported injuries. The agriculture, forestry and fisheries sectors totalled $248.755 million in damage, the environmental effects included, landslides, flooding, and siltation of rivers and streams

In 2007, the total estimate of damage incurred as a result of Hurricane Dean was $22.89 billion JMD (Table 3). The areas affected were the productive sector, where the sector represented the greatest portion of damage accounting to over 50% of the total; agricultural sector, road and infrastructure (minimal damage), the social sector where 266,326 persons (10% of population) from 169 communities were directly affected, educational sector where an estimated 518 schools were damaged, the housing sector where an estimated 70,000 houses were damaged, livelihood where 56,537 food crops, 7,170 livestock and over 3,500 fisher folk and 3,000 banana workers were directly affected, the health sector accounted for 279.53 million. There were six (6) confirmed deaths.

Table 3. Preliminary cost of damage and losses caused by Hurricane Dean ($ million)

Sector and sub-sector	$ million				
	Direct	Indirect	Total	Private	Public
Total	14,226.67	8,658.78	22,885.45	15,982.15	6,236.25
• Social	6,978.25	77.18	7,055.43	5,294.63	1,093.75
• Housing	5,961.86		5,961.68	5,294.63	
• Education and Culture	727.86		727.86		727.86
• Health	202.36	77.18	279.54		279.54
• Correctional Facilities	77.08		77.08		7.08
• Heritage Sites	9.27		9.27		9.27
Productive	3,878.19	7,708.60	11,586.79	9,416.59	2,170.20
• Domestic Crop	904.37		904.37	904.37	
• Livestock	74.50		74.50	74.50	
• Greenhouse/Protected Cultivation	52.47		52.47	52.47	
• Agricultural Crops*1	2,357.45	5603.00	7,960.45	7960.45	
• Fisheries*2	310.00	75.60	385.60	385.60	
• Irrigation	17.20	0.00	17.20	0.00	17.20
• Mining		2,030.00	2,030.00	0.00	2,030.00
• Tourism	39.20	0.00	39.20	39.20	
• Manufacturing		0.00	0.00	0.00	
• Recovery and Relief Assistance	123.00	0.00	123.00	0.00	123.00
Infrastructure	3,370.23	150.00	3,520.23	1,270.93	2,249.30
• Electricity*3	1.073.25		1,073.25	1,073.25	
• Water Supply and Sanitation	52.00	150.00	202.00		202.00
• Transport/Roads and Bridges	2,047.30		2,047.30	197.68	2,047.30
• Telecommunications*4	197.68		197.68		
• Airport			0.00		
Environment	0.00	120.00	120.00		120.00
• Forestry			0.00		0.00
• Waste Management		120.00	120.00		120.00
Emergency Operations		603.00	603.00		603.00
• Government Relief Assistance		580.00	580.00		580.00
• ODPEM Recovery Activities		23.00	23.00		23.00

In 2008 Hurricane Gustav caused damage totalling $15.16 billion in damage. A breakdown of the damage costs is presented in Table 4.

Table 4. Preliminary cost of damage and losses caused by Tropical Storm Gustav ($ million)

Sector and sub-sector	$ million				
	Damage	Loss	Total	Private	Public
Total	14,362.71	796.75	15,159.46	2,763.47	12,395.99
Social	12,60.77	120.00	1,380.77	1,046.27	354.30
Housing* 1	906.47	120.00	1,026.47	1,026.47	
Education and Culture	200.05		200.05		200.05
Health	147.84		147.84		147.84
Correctional Facilities	6.41		6.41		6.41
Productive	1,678.33	33.75	1,712.08	1,629.00	83.08
Domestic Crop	519.10		519.10	519.10	
Livestock	16.70		16.70	16.70	
Greenhouse/Protected Cultivation	19.70		19.70	19.70	
Agricultural Crops	1.063.50		1.063.50	1.063.50	
Fisheries	10.00		10.00	10.00	
Irrigation	49.33		51.68		
Mining		1.75	0.00		51.68
Tourism			0.00		0.00
Manufacturing			32.00	0.00	0.00
Recovery and Relief Assistance					32.00
Infrastructure					
Electricity	11,410.38	630.00	12,040.38	108.00	11,932.38
Water Supply and Sanitation	108.00		188.00	108.00	
Transport/Roads and Bridges	197.10	200.00	397.10		393.10
Telecommunications	2.500.00	10.00	7,530.00		7,530.00
Airport	3,600.00	400.00	4,000.00		4,000.00
Environment	5.28		5.28		5.28
Forestry	13.23	0.00	13.23	0.00	13.23
Waste Management					
Emergency operations	13.23				
Government Relief Assistance	0.00	13.00	13.23		13.23
ODPEM Recovery Activities		1.50	1.50		1.50
		11.50	11.50		11.50

As a result of Hurricane Sandy in 2012, 681,018 persons (25.2% of population) were affected from 123 communities. The impact on livelihood was that poverty rate increased by 1.7% to 23.2%. There was only one reported casualty. The damage to the health sector was estimated to be $341 million. About 152 educational institutions sustained damage. There were a total of 17,198 houses that sustained damage where a total of 807 were completely destroyed. The correctional services reported damage amounting to $5.1 million. The agricultural sector had damage amounting to $1.452 million and the fishing industry had damage totalling 13.5 million. Damage and loss of infrastructure totalled 2,688.87 million. As a result of the hurricane, water and electricity prices increased (Table 5).

Table 5. Total cost of damage and losses caused by Hurricane Sandy

Sector and sub-sector	$ Million					
	Damage	Losses	Private	Public	Total	% Share
	9,362.69	348.69	6,642.54	3,068.75	9,311.49	
	96.41	3.59	65.40	31.60		
Social	4,524.17	161.5	4,270.82	414.85	4,685.47	48.25
· Housing	4,270.82		4,270.82		4,270.82	43.98
· Education and Culture	17			17	17	0.18
· Health	180.15	161.5		180.15	180.15	3.52
· Correctional Facilities	5			5	5	0.05
· Heritage Sites	2.9			2.9	2.9	0.03
· Residential Child Care Facilities	10.9			10.9	10.9	0.11
· Jamaica Constabulary Force	6.3			6.3	6.3	0.06
· Jamaica Defence Force	31			31	31	0.32
Productive	1,573.10	101.1	1.657.92	16.48	1,674.20	17.24
· Domestic Crop	1,250.00		1,250.00		1,250.00	12.87
· Livestock	95		95		95	0.98
· Coffee	9	101	110		110	1.13
· Spices	50.5		50.5		50.5	0.52
· Greenhouse/Protected Cultivation					0	0
· Fisheries	90.37	0.1	90.37		90.37	0.93
· Irrigation	61.75		61.75		61.85	0.64
· Mining			0		0	0
· Tourism			0		0	0
· Manufacturing			0		0	0
· CASE Tutorial Farm	16.48			16.48	16.48	0.17
Infrastructure	2,582.42	86	714	1,954.42	2,668.42	27.48
· Electricity	644		644		644	0.07
· Water Supply and Sanitation	129.07	86		215.07	215	0.02
· Transport/Roads and Bridges	1,739.35			1,739.35	1,739.35	0.18
· Telecommunications	70		70		70	0.01
· Airport						
· Environment	0	0		0	0	0
· Forestry				0		0

· Waste Management				0		0
· Emergency Operations	683	0		683	683	7.03
· Government Relief Assistance	633			633	633	6.52
• ODPEM Recovery Activities	50			50	50	0.51

3.9.2.5 Damage to Health Sector Resulting from Disasters Jamaica 2004-2010

The total damage incurred in 2004 as a result of hurricane Ivan was $35,930,900,000 spread across various sectors, whereas the health sector incurred damage amounting to $758,400,000, there were 17 casualties as a result (Table 6).

In 2005, the total damage incurred as a result of Hurricane Dennis and Emily was $5,259,800,000 with the health sector incurring $29,580,000 worth of damage and 6 casualties. Additionally in 2005 Hurricane Wilma caused damage totalling $6,171,880,000, where the total damage incurred by the health sector were $45,230,000 and only one casualty.

In 2006, the November rains caused damage totalling $ 48,862,500, the health sector incurred no damage.

In 2007 Hurricane Dean caused damage totalling $23,053,920,000, and the health sector incurred damage totalling $ 298,530,000 as a result with six (6) casualties.

In 2008, Tropical Storm Gustav caused damage amounting to $ 15,514,560,000 of which the health sector incurred $423,830,000 with casualties amounting to 12 persons.

In 2010, Tropical Storm Nichole caused damage across several sectors amounting to $20,573,502,217 where the health sector incurred $270,362,557 and caused 16 casualties. From 2004 to 2010 the health sector has incurred damage totalling $1,825,932,557.

In 2008, the total structural damage to hospitals in all regions totalled J$87,950,000.00 while the total damage to equipment and supplies totalled J$2,350,000.00. Damage to health centres totalled J$38,895,000.00 with no damage to equipment and supply. Structural damage to health department totalled J$2,950,000.00 with no damage to equipment and supplies.

Table 6. Damage caused in the Health Sector by different events

Event	Year	Total Damage	Health Sector Damage
Hurricane Ivan	2004	$35,930,900,000	$758,400,000
Hurricane Dennis and Emily	2005	$5,259,800,000	$29,580,000
Hurricane Wilma	2005	$6,171,880,000	$45,230,000
Heavy Rains	2006		$48,862,500
Hurricane Dean	2007	$23,053,920,000	$298,530,000
Tropical Storm Gustav	2008	$ 15,514,560,000	$423,830,000
Tropical Storm Nichole	2010	$ 20,573,502,217	$270,362,557

3.9.2.6 Damage to National Water Commission (NWC) infrastructure from Disasters

NWC is not spared from the damage caused by storms, hurricanes and droughts. Access roads, worsening of raw water quality (due to increase in silt), blocked dams, blocked intakes, dislocated pipes, and shorter operation of filters, among others, are the mains damage caused by the above natural events.

It is important to underline the effects of droughts, such as the one in 2010, which also affected the operation of NWC facilities. Like several other water supply systems in mainly southern parishes, the water supply systems serving the Corporate Area were severely impacted by a prolonged period of below-normal rainfall caused by El Niño and other abnormal weather phenomena since 2009.

A summary of the damage caused to NWC by different events is presented in Table 7.

Table 7. Damage caused to NWC by different events in million Jamaican dollars

Event	Year	NWC Damage
Portland Flood Events	1998	$11.2
Hurricane Ivan	2004	$67.84
Hurricanes Dennis and Emily	2005	$30.16
Hurricane Dean	2007	$202.
Tropical Storm Gustav	2008	397.1
Hurricane Sandy	2012	$215.07

3.9.2.7 New Evidence on Climate Change a Health and Prediction Methods

3.9.2.8 Introduction

The second communication on climate change prepared by Jamaica presents only a partial picture of the full extension of potential health impacts that climate change can cause. This chapter presents full detailed impacts on health by climate change.

Over the past decade or more, there has been a shift in Jamaica's epidemiological profile from communicable to non-communicable diseases (NCDs) arising largely from lifestyle changes. These rapid changes in the conditions and pattern of diseases as a result of changes in the global environment continue to have a major impact on Jamaica's health conditions.

Since 1982 cardiovascular diseases, diabetes and cancers have been the leading causes of death in Jamaica. 2009 figures show that NCDs accounted for approximately 60% of deaths among men and 75% of deaths among women. Hypertensive diseases and ischemic heart disease were ranked third and fourth while breast cancer and cervical cancer ranked sixth and eighth.

The four underlying risk factors – tobacco use, unhealthy diets, physical inactivity and the harmful use of alcohol – are largely responsible for the development of NCDs. These risk factors are fairly common in Jamaica. The 2008 Jamaica Health and Lifestyle Survey show that 65% of the population 15-74 years old currently uses alcohol. By the age of 16 years, 19% of smokers had initiated smoking and 14.5% currently smoke cigarettes. Almost a half of the adult population was classified as having low physical activity or being inactive. Over 90% of persons who were diagnosed as being obese, having a high blood pressure and having high cholesterol were not on a specific diet for their condition and about 99% of Jamaicans currently consume below the daily recommended portions of fruits and vegetables.

3.9.2.9 The New Evidence

3.9.2.10 Asthma, Respiratory Allergies, and Airway Diseases

Respiratory allergies and diseases may become more prevalent because of increased human exposure to pollen (due to altered growing seasons), molds (from extreme or more frequent precipitation), air pollution and aerosolized marine toxins (due to increased temperature, coastal runoff, and humidity) and dust (from droughts).

Although data on asthma admissions to hospital were available, a time series could not be established as there were several factors not related to climate change which could explain asthma admissions. For example, in the year 2000, an intervention at Bustamante Hospital for Children, which focused on improving the management of asthma, resulted in a reduction in hospital admissions by 85% (when 2002 admissions were compared with the 2000 implementation base year) (MOH, 2004). Aggressive management of asthma has been a priority of the Ministry of Health and management protocols were improved to reduce morbidity and mortality.

3.9.2.11 Cancer

Many potential direct effects of climate change on cancer risk, such as increased duration and intensity of ultraviolet (UV) radiation, are well understood; however the potential impact of changes in climate on exposure pathways for chemicals and toxins requires further study.

3.9.2.12 Cardiovascular Disease and Stroke

Climate change may exacerbate existing cardiovascular disease by increasing heat stress, increasing the body burden of airborne particulates, and changing the distribution of zoonotic vectors that cause infectious diseases linked with cardiovascular disease.

3.9.2.13 Foodborne Diseases and Nutrition

Climate change may be associated with staple food shortages, malnutrition, and food contamination (of seafood from chemical contaminants, biotoxins, and pathogenic microbes, and of crops by pesticides).

3.9.2.14 Heat-Related Morbidity and Mortality

Heat-related illness and deaths are likely to increase in response to climate change but aggressive public health interventions such as heat wave response plans and health alert warning systems can minimize morbidity and mortality.

3.9.2.15 Human Developmental Effects

Two potential consequences of climate change would affect normal human development: malnutrition—particularly during the prenatal period and early childhood as a result of decreased food supplies, and exposure to toxic contaminants and bio-toxins—resulting from extreme weather events, increased pesticide use for food production, and increases in harmful algal blooms in recreational areas.

3.9.2.16 Mental Health and Stress-Related Disorders

By causing or contributing to extreme weather events, climate change may result in geographic displacement of populations, damage to property, loss of loved ones, and chronic stress, all of which can negatively affect mental health

3.9.2.17 Neurological Diseases and Disorders

Climate change, as well as attempts to mitigate and adapt to it, may increase the number of neurological diseases and disorders in humans.

3.9.2.18 Violence

A number of studies have demonstrated an empirical relationship between higher ambient temperatures and substrate violence, which have been extrapolated to make predictions about the security implications of climate change. This literature rests on the untested assumption that the mechanism behind the temperature-conflict link is that disruption of agricultural production provokes local violence.

3.9.2.19 Occupational Health

The effects of climate change (CC) are often discussed in terms of its impacts on the environment and the general population. To date, the scientific community has focused very little on its repercussions on occupational health and safety (OHS), yet workers can be affected both directly and indirectly by climate change, notably by the heat stress to which they may be exposed and by changes in the ecosystems that form the basis of their economic activities

3.9.2.20 Physical Activity

Based on an analysis of existing literature, links between climate change, physical activity and health have been found. It highlights the importance of physical activity for health, explores current understandings of factors influencing participation in sport and physical activity, and develops some hypotheses about the ways in which climate change may impact on the factors influencing physical activity and thereby on the level of participation in physical activity. Climate change has the potential to be a barrier to participation in physical activity, particularly in areas where temperatures are already relatively high, and that a reduction in physical activity across the population is likely to have detrimental health impacts. The need for research to clarify the nature and extent of the threat posed to physical activity participation is highlighted, as is the need to take into account the direct and indirect costs of any changes or reductions in physical activity in any assessment of the costs of climate change and/or its mitigation.

3.9.2.21 Human Health Sector Tools (WHO (2003))

The health tools that have been developed, listed in Table 8, differ significantly in their scope and application. Some facilitate the investigation of multiple or overall disease burden and how this burden responds to a number of environmental stressors, including climate change (MIASMA and Environmental Burden of Disease Assessment). Others are more narrowly focused and model the health impacts or transmission dynamics of particular diseases (CIMSiM and DENSiM, LymSim, and MARA LITe). They aid in identifying areas of high risk, and are particularly useful for areas currently endemic to diseases like malaria, dengue fever, and Lyme disease or in close proximity to such areas. Modelling adaptation strategies in the health sector is an emerging field, so the number of tools and approaches available explicitly designed for this purpose is still limited. The UNFCCC Guidelines is one such example. However, all the human health tools detailed in this section are suited to examining impacts of climate change on human health and potential adaptations. In our case the LymSim and MARA LITe models are not going to be considered.

Table 8. Tools covered in human health sector

	Data Required	Output
MIASMA (Modelling Framework for the Health Impact Assessment of Man-Induced Atmospheric Changes)	Maximum and minimum temperature, column loss of the stratospheric ozone, rainfall, immunity and malaria drug resistance malaria.	Cardiovascular, respiratory, and total mortality; malignant melanoma and non-melanoma skin cancer; malaria cases and fatalities, and dengue and schistosomiasis incident cases
Environmental Burden of Disease Assessment	Baseline burden of climate-sensitive diseases; estimated increase in the risk of disease/disability per unit increase in exposure to climate change; future population distribution of exposure.	DALYs (disability adjusted life years) or avoided deaths that can be compared between populations and between specific health impacts of climate change.
CIMSiM and DENSiM (Dengue Simulation Model)	A pupal/demographic survey, maximum/minimum temperature, rainfall, and saturation deficit.	Demographic, entomologic, serologic, and infection information on a human age-class and/or time basis.
UNFCCC Guidelines: Methods of Assessing Human Health Vulnerability and Public Health Adaptation to Climate Change	Literature search focused on the goals of the assessment, quantitative assessment using available data, quantification of effects, and a formal peer review of results	Description of current distribution and burden of climate-sensitive diseases; and of the adaptation baseline; evaluation of health implications of the potential impact of climate change on other sectors; estimates of the future potential health impact of climate change and identification of additional adaptation measures to reduce current and future vulnerability.

3.9.2.22 MIASMA (Modelling Framework for the Health Impact Assessment of Man-Induced Atmospheric Changes)

MIASMA is a Windows-based modelling application that models several health impacts of global atmospheric change and include simulation for several modules: 1) vector-borne diseases, including malaria, dengue fever, and schistosomiasis; 2) thermal heat mortality; and 3) UV-related skin cancer due to stratospheric ozone depletion. The models are driven by both, population and climate/atmospheric scenarios, applied across baseline data on disease incidence and prevalence, climate conditions, and the state of the stratospheric ozone layer.

MIASMA can be used to link GCM output of climate change or scenarios of stratospheric ozone depletion to any of the human health outcomes mentioned above. Applicability of this model is limited only by the scope of available data. Additional Information is presented in Table 15.

3.9.2.23 Environmental Burden of Disease Assessment

The global burden of disease attributable to climate change was recently estimated as part of a comprehensive World Health Organisation (WHO) project. The project sought to use standardized methods to quantify disease burdens attributable to 26 environmental, occupational, behavioural, and life-style risk factors in 2000 and at selected future times up to 2030. The Environmental Burden of Disease (EBD) tools include guidelines on how to estimate the approximate magnitude of the health impacts of various environmental factors, including climate change, at national or regional level, to help determination of priorities for action.

An EBD assessment for climate change will indicate which impacts could be greatest and in which regions, and how much of the climate-attributable disease burden could be avoided by emissions reduction. It also will guide health-protective strategies.

3.9.2.24 CIMSiM and DENSiM (Dengue Simulation Model)

CIMSiM is a dynamic life-table simulation entomological model that produces mean-value estimates of various parameters for all cohorts of a single species of Aedes mosquito within a representative 1 ha area (Focks et al., 1993).

The models can be used to 1) optimize dengue control strategies using multiple control measures; 2) develop transmission thresholds in terms of Ae. Aegypti pupae per person as a function of temperature and herd immunity; and 3) evaluate the impact of climate change.

3.9.2.25 UNFCCC Guidelines: Methods of Assessing Human Health Vulnerability and Public Health Adaptation to Climate Change

It provides information on qualitative and quantitative methods of assessing human health vulnerability and public health adaptation to climate change. Objectives and the steps for assessing vulnerability and adaptation are described. For a range of health outcomes, methods are presented for evaluation of evidence that climate change could affect morbidity and mortality; projection of future impacts; and identification of adaptation strategies, policies, and measures to reduce current and future negative effects. The health outcomes considered are morbidity and mortality from heat and heat-waves, air pollution, floods and windstorms, and food insecurity; vector-borne diseases; water- and food-borne diarrheal diseases; and adverse health outcomes associated with stratospheric ozone depletion.

3.9.2.26.1 Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s

3.9.2.26.1 Introduction

The World Health Organisation prepared a report on "Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s". This report summarises the potential impact of climate change on health metrics and attributable mortality for two future time periods: 2030 and 2050 (WHO, 2014).

The assessment is an advance on previous studies(Campbell-Lendrum, 2006), but it is still constrained by limited quantitative information about, and understanding of, causal mechanisms linking climate with health impacts on a global and local scale. They did not assess the current burden of disease due to observed climate change (warming since the 1960s) (WHO 2009a).

Climate change risks are systemic and long term in nature, requiring a different approach to assessment compared with other environmental exposures. Global burden of disease studies have focused on proximal risk factors and historical patterns with relatively little attention paid to upstream causes (Lima, et al 2012).

Burden of disease studies also focus on current exposures rather than future exposure and the long timescales required by climate change assessments. Climate change poses qualitatively different risks to human health, mainly via indirect pathways (McMichael AJ, 1999). These features result in unique challenges for health risk assessment. There is a need to improve estimates of the effects of climate change on health on a global and regional scale (Campbell-Lendrum, et al. 2009). The latest assessment of the Intergovernmental Panel on Climate Change (IPCC) found significant evidence gaps (Smith, et al. 2014). For example, uncertainties about future vulnerability, exposure and responses of interlinked human and natural systems were acknowledged to be large, indicating the need to explore a wide range of socioeconomic futures in assessments of climate change-related risks.

Since the first global risk assessment was published (McMichael, et al (2004)), there has been some development of global models to estimate climate change impacts for a range of health issues, particularly for malaria (Caminade, et al, 2014) and under-nutrition (Nelson, et al, 2010; Lloyd, et al, 2011).

The health impacts of climate change described in WHO report are mortality caused by heat, coastal flooding, diarrhoeal disease, malaria, dengue and under-nutrition (Figure 1). Models were run with a consistent set of climate, population and socioeconomic scenarios, as far as was technically possible. In keeping with current approaches to scenario-based climate impacts assessment, climate and non-climate scenarios were kept separate in the presentation of results.

They also assessed, as far as possible, uncertainties associated with each impact model. They assessed the effect of climate model uncertainty by including a range of climate model projections. Estimates were done with and without inclusion of adaptation to climate change, as far as technically feasible (Table 6.1).

Because of the above, in this report, it is not possible to use the models developed by WHO because of the following:

- Models' outputs are for the Caribbean Region
- Models estimate only mortality, but morbidity represents a high expenditure in health care services, so the adaptation costs using these models will not be representing the true costs.

The outputs of the models are regional (Caribbean Region). However, there is a big difference in the social, economic and health conditions among the Caribbean countries (Table 9). From the table it is possible to observe the big differences in population size where Cuba, Haiti and the Dominican Republic are the countries with the largest population. In the case of under-five, chronic malnutrition Jamaica, Cuba and Trinidad and Tobago have very low rates of malnutrition compared with Haiti. The same situation exists with the under-five mortality rate.

Due to these constraints, this report is using mathematical models developed by ECLAC (2011) regarding gastroenteritis, dengue, and leptospirosis, to estimate the impacts and the adaptation costs for years 2030 and 2050.

Table 9. Socio-Economic and health indicators in some Caribbean Countries

Country	Total Population	Population without access to sanitation improved (per thousands) (1)		Gini Coefficient (10)	Under-five mortality rate (probability of dying by age 5 per 1000 live births) (11)	Under-five chronic xamalnutrition (2009-2013) (12)	Diarrhoeal Diseases (per 100 under-five children) (13)	Diabetes Age Adjusted Death Rate/100,000 (14)	Life Expectancy (15)	GDP Per Capita (16)
	Thousand	Urban	Rural							
Antigua and Barbuda	92	2	6	NI	9.3	NI	NI	No Data	75.4	23700
Barbados	283	3	7	NI	14.4	NI	NI	44.94	78.1	16700
Cuba	11411	491	292	NI	6	7x	51	16.35	78.3	10200
Guyana	764	26	99	44.6	36.6	20	50	128.6	63.5	7200
Haiti	10,608	3,347	4,503	60.8	72.8	22	53	72.13	62.8	1800
Jamaica	2783	300	205	45.5	16.6	5	64	76.62	74.4	8800
Dominican Republic	10408	1,059	666	47.1	28.1	10x	48	25.25	73.7	14900
Saint Vincent	109	13	13	NI	19	NI	NI	No Data	73.9	11000
Suriname	538	41	70	57.6	22.8	9	42	38.58	77.2	16700
Trinidad and Tobago	1354	10	104	NI	21.3	5x	NI	128.4	70.5	32800

(1)CEPALSTAT. http://interwp.cepal.org/perfil_ODM/

(2) World Bank Indicators ver: http://wdi.worldbank.org/table/2.9

(3) WHO. 2015. World Health Statistics 2015. http://apps.who.int/iris/bitstream/10665/170250/1/9789240694439_eng.pdf?ua=1

(4) UNICEF. 2013. Improving child nutrition. The achievable imperative for global progress http://data.unicef.org/corecode/uploads/document6/uploaded_pdfs/corecode/NutritionReport_April2013_Final_29.pdf

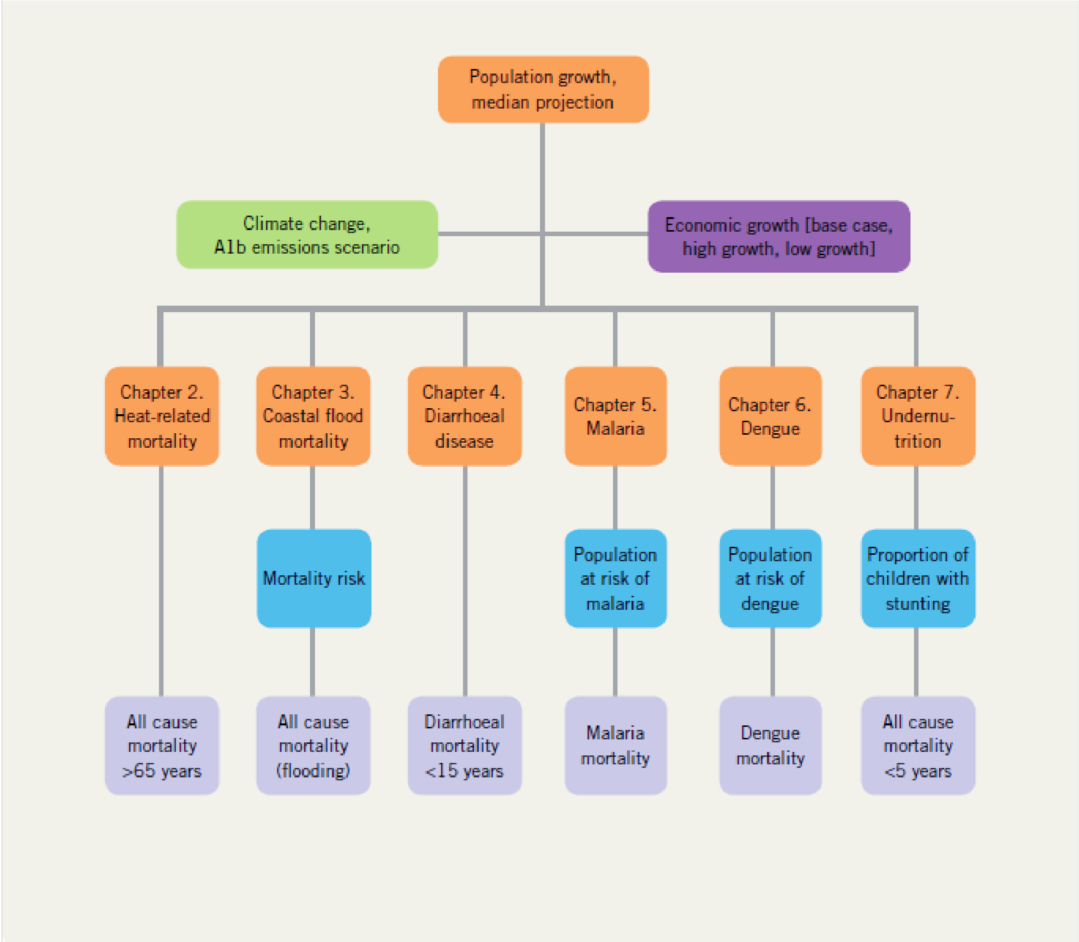
(5) UNICEF. 2014. Estado Mundial de la Infancia 2015. Porcentaje de niños menores de 5 años con diarrea durante las dos semanas que precedieron a la encuesta y que recibieron SRO. http://www.unicef.org/spanish/publications/files/SOWC_2015_Summary_Spanish_Web.pdf

(14)http://www.worldlifeexpectancy.com/world-diabetes-report

(15) http://www.worldlifeexpectancy.com/your-life-expectancy-by-age

(16)http://www.worldlifeexpectancy.com/gdp-per-capita-by-country

Figure 1 Models used in WHO's assessment, with output metrics



3.9.27 The Health Status of Communities

3.9.27.1 Introduction

To assess the disease situation in the Jamaican communities, information from different sources was used, as follows:

1. Global Burden of Disease Profile: JAMAICA. Institute for Health Metrics and Evaluation, 2010
2. Annual Summary Reports (2000 – 2014) of Clinical Activities: Curative Services. MCSR System, Ministry of Health.
3. A survey commissioned by the Jamaica Environment Trust (JET) as part of a project entitled Building Capacity in Jamaican Mining Communities to protect their Environmental Rights, funded by the Inter-American Foundation (IAF). The survey was carried out by a team of researchers led by the author.
4. A health survey in five rural and urban communities in the Kingston Metropolitan Area (Hannah Town, Ra Town and Kintyre) and in rural communities (Kitson, St. Catherine and Barret Town). This survey was conducted as part of this contract.
5. A study done by Dr. Aye (2014)called "Comparison of different factors affecting the control of hypertension in selected urban and rural patients", prepared by Dr. Moe Aye

A study done by Dr. Thu Ya (2014). "Barriers to Self- Management of Diabetes Patients (Patient's Perspective) in St. Mary, Jamaica"

In this report, two main diseases will be discussed: Vector-Borne disease and chronic diseases.

3.9.27.2 Vector-borne diseases

Aedes aegypti is a species of international concern because it can transmit to humans several important diseases: yellow fever, dengue and Chikungunya, which have spread to all continents (Lima, et al, 2015). As of the year 2015, a fourth disease condition, the Zika virus, has become of international public health concern as an association has been established between having this infection; Guillain-Barre syndrome and microcephaly. The main one of these diseases is still dengue, whose incidence has increased 30 fold in the past 50 years, with increasing geographic expansion to new countries. In the last 10 years it has also expanded to smaller towns and rural areas (Lima, et al, 2015).

Population explosion and the rapid growth of cities lead to deterioration in sanitary conditions. The reduction of vegetation and shade outside houses, together with an increase in water deficit in water distribution which has forced people to use man-made containers for drinking water, promotes the breeding of Aedes Aegypti (Kantachuvessiri, A. 2002). The mosquito has a wide variety of breeding sites and thrives in urban settings with poor sanitation. It has evolved to adapt to drought conditions, as the eggs can resist desiccation for one year and continue their life cycle when breeding sites get flooded with water (WHO, 1997).

The last major epidemic in Jamaica was in 1998 when 1,509 persons were infected and 42 cases of dengue haemorrhagic fever/dengue shock syndrome were confirmed (CAREC, 2008). The total number of dengue fever cases reported each month for the period 1995-2007 was obtained from the Ministry of Health, Jamaica (ECLAC, 2011). The maximum number of cases seen per month during this period was 850. The mean number of cases seen was 32 (+ 118) cases. The trend in the number of dengue cases per month showed a decline over time at a rate of -0.128. Rainfall and maximum temperature increased with time (see table 8).

Table 8: Descriptive statistics of historical disease and climate variables(dengue fever)

	N	Minimum	Maximum	Mean	Std. Deviation	Trend/gradient
Dengue	156	0	850	32.15	118	*-0.128
Historical Rain	156	7	595	161.62	112	**0.155
Historical Temperature Max	156	26.52	32.19	29.66	1.36	**0.048

Note: *Generated from lineal trend ** Generated from Holt-Winter exponential smoothing
Source: ECLAC, 2011

The study of the potential impact of climate change on the transmission of dengue fever is of particular importance to Jamaica, as the country has the three main predictors of transmission. These include:

(a) The abundance and geographical distribution of the vector.

(b) The circulation of all four dengue fever serotype (1-4) viruses.

(c) Viable breeding sites in the wet (poor sanitation and blocked drains) and dry (water storage tanks and septic tanks in the home) seasons.

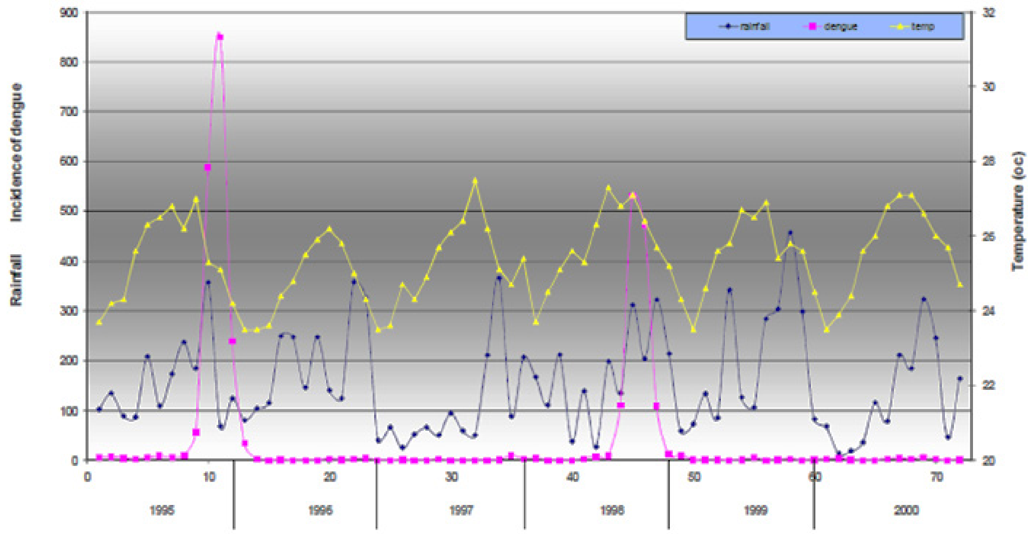
The incidence of the disease is associated with climatic factors; warmer temperatures increase the transmission by increasing the rate of mosquito development and viral multiplication (Wilson, 2001). Increasing temperatures reduce the incubation period of the virus within the mosquito, which results in potentially higher transmission rates (Watts, et al., 1987). It has also been shown that increasing temperature is associated with increases in the intake of blood meals by the vector (McDonald, G., 1957).

An analysis of dengue records and climate variability data by Heslop-Thomas and colleagues (2006) indicates a clear seasonality to dengue outbreaks within the Caribbean, with a tendency to peak in the latter months of the year. Dengue outbreaks lagged 3-4 weeks after maximum rainfall of between 200-400 mm, and 6-7 weeks after an increase in temperature of 1°-2° Celsius (Figure 2) (Chen, et al., 2006).

There has been considerable research on the potential disease burden of dengue due to climate change. Chen (2007) indicates that dengue fever transmission in the Caribbean will increase by approximately threefold, as increased temperature reduces the time for the parasite to incubate in mosquitoes, resulting in more rapid transmission of the disease. An estimated figure of approximately 60,037 disability-adjusted life years (DALYs) would be lost in Jamaica in a population of approximately 3 million. In addition, the chances of transmission of the more serious dengue haemorrhagic fever will be increased (GOJ, 2011).

A retrospective review of dengue fever cases (1980-2002) was carried out in relation to ENSO events in the Caribbean (Amarakoon, et al., 2005). The review showed that there were more occurrences of dengue fever in the warmer, drier period of the first and second years of El Niño events. Normally, however, it is during the wet season that Caribbean countries are at greatest risk of dengue fever transmission, suggesting that vector mitigation programmes should be targeted at that time of year to reduce mosquito breeding and dengue fever transmission (Chadee, et al., 2006).The threat of dengue fever may not be diminished by reduced rainfall, since water is expressly stored in 40-gallon tanks during times of water shortage, and these containers are perfect incubators for Aedes aegypti mosquitoes. Linkages established by using real-time data collected during the project (Prospective study) and 40 gallon drums were found to be major breeding habitats for the dengue vector (Chen, et al., 2006).

Figure 2. Time series graph of reported cases of dengue with rainfall and temperature for Jamaica



*Monthly rainfall (mm), incidence of dengue number of new cases
Source: CSGM Reproduced with permission

Source: Climate Studies Group Mona (CSGM), University of the West Indies

Regarding the Chikungunya Virus in Jamaica and sanitation conditions, results obtained from the community survey conducted under this study indicate that there is an odds ratio of 2.497 between those who do not have water 24 hours a day (Intermittent service)(exposed) and those who do(non-exposed). Also, there is an odds ratio of 2.395 between those who are not connected to a sewer system (on-site disposal) (exposed) and those who do (non-exposed). Finally there is an odds ratio of 3.353 between those who have an intermittent water supply and on-site system (exposed) and those who have a continuous water supply and are connected to a sewer system (no-exposed). What it means in the last case is that for every person non-exposed there are 3.353 persons exposed/affected by Chikungunya. The results are statistically significant at a 95% confidence level (Table 10).

Table 10. Risk Estimate of Chikungunya and water and sanitation conditions

	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for Piped water 24 hours (Yes / No)	2.497	1.507	4.138
Odds Ratio for Connected to Sewer (Yes / No)	2.395	1.398	4.101
Odds Ratio Intermittency and Onsite / Continuity and sewer	3.353	1.806	6.224

In light of potentially higher incidence of dengue and other previously controlled communicable diseases, vector control will be critical. Better management of garbage (See Chapter, for a discussion garbage collection) and improved hygiene will become increasingly important in developing adaptation strategies against these threats in the face of changing climate.

Serious outbreaks of dengue epidemics in Jamaica would have negative effects, as funds earmarked for social and economic development would have to be diverted from these priorities. Given Jamaica's limited fiscal space, these trade-offs may be detrimental to development.

3.9.27.3 Chronic Diseases

What is the real health status of the communities in Jamaica, especially in chronic diseases? There are a number of diseases that are known as "silent killers" because they gradually consume the individual without causing any serious symptoms in the early stages.

Heart disease, hypertension and diabetes are major silent killer diseases. Heart disease is the number one silent killer disease. The main risk factors that contribute to this increased risk include hypertension, smoking, sedentary lifestyle, obesity, and raised cholesterol.

Regular medical check-ups and early diagnosis of unexplained or vague symptoms can save many lives. Unfortunately, many persons go the health care system when is too late. This situation prevents us of having a real picture of the diseases present in the community.

The Government of Jamaica uses approximately 33 billion Jamaican dollars each year (2013-2014 Jamaica Budget report, Ministry of Finance) compared to 15 billion Jamaican dollars usage (2005-2006 Jamaica Budget report, Ministry of Finance) before introducing the no user fee policy. According to the National Health Fund, chronic non-communicable diseases, including diabetes, are a major health care burden of Jamaica.

In Jamaica, the incidence of type 2 diabetes has been steadily increasing since 1960. Wild et al. (2004) predicted that Jamaica is to see an increase from 3.1% in 2000 to 5.5% by 2030. However, the prevalence of diabetes as defined by the WHO 2006 (Ezzait, M, et al., 2002) was 7.9 % of the population.

The Jamaica Health and Lifestyle Survey 2007–2008 (Ferguson, et al.) revealed that 8% of Jamaicans had diabetes; 12% has hypercholesterolemia and 25% had obesity. A higher proportion of women than men were found to have diabetes, obesity and hypercholesterolemia. According to Ragoobirsingh (1995), diabetes affects 17.9% of the population. Approximately 327,000 Jamaicans had diabetes in 2001, and it is projected to be approximately 450,000 in 2025. 50% of the Jamaican population is unaware of the risk of having diabetes and its complications.

The recent data from the Ministry of Health and Registrar General's Department in Jamaica continue to show a high mortality for diabetes in Jamaica. In 1999, diabetes was ranked as the third leading cause of death in Jamaica with a death rate of almost 60/100,000, while in 2004 it was ranked second with a death rate of 70/100,000. Therefore, Diabetes is the second leading cause of death in Jamaica (Registrar General Office, Statin, 2007).

The growing numbers of people with diabetes among other chronic non-communicable diseases are the heaviest users of health care services with high utilisation rates in all major services such as hospitalisations, office visits, home health care, and prescription drugs (Shrivastava, S. R. et al, 2013). It was found that the annual cost of diabetes in the year 2001 was 221 million USD in Jamaica (MOH, 2013).

It is worth it to mention that Diabetes Mellitus is not the only challenge faced by patients, but McCarthy (2000) argues that approximately 30% to 60% of diabetics also suffer from depression, which is a psychiatric illness. Such a situation further complicates the woes of the elderly as they seek to balance other psycho-sociological conditions with the diabetes and hypertension as well as the stress that is frequently associated with the illness.

The unpublished report from Annotto Bay Health Centre Diabetic Clinic, St. Mary, Jamaica (2012) indicated that:

- The 358 clients (78.9% of total) on the register had a dual diagnosis of both diabetes and hypertension, which significantly increases their risk of cardiovascular complications.
- About 78.6% of them were female.
- Only about 54.6 % of them had HbA1c results in their dockets.
- Very few about 4.2% had good control of diabetes.
- More than 56% of them had mild/moderate "lack of control".
- More than 39.8% of them were uncontrolled.

3.9.27.4 Burden of Disease

The Global Burden of Disease Study 2010 (Institute for Health Metrics and Evaluation, 2010) is a collaborative project of nearly 500 researchers in 50 countries led by the Institute for Health Metrics and Evaluation (IHME) at the University of Washington. It is the largest systematic scientific effort in history to quantify levels and trends of health loss due to diseases, injuries, and risk factors. The Global Burden of Disease (GBD) serves as a global public good to inform evidence-based policymaking and health systems design.

Profile overview. In terms of the number of years of life lost (YLLs) due to premature death in Jamaica, HIV/AIDS, cerebrovascular disease, and interpersonal violence were the highest ranking causes in 2010. Of the 25 most important causes of burden, as measured by disability-adjusted life years (DALYs), diarrheal diseases showed the largest decrease, falling by 60% from 1990 to 2010. The leading risk factor in Jamaica is dietary risks.

All-Cause Mortality Rate. Graph 1 shows the change in mortality rate at every age range. The points above 0 on the chart indicate positive declines in the all-cause mortality rate, while points below 0 indicate an increase in mortality rate between 1990 and 2010.The greatest reductions in all-cause mortality rate were experienced by females aged 1-4 years (46%). Males aged 30-34years saw the largest increase in mortality rate (107%).

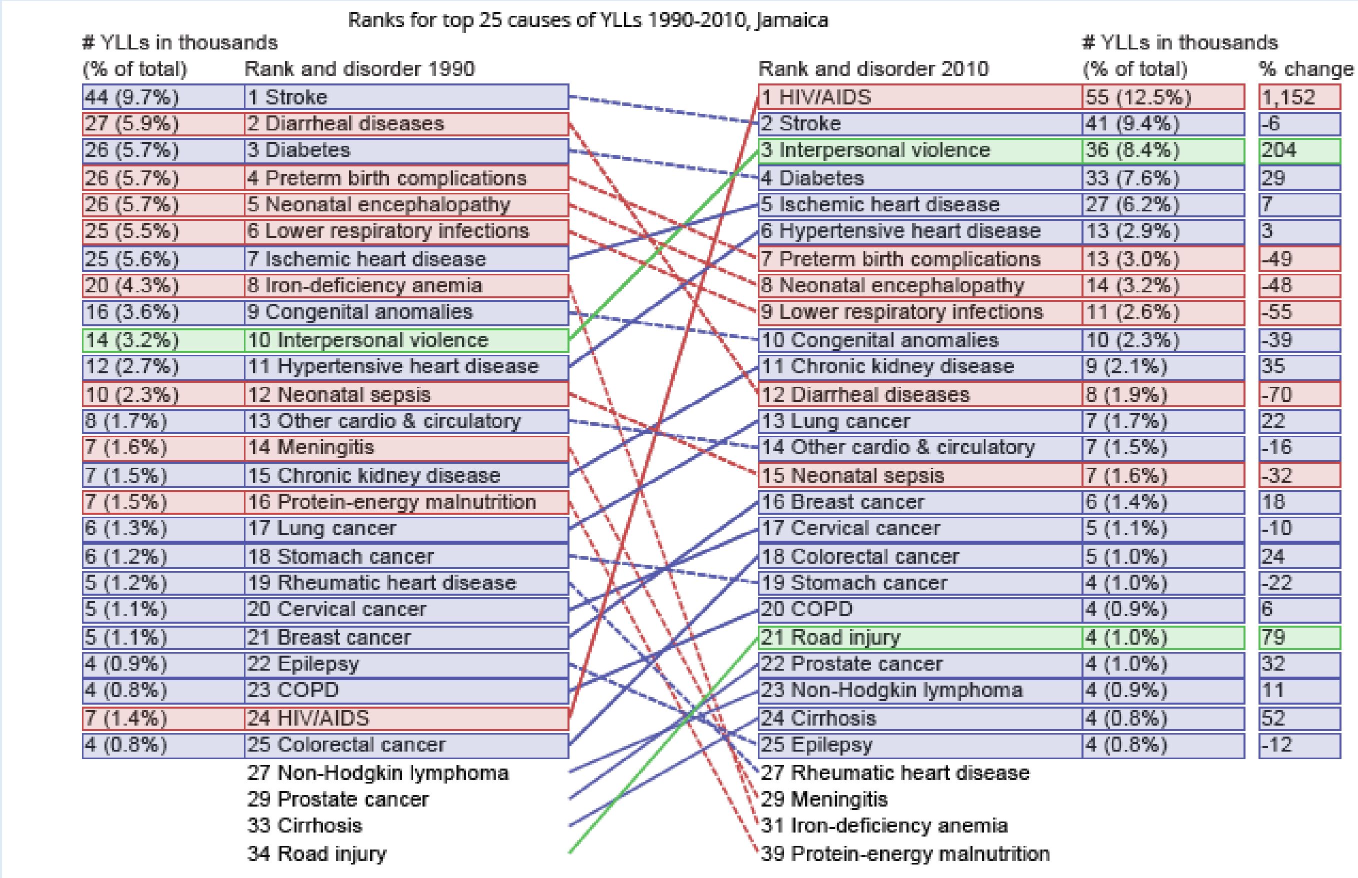
Causes of Premature Death. Years of life lost (YLLs) quantify premature mortality by weighting younger deaths more than older deaths. Graph 1 shows the change in the top 25 causes of YLLs due to premature mortality from 1990 to 2010.

Solid lines indicate a cause has moved up in rank or stayed the same. Broken lines indicate a cause has moved down in rank. The causes are coded by blue for non-communicable diseases, green for injuries, and red for communicable, maternal, neonatal, and nutritional causes of death.

Graph 1 Per cent decline in age-specific mortality rate by sex from 1990-2010 in Jamaica

Source: Institute for Health Metrics and Evaluation (2010)

Figure 3. Ranks for top 25 causes of YLLs 1990-2010, Jamaica

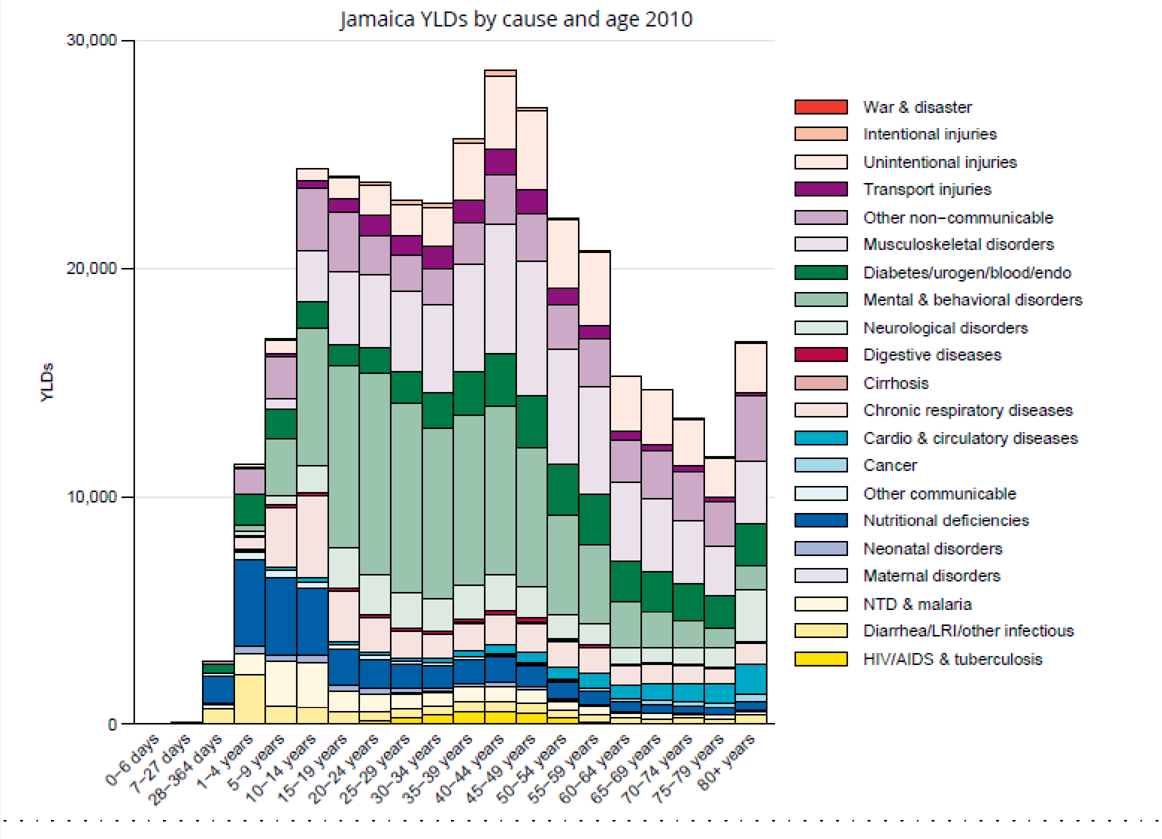


Source: Institute for Health Metrics and Evaluation (2010)

Years Lived with Disability (YLDs). Years lived with disability (YLDs) are estimated by weighting the prevalence of different conditions based on severity. The top five leading causes of YLDs in Jamaica are major depressive disorder, lower back pain, iron-deficiency anaemia, anxiety disorders, and diabetes mellitus (Figure 4). The size of the colour portion in each bar represents the number of YLDs attributable to each cause. The height of each bar shows which age groups had the most YLDs in 2010. The causes are aggregated. For example, musculoskeletal disorders include lower back pain and neck pain. Table 11 presents YLDs for the 7 largest conditions.

Disability-Adjusted Life Years (DALYs). They quantify both premature mortality (YLLs) and disability (YLDs) within a population. In Jamaica, the top three causes of DALYs in 2010 were HIV/AIDS, diabetes mellitus, and cerebrovascular disease (Figure 5). The top 25 causes of DALYs (Figure 5) are ranked from left to right in order of the number of DALYs they contributed in 2010. Bars going up show the per cent by which DALYs have increased since 1990. Bars going down show the per cent by which DALYs have decreased. Two causes that appeared in the 10 leading causes of DALYs in 2010 and not 1990 were HIV/AIDS and interpersonal violence. Globally, non-communicable diseases and injuries are generally on the rise, while communicable, maternal, neonatal, and nutritional causes of DALYs are generally on the decline.

Figure 4. Jamaica YLDs by cause and age 2010



Source: Institute for Health Metrics and Evaluation (2010)

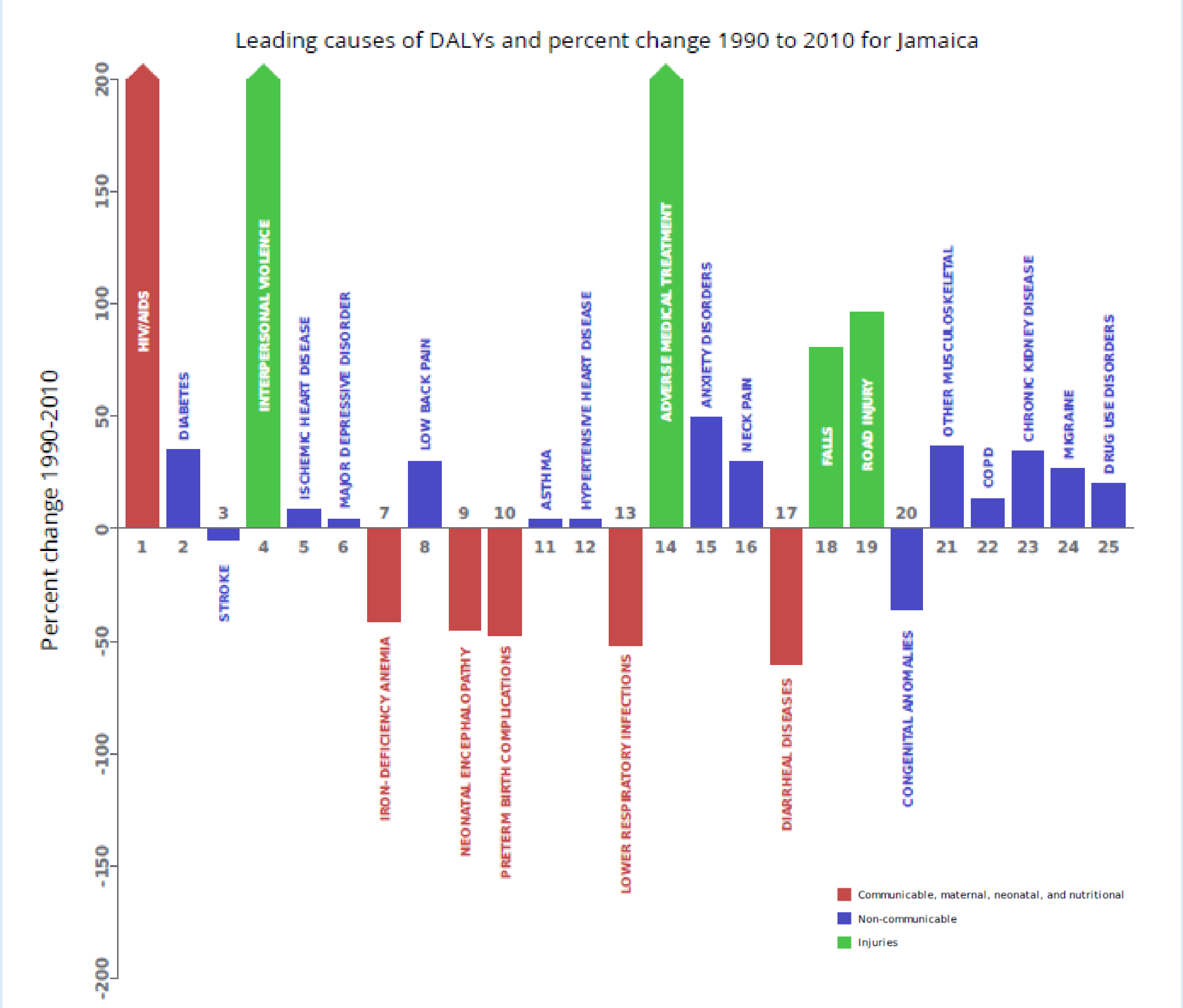
Table 11. Years lived with disability (YLDs) by cause and age 2010, Jamaica

1	Mental & Behavioural Disorders	76,415
2	Musculoskeletal Disorders	56,604
3	Other Communicable	34,340
4	Unintentional Injuries	32,642
5	Diabetes/Urogen/Blood/Endo	29,057
6	Chronic Respiratory Diseases	23,019
7	Cardio & Circulatory Diseases	8,208
	Total Years lost for Disability	260,283

Risk Factors. Overall, the three risk factors that account for the most disease burden in Jamaica are dietary risks, high blood pressure, and high fasting plasma glucose. The leading risk factors for children under 5 and adults aged 15-49 years were iron deficiency and dietary risks, respectively, in 2010. Graph 2 shows the top 15 risk factors for Jamaica. The colour portion of each bar represents the specific diseases attributable to that risk factor while bar size represents the percentage of DALYs linked to specific risk factors.

As it can be observed several of the risk factors are associated especially dietary risks, high blood pressure, high fasting glucose, high body-mass index and physical inactivity.

Figure 5. Leading causes of DALYs and per cent change 1990 to 2010 for Jamaica



Source: Institute for Health Metrics and Evaluation (2010)

3.9.28 Annual Summary Reports (2000 – 2014) of Clinical Activities: Curative Services.

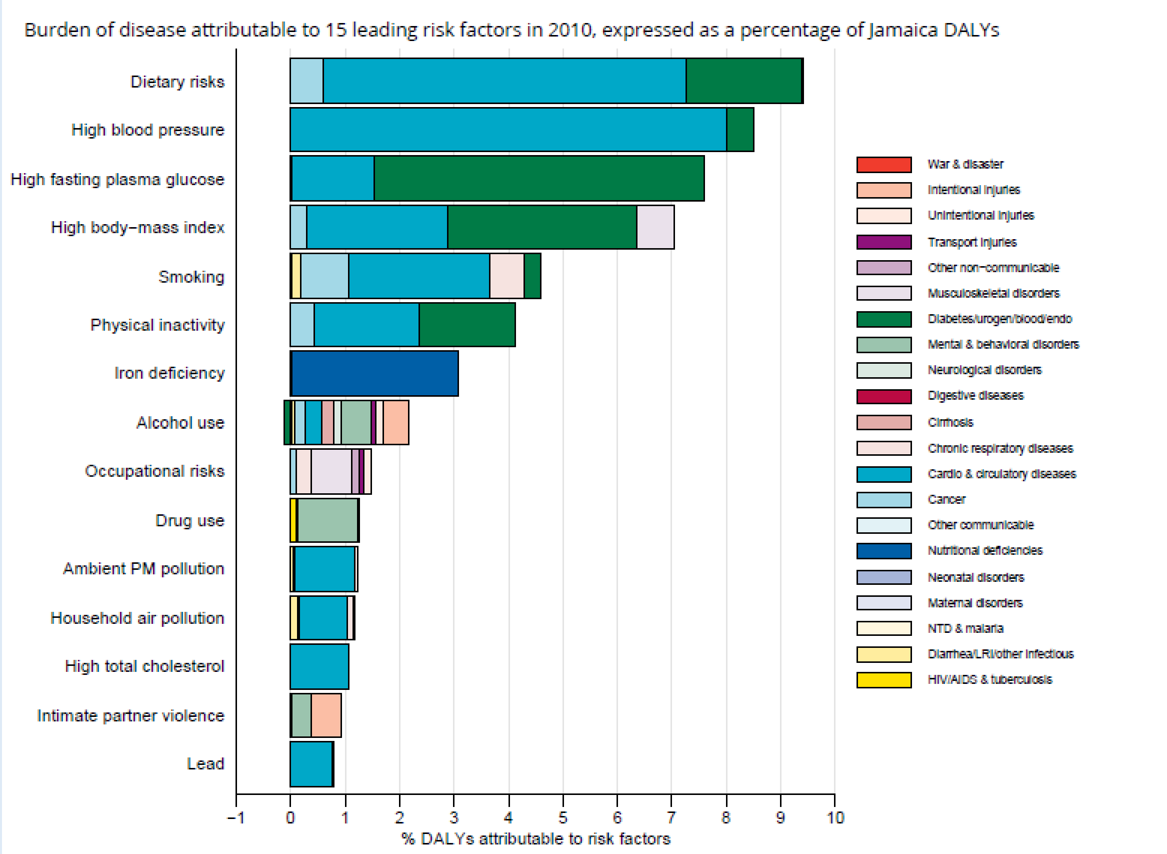
Information about curative services on Diabetes, Hypertension, Mental Health, Upper Respiratory Diseases, and Asthma was obtained from the Ministry of Health. Tables 12, 13, and 17, presents summary of the results. From here we can observe the following:

- A 10.4% reduction of curative services in patients with diabetes, however there has been an increase of 152% in curative services in patients that present both diabetes and hypertension (10.9% increase per year).
- A 96% increase of persons attended for hypertension (6.9% increase per year).
- A 91.3% increase of total diabetes and hypertension Visits (6.5 % increase per year).
- Diabetes, hypertension and diabetes/hypertension is a gender issue (Table 13), for diabetes females visit the health care facilities 2.53 more times than male, for Hypertension 3.1 times than male and for Diabetes/Hypertension 3.64 times. However, number of visits has increased at a faster rate in males than in females. For example in the case of hypertension during the period of 2000 to 2014, the number of male visits increased from 25,529 to 51,061 (100% increase), while female visits increased from 94,211 to 158,380 (a 68% increase). See Graph 3.
- In the case of psychiatry services (Table 17) the number of visits has increased 2.61 times (from 24,035 to 62,633). This represents an increase of

161.6% during the period or a 10.7 % per year.

- The rate of increase of psychiatry visits by gender is higher in males (2.85 times) than in females (2.37 times).
- Regarding visits for Upper Respiratory Tract Infections (URTIs) an increase of 19% during the period. There are 1.62 more female visits than males. There increase of visits during the period is higher in females (1.22) than males (1.14).
- In the case of Asthma visits, an increase of 76.1 % occurred during the period or 5.1 % per year. There are more 1.744 times females' visits than males. Also the rate of increase of visits is higher in females (2.322 times) than in males (1.76 times).

Graph 2. Burden of disease attributable to 15 leading risk factors in 2010, expressed as a percentage of Jamaica DALYs



Source: Institute for Health Metrics and Evaluation (2010)

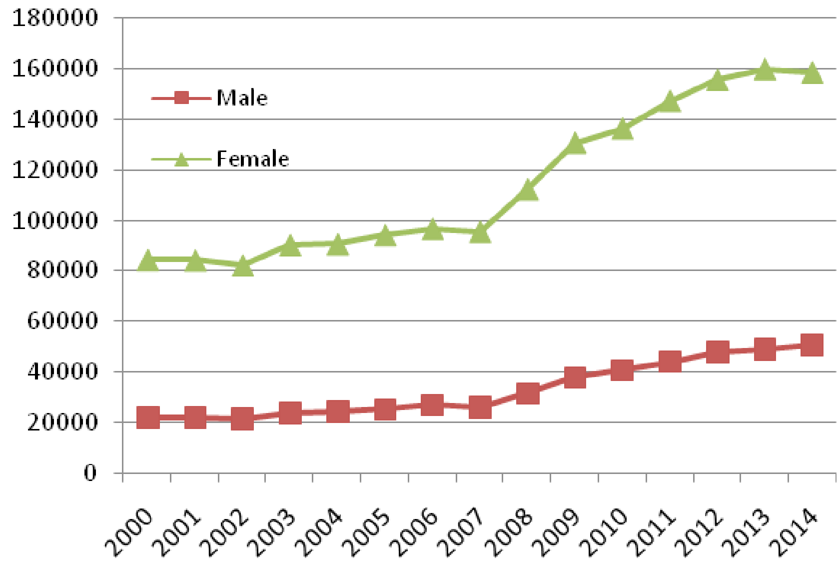
Table 12 Visits to MOH Health Care Facilities for Diabetes and Hypertension Medical care

	DIABETES Total Attended	HYPERTENSION Total Attended	DIABETES/ HYPERTENSION Total Attended	TOTAL DIABETES & HYPERTENSION VISITS Total Attended
Year	No	No	No	No
2000	32579	106706	45546	184831
2001	31937	106699	49247	187883
2002	31225	103916	51903	187044
2003	30630	114279	60595	205504
2004	28910	115097	63632	207639
2005	27080	119740	65327	212147
2006	25560	123830	68829	218219
2007	24519	122130	67679	214328
2008	28085	144232	75878	248195
2009	31493	168819	90530	290842
2010	30511	177317	95844	303672
2011	30366	191582	102927	324875
2012	31364	203465	111946	346775
2013	29657	208807	113424	351888
2014	29191	209441	114984	353616

Table 13 Visits by Gender to MOH Health Care Facilities for Diabetes and Hypertension Medical care

	DIABETES Total Attended		HYPERTENSION Total Attended		DIABETES/HYPERTENSION Total Attended		TOTAL DIABETES & HYPERTENSION Total Attended
Year	M	F	M	F	M	F	
	No	No	No	No	No	No	No
2000	7447	25132	22339	84367	8449	37097	184831
2001	7487	24450	22479	84220	9035	40212	187883
2002	6989	24236	21710	82206	9003	42900	187044
2003	7094	23536	24031	90248	10486	50109	205504
2004	6852	22058	24513	90584	11247	52385	207639
2005	6381	20699	25529	94211	11878	53449	212147
2006	6133	19427	27180	96650	12639	56190	218219
2007	5766	18753	26533	95597	12367	55312	214328
2008	6902	21183	31912	112320	13992	61886	248195
2009	7902	23591	38151	130668	17685	72845	290842
2010	7766	22745	41032	136285	19357	76487	303672
2011	7753	22613	44438	147144	20877	82050	324875
2012	8114	23250	47950	155515	23115	88831	346775
2013	7840	21817	49142	159665	24139	89285	351888
2014	8280	20911	51061	158380	24793	90191	353616

Graph 3 Increase of hypertension by gender during the period of 2000 to 2014



The Statistical Package for the Social Sciences (SPSS) version 21 was used to obtain the predictive models. The Moving Average Method for 3 consecutive years was used to predict the future conditions for 2030 and 2050 for the above diseases. The statistical results are presented in Table 14 and the models obtained in Table 15.

Disease projection for 2030 and 2050 are presented in Table 16. From information obtained from STATIN/PIOJ/UWI Population Projections the Jamaican Population by 2015 was 2,761,000, by 2030 is expected to be 2,872, 000 (an increase of 3.8%) and for 2050 2,819,000 (an increase of 2.05%). Therefore, the rate of disease increase of any category of disease is much higher than the increase of population. For example in the case of hypertension for period 2015 to 2030 the percentage of increase is 57.86%, while the population will only increase 3.8% during that period.

In summary, it is possible to conclude that:

- The number of visits to health care facilities has increased, except for diabetes, for hypertension, diabetes/hypertension, psychiatry, URTI and asthma.
- Psychiatry visits present the highest rate of increase follow by diabetes/hypertension.
- Except for psychiatry services, female visits are much higher than male visits.

Rate of increase of all diseases will be higher than the rate of population growth. Therefore, it is expected to have a sicker population in all aspects.

Table 14. Model Summary of moving averages for diseases

Model	R	R Square	F	Sig	Constant	b
Diabetes	.147[a]	.021	0.285	0.602	62336	2.44E-06
Hypertension	0.955	0.912	135.4	0.001	86638	8728.464
Diabetes/Hypertension	0.981	0.962	330.7	0.001	41183	5338.43
Total Diabetes Hypertension	0.958	0.918	145.7	0.001	157902	13989.75
Total Diabetes	0.96	0.922	154.2	0.001	71264	5261.28
Total Hypertension	0.967	0.936	188.7	0.001	127822	14066.9
Psychiatric Total	0.955	0.951	276	0.001	26209	2751.5
Upper Respiratory Tract Infection	0.65	0.423	9.54	0.009	82803	3039.9
Asthma	0.9	0.811	55.7	0.001	6603	1008.9

Table 15. Predictive models estimated for selected diseases

Hypertension	Hypertension = 86638 + 8728.464xYear
Diabetes/Hypertension	Diabetes/Hypertension= 41183 + 5338.43xYear
Total Diabetes Hypertension	Total Diabetes Hypertension= 157902 + 13989.75xYear
Total Diabetes	Total Diabetes= 71264 + 5261.28
Total Hypertension	Total Hypertension= 127822 + 14066.9xYear
Psychiatric Total	Psychiatric Total= 26209 + 2751.5xYear
Upper Respiratory Tract Infection	URTI= 82803 + 3039.9xYear
Asthma	Asthma = 6603 + 1008.9xYear

Table 16 Estimated selected diseases cases for years 2030 and 2050 using as base year 2015

Disease	2015	2030	% Increase	2050	% Increase
Hypertension	226,293	357,220	57.86	31,790	135.00
Diabetes/Hypertension	126,598	206,674	63.25	313,443	147.59
Total Diabetes Hypertension	381,738	591,584	54.97	871,379	128.27
Total Diabetes	155,444	234,364	50.77	339,589	118.46
Total Hypertension	352,892	563,896	59.79	845,234	139.52
Psychiatric Total	70,233	111,506	58.77	166,536	137.12
Upper Respiratory Tract Infection	131,441	177,040	34.69	237,838	80.95
Asthma	22,745	37,879	66.53	58,057	155.25

Table 17. Number of visits for Psychiatry, Upper Respiratory Tract Infections (URTI), Lower Respiratory Infections(LRTI) and Asthma (2000-2014)

	Psychiatry			URTI			LRTI			ASTHMA		
	M	F	Total	M	F	Total	M	F	Total	M	F	Total
2000	11918	12117	24035	34879	52636	87515	8618	10278	18896	4527	5985	10512
2001	12527	13343	25870	35186	51490	86676	8509	9886	18395	3788	5350	9138
2002	13998	15010	29008	33363	49058	82421	7827	9525	17352	3655	4925	8580
2003	16974	18247	35221	39378	59754	99132	9088	11558	20646	4330	5883	10213
2004	19496	20383	39879	36160	55835	91995	8518	10672	19190	4283	5954	10237
2005	21897	22147	44044	33632	51202	84834	7869	9965	17834	4185	5745	9930
2006	22082	21916	43998	34943	51755	86698	8453	11004	19457	4022	5743	9765
2007	22941	22157	45098	33877	49077	82954	7100	8827	15927	3761	5270	9031
2008	24890	23842	48732	45235	71335	116570	8469	11178	19647	5156	7437	12593
2009	28093	26216	54309	57686	89524	147210	11534	15306	26840	6064	9109	15173
2010	28839	27336	56175	47270	77276	124546	8539	10991	19530	6342	10290	16632
2011	30555	27818	58373	48944	79275	128219	9781	12150	21931	7214	11633	18847
2012	28530	25730	54260	51585	79935	131520	10972	13317	24289	8048	13042	21090
2013	32067	28339	60406	40570	66382	106952	9311	11344	20655	8011	13363	21374
2014	33971	28662	62633	39696	64303	103999	8614	10283	18897	7970	13898	21868

3.9.29 Information on Chronic Diseases from other sources

The information to be presented in sections 4.2.3.1 and 4.2.3.2 come from two research thesis. This information is important because they studied the relationship between obesity and diabetes, cholesterol and Peripheral Vascular Disease (PVD) in patients with either hypertension or diabetes.

3.9.30 MSc Thesis "Comparison of different factors affecting the control of hypertension in selected urban and rural patients".

The study was conducted in three urban and two rural health centres in Kingston and St. Andrew area and St. Mary, Jamaica. Questionnaires were commenced and completed by 302 participants where 20.2% were male and 79.8% were female patients who were diagnosed and treated for hypertension. Participants were selected randomly to reduce bias.

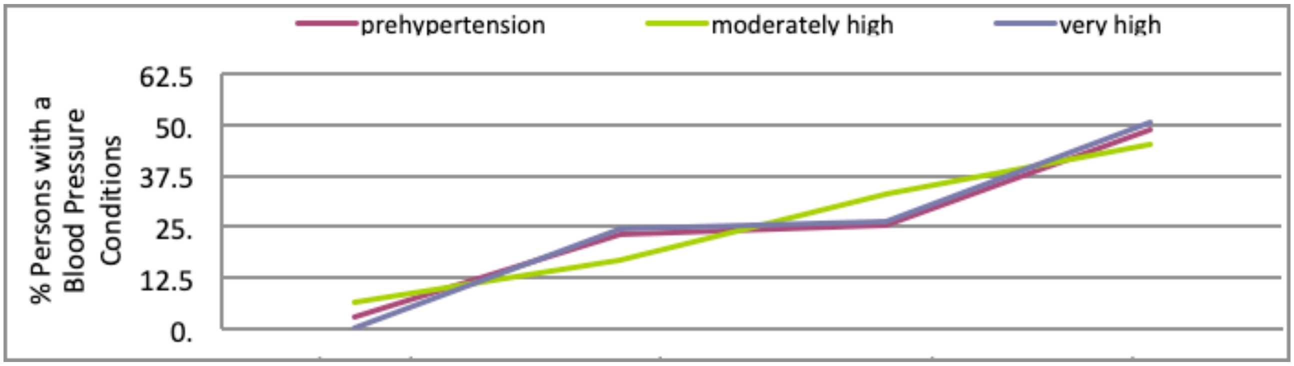
Information provided indicates that 46% of the participants were obese and 28.33% overweight. Also, the proportion of overweight and obese patients is higher in urban centres (77.4%) than rural centres (68.3%).

The distribution of BMI within gender indicates that in females obesity represents 53.1%, compared with only 18.0% in males. In the case of BMI Classification by gender, females represent a higher percentage in each class. In the case of obesity cases, 92% are females and only 8% are males. Information from this study was used to relate BMI with blood pressure, % of patients with diabetes, % of patients with cholesterol and % of patients with peripheral vascular disease. Table 18 and Graph 3 presents information on BMI and blood pressure. From them it can be observed that there is a clear increase % of blood pressure condition and BMI Class.

Table 18. Distribution of Mean Blood Pressure within BMI Class

BMI	Normal BP	Prehypertension	Stage 1 Hypertension	Stage 2 Hypertension
Underweight	10.5	3	6.1	0
Normal	36.8	23.2	16.7	24
overweight	21.1	25.3	32.6	26
Obese	31.6	48.5	44.7	50

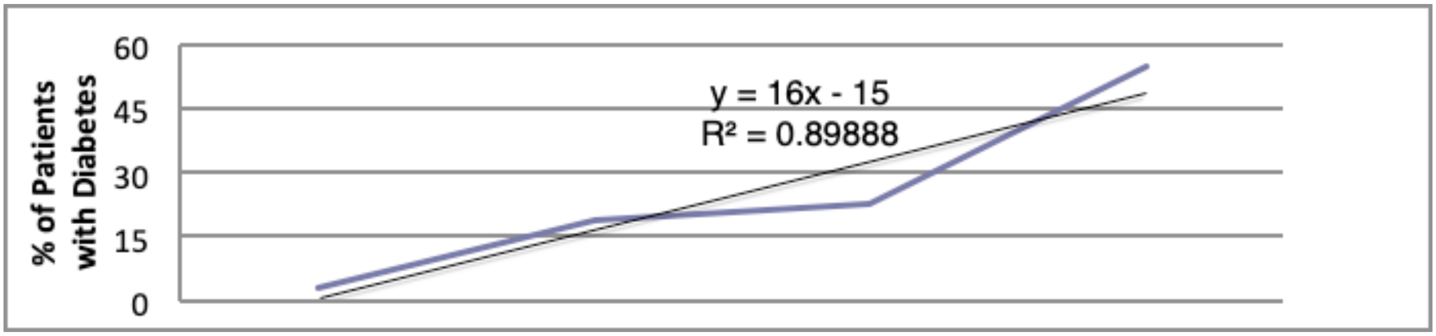
Graph 3. % Distribution of Blood Pressure condition versus BMI



Source: Prepared by the author using data from Aye (2014)

Graph 4 presents the relationship between BMI and % of patients with diabetes. It can be observed that % of patients with diabetes increase with an increase of BMI. There is a very good fit between the two variables (R^2=0.8989). The equation obtained indicates that 1 unit of increase of the BMI Class there is an increment of 16% in the number of diabetics.

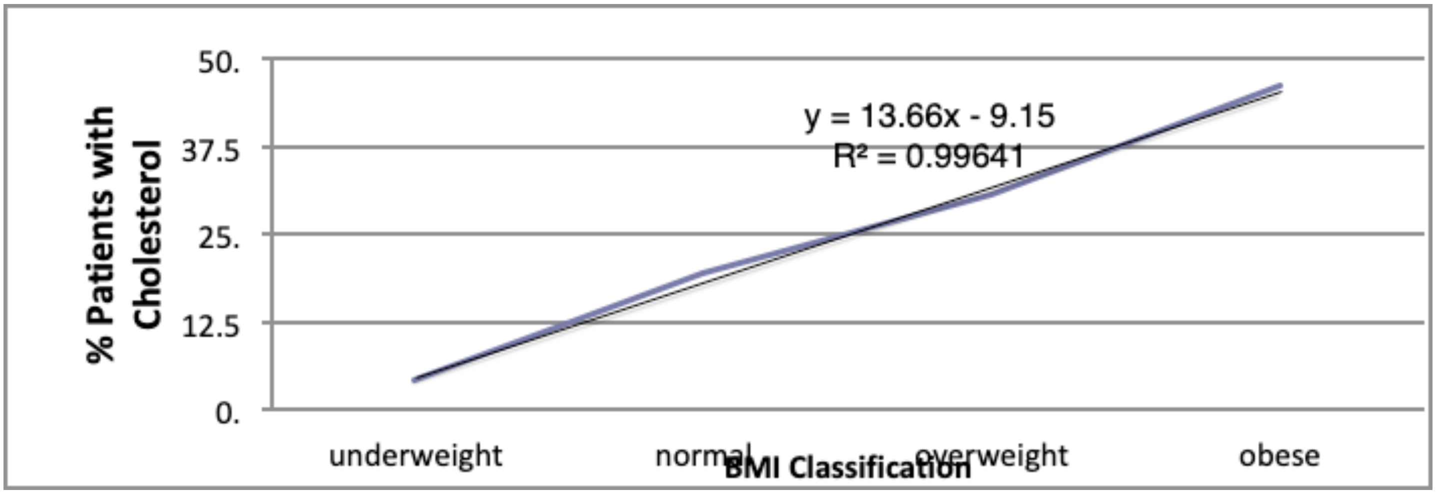
Graph 4. % of Diabetes versus BMI



Source: Prepared by the author using data from Aye (2014)

Graph 5 presents the relationship between BMI and % of patients with cholesterol. It can be observed that % of patients with cholesterol increase with an increase of BMI. There is an almost perfect fit between the two variables (R^2=0.9964). The equation obtained indicates that 1 unit of increase of the BMI Class there is an increment of 13.66 % in the number of patients with cholesterol.

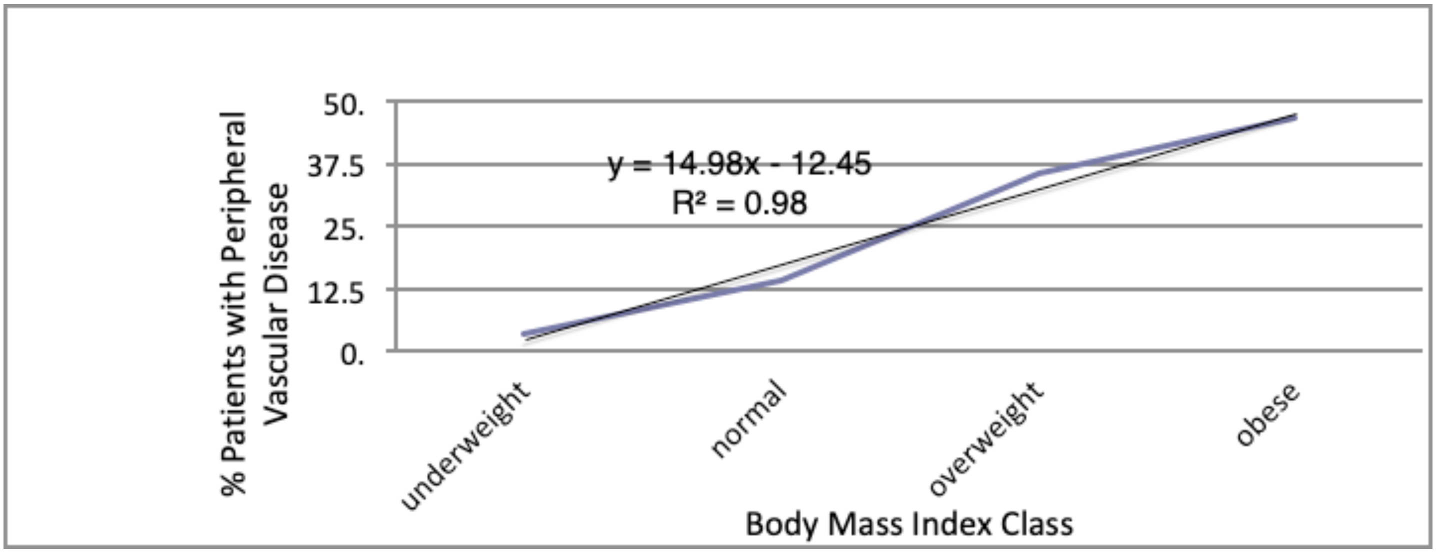
Graph 5. % Patients with High Cholesterol versus BMI



Source: Prepared by the author using data from Aye (2014)

Finally, Graph 6 presents the relationship between BMI and % of patients with Peripheral Vascular Disease (PVD). It can be observed that % of patients with PVD increase with an increase of BMI. There is an almost perfect fit between the two variables (R^2=0.98). The equation obtained indicates that for every 1 unit of increase of the BMI Class, there is an increment of 14.98 % in the number of patients with PVD.

Graph 6 % Patients with Peripheral vascular disease versus BMI



Source: Prepared by the author using data from Aye (2014)

3.9.31 Thesis Barriers to Self- Management of Diabetes Patients (Patient's Perspective) in St. Mary, Jamaica prepared by Dr. Aung Thu Ya

Appropriate self-management is essential to satisfactory control of diabetes. This descriptive study explores the barriers to self-management of diabetes, and their relationships to glycaemic control in adults with Type 2 diabetes in St. Mary, Jamaica. Completion of interviewer administered questionnaire and anthropometric measurements were carried out on 192 women and 56 men that attending diabetic clinics at Type III Health Centres in St. Mary. HbA1C and Fasting Blood Sugar (FBS) were used as the index of glycaemic control. Data were analysed using the SPSS-16 package. The majority of respondents did not reach their glycaemic target; 79% had uncontrolled FBS (> 130mg/dl) and only 21.8% were controlled to HbA1c 7%. The 64.2% were overweight. This study revealed inadequate knowledge, poor attitude, weak practice and other important barriers to self-management of diabetes and glycaemic control in this population. The findings presented and highlighted the importance of barriers on self-management of diabetic patients in St. Mary, Jamaica.

Results of this study need to be taken with caution since 80.2% of the responders were 50 years and older (Table 19).

Table 19. Age of responders

	Count	%
under 30 years	5	2.0%
31-39 years	7	2.8%
40-49 years	37	15.0%
50 years and over	198	80.2%

Obesity, as in other results, increases with age. In the group under 30 years, 0% are obese, compared with 37.9% in the 50 years and over group (Table 20).

Table 20. Weight of respondents

Age of responders	normal weight	over weight	obesity
Under 30 years	60.0%	40.0%	0.0%
31-39 years	42.9%	28.6%	28.6%
40-49 years	18.9%	48.6%	32.4%
50 years and over	25.8%	36.4%	37.9%

Regarding the distribution of BMI within gender, overweight represents the highest percentage in females while obesity in males. However, only 20.4% of females have a normal weight compared with 33.3% in males (Table 21).

Table No 21 Distribution of BMI within Gender of Responders

	Gender of Responders	
BMI	Male	Female
normal weight	33.3%	20.4%
over weight	30.6%	43.8%
obesity	36.1%	35.8%

3.9.32 Community Health Survey Results

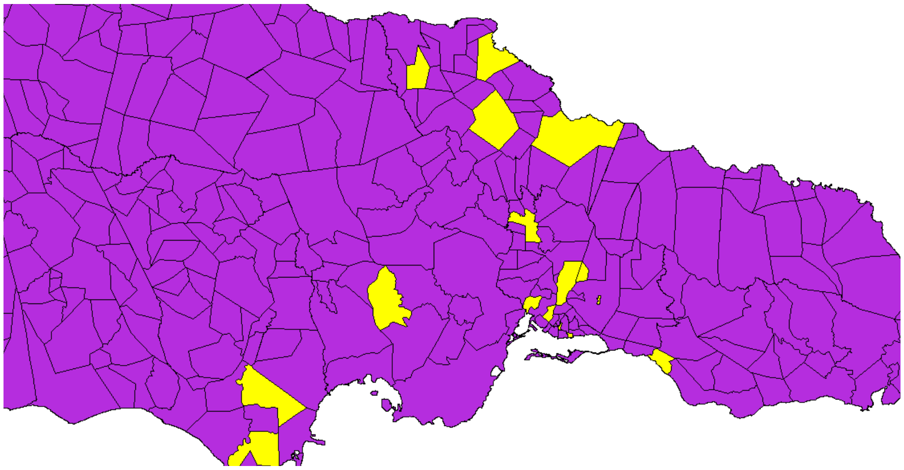
Information from two field surveys was used to make comments on the disease status of 8 communities.

The first one (Survey 1) is a health survey conducted for the preparation of this report in five rural and urban communities in the Kingston Metropolitan Area (Hannah Town, Rae Town and Kintyre) and in rural communities (Kitson, St. Catherine and Barret Town, St. James). In this survey, 278 persons (representing a total of 1,067 persons) were interviewed during the period of April through June 2016.

The second one (Survey 2) is a survey commissioned by the Jamaica Environment Trust (JET) as part of a project entitled "Building Capacity in Jamaican Mining Communities to Protect their Environmental Rights", funded by the Inter-American Foundation (IAF). The survey was carried out by a team of researchers led by the author. Three hundred (300) persons (representing a total of 1,388 persons) were interviewed in the communities of Hayes, Lionel Town in Clarendon and Albion in St. Thomas.

The following paragraphs present the health profile of the communities (Figure 7) that were studied:

Figure 7. Location of studied communities



3.9.32.1 Demographic Conditions

Information used comes from both surveys.

Of the total persons interviewed, 260 were male and 303 female. The age distribution is presented in Table 22. From this table it can be observed that 41% of the population is 50 years and older.

Table 22. Age Group of the Respondent

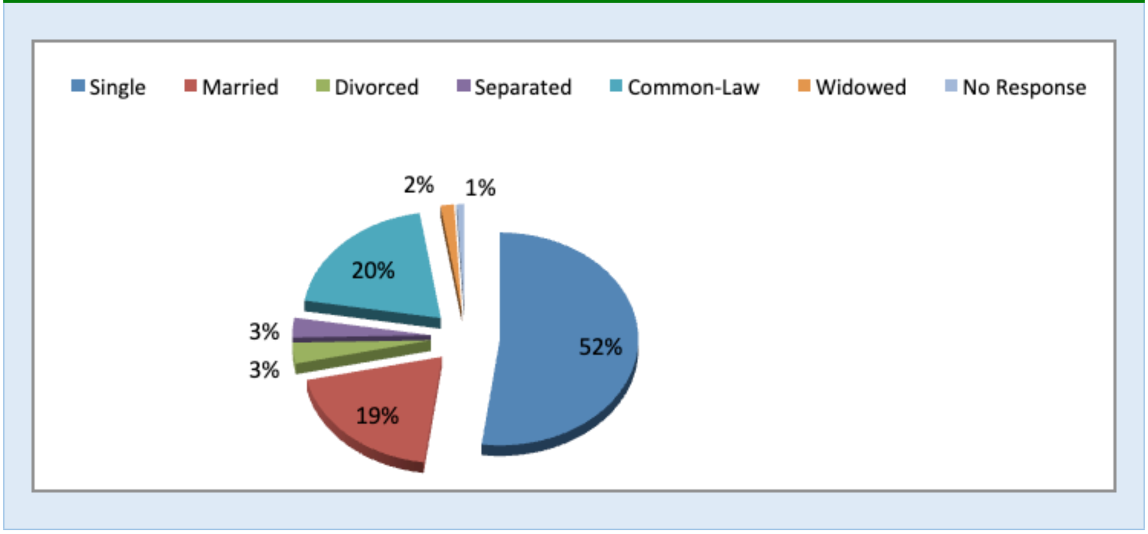
	Number	%
15-19	35	6.3%
20-29	101	18.1%
30-39	90	16.1%
40-49	104	18.6%
50-59	109	19.5%
> 60	120	21.5%

Regarding marital status, from Graph 8, it can be observed that 52% of the respondents were single, 3% were separated and 2 % were widowed, while 39 % were either married or in a common-law relationship. When marital status and age groups are combined (Table 23) , 45.9 % of those married are older than 60 years and 12 % of the singles are younger than 19 years of age.

Table 23. Marital Status of the Respondent

	Age Group of the Respondent					
	15-19	20-29	30-39	40-49	50-59	> 60
Single	11.8%	23.9%	14.2%	17.6%	18.3%	14.2%
Married	0.0%	3.7%	7.3%	22.0%	21.1%	45.9%
Divorced	0.0%	5.6%	11.1%	11.1%	33.3%	38.9%
Separated	0.0%	0.0%	11.8%	23.5%	35.3%	29.4%
Common-Law	.9%	23.4%	31.5%	18.9%	15.3%	9.9%
Widowed	0.0%	0.0%	0.0%	11.1%	33.3%	55.6%
No Response	0.0%	20.0%	40.0%	0.0%	20.0%	20.0%

Graph 8. Marital Status of Respondents



Information regarding level of employment indicates that 33% of them are unemployed, 29% are employed and 26% are self-employed (Graph 9). Of those unemployed, 28.9% are the head of the household (Table 24), so it is expected that they are in poverty. The 60 years and older age group is the largest of unemployed with 29.7%, followed by the 20-29 age group with 21.4% (Table 25).

Graph 9. Employment Status of the Respondent

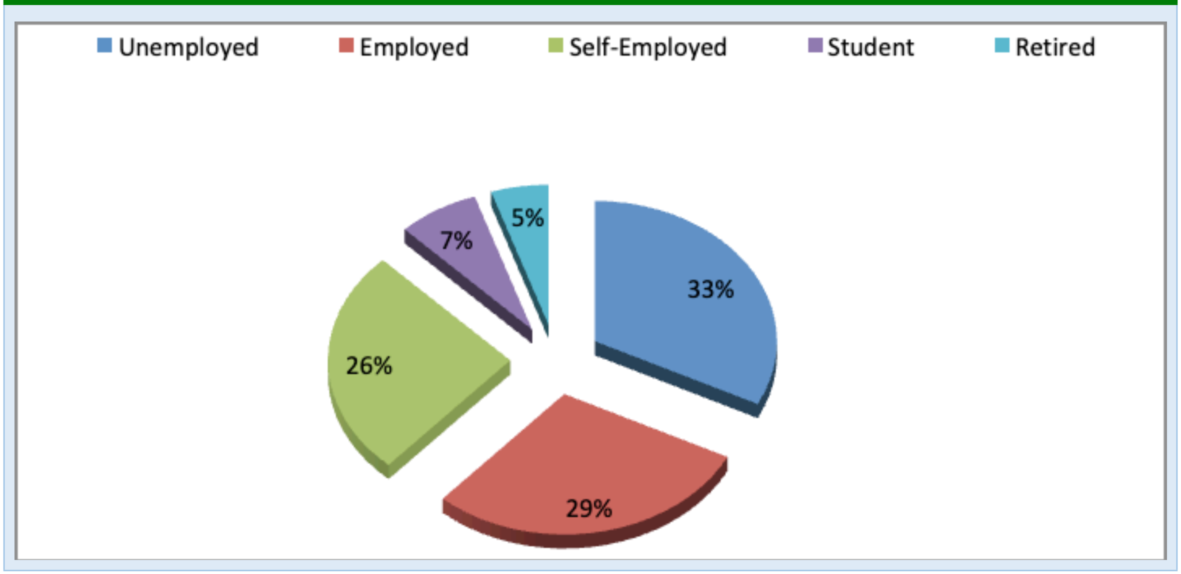


Table 24. Employment Status of the Respondent and head of the household Status

	Head of Household	
	Yes	No
Unemployed	28.9%	37.6%
Employed	30.3%	27.8%
Self-Employed	33.1%	13.7%
Student	1.4%	17.6%
Retired	6.2%	3.4%

Table 25. Employment Status of the Respondent and Age

	Age Group of the Respondent					
	15-19	20-29	30-39	40-49	50-59	> 60
Unemployed	3.8%	21.4%	13.2%	14.3%	17.6%	29.7%
Employed	1.8%	20.0%	24.2%	23.0%	22.4%	8.5%
Self-Employed	.7%	14.0%	16.1%	25.2%	26.6%	17.5%
Student	61.5%	23.1%	7.7%	5.1%	0.0%	2.6%
Retired	0.0%	0.0%	0.0%	3.4%	6.9%	89.7%

Table 26 presents the level of education of respondents. About 55.6% have completed or started secondary education and 16.5% have a tertiary-level education.

Table 26. Highest Level of Education of the Respondent

	Count	%
Primary Education	93	16.4%
All-Age Education	28	4.9%
Secondary Education	316	55.6%
Vocational Training	36	6.3%
Tertiary Education	94	16.5%
No Response	1	.2%

Table 27 presents the number of persons living in the house. Some of the homes are overcrowded, with 10 to 16 persons living in them. The typical home (119) holds 3 persons. In those overcrowded homes, transmission of infectious diseases is facilitated.

Table 27. Number of people in household

Number of persons in Home	Number of Homes	%
1	76	13.4%
2	111	19.5%
3	119	21.0%
4	93	16.4%
5	71	12.5%
6	46	8.1%
7	19	3.3%
8	14	2.5%
9	7	1.2%
10	4	.7%
11	1	.2%
12	3	.5%
13	1	.2%
15	2	.4%
16	1	.2%

3.9.32.2 Use of Health Services

Information presented here is from both surveys.

Information gathered from communities indicates that 35.8% of the persons interviewed receive health care from a private facility, 39.7% from health centres and 23.2% in public hospitals. Hence a large % of the population (62.9%) use the health services provided by the Government (Table 28).

Table 28. Do you access health care at a Health Centre?

	Count	Column N %
No visit	7	1.2%
Private	202	35.8%
Health Centre	224	39.7%
Public Hospital	131	23.2%

Regarding the number of visits per year, 50.5% of the interviewed reported to visit a health facility, either public or private, 2 – 4 times a year and 27.7% once a year. Also, 4.3% reported no visits and by 3.4% reported more than 10 visits per year (Table 29). It is expected that the number of visits will increase through the years, because of population aging with the consequent increase of chronic diseases such as diabetes, hypertension, and cholesterol among others. This will impose a high financial burden on the meagre resources of the Ministry of Health.

Table 29. How much visits per year do you make?

	Count	%
No visit	24	4.3%
1 time	156	27.7%
2-4 times	285	50.5%
5 times	43	7.6%
6-10 times	32	5.7%
>10 times	19	3.4%
No Response	5	.9%

Regarding the number of visits per community, Hannah Town reported the highest percentage of 2 – 4 visits (60.4%), followed by Lionel Town (59.0%). Barrett Town and Kintyre reported the highest percentage of no visits to health care institutions (Table 30).

Table 30. How much visits per year do you make?

	Albion	Barrett Town	Hannah Town	Hayes	Kintyre	Kitson Town	Lionel Town	Rae Town
No visit	0.0%	15.1%	3.8%	0.0%	13.2%	4.8%	0.0%	7.7%
1 time	31.6%	32.1%	24.5%	16.1%	30.2%	37.1%	20.0%	40.4%
2-4 times	56.1%	37.7%	60.4%	52.7%	37.7%	50.0%	59.0%	36.5%
5 times	5.1%	7.5%	5.7%	14.0%	7.5%	1.6%	11.0%	3.8%
6-10 times	5.1%	1.9%	3.8%	8.6%	5.7%	4.8%	5.0%	9.6%
>10 times	2.0%	3.8%	1.9%	6.5%	5.7%	1.6%	3.0%	1.9%
No Response	0.0%	1.9%	0.0%	2.2%	0.0%	0.0%	2.0%	0.0%

3.9.32.3 Health Conditions of Respondents

Questions were asked of the respondents regarding the diseases they and their families suffer. Information collected was related to: Eczema conditions, Hives/Rashes, Hay fever/Allergic Rhinitis, Asthma, High Blood Pressure, Cholesterol, Diabetes, Anaemia, Gastroenteritis, Dengue, Chick-V, Leptospirosis and Depression.

Table 31 presents results of diseases suffered by the respondents and their families.

In the case of respondents, Chikungunya was the disease with the highest reported rate with 65.1% of the respondents, followed by hay fever/allergic rhinitis (17.9%) and high blood pressure (10.6%). Around 9% suffer from depression.

In the case of family members, again, Chikungunya was the one with the highest reported rate with 45.4 % of the respondents (Table 31) followed by high blood pressure (9.7 %), but only 0.9% suffer from depression. The low percentages reported for family members may be explained by the fact that depression is only noticeable when it reaches critical conditions.

It is worth it to mention that the majority of the Chikungunya cases were self-diagnosed, only 36.5% were diagnosed by a medical doctor.

Table 31. Summary of Disease Conditions within interviewed persons and their families

	Persons Interviewed			Family Members in household			Persons Interviewed and		
	Number	Cases	Rate (%)	Number	Cases	Rate (%)	Total	Total Cases	Rate (%)
Eczema	567*	57	10.1	789*	68	8.6	1356	125	9.2
Hives/Rashes	564*	33	5.9	789*	29	3.7	1353	62	4.6
Hay Fever/Allergic rhinitis	563*	101	17.9	1877*	38	2.0	2440	139	5.7
Asthma	554*	31	5.6	1877*	122	6.5	2431	153	6.3
High Blood Pressure	556*	59	10.6	1877*	182	9.7	2433	241	9.9
Cholesterol	278	18	6.5	1877*	36	1.9	2155	54	2.5
Diabetes	278	17	6.1	1877*	61	3.2	2155	78	3.6
Anaemia	278	14	5.0	1877*	21	1.1	2155	35	1.6
Gastroenteritis	278	9	3.2	789	5	0.6	1067	14	1.3
Dengue	278	3	1.1	789	0	0.0	1067	3	0.3
Chik-V	278	181	65.1	789	358	45.4	1067	539	50.5
Leptospirosis	278	3	1.1	789	9	1.1	1067	12	1.1
Depression	278	25	9.0	789	7	0.9	1067	32	3.0

**Information includes data from JET's community survey*

3.9.32.4 Body Mass Index (BMI) (from Surveys 1 and 2)

Height, weight and waist circumference was measured to all respondents. BMI was calculated using an online Adult BMI Calculator developed by the US Centres for Disease Control and Prevention. BMI is classified as follows (Table 32):

Table 32 BMI Classification

BMI	Weight Status
Below 18.5	Underweight
18.5—24.9	Normal
25.0—29.9	Overweight
30.0 and Above	Obese

We have an obese population; 53.3% of the respondents were found either overweight or obese (Table 33). The percentage of respondents with a high BMI increases with age (Table 34). In the case of overweight, 68.9% are 40 years and older and in the case of obesity, 62.1% (Table 34).

Table 33. Body Mass Index in Respondents

	Count	%
Underweight	33	5.9%
Normal	230	40.8%
Overweight	183	32.4%
Obese	118	20.9%

Table 34. Age Group of the Respondent

	BMI Class			
	Underweight	Normal	Overweight	Obese
15-19	31.3%	9.3%	1.7%	.9%
20-29	25.0%	19.5%	13.3%	19.0%
30-39	9.4%	16.4%	16.1%	18.1%
40-49	3.1%	17.3%	22.8%	18.1%
50-59	15.6%	15.5%	21.1%	26.7%
> 60	15.6%	22.1%	25.0%	17.2%
Respondents >40 Years			68.9%	62.1%

Obesity is a gender issue, 64.8 % of female are either overweight or obese and only 40.9 % are Male (Table 35).

Table 35. Distribution of BMI Class within Gender

	Underweight	Normal	Overweight	Obese
Male	7.0%	52.1%	30.0%	10.9%
Female	4.7%	30.6%	35.2%	29.6%

Moreover, of those classified as obese 76.1% are female and 23.9% are male, that is, for every 100 obese male, there are 318 females. See Table 36.

Table 36. Distribution of Gender within BMI Class

	Underweight	Normal	Overweight	Obese
Male	56.3%	59.0%	42.1%	23.9%
Female	43.8%	40.5%	57.9%	76.1%

Finally, Albion is the most obese community (Table 37) where 71.4% of the respondents were found to be either overweight or obese, followed by Kitson Town with 60% and Barret Town with 58.2%. The communities with the least percentage of overweight and obese respondents were Kintyre (33.3%) and Rae Town (39.2%). From this, it seems that obesity is a rural problem.

Table 37. Distribution of BMI Class within communities

	Underweight	Normal	Overweight	Obese	Overweight and Obese
Albion	1.0%	27.6%	46.9%	24.5%	71.4%
Barrett Town	3.6%	38.2%	43.6%	14.5%	58.2%
Hannah Town	13.2%	39.6%	22.6%	24.5%	47.2%
Hayes	6.5%	39.8%	34.4%	19.4%	53.8%
Kintyre	7.4%	59.3%	16.7%	16.7%	33.3%
Kitson Town	3.3%	36.7%	25.0%	35.0%	60.0%
Lionel Town	4.0%	46.0%	31.0%	19.0%	50.0%
Rae Town	13.7%	47.1%	27.5%	11.8%	39.2%

3.9.32.5 Hypertension (from Surveys 1 and 2)

Blood pressure was measured in all respondents. The reported blood pressure reading was done twice, at the start and at the end of the interview. The average blood pressure is reported.

Blood pressure was classified using the Blood Pressure (BP) Classification (The seventh report of Joint National Committee). Table 38 presents this information.

Table 38. Blood Pressure (BP) Classification

Blood Pressure Classification	SBP (mmHg)	DBP (mmHg)
Normal	<120	and <80
Prehypertension	120–139	or 80–89
Stage 1 Hypertension	140–159	or 90–99
Stage 2 Hypertension	≥160	or ≥100

We have a hypertensive problem, 79.7% of the respondents were found with prehypertension (38.9%), Stage 1 Hypertension (21.9%) and Stage 2 Hypertension (18.9%). See Table ___. Here it can be observed the large lack of knowledge of the blood pressure status of the population regarding their blood pressure condition, since only 10.6% reported a hypertensive condition, a large difference with what was found when blood pressure was measured to respondents (40.8% stage 1 and 2 hypertension).

Table 39. Blood Pressure conditions in Communities

	Count	%
Normal	114	20.3%
Prehypertension	218	38.9%
Stage 1 Hypertension	123	21.9%
Stage 2 Hypertension	106	18.9%

As is mentioned in the literature, problems with high blood pressure are more frequent at older age. The problem starts at age 40 or older: 47.5% of the 40 – 49 age group have either Stage 1 hypertension or Stage 2. This condition increases to 58.3% for the 50-59 age group and to 71.1% for the > 60 age group (Table 40).

Table 40. Distribution of Hypertension Condition by Age Group

Age Group	Normal	Prehypertension	Stage 1 Hypertension	Stage 2 Hypertension
15-19	69.7%	30.3%	0.0%	0.0%
20-29	34.0%	48.0%	10.0%	8.0%
30-39	33.7%	55.1%	5.6%	5.6%
40-49	15.5%	36.9%	29.1%	18.4%
50-59	2.8%	38.9%	32.4%	25.9%
> 60	6.8%	22.0%	36.4%	34.7%

From Table 41, it can be observed that the 50-59 age group only 2.6% have normal blood pressure and the age group > 60 only 7.0%.

Table 41. Blood Pressure Condition within Age Group

Age Group	Normal	Prehypertension	Stage 1 Hypertension	Stage 2 Hypertension
15-19	20.2%	4.7%	0.0%	0.0%
20-29	29.8%	22.5%	8.1%	7.9%
30-39	26.3%	23.0%	4.1%	5.0%
40-49	14.0%	17.8%	24.4%	18.8%
50-59	2.6%	19.7%	28.5%	27.7%
> 60	7.0%	12.2%	35.0%	40.6%

Regarding gender and distribution of blood pressure condition, it can be observed (Table 42) that females are more affected than males. In the case of Stage 2 hypertension, 61% are females and 39% are males.

Table 42. Distribution of Hypertension condition between Gender

	Normal	Prehypertension	Stage 1 Hypertension	Stage 2 Hypertension
Male	38.4%	49.1%	53.7%	39.0%
Female	60.7%	50.9%	46.3%	61.0%

The distribution of blood pressure condition by gender indicates that Stage 1 and 2 hypertension conditions are similar in males and females, 41.8% within males and 40.5% within females (Table 43).

Table 43. Distribution of Hypertension condition within Gender

	Normal	Prehypertension	Stage 1 Hypertension	Stage 2 Hypertension
Male	16.8%	41.4%	25.8%	16.0%
Female	22.7%	36.8%	19.1%	21.4%

Regarding blood pressure condition among towns, Kintyre presents the lowest rate of Stage 1 and 2 hypertension with 24.1 % and Lionel Town the highest with 52.5% (Table 44).

Table 44. Blood Pressure distribution in communities

	Normal	Prehypertension	Stage 1 Hypertension	Stage 2 Hypertension	Stage 1 and 2 Hypertension
Albion	12.5%	46.9%	27.1%	13.5%	40.6%
Barrett Town	21.8%	47.3%	14.5%	16.4%	30.9%
Hannah Town	24.1%	31.5%	7.4%	37.0%	44.4%
Hayes	23.1%	30.8%	27.5%	18.7%	46.2%
Kintyre	27.8%	48.1%	14.8%	9.3%	24.1%
Kitson Town	20.0%	40.0%	18.3%	21.7%	40.0%
Lionel Town	11.1%	36.4%	33.3%	19.2%	52.5%
Rae Town	34.6%	30.8%	15.4%	19.2%	34.6%

3.9.32.6 Cholesterol (from Survey 1)

Eighteen (18) (6.9%) of the respondents reported having a cholesterol condition. The community with the highest rate was Hannah Town with 11.1 % of the respondents reporting this condition (Table 45). Rae Town is the community with the lowest rate with 3.8%. Females are more affected than males, 55.6% and 44.4% respectively (Table 46). Cholesterol rates increase by age; the most affected are persons 60 years and older with 56.3% of the cases (Table 47).

Table 45. Self-Reported Cholesterol Condition by Community

	No		Yes	
	Count	%	Count	%
Barrett Town	53	94.6%	3	5.4%
Hannah Town	48	88.9%	6	11.1%
Kintyre	50	92.6%	4	7.4%
Kitson Town	59	95.2%	3	4.8%
Rae Town	50	96.2%	2	3.8%
Total	260		18	

Table 46. Self-reported Cholesterol Condition by Gender

	No		Yes	
	Count	%	Count	Column N %
Male	145	56.9%	8	44.4%
Female	110	43.1%	10	55.6%

Table 47. Self-reported Cholesterol Condition by Age Group

	No		Yes	
	Count	%	Count	%
15-19	16	6.3%	0	0.0%
20-29	60	23.8%	0	0.0%
30-39	45	17.9%	0	0.0%
40-49	51	20.2%	4	25.0%
50-59	44	17.5%	3	18.8%
> 60	36	14.3%	9	56.3%

3.9.32.7 Diabetes

Seventeen (6.1%) of the respondents reported having a diabetic condition. Of the total cases, 52.9% occurred with females and 47.1% with males (Table 48). Also, 7.5% of the females reported being diabetic, compare with 5.2% of males (Table 49). Unfortunately, levels of glucose were not measured in the field. Females are more affected with diabetes than males.

Diabetes is found in all age groups, however, except for the age group 15-19, diabetes cases increase with age (Table 50).

Table 48. Distribution of Cases of Self-reported Diabetes Condition by Gender

	No	Yes
Male	56.6%	47.1%
Female	43.4%	52.9%

Table 49. Self-reported Diabetes Condition within Gender of the Respondent

	No	Yes
Male	94.8%	5.2%
Female	92.5%	7.5%

Table 50. Self-reported Diabetes condition by Age Group

	DIABETES	
	No	Yes
15-19	93.8%	6.3%
20-29	98.3%	1.7%
30-39	97.8%	2.2%
40-49	92.7%	7.3%
50-59	89.4%	10.6%
> 60	88.9%	11.1%

All communities reported cases of diabetes, Kintyre (Table 51) has the highest percentage of cases reported by respondents (9.3%), followed by Barret Town (8.9%). Kitson Town has the lowest rate of diabetes, followed by Rae Town.

Table 51. % of Self-reported Cases of Diabetes by Community

	No	Yes
Barrett Town	91.1%	8.9%
Hannah Town	94.4%	5.6%
Kintyre	90.7%	9.3%
Kitson Town	96.8%	3.2%
Rae Town	96.2%	3.8%

Regarding family members with diabetes, information from survey 2 was used (Table 52). In total, 43 cases were reported. Again, 65.1 % of the cases are among females. Percentages of diabetes cases increase with age.

Table 52. Cases of Self-reported Diabetes per Age group and Gender in family members

	Diabetes Females Number	Percent	Diabetes Males Number	Percent	Diabetes Total
0 to 9	0	0	0	-	0
10 to 19	0	-	0	-	0
20 to 29	0	-	0	-	0
30 to 39	1	3.6	0	-	1
40 to 49	2	7.1	3	20.0	5
50 to 59	8	28.6	2	13.3	10
> 60	17	60.7	10	66.7	27
Total	28	65.1	15	34.9	43

3.9.32.8 Hay fever / allergic rhinitis

Hayes (parish of Clarendon) is the community with the highest rate of allergies with 30.7% of the respondents reporting this condition, followed by Albion with 22.8% (Table 53). Rae Town is the community with the lowest rate, with 3.0%.

Table 53. Cases of Self-reported hay fever / allergic rhinitis by Community

	No	Yes
Albion	15.8%	22.8%
Barrett Town	10.6%	6.9%
Hannah Town	9.7%	8.9%
Hayes	13.2%	30.7%
Kintyre	9.1%	11.9%
Kitson Town	11.3%	9.9%
Lionel Town	19.7%	5.9%
Rae Town	10.6%	3.0%

Information about depression was collected from respondents (Table 54). Rae Town is the community with the highest rate of depression Followed by Kintyre, while Hannah Town presented the lowest rate of depression followed by Rae Town.

Table 54. Self-reported Depression by community

Community	No	Yes
Barrett Town	92.9%	7.1%
Hannah Town	94.4%	5.6%
Kintyre	88.9%	11.1%
Kitson Town	90.3%	9.7%
Rae Town	88.5%	11.5%

3.9.33 Vulnerability and Adaptation

3.9.33.1 Vulnerability and Health

The analysis done indicate that Jamaican is very vulnerable to climate change effects on health as delineated in this Section. There is a high vulnerability in the population and on the protective factors (determinants of health). The table below outline the vulnerability to climate change impacts and some of the measures to adapt to these impacts.

Vulnerability and Adaptation on Human Health

	Vulnerability	Adaptation
Population Aging	• Elderly persons (aged 60 years and over) constitute the fastest growing age group with an annual population growth rate of 1.9%. • In 2015 there were 304,426 persons older than 60 years, by 2030 it is expected to be 453,177 (an increase of 48.8%) and by 2050 there will be 614,902 persons (an increase of 102%). This group will represent 21.8% of the total population. • Rates of chronic diseases (diabetes, hypertension, high cholesterol, obesity, etc.) are higher in this age group. • Elderly are at particularly high risk of adverse health effects from extreme heat exposure • Diminished ability to regulate body temperature and to adapt physiologically to heat • largest concentration of these groups are located in the KMA and Portmore Areas	• Create an implement a National Policy and Act on healthy aging, which includes
Chronic Diseases	Obesity • Prevalence: 64% in 2030 and 75% in 2050. • Comorbidities by Obesity will be: Diabetes mellitus, Hypertension, Coronary Heart Disease, Stroke, Gallbladder Disease, Breast and Colon Cancers, Osteoarthritis, and high cholesterol. • Increase of comorbidities by obesity will cost: US$ 2.87 billion by 2030 and US$ 3, 24 billion by 2050. • Women and senior citizen will be the most impacted	• Ensure proper financing to and full implementation of the National Strategic and Action Plan for the Prevention and Control Non-Communicable Diseases (NCDs). • Increase the availability of green areas and parks green areas for physical activity and leisure to meet WHO guideline of 12 m^2 per capita and access distance of less than 1000 meters. • Ensure that parks are suitable to do exercise must be shaded, safe and with good walking paths, among others. • Impose a 20% tax to "junk food" • Eliminate importation and GCT taxes to Low Glycaemic Index and Load foods. Such as: cherries, grapes, apples, plums, peach, etc. • Promote the local production of Low Glycaemic Index and Load foods. • Support the construction of healthy houses and homes to eliminate in the shortest time the housing deficit. • Promote the reuse of treated wastewater for irrigation of parks.
	Diabetes • 18% prevalence by 2030 and 26% by 2050. • The Direct Cost will be US$ 205 million and by 2050 US$ 291 • Women and senior citizen will be the most impacted	• Same as above
	Hypertension • Will increase from 25% in 2007, to 64% in 2030 and to 96% in 2050. • Direct Cost in 2030 $681,757,158 and $999,600,215 by 2050 • Women and senior citizen will be the most impacted	• Same as above

	Vulnerability	Adaptation
Chronic Diseases	**Asthma** • In 2007, 16.7% of children 5 to 10 years old. • The number of health care visits in 2014 was 21,868. • It is expected to increase 3 times by 2030 and 4.6 times by 2050. • The estimated direct cost is US$ $211 million in 2030 and US$ $283 million in 2050. • Children females are more affected than males, 1.74 times	• Develop national strategies and action plans to improve asthma management and reduce costs; • Ensure availability asthma management guidelines • Provide universal access to essential asthma medicines; • Training to health staff on asthma research and policy; • Monitor trends in asthma over time in children and adults • Report rates of asthma deaths in children and adults
	Mental Health • JHLSII 2008 reports self-reported prevalence for mental health problems for 2.4% in males and 3.7% in females, for a total of 3.1 %. • The number of Jamaicans age 17 to 74 years, would be 58,622 persons and by year 2030, we calculated to be 147,990 patients and 216,203 by 2050. • In 2014 the number of health care visits for mental health care was 62,633. • The calculated cost for mental health care is US$152 million in 2030 and US$222 million by 2050	• Ensure proper financing to and full implementation of the National Strategic and Action Plan for the Prevention and Control Non-Communicable Diseases (NCDs). • Increase the availability of green areas and parks green areas for physical activity and leisure to meet WHO guideline of 12 m^2 per capita and access distance of less than 1000 meters. • Ensure that parks are suitable to do exercise must be shaded, safe and with good walking paths, among others • Support the construction of healthy houses and homes to eliminate in the shortest time the housing deficit. • Ensure proper nutrition to elderly persons
Vector borne Diseases	**Dengue** • Number of cases 3,350 (2021-2030) and 4,502 (2041-2050) • New transmitted viruses appear every few years: Chikungunya, Zika A. • Dengue is still the predominant disease • Poor housing conditions • Poor neighbourhood conditions • Crowding both in homes and neighbourhoods • Inadequate frequency of garbage collection (37.8% population receives garbage collection service once per week) • Inadequate coverage of garbage collection (74.1 % national coverage)	• Increase twice a week garbage collection • Eliminate the water deficit in water distribution systems • Strengthen community programmes for the reduction of garbage dumping in empty lots • Strengthen community vector surveillance

CHAPTER 4
GENERAL DESCRIPTION OF STEPS TO MITIGATE CLIMATE CHANGE

4.1 Mitigation Actions

Each mitigation action is explored using a dedicated scenario in the national LEAP model of Jamaica's energy system and GHG emissions. These scenarios quantify the incremental cost and emissions impact of the actions compared to the baseline scenario selected for this analysis.

Table 3 lists and describes the mitigation actions, including which sectors are targeted and whether each action is planned or potential. Planned activities are identified directly from national policy or planning documents, or they propose a basic representation of a measure which is specifically named in these sources. Potential activities are identified from academic studies, from reports produced by non-governmental organizations, from appropriate mitigation options selected from other countries' experiences, or through SEI's best judgement. Potential activities may also represent a more aggressive extrapolation of planned activities.

Thorough descriptions of each mitigation action, as well as necessary quantitative modelling assumptions, are included in the subsections that follow.

Table 3: Summary of Mitigation Actions

Sector	Type	Action
Residential & Commercial Buildings	Potential	Solar hot water: Percentage of households using solar water heating in lieu of electricity or LPG increases from current levels to 60% by 2030 and 85% by 2050.
Residential & Commercial Buildings	Potential	Residential light-emitting diode (LED) lighting: By 2030, LED lamps are used for all electric lighting in residential buildings, displacing compact fluorescent lamp (CFL) technology.
Residential & Commercial Buildings	Planned	T8 fluorescent lighting in schools and hospitals: By 2030, all schools and hospitals convert from T12 linear fluorescent lamps to efficient T8 lighting.
Residential & Commercial Buildings	Potential	Public and commercial LED lighting: By 2030, all incandescent, linear, and compact fluorescent lighting in public and commercial buildings is replaced by equivalent LED lighting.
Industry	Planned	CNG for alumina production at Alpart: The recently re-opened Alpart alumina refinery switches from consuming fuel oil to compressed natural gas (CNG) to meet its process heat requirements.
Industry	Potential	CNG for alumina production: All fuel oil consumed across the alumina-refining sector is displaced by CNG by 2025.
Industry	Planned	Increased cogeneration efficiency: Efficient combined heat and power (CHP) steam generators are deployed for alumina production, gradually increasing CHP efficiency for the industry to 90% by 2030.
Transport	Planned	Natural gas buses: Introduction of 136 LNG-fuelled public transport buses serving St. James Parish and Montego Bay by 2025.
Public Services	Planned	Smart LED street lighting: JPS's Smart LED project. Beginning in 2017 and wrapping up in 2020, all grid-connected streetlights are converted to LED technology equipped with pedestrian and traffic sensors.
Public Services	Planned	Reduced water distribution loss: Beginning in 2018, water loss in aging distribution systems operated by NWC is reduced from 53% to 37% within two years, 30% within three years, and 20% within five years.
Final Demands	Planned	B5 blending: By 2017, 189 million liters (50 million gallons) per year of biodiesel production capacity (Staff writer 2015) is deployed to satisfy an impending 5%-by-volume biodiesel mandate (Bandy 2016). Biodiesel is produced domestically from (primarily) jatropha feedstock, with a small amount of waste cooking oil (Ministry of Energy and Mining 2010c).
Final Demands	Potential	B20 blending: Identical to B5 blending scenario above, before reaching 20%-by-volume biodiesel in 2030 (Ministry of Energy and Mining 2010c).
Final Demands	Planned	E10 blending, with domestic production: By 2020, 7.56 million liters (20 million gallons) per year of sorghum bioethanol production capacity (Staff writer 2016) is deployed to satisfy Jamaica's E10 blending mandate using domestic resources. Additional sugarcane production capacity is added as needed to meet growing gasoline-bioethanol blending requirements.
Final Demands	Potential	E85 blending: Identical to E10 production and blending above, reaching 85%-by-volume bioethanol blend in 2030.
Electricity Production	Planned	Reduced electricity losses: By 2020, electricity transmission and distribution losses are reduced by 4.1% of net generation. Technical losses are lowered by 1.5%, and non-technical losses are cut by 2.6% (Ministry of Energy and Mining 2010d).
Electricity Production	Potential	Biomass cogeneration: Surplus electricity production from biomass combustion at sugar mills and bioethanol distilleries (if co-implemented with E10/E85 measure), beyond that necessary to meet their processing needs, is exported to the grid.

Sector	Type	Action
Electricity Production	**Potential**	Utility-scale wind power: By 2030, sufficient new utility-scale, on-shore wind capacity is deployed to ensure that 30% of electricity generation is from renewable sources (baseline renewable facilities plus the new wind capacity). The build-out of new wind is limited to 507 MW, however (Ministry of Science, Technology, Energy and Mining 2013; Worldwatch Institute 2013).
Electricity Production	**Potential**	Utility-scale solar photovoltaic (PV) power: By 2030, sufficient new utility-scale solar PV capacity is deployed to ensure that 30% of electricity generation is from renewable sources (baseline renewable facilities plus the new solar capacity). The build-out of new solar is limited to 919 MW, however (Ministry of Science, Technology, Energy and Mining 2013; Worldwatch Institute 2013).
Electricity Production	**Potential**	Run-of-river hydropower: By 2030, 54.3 MW of new run-of-river hydropower capacity is deployed at 11 sites identified in Ministry of Science, Technology, Energy and Mining (2013).
Electricity Production	**Planned**	Net billing: By 2020, 12.8 MW of distributed solar PV capacity is deployed under MSET's Net Billing program – an increase of 12.08 MW over the baseline (Ministry of Science, Energy and Technology 2016).
Agriculture	**Potential**	Animal waste digestion power: By 2030, a portion of livestock manure is routed to anaerobic digesters to produce biogas, which is then used to generate electricity. The total electric capacity deployed is 28.2 MW.
Waste & Wastewater	**Potential**	Municipal solid waste (MSW) incineration power: 56 MW of waste incineration electricity generating capacity is deployed in 2025 at the Riverton and Retirement dumpsites.
Waste & Wastewater	**Potential**	Landfill Gas (LFG) Power: LFG collection systems and electricity generation equipment are installed in 2020 at the Riverton and Retirement dumpsites. Two cases are explored: 1) LFG only – No MSW incineration is deployed at the sites, so more LFG is available over the long term. 4.06 MW of LFG capacity is installed. 2) LFG and MSW incineration – MSW incineration is deployed at the sites in 2025, reducing the amount of LFG available over the long term. 2.598 MW of LFG capacity is installed.

4.1.1 Solar Hot Water

This potential action involves the deployment of solar water heaters (SWHs) in newly constructed homes and the retrofitting of existing homes with SWHs. The measure reduces both indirect emissions from the electricity sector (by reducing consumption from electric water heaters) and direct emissions from households (by reducing consumption of LPG used to heat water on stovetops). With the correct mixture of policies, Gardner (2011) estimates that 60% of households in the Caribbean region can make use of SWHs over a period of about ten years. SEI includes this measure by increasing current penetration levels to 60% by the year 2030, finally reaching 85% of households by 2050 (current levels in Israel, the world leader in per-capita use of SWH (Gardner 2011)). Energy, emissions, and cost savings from reduced electricity production are calculated on the supply side of the LEAP model. Additional costs are incurred in the residential sector for the solar heating equipment (Table 4), compared with an equivalent conventional electric heater.

Table 4: Modelling Parameters for Solar Hot Water Mitigation Action

Parameter	Value	Source	Notes
Capital cost of solar heater	1,115 2015 USD/ household	(ATL Appliance Traders Jamaica n.d.)	While operation and maintenance (O&M) costs are typically lower for solar than for electric heaters (Gardner 2011), installation costs may be higher. SEI elects to exclude both.
Capital cost of electric heater	472 2015 USD/ household	(ATL Appliance Traders Jamaica n.d.)	While operation and maintenance (O&M) costs are typically lower for solar than for electric heaters (Gardner 2011), installation costs may be higher. SEI elects to exclude both.
Water heater lifetime	10 years	(Gardner 2011)	Conservative estimate.

4.1.2 Residential LED Lighting

In this potential action, residential lighting needs met by CFLs in the baseline scenario are satisfied instead by equivalent 800 lumen LEDs by 2030. Electricity demand is lowered, inducing energy, emissions, and cost savings in electricity production. Additional costs are incurred for the LED bulbs, which are more expensive than CFLs although they last longer.

Table 5: Modelling Parameters for Residential LED Lighting Mitigation Action

Parameter	Value	Source	Notes
CFL wattage	13 W	(U.S. Energy Information Administration 2016b)	"Typical" CFL bulb, 2020 estimate.
LED wattage	5 W	(U.S. Energy Information Administration 2016b)	"Typical" LED A19 bulb, 2020 estimate.
CFL capital cost	2.29 2015 USD/bulb	(U.S. Energy Information Administration 2016b)	"Typical" CFL bulb, 2020 estimate.
LED capital cost	3.95 2015 USD/bulb	(U.S. Energy Information Administration 2016b)	"Typical" LED A19 bulb, 2020 estimate.
CFL life	10,300 hours	(U.S. Energy Information Administration 2016b)	"Typical" CFL bulb, 2020 estimate.
LED life	25,000 hours	(U.S. Energy Information Administration 2016b)	"Typical" LED A19 bulb, 2020 estimate.
Bulbs per dwelling	8	SEI assumption	
Hours of use	180 hours/month	SEI assumption	

4.1.3 T8 Fluorescent Lighting in Schools and Hospitals

This planned action assumes that schools and hospitals convert from mostly 40W T12 to 32W T8 fluorescent lighting by 2030. Electricity demand is reduced, lowering energy use, emissions, and costs in electricity production.

The measure is adapted directly from a 2010 audit of public-sector electricity consumption, scaled as necessary to projected electricity demand in the future. The audit quantified the achievable energy savings from switching to T8 linear fluorescent lighting in the two public subsectors. Direct investment costs are annualized over the lifetime of the new technology, while additional cost savings arise from the electricity production sector.

Table 6: Modelling Parameters for T8 Fluorescent Lighting in Schools and Hospitals Mitigation Action

Parameter	Value	Source	Notes
Electricity consumption for lighting, education	5,026 MWh	(Tetra Tech 2011)	2010 value for education institutions.
Electricity consumption for lighting, health	6,730 MWh	(Tetra Tech 2011)	2010 value for healthcare institutions.
T8 Vs. T12 saved electricity consumption, education	903 MWh	(Tetra Tech 2011)	2010 value for education institutions.
T8 Vs. T12 saved electricity consumption, health	1,412 MWh	(Tetra Tech 2011)	2010 value for healthcare institutions.
Total investment cost, education	106,007 2015 USD	(Tetra Tech 2011)	Capital + installation cost of switching existing (2010) T12 to T8 bulbs. Cost per saved energy also used for hospitals.
T8 bulb lifetime	10.01 years	(Tetra Tech 2011)	24,000 hour lifetime, 2,397 annual hours of operation.

4.1.4 Public and Commercial LED Lighting

This potential action assumes that all commercial and public buildings deploy equivalent LED lights to replace incandescent bulbs and compact and linear fluorescent lamps (both T8 and T12) by 2030. Electricity demand is reduced, lowering energy use, emissions, and costs in electricity production.

The measure is adapted directly from a 2010 audit of public-sector electricity consumption, scaled as necessary to projected electricity demand in the future. It assumes that the percentage energy savings achievable in public sector buildings (i.e., excluding NWC and street lighting consumption) are also achievable in the private sector, and at the same average cost. Direct investment costs are annualized over the lifetime of the new LED technology, while additional cost savings arise from the electricity production sector.

Table 7: Modelling Parameters for Public and Commercial LED Lighting Mitigation Action

Parameter	Value	Source	Notes
Electricity consumption for public sector, minus NWC and street lighting	154.9 GWh/year	(Tetra Tech 2011)	2010 value.
Savings from efficient lighting	9.8 GWh/year	(Tetra Tech 2011)	2010 value.
Total investment cost	15.0 million 2015 USD	(Tetra Tech 2011)	35,000 hour lifetime, 2,397 annual hours of operation.

4.1.5 CNG for Alumina Production at Alpart

For this planned action, energy requirements for fuel oil in the newly reopened Alpart refinery are instead satisfied by CNG (in line with Scenario 2 of Jamaica's Second National Communication (Ministry of Local Government and the Environment and Environment and Disaster Management Unit 2011)).Starting in 2019. Equipment and operation costs of gas and oil combustion turbines are taken to be the same (Office of Utilities Regulation 2010), and so the cost of the measure is based only on the difference in the price of the fuels.

Table 8: Modelling Parameters for CNG for Alumina Production Mitigation Action

Parameter	Value	Source	Notes
Residual fuel oil price	0.328 2015 USD/ liter	(Petrojam 2017)	2015 value only. Source cited details prices in other years, and future prices are tied to the growth in the price of crude oil.
CNG price	12.53 2015 USD/ MMBTU	(Jamaica Public Service Company 2014)	2015 value only, for liquefied natural gas (LNG). Value in each year is reconstructed from Henry Hub price, following method described in source. Future prices are tied to the Japanese LNG import price.
Fuel switching year	2019	SEI assumption	
Share of national alumina production at Alpart	44%	(Rusal 2016b; Rusal 2016a; Ministry of Local Government and the Environment and Environment and Disaster Management Unit 2011)	Calculated using share of production capacities: 1.673 million tonnes at Alpart, 2.095 million tonnes at Windalco Ewarton and Jamalco plants.

4.1.6 CNG for Alumina Production

This potential action is an extrapolation of the measure described above, targeting the whole alumina production sector. The measure builds from the introduction of CNG at Alpart (displacing 44% of fuel oil with CNG, as described above), eventually displacing 100% of fuel oil consumed for alumina refining by the year 2025. No additional assumptions or modelling parameters are required.

4.1.7 Increased Cogeneration Efficiency

In this planned action, efficient steam turbine CHP technologies are used to meet heat and power requirements for the alumina-refining sector. Current (2010) technologies provide a combined average efficiency of between 75% and 85%, but the Jamaican government has long planned to improve this to 90% sector-wide (Watson 2010). Newer, more efficient generators are not expected to bring about the early retirement of older, still-functional generators. Therefore the measure is assumed to be introduced gradually as the old generators would naturally retire, through 2030.

The measure reduces the energy intensity per unit of alumina produced for grid-based electricity at alumina refineries, causing lower emissions from the power sector.

Table 9: Modelling Parameters for Increased Cogeneration Efficiency Mitigation Action

Parameter	Value	Source	Notes
Percent increase in cogenerated electricity from fuel oil, by 2030	10%	(Watson 2010)	Difference between old (assumed 80%) and target CHP efficiency.
Investment cost, O&M cost	-	SEI assumption	It is not clear that the cost of an efficient unit would be different than any modern unit used to replace existing CHPs at the end of their life.

4.1.8 Natural Gas Buses

The Jamaica Urban Transit Company (JUTC) is embarking on plans to introduce LNG buses into its fleet. Although natural gas-powered vehicles tend to be less fuel efficient than their conventional counterparts (Posada 2009; Barnitt and Chandler 2006), the age of JUTC's diesel fleet means that switching from diesel to natural gas buses can reduce energy consumption by up to 25% (Linton 2017). This planned mitigation action is also effective at reducing tailpipe emissions, as the emissions characteristics of LNG-powered buses are more favourable.

For this action, public bus ridership (measured in bus seats per capita) in Montego Bay/St. James Parish is assumed to be comparable with Kingston and St. Andrew. From this assumption, an estimated 136 buses would be required to serve the Montego Bay area and St. James Parish, which are all assumed to be replaced with LNG buses from 2020 - 2025. After 2025, the share of LNG among all fuels consumed for road transport will be held constant.

Table 10: Modelling Parameters for Natural Gas Buses Mitigation Action

Parameter	Value	Source	Notes
Parish population	666,041 (St. Andrew), 184,662 (St. James)	(Statistical Institute of Jamaica 2013)	2012 end-of-year population.
Population served per bus	1,359 people/bus	(Reynolds-Baker 2014)	Based on 25,000 seats/day served by 490 buses in Kingston Metropolitan Transport Region, home to 666,041 people.
Diesel consumption per conventional bus	10,440 GGE/year	(Alternative Fuels Data Center 2015)	US estimate. Local data for Jamaica could not be located.
Fuel savings, from diesel to LNG	25%	(Linton 2017)	
Incremental cost of LNG vs. diesel bus	26,700 2015 USD	(Barnitt and Chandler 2006)	
Investment cost of filling station	114,000 2015 USD/bus	(Mitchell 2015)	Average cost of CNG-fueling station.
LNG bus lifetime	15 years	(Yang et al. 2013)	
Filling station lifetime	20 years	(Yang et al. 2013)	

4.1.9 Smart LED Street Lighting

Based on JPS's Smart LED program, this planned action involves upgrading all grid-connected streetlights to LEDs by 2020. Compared to conventional lamps, the new lamps use less electricity, reducing energy inputs, emissions, and costs in electricity production. In addition, a sensor network is assumed to be deployed alongside the LED lamps, dimming (or switching off) the lamps as needed depending on pedestrian and motorist traffic - effectively reducing the number of hours of daily usage.

Additional equipment and installation costs for the LED lights are incurred on the demand side of the LEAP model for each lighting technology.

Table 11: Modelling Parameters for Smart LED Street Lighting Mitigation Action

Parameter	Value	Source	Notes
Capital and installation cost	177 – 210 2015 USD	(Jiang et al. 2015) (250 and 400W only)	70 - 400W high pressure sodium (HPS) lamps.
Capital and installation cost	320 2015 USD	(Jiang et al. 2015) (350W metal halide lamp)	125 - 400W mercury vapor lamps (MVL) and 160W tungsten lamps.
Capital and installation cost	290 - 385 2015 USD	(Rowe 2017)	43 - 161W LED lamps.
O&M Savings	50 2015 USD/year	(New York State Energy Research and Development Authority 2014)	LED lamps only, expressed relative to other technologies.
Lifetime	22,000 hours	(Clinton Climate Initiative 2010)	HPS lamps, average of two estimates.
Lifetime	28,000 hours	(Clinton Climate Initiative 2010)	MVL and tungsten lamps.
Lifetime	60,000 hours	(Clinton Climate Initiative 2010)	LED lamps, estimate based on range of lifetimes.
Reduction in usage for smart street-lights	55%	(Lau et al. 2015)	Relative to conventional management scheme.

4.1.10 Reduced Water Distribution Loss

Jamaica's National Water Commission is the largest public consumer of energy in the country, and the majority of its consumption is used for water pumps, motors, and drives. In this planned action, reductions in water loss are assumed to have a proportional impact on NWC's electricity consumption. The measure is introduced in 2018, reducing lost water from 53% to 37% in 2020, 30% in 2021, and 20% by 2023.

Table 12: Modelling Parameters for Reduced Water Distribution Loss Mitigation Action

Parameter	Value	Source	Notes
Share of NWC electricity used for water distribution	90%	(Tetra Tech 2011)	Pumping, motors, and variable speed drives.
Total investment cost	4.9 million 2015 USD	(Smith-Edwards 2015)	Implementation costs are not specific enough for annualisation, so they are spread equally among six project years.

4.1.11 B5 Blending

Biodiesel production using non-food crops grown on marginal lands is of national interest. Proposed crops include castor and jatropha, (Ministry of Energy and Mining 2010c), and processing of waste vegetable oil (WVO) into biodiesel is also being explored on a demonstration basis. While no commercial-scale biodiesel producers are currently operating in Jamaica, a B5 fuel mandate is under development (Bandy 2016) and should coincide with commissioning of the country's first production facility.

Under this planned mitigation action, biodiesel is produced from the oily seeds of the jatropha plant. It is then blended 5%-by-volume with ordinary diesel fuel for all final end-uses in the transport, industrial, commercial, residential, and agricultural sectors, but not for grid-based power generation. A small amount – 0.378 million litres per year – of WVO biodiesel production capacity is also included in the measure.

Table 13: Modelling Parameters for B5 Blending Mitigation Action

Parameter	Value	Source	Notes
Production Efficiency	64.98%	(Argonne National Laboratory 2012)	Jatropha pathway.
Production Efficiency	97.01%	(Argonne National Laboratory 2012)	WVO pathway.
Availability Factor	50%	SEI assumption, based on six-month crushing season for sugarcane (Landell Mills Development Consultants 2011)	Jatropha pathway.
Availability Factor	100%	SEI assumption	WVO pathway.
Auxiliary energy use	0.0752 GJ/GJ produced	(Argonne National Laboratory 2012)	WVO pathway. Composed of methanol (64.7%), natural gas (30.7%), and electricity (4.6%).
Auxiliary energy use	0.1301 GJ/GJ produced	(Argonne National Laboratory 2012)	Jatropha pathway. Includes auxiliary requirements from WVO pathway, plus 0.0549 GJ natural gas per GJ biodiesel produced required for oil extraction from jatropha plant.
Total cost of production	0.9957 2015 USD/liter biodiesel, shrinking at 1.05%/annum	(International Renewable Energy Agency 2013; OECD 2017)	Cost of Malaysian palm oil biodiesel, having subtracted 0.135 2015 USD/liter difference between jatropha and palm feedstock costs. Use for both jatropha and WVO biodiesel.

4.1.12 B20 Blending

A B20 mandate (20%-by-volume biodiesel blend) for all end-use diesel consumption by 2030 will also be considered. Other modelling parameters for this measure are identical to those for the B5 Blending measure.

4.1.13 E10 Blending, with Domestic Production

While Jamaica has long used imported ethanol to fulfil its E10 mandate, the country has yet to produce ethanol from domestic feedstock. In this planned action, 3.78 million litres of sorghum bioethanol production capacity is added in 2017, with a doubling by 2020 (Staff writer 2016). This is sufficient to satisfy the ethanol mandate in the short term, and additional sugarcane-derived ethanol production capacity is added as needed to meet E10 requirements in the longer run. Ethanol produced under this measure is blended with gasoline consumed in the transportation, industrial, commercial, and agricultural sectors.

Table 14: Modelling Parameters for E10 Blending with Domestic Production Mitigation Action

Parameter	Value	Source	Notes
Production efficiency	21.18%	(Argonne National Laboratory 2012)	Sorghum pathway.
Production efficiency	40.93%	(Ministry of Energy and Mining 2010c)	Sugarcane pathway, 70 tonnes of cane per liter of ethanol.
Availability factor	50%	SEI assumption based on sugarcane pathway	Sorghum pathway.
Availability factor	50%	Based on six-month crushing season (Landell Mills Development Consultants 2011)	Sugarcane pathway.
Total cost of production	0.993 2015 USD/lge, growing at 0.27%/annum	(International Renewable Energy Agency 2013; OECD 2017)	Sugarcane ethanol only, used for both cane and sorghum.

4.1.14 E85 Blending

Given Jamaica's history of growing and processing sugarcane, as well as successes in other Caribbean countries, an E85 mandate for all end-use gasoline consumption by 2030 has also been assessed. Other modelling parameters for this measure are identical to those for the E10 Blending measure.

4.1.15 Reduced Electricity Losses

In this planned action, losses in electricity transmission and distribution are reduced by 4.1% of net generation by 2020. Technical losses decrease by 1.5%, and non-technical losses are lowered by 2.6% (Ministry of Energy and Mining 2010d). Upgraded billing, inspection, and enforcement systems produce these outcomes, which lead to energy, emissions, and cost savings in electricity production.

Table 15: Modelling Parameters for Reduced Electricity Losses Mitigation Action

Parameter	Value	Source	Notes
Reduction in technical losses	1.5%	(Ministry of Energy and Mining 2010d)	
Reduction in non-technical losses	2.6%	(Ministry of Energy and Mining 2010d)	
Implementation cost	70.7 million 2015 USD	(Ministry of Energy and Mining 2010d)	Assumed to be a one-time cost to establish new norms and systems.

4.1.16 Biomass Cogeneration

Existing sugar mills and newly constructed bioethanol distilleries are both good candidates for generating surplus electricity, which can be sold to the national grid. With an appropriate choice of technology, this electricity can be generated easily from CHP boilers used to meet the internal heat and power requirements at the mills and distilleries.

In this potential action, additional electricity is produced beyond the needs of Jamaica's sugar industry, as well as in any bioethanol plants which may be built in the future. Once on the grid, the electricity replaces a portion of what would otherwise need to be generated by conventional power plants. The electricity production is modelled as a co-product of raw sugar milled or bioethanol produced, respectively, and so the cost of the measure depends on the sector from which electricity is co-produced.

Table 16: Modelling Parameters for Biomass Cogeneration Mitigation Action

Parameter	Value	Source	Notes
Surplus electricity production	244 kWh year-round /tonne cane processed in crushing season	Based on 90 kWh surplus per tonne of cane if using only bagasse (Landell Mills Development Consultants 2011)	Surplus electricity generated by bagasse during the growing season, mixed biomass during other seasons.
Total production cost	0.1153 2015 USD/kWh	(Landell Mills Development Consultants 2011)	Average cost of co-produced electricity at existing sugar mills.
Surplus electricity production	43.2 kWh/liter produced	Sorghum éthanol pathway "IIIa" (Cai et al. 2013)	From sorghum ethanol production.
Surplus electricity production	60 kWh/tonne cane processed	Conventional boiler technology yielding 60 kWh surplus per tonne of cane (Leal et al. 2013)	From sugarcane ethanol production.
Overnight capital cost, CHP boiler	3,097 2015 USD	(Ministry of Science, Technology, Energy and Mining 2013)	For CHP boiler used in bioethanol distillery.
Fixed O&M cost, CHP boiler	108.6 2015 USD/kW	(U.S. Energy Information Administration 2016a)	For CHP boiler used in bioethanol distillery.
Variable O&M cost, CHP boiler	5.41 2015 USD/MWh	(U.S. Energy Information Administration 2016a)	For CHP boiler used in bioethanol distillery.
Availability factor, CHP boiler	83%	(U.S. Energy Information Administration 2015)	For CHP boiler used in bioethanol distillery.
Weighted average cost of capital (WACC)	11.95%	(Office of Utilities Regulation 2010)	For CHP boiler used in bioethanol distillery.
Construction loan period	10 years	SEI assumption	For CHP boiler used in bioethanol distillery.

4.1.17 Utility-scale Wind Power

This potential action envisions constructing enough new utility-scale, on-shore wind capacity by 2030 to ensure that 30% of electricity generation is from renewable sources (baseline renewable facilities plus the new wind capacity). The goal of 30% renewable electricity is based on the latest target from MSET (Ministry of Science, Energy and Technology 2016) and is also a level up to which renewable energy may integrated into the electricity supply without supplemental, non-baseline grid investments (Ministry of Science, Technology, Energy and Mining 2013). The maximum amount of new wind that may be deployed under the action is 507 MW, corresponding to the potential of all candidate sites in Ministry of Science, Technology, Energy and Mining (MSTEM) (2013) and Worldwatch (2013) except Kemps Hill (omitted due to its low capacity factor). The build-out of new wind each year may not exceed 100 MW.

Implementing new renewable electricity capacity such as on-shore wind reduces the need for conventional fossil-fuelled generation and the associated GHG emissions. It changes the balance of electricity production costs since renewable facilities often have higher capital costs and lower running costs than conventional technologies. When the renewable resource is intermittent, as wind is, the intermittency must be balanced by storage or other generation options. The LEAP model resolves this question in the least-cost way, weighing availabilities and capital, O&M, and fuel requirements.

Table 17: Modelling Parameters for Utility-scale Wind Power Mitigation Action

Parameter	Value	Source	Notes
Facility life	25 years	(Ministry of Science, Technology, Energy and Mining 2013)	
Availability factor	Varies by hour of year	(Worldwatch Institute 2013; Ministry of Science, Technology, Energy and Mining 2013)	Capacity-weighted average of availability at candidate sites.
Capacity credit	34%	(Worldwatch Institute 2013; Ministry of Science, Technology, Energy and Mining 2013)	Based on availability at time of peak load.
Overnight capital cost	From 1,879 2015 USD/kW in 2017 to 1,687 2015 USD/kW in 2050	(Ministry of Science, Technology, Energy and Mining 2013; National Renewable Energy Laboratory 2016)	
Fixed O&M cost	0 2015 USD/kW-year	(Ministry of Science, Technology, Energy and Mining 2013)	
Variable O&M cost	10.3 2015 USD/MWh	(Ministry of Science, Technology, Energy and Mining 2013)	
Weighted average cost of capital (WACC)	11.95%	(Office of Utilities Regulation 2010)	
Construction loan period	10 years	SEI assumption	

4.1.18 Utility-scale Solar PV Power

Paralleling Utility-scale Wind Power, this potential action involves constructing enough new utility-scale solar PV capacity by 2030 to ensure that 30% of electricity generation is from renewable sources (baseline renewable facilities plus the new solar capacity). The maximum amount of new solar that may be deployed under the action is 919 MW, corresponding to the potential of all candidate sites in MSTEM (2013) and Worldwatch (2013) except Paradise 2 (omitted because it is assumed to be supplanted by the Paradise Park solar facility now in development). The build-out of new solar each year may not exceed 100 MW. The energy, cost, emissions, and grid balancing implications of new solar power are conceptually similar to those for new wind. Solar energy is of course not available at night, which makes balancing potentially more challenging.

Table 18: Modelling Parameters for Utility-scale Solar Power Mitigation Action

Parameter	Value	Source	Notes
Facility life	25 years	(Ministry of Science, Technology, Energy and Mining 2013)	
Availability factor	Varies by hour of year	(Ministry of Science, Technology, Energy and Mining 2013; Worldwatch Institute 2013; aleo solar AG 2010)	Capacity-weighted average of availability at candidate sites.
Capacity credit	0%	(Ministry of Science, Technology, Energy and Mining 2013; Worldwatch Institute 2013; aleo solar AG 2010)	Based on availability at time of peak load.
Overnight capital cost	From 2,156 2015 USD/kW in 2017 to 1,267 2015 USD/kW in 2050	(Ministry of Science, Technology, Energy and Mining 2013; National Renewable Energy Laboratory 2016)	
Fixed O&M cost	6.7 2015 USD/kW-year	(Ministry of Science, Technology, Energy and Mining 2013)	
Variable O&M cost	0 2015 USD/MWh	(Ministry of Science, Technology, Energy and Mining 2013)	
Weighted average cost of capital (WACC)	11.95%	(Office of Utilities Regulation 2010)	
Construction loan period	10 years	SEI assumption	

4.1.19 Run-of-river Hydropower

For this potential action, 54.3 MW of new run-of-river hydropower capacity is deployed by 2030. The capacity is assumed to be built at 11 candidate sites identified in MSTEM (2013) (excluding Dry River since it is deprecated in MSTEM's analysis). The maximum addition of new capacity per year is 10 MW. Additional hydropower displaces conventional fossil-fuelled generation, with impacts on energy requirements, costs, and emissions. The hydropower resource does vary during the year – following MSTEM (2013), it is modelled with a high season in November and December, a low season in July and August, and a medium season the rest of the year – which affects the role hydro can play in meeting demand and load.

Table 19: Modelling Parameters for Run-of-river Hydropower Mitigation Action

Parameter	Value	Source	Notes
Facility life	40 years	(Ministry of Science, Technology, Energy and Mining 2013)	
Availability factor	Varies by hour of year	(Ministry of Science, Technology, Energy and Mining 2013)	Capacity-weighted average of availability at candidate sites.
Capacity credit	61%	(Ministry of Science, Technology, Energy and Mining 2013)	Based on availability at time of peak load.
Overnight capital cost	3,601 2015 USD/kW	(Ministry of Science, Technology, Energy and Mining 2013)	
Fixed O&M cost	51 2015 USD/kW-year	(Ministry of Science, Technology, Energy and Mining 2013)	
Variable O&M cost	0 2015 USD/MWh	(Ministry of Science, Technology, Energy and Mining 2013)	
Weighted average cost of capital (WACC)	11.95%	(Office of Utilities Regulation 2010)	
Construction loan period	10 years	SEI assumption	

4.1.20 Net Billing

This planned action assumes that 12.8 MW of distributed solar PV capacity is deployed under MSET's Net Billing program by 2020. The Net Billing program was piloted from 2012-2015 (Doris et al. 2015), then was updated and resumed in 2016 (Ministry of Science, Energy and Technology 2016). In the pilot phase 1.4 MW of distributed solar PV capacity was connected to the grid (Doris et al. 2015). According to MSET's Registry of Net Billing Licenses, 0.72 MW of this capacity connected in 2012 and 2013 (Ministry of Science, Energy and Technology 2017b). The overall cap for grid-tied capacity under the Net Billing program is 12.8 MW (Ministry of Science, Energy and Technology 2016).

The electricity production impacts of net billing (and other distributed generation) capacity deployed through 2013 are captured in the baseline scenario. This is because the baseline electricity demand projection is for demand net of production by these resources. The net billing mitigation action is thus for 12.08 MW of capacity implemented during 2014-2020 (and rebuilt as needed thereafter to be operational through 2055). This capacity is assumed to be solar PV whose output is not subject to normal transmission and distribution losses. As Doris et al. (2015) suggest, its deployment is not expected to necessitate additional grid investments relative to the baseline.

Electricity generation by net billing installations reduces the need for centrally produced electricity, changing energy use, emissions, and costs in the electricity sector. New costs are incurred for the distributed PV equipment, its installation and O&M, and administration of the Net Billing programme.

Table 20: Modelling Parameters for Net Billing Mitigation Action

Parameter	Value	Source	Notes
Distributed solar PV life	20 years	(National Renewable Energy Laboratory 2016)	
Distributed solar PV availability factor	Varies by hour of year	(Ministry of Science, Technology, Energy and Mining 2013; Worldwatch Institute 2013; aleo solar AG 2010)	
Distributed solar PV capacity credit	0%	(Ministry of Science, Technology, Energy and Mining 2013; Worldwatch Institute 2013; aleo solar AG 2010)	Based on availability at time of peak load.
Distributed solar PV overnight capital cost	From 2,724 2015 USD/kW in 2014 to 997 2015 USD/kW in 2050	(National Renewable Energy Laboratory 2016)	
Distributed solar PV fixed O&M cost	From 15.6 2015 USD/kW-year in 2014 to 7.8 2015 USD/kW-year in 2025	(National Renewable Energy Laboratory 2016)	
Distributed solar PV variable O&M cost	0 2015 USD/MWh	(National Renewable Energy Laboratory 2016)	
Distributed solar PV weighted average cost of capital (WACC)	11.95%	(Office of Utilities Regulation 2010)	
Distributed solar PV construction loan period	10 years	SEI assumption	
Cost of administering Net Billing program	90.6 2015 USD/kW	(Doris et al. 2015)	

4.1.21 Animal Waste Digestion Power

Under this potential action, a portion of the manure from Jamaica's four most populous livestock animals is redirected to anaerobic digesters to produce biogas for power generation. These animals include all cattle (dairy or other), chickens (layer, broilers), swine (market or breeding), and goats. Only manure which in the baseline is managed using liquid/slurry, solid storage, or dry-lot schemes is sent to the newly built digesters. The digesters encourage methanogenesis, converting 80%[108] of the available energy in the influent into methane (National Greenhouse Gas Inventories Programme 2006b) and resulting in a 65% methane-by-volume biogas (World Bank and Global Methane Initiative 2016).

Jamaica's latest GHG inventory (Dore 2015b) indicates that 40% of dairy cattle manure, 30% of other cattle manure, 80% of swine manure, 70%/80% of layer/broiler chicken manure, and 30% of goat manure is managed using one of the three practices mentioned above. If this manure was instead managed using anaerobic digestion, over 74 million m^3 of methane could be produced, calculated using livestock populations embedded in GHG inventory calculations and methane production rates for each species included inTable 21 (National Greenhouse Gas Inventories Programme 2006a). If captured, this biogas could be entirely consumed using 28.2 MW of internal combustion engine capacity, with costs and characteristics described in Table 21: Modelling Parameters for Animal Waste Digestion Power Mitigation Action.

The measure reduces non-energy emissions of both methane and nitrous oxide by shifting manure away from conventional management practices. While anaerobic digesters produce large quantities of methane for the same amount of manure (relative to other management strategies with low MCF values (National Greenhouse Gas Inventories Programme 2006b)), all of this methane is assumed to be combusted to generate electricity. None of the nitrogen in the manure is converted to nitrous oxide in the digester (National Greenhouse Gas Inventories Programme 2006a).

Table 21: Modelling Parameters for Animal Waste Digestion Power Mitigation Action

Parameter	Value	Source	Notes
Facility life	15 years	(Vazquez Alvarez and Buchauer 2015)	
Gross heat rate	11,858 kJ/kWh	(U.S. Environmental Protection Agency 2017b)	From landfill gas internal combustion engine.
Planned outage rate	4.3%	(International Renewable Energy Agency 2012)	Outage split equally between planned and unplanned after accounting for own-use.
Unplanned outage rate	4.3%	(see above)	
Capacity credit	83%	(International Renewable Energy Agency 2012)	Based on availability at time of peak load.
Electricity own-use rate	7%	(U.S. Environmental Protection Agency 2017b)	From landfill gas internal combustion engine, excluding energy for gas collection and flaring.
Overnight capital cost	5,748 2015 USD/kW	(International Renewable Energy Agency 2012; U.S. Environmental Protection Agency 2017b)	Includes costs for digester and electricity generating equipment.
Fixed O&M cost	152 2015 USD/kW-year	(International Renewable Energy Agency 2012)	Includes costs for digester and electricity generating equipment.
Variable O&M cost	5 2015 USD/MWh	(International Renewable Energy Agency 2012)	
Weighted average cost of capital (WACC)	11.95%	(Office of Utilities Regulation 2010)	
Construction loan period	10 years	SEI assumption	
Annual CH_4 production in anaerobic digester, dairy cattle	163.7 kg/head	(National Greenhouse Gas Inventories Programme 2006a)	Average of North American and Latin American livestock.
Annual CH_4 production in anaerobic digester, other cattle	69.06 kg/head	(National Greenhouse Gas Inventories Programme 2006a)	Average of North American and Latin American livestock.

108 *This conversion ratio, called the "methane conversion factor" or MCF, differs widely depending on the manure management practice.*

Parameter	Value	Source	Notes
Annual CH_4 production in anaerobic digester, market swine	21.19 kg/head	(National Greenhouse Gas Inventories Programme 2006a)	Average of North American and Latin American livestock.
Annual CH_4 production in anaerobic digester, breeding swine	31.99 kg/head	(National Greenhouse Gas Inventories Programme 2006a)	Average of North American and Latin American livestock.
Annual CH_4 production in anaerobic digester, layer chickens	8.0 kg/head	(National Greenhouse Gas Inventories Programme 2006a)	Estimated using CH_4 production from conventional practices, and MCF ratio of conventional practice to anaerobic digestion.
Annual CH_4 production in anaerobic digester, broiler chickens	0.8 kg/head	(National Greenhouse Gas Inventories Programme 2006a)	Estimated using CH_4 production from conventional practices, and MCF ratio of conventional practice to anaerobic digestion.
Annual CH_4 production in anaerobic digester, goats	8.8 kg/head	(National Greenhouse Gas Inventories Programme 2006a)	Estimated using CH_4 production from conventional practices, and MCF ratio of conventional practice to anaerobic digestion.

4.1.22 MSW Incineration Power

This potential action contemplates deploying 56 MW of MSW incineration capacity at the Riverton and Retirement solid waste disposal sites by 2030. The amount of capacity is sized to the waste disposed at each site: 36 MW at Riverton (Caribbean Policy Research Institute 2015) and 20 MW at Retirement (Ministry of Science, Technology, Energy and Mining 2013). The incinerators consume MSW that would otherwise be buried. The incineration capacity is built between 2026 and 2030, with the exact implementation schedule selected to minimize costs. After the initial deployment, the capacity is rebuilt as necessary to remain operational through 2055.

Incinerating MSW not only provides electricity that can displace conventionally produced power (with attendant energy, costs, and emissions impacts) but also reduces non-energy emissions from burying waste. GHG emissions from waste burying are calculated in the LEAP model using the first order decay technique (National Greenhouse Gas Inventories Programme 2006b), which depends on the mass and composition of buried waste, the time elapsed since burial, management practices at the disposal site, and other factors. This method was also used in Jamaica's most recent GHG inventory (Dore 2015a). Diverting waste from burying to incineration affects the first order decay calculations in two ways: by reducing the amount of new waste buried and by changing the proportions of waste buried at different types of disposal sites (unmanaged shallow, unmanaged deep, and managed deep).[109] In the baseline scenario, the share of waste buried at each type of disposal site is based on historical data from 2013 (Dore 2015b). The shares change when less waste is buried at Riverton, a managed deep disposal site, and Retirement, an unmanaged shallow site. MSW consumed in incineration is assumed to be diverted from each site in proportion to its potential capacity. Lowering the total amount of waste buried also reduces non-energy emissions of non-methane volatile organic compounds (NMVOC).

Table 22: Modelling Parameters for MSW Incineration Power Mitigation Action

Parameters	Value	Source	Notes
Facility life	25 years	(Ministry of Science, Technology, Energy and Mining 2013)	
Gross heat rate	14,400 kJ/kWh	(Ministry of Energy and Mining 2010b)	
Lower heating value of MSW	8.87 MJ/kg	(Ministry of Energy and Mining 2010b)	
Planned outage rate	11.5%	(Ministry of Science, Technology, Energy and Mining 2013)	
Unplanned outage rate	11.5%	(Ministry of Science, Technology, Energy and Mining 2013)	
Capacity credit	69.7%	(Ministry of Science, Technology, Energy and Mining 2013; Astrup et al. 2015)	Based on availability at time of peak load.
Electricity own-use rate	9.5%	(Astrup et al. 2015)	
Overnight capital cost	5,403 2015 USD/kW	(Ministry of Science, Technology, Energy and Mining 2013)	
Fixed O&M cost	343 2015 USD/ kW-year	(Ministry of Science, Technology, Energy and Mining 2013)	
Variable O&M cost	28 2015 USD/ MWh	(Ministry of Science, Technology, Energy and Mining 2013)	
Weighted average cost of capital (WACC)	11.95%	(Office of Utilities Regulation 2010)	
Construction loan period	10 years	SEI assumption	
Fraction of incinerated waste diverted from unmanaged shallow disposal sites	36.4%	(Caribbean Policy Research Institute 2015; Ministry of Science, Technology, Energy and Mining 2013)	
Fraction of incinerated waste diverted from managed deep disposal sites	63.6%	(Caribbean Policy Research Institute 2015; Ministry of Science, Technology, Energy and Mining 2013)	

109 *Each type has a different potential to create CH_4 from waste.*

4.1.23 LFG Power

In this potential action, LFG collection systems and electricity generation equipment are installed in 2020 at the Riverton and Retirement dumpsites. LFG emissions are caused by burying waste and are assumed to be 50% methane (U.S. Environmental Protection Agency 2017a). As indicated in Section below, these emissions are calculated in the LEAP model using the first order decay method.[110] Since the method depends on the amount of waste buried, there is a potential interaction between the LFG Power and MSW Incineration Power actions. If incineration is implemented at Riverton and Retirement, less waste is buried from the commissioning date, and future LFG production is lower. Accordingly, two scenarios for LFG utilization are explored:

1) Case 1 (LFG only) - No MSW incineration is deployed at Riverton and Retirement, so more LFG is available over the long term. 4.06 MW of LFG electricity generation capacity is installed in 2020 and rebuilt as needed to remain operational through 2055.

2) Case 2 (LFG and MSW incineration) - MSW incineration is deployed at Riverton and Retirement in 2025 (i.e., the MSW Incineration Power action is implemented), reducing the amount of LFG available over the long term. 2.598 MW of LFG capacity is installed in 2020 and is not rebuilt at the end of its life.

The amount of capacity in each case was determined through site-specific modelling of Riverton and Retirement using the LFGcost-Web Model (U.S. Environmental Protection Agency 2017b). This model was also used to calculate a number of technical and cost parameters of LFG systems that depend on the capacity deployed (Table 23). Site-specific inputs for the LFGcost-Web modelling, including waste disposal history and methane generation rates and potential, were derived primarily from Jamaica's last GHG inventory (Dore 2015b). Electricity production with internal combustion engine generators was simulated.

Like MSW incineration, capturing and using LFG for electricity has a dual GHG emission benefit. The resulting electricity can substitute for higher-carbon power, and non-energy emissions of CH_4 from waste burying are reduced when the captured LFG is burned. NMVOC emissions from buried waste are also lowered by burning LFG.

Table 23: Modelling Parameters for LFG Power Mitigation Action

Parameter	Value	Source	Notes
Facility life	15 years	(U.S. Environmental Protection Agency 2017b)	
Gross heat rate	11,858 kJ/kWh	(U.S. Environmental Protection Agency 2017b)	
Planned outage rate	4.2% (Case 1) 13.6 (Case 2)	(U.S. Environmental Protection Agency 2017b)	Reflects fluctuations in LFG production as well as maintenance and other downtime requirements.
Unplanned outage rate	4.2% (Case 1) 13.6 (Case 2)	(U.S. Environmental Protection Agency 2017b)	Reflects fluctuations in LFG production as well as maintenance and other downtime requirements.
Capacity credit	80.1% (Case 1) 63.4% (Case 2)	(U.S. Environmental Protection Agency 2017b)	Based on availability at time of peak load.
Electricity own-use rate	11.9% (Case 1) 12.9% (Case 2)	(U.S. Environmental Protection Agency 2017b)	Includes own use by generation and LFG capture equipment.
Overnight capital cost	3,814 2015 USD/kW (Case 1) 5,195 2015 USD/kW (Case 2)	(U.S. Environmental Protection Agency 2017b)	Includes costs for generation and LFG capture equipment.
Fixed O&M cost	90 2015 USD/kW-year (Case 1) 141 2015 USD/kW-year (Case 2)	(U.S. Environmental Protection Agency 2017b)	Includes costs for generation and LFG capture equipment.
Variable O&M cost	26 2015 USD/MWh	(U.S. Environmental Protection Agency 2017b)	Includes costs for generation and LFG capture equipment.
Weighted average cost of capital (WACC)	11.95%	(Office of Utilities Regulation 2010)	
Construction loan period	10 years	SEI assumption	

110 *Specifically, the first order decay modelling yields emissions of CH_4, and LFG emissions are calculated as twice the CH_4 emissions.*

Parameter	Value	Source	Notes
% CH_4 in LFG	50%	(U.S. Environmental Protection Agency 2017a)	
% NMVOC in LFG	1.3%	(European Environment Agency 2016)	
Area of Riverton and Retirement dumpsites	106 acres (Riverton) 27 acres (Retirement)	(National Solid Waste Management Authority 2015)	
Year Riverton and Retirement opened	1983 (Riverton) 1985 (Retirement)	(National Solid Waste Management Authority 2015)	
Waste disposal histories for Riverton and Retirement	Multiple historical values	(Dore 2015b)	

4.2 Mitigation Pathways

In addition to quantifying the mitigation potential and cost of each individual action, SEI defined three combined policy scenarios that include a selection of actions available in Jamaica. The purpose of these combined scenarios is to explore consistent, plausible future emission trajectories for Jamaica, while accounting for the various interacting effects that each of the separate measures may have on one another.

4.2.1 All Planned Measures

Under this combined policy scenario, all planned mitigation actions are included as described in the preceding section. The GHG abatement resulting from the combination of these measures extrapolates Jamaica's current emission trajectory, assuming that all options currently being discussed come to fruition according to the schedule described in this report.

4.2.2 Unconditional Nationally Determined Contribution

For this combined policy scenario, mitigation actions are layered to create a plausible future scenario in which Jamaica's unconditional Nationally Determined Contribution (NDC) targets are met (Ministry of Water, Land, Environment and Climate Change 2015). These targets consist of a mid-term emission reduction by 2025, as well as a final additional reduction achieved by 2030.

The abatement levels described in the NDC itself are expressed relative to a reference case, which was developed separately from the baseline analysis for this report. As a result, the absolute emissions estimates from the NDC baseline may differ from the baseline projection in the LEAP model. To ensure that Jamaica's contribution to the global abatement burden (which it committed to in its NDC) is materially unchanged, the absolute emission reductions from the NDC are adopted in this pathway scenario. These are summarized in Table 24.

Table 24: Absolute emissions reduction targets embodied by Jamaica's unconditional NDC

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

The NDC specifies that emission reduction targets apply only to the energy sector: that is, excluding non-energy emissions from industrial products and product use, agriculture, forestry and other land use, and waste[111]. Therefore only abatement which occurs within the energy sector of the LEAP model is eligible to meet the targets. For the waste management measures explored in this analysis that span the energy and non-energy sectors, only the abatement which is directly related to their energy production is counted.

The selection of measures to include in in the Unconditional NDC Pathway begins with measures of highest cost-effectiveness at reducing GHG emissions. Measures are added in order of their cost until both the 2025 and 2030 mitigation targets are either met or exceeded, relative to the model's baseline scenario.

4.2.3 Conditional Nationally Determined Contribution

As an extension to the combined scenario which meets Jamaica's unconditional NDC goals, a policy scenario satisfying Jamaica's conditional NDC goals was assessed. These goals are moderately more aggressive, contingent on the accessibility of international finance mechanisms. Table 25 describes the targets.

Table 25: Absolute emissions reduction targets embodied by Jamaica's conditional NDC

Year	Abatement Target
2025	1.344 Mt CO_2e
2030	1.449 Mt CO_2e

Measures are selected for the Conditional NDC Pathway in the same way as for the Unconditional NDC Pathway, in order of their cost-effectiveness.

111 While the emissions objective in the unconditional NDC combined policy scenario targets only the energy sector, it should be noted that the LEAP model covers all sectors and sources of emissions, including non-energy sources.

4.3 Modelling Results

4.3.1 Baseline Scenario

To contextualize the scale of the GHG reductions described in the next section, emission results for the baseline scenario are presented first.

Figure 2 shows the contribution from each sector (both energy and non-energy sectors) to the national GHG emissions total, while Table 26 examines the contribution of each of the major greenhouse gases, including CO_2 from land use, land-use change, and forestry.

Figure 2: Baseline GHG emissions for Jamaica112 through 2055, by sector

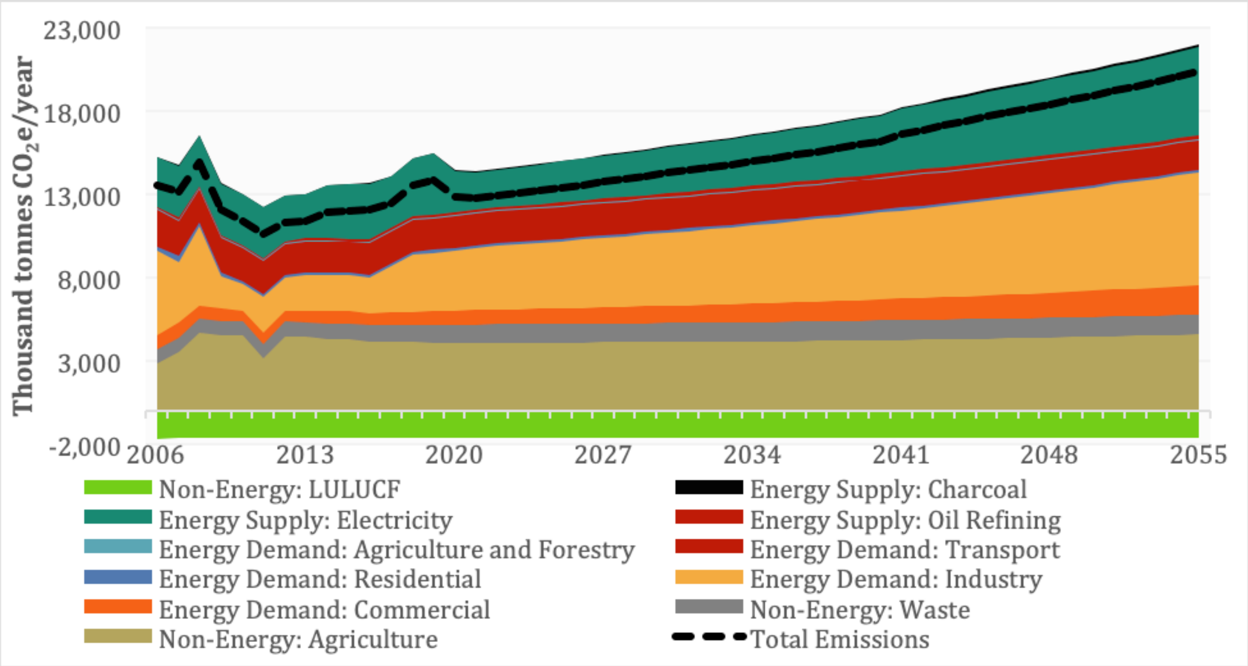


Table 26: National emissions through 2055, by GHG (thousands tonnes CO2e)

GHG	2015	2020	2025	2030	2035	2040	2045	2050	2055
CO_2	6,527	7,395	7,915	8,702	9,501	10,421	11,757	12,868	14,150
CH_4	1,380	1,493	1,571	1,628	1,679	1,725	1,769	1,813	1,860
N_2O	3,997	3,828	3,831	3,849	3,890	3,957	4,047	4,160	4,294
HFCs	94	85	78	72	67	63	59	56	53
Total	11,997	12,801	13,395	14,251	15,137	16,166	17,633	18,897	20,358

112 The reader's attention should be directed to emissions from earlier historical years in Figure 2. Historical emissions which are generated by the Jamaican national LEAP model tend to be 5 – 15% lower than those seen in Jamaica's GHG inventory (Dore 2015a). This is mainly attributable to a difference in choice of global warming potential (GWP) values. The inventory selects GWPs from the Intergovernmental Panel on Climate Change's Second Assessment Report, while GWPs from the Fifth Assessment Report are used in the LEAP model. The discrepancy is especially important for non-CO2 GHGs.

4.4 Mitigation Actions

This section details two key results from the modelling of each mitigation action. The first is the mitigation benefit of the action, expressed as the cumulative amount of CO_2e abated from the onset of the action to the end of the scenario-planning horizon. The second result is the average social cost (or savings) for accessing the action's abatement, expressed in cumulative discounted dollars per unit of CO2e abatement.

These results are comparative, and must necessarily be expressed relative to a scenario that does not contain the measure in order to evaluate emissions and cost differences. Results from two comparative strategies are given here: one in which measures are compared directly to the model's baseline scenario, and one in which the measures are compared to a scenario which already includes mitigation measures with lower cost of abatement. Using vocabulary borrowed from Sathaye and Meyers (1995), we refer to the first strategy as the "partial" or individual approach, and the second strategy as the "retrospective" approach.

4.4.1 Mitigation Action Results: Partial Approach

Table 27 provides the following results for each mitigation action, using the partial approach in which each measure is shown independently of one another. This method does not account for interactive effects of one measure with another, which may increase or reduce their mutual effectiveness at abating emissions.

a) The annual GHG mitigation potential of the action. Expressed in tonnes of equivalent CO_2 per year, relative to the baseline scenario. Decadal results are given, expressed as negative values because they represent a reduction in emissions relative to the baseline.

b) The GHG abatement cost of the action. Expressed as the net present value[113] (NPV) of all direct costs or benefits associated with the measure, per unit of cumulative (2017 – 2055) GHG abatement. Measures are listed in order of ascending abatement cost. Negative values indicate savings.

Table 27: Key modelling results for each separate mitigation action

Measure	Annual Mitigation Potential for Select Years (kt CO_2e/year)				Abatement Cost (discounted 2015 USD/ tonne CO_2e)
	2020	2030	2040	2050	
Smart LED Street Lighting	43.0	30.2	30.1	30.1	-230.94
Residential LED Lighting	3.1	3.8	3.7	3.5	-206.07
Increased Cogeneration Efficiency[1]	385.3	709.5	843.8	1,008.4	-96.67
Reduced Electricity Losses	246.3	166.2	201.5	248.8	-96.07
T8 Fluorescent Lighting in Schools and Hospitals	1.5	2.8	3.9	5.6	-83.29
Natural Gas Buses	-	6.2	5.6	5.4	-70.49
Utility-Scale Wind Power	1,053.0	732.4	736.4	743.6	-60.72
Run-of-River Hydropower	211.3	120.6	121.8	122.2	-57.61
Reduced Water Distribution Losses Kingston	24.0	15.8	15.4	14.5	-46.45
Reduced Water Distribution Losses National	106.9	71.8	70.3	65.8	-46.29
Net Billing	25.3	12.7	13.4	13.7	-36.78
Utility-Scale Solar PV Power	100.5	755.9	776.9	779.0	-24.82
Public and Commercial LED Lighting	38.8	72.4	102.5	145.3	-14.18
Biomass Cogeneration	149.5	255.9	335.8	441.3	-13.66
B20 Blending	38.7	176.6	179.1	190.1	-12.07
B5 Blending	38.7	43.5	44.1	46.8	-6.30
Animal Waste Digestion Power	1,205.6	1,140.2	1,169.2	1,224.8	-0.61
LFG Power	796.1	784.3	784.3	784.3	-0.19
MSW Incineration Power	-	522.9	698.4	758.7	7.72
CNG for Alumina Production	408.0	1,061.4	1,238.1	1,444.1	11.48
CNG for Alumina Production at Alpart	336.6	467.0	527.8	595.4	12.76
Solar Hot Water	7.2	11.5	14.3	16.7	110.79
E85 Blending	-	1,066.0	1,023.9	984.0	165.19
E10 Blending, with Domestic Production	-	-	-	-	n/a[2]

113 *The net present value of a measure is defined as the sum of all discounted costs (or benefits, if values are negative) of the measure relative to the model baseline. Costs are discounted from the year in which they are incurred back to the 2015 monetary year, using an annual social discount rate of 5%.*

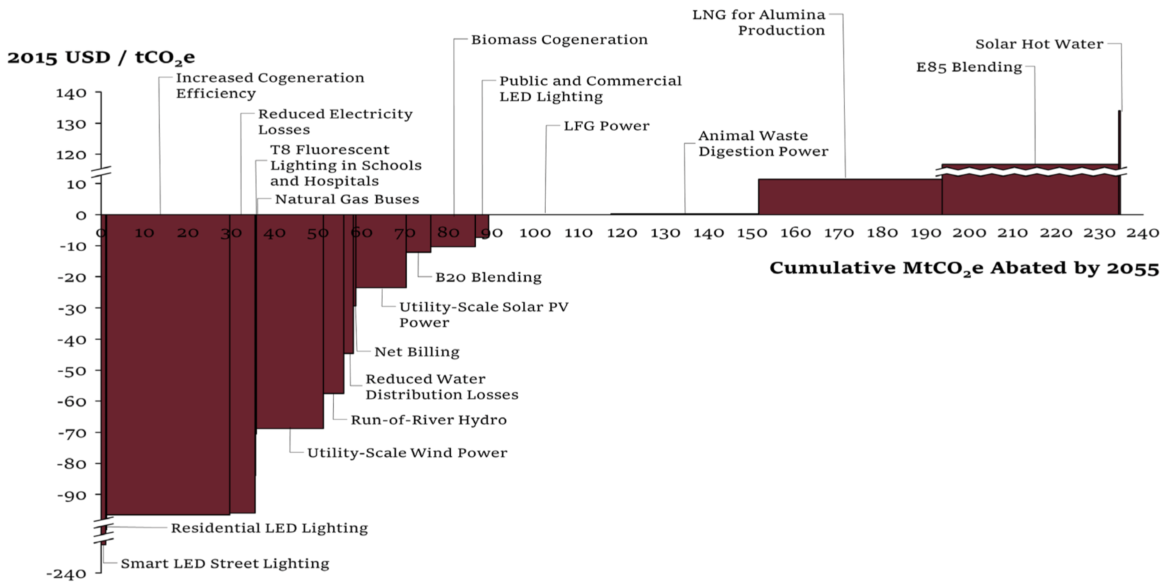
4.4.2 Mitigation Action Results: Retrospective Approach

To implement the retrospective approach, mitigation actions were deployed one-by-one in the model in order of their partial abatement cost in Table 27. The incremental or marginal impacts of adding each action were then assessed. This illustrates the marginal GHG abatement and abatement costs calculated by this method. The abatement is the cumulative abatement during 2017-2055, and the costs are cumulative discounted costs for the same period divided by the cumulative abatement (i.e., cost per tCO_2e). The figure orders actions by abatement cost.

Technically speaking, the abatement shown for each action is its contribution to total mitigation in a scenario in which all of the displayed actions are implemented. The overall mitigation potential in this case is the sum of the marginal abatements along the x-axis. Since constructing the chart (and following the retrospective approach) requires simulating the simultaneous deployment of all actions, the measures must be combinable without inconsistencies. This restriction necessitated a few changes in the set of actions analysed with the retrospective approach:

- Where two actions describe different penetration levels of the same technical or behavioural change (e.g., LNG for Alumina Production and LNG for Alumina Production at Alpart), SEI selected only the higher penetration option for the retrospective analysis.
- For Utility-scale Wind Power and Utility-scale Solar PV Power – two actions that are defined by the same objective but use different technologies to achieve it – SEI included some of each technology. Specifically, the utility-scale wind measure includes only enough renewable electricity to satisfy 20% of generation requirements by 2030 (this differs from the 30%-of-generation target considered in Table 27). The utility-scale solar measure, which implicitly builds on the wind measure as well as other actions of lesser partial abatement cost, includes enough renewables to meet 30% of generation requirements by 2030.
- The MSW Incineration Power mitigation action was included in the retrospective analysis but is omitted because it was found not to have abatement potential. With its comparatively high partial abatement cost (Table 27), MSW Incineration Power comes toward the end of the retrospective ordering. Thus, its marginal impacts are calculated relative to a scenario comprising several lower-cost clean power measures. In this case – as opposed to when compared with the baseline only – it does not provide additional mitigation benefits.

Figure 0-3: GHG Abatement Potential and Abatement Costs of Mitigation Actions Calculated Using Retrospective Approach



4.4.3 Gender-differentiated Impacts

The design and implementation of mitigation actions can have important consequences for gender equality. For example, actions affecting energy options for households can disproportionately impact women, who are often the primary household energy managers and the primary users of energy-intensive home appliances (Glemarec et al. 2016). Measures that support public transit can increase the mobility of women who may otherwise have limited transportation options. Recognizing the nexus between gender and mitigation, the UNFCCC's Paris Agreement calls on parties to consider gender equality and the empowerment of women when devising climate actions (United Nations 2015).

Jamaica ranks 51st in the World Economic Forum's 2017 Global Gender Gap Index, which assesses gender disparities in economic opportunity, education, health, and political potential (World Economic Forum 2017). While women attain higher levels of post-secondary education in Jamaica than men (The World Bank 2017a), their unemployment rate is greater and their incomes are substantially lower for similar work (Bellony et al. 2010; World Economic Forum 2017). Related to women's lower earning potential, the incidence of poverty in female-headed households – which constitute almost half of all households in Jamaica (Planning Institute of Jamaica and Statistical Institute of Jamaica 2007) – is significantly higher than in male-headed households (Planning Institute of Jamaica 2017; United Nations Department of Economic and Social Affairs 2010).

Employment opportunities for women are unevenly distributed across sectors. Female employment is much higher in the service sector than in industry and agriculture, which are dominated by men. Looking deeper, the construction and mining and quarrying subsectors employ particularly low percentages of women (less than 20% average since 2012), while education, health, and social work occupations are overwhelmingly female (over 75% of the workforce) (Statistical Institute of Jamaica 2017a). Women are also notably under-represented in the electricity, gas, and water supply sectors.

Though women have exhibited greater overall awareness of energy-saving appliances and behaviours around the home, usage – and frequency of usage - of major household cooking fuels (LPG, charcoal, wood, and kerosene) tends to be higher in female-headed households than in those headed by males (Planning Institute of Jamaica and Statistical Institute of Jamaica 2007). Female-headed households have historically shown less familiarity with new solar technologies for hot water and electricity than male-headed households, and they are less conversant with reading their electricity meter (Planning Institute of Jamaica and Statistical Institute of Jamaica 2007). Male-headed households have historically had higher rates of private vehicle ownership, while female-headed households have relied more on public transportation (Planning Institute of Jamaica and Statistical Institute of Jamaica 2007).

Considering this background, as well as guidance on including gender perspectives in model-based analyses in Escobar et al. (2017), SEI explored gender-differentiated impacts of the mitigation actions in four areas: employment and income generation, security, the affordability of energy and other services, and health.

Table 0-28 summarizes the findings. Impacts are indicated by either an upward-pointing arrow (an action has the potential to alleviate gender disparities) or a downward-pointing arrow (an action has the potential to exacerbate gender disparities – in particular, to affect women adversely).
A brief explanation of impacts is provided in the final column.

Table 0-28: Potential Gender Equality Co-benefits of Mitigation Actions

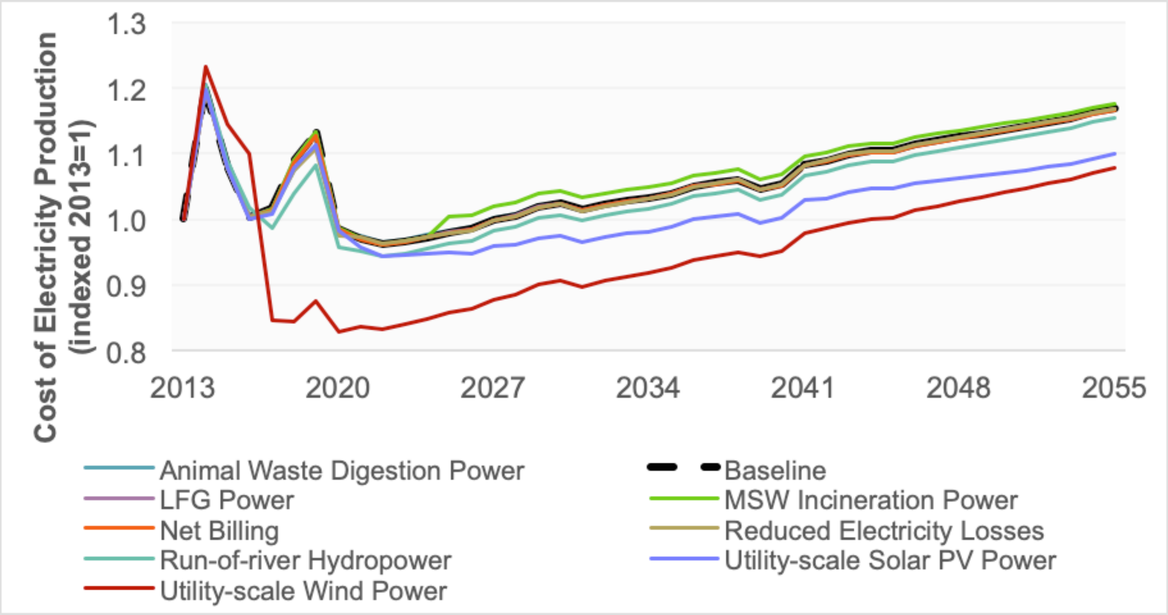
Mitigation Action	Employment and Income	Security	Afford-ability	Health	Explanation
Animal Waste Digestion Power	n/a	n/a	n/a	n/a	No clear gender differences.
B5 and B20 Blending	-	n/a	n/a	-	The sale of WVO is a possible revenue stream for businesses in the hospitality sector, whose labour force is majority-female. See also E10 and E85 Blending.
Biomass Cogeneration	n/a	n/a	n/a	n/a	No clear gender differences.
E10 and E85 Blending	n/a	n/a	†	-	Ethanol is projected to cost more than conventional gasoline (an average of 66% more during 2017-2055), so enhanced ethanol blends could lead to higher transportation costs for households. Emerging energy crop industries are likely to increase pesticide releases. Many pesticides are known endocrine disruptors, affecting men's and women's health differently (Bretveld et al. 2006). In agricultural professions, males are more susceptible to occupational hazards, but females can also experience adverse effects through environmental exposure.
Increased Cogeneration Efficiency	n/a	n/a	n/a	n/a	No clear gender differences.
LFG Power	n/a	n/a	n/a	n/a	No clear gender differences.
LNG for Alumina Production (at Alpart and Nationally)	n/a	n/a	n/a	n/a	No clear gender differences.
MSW Incineration Power	n/a	n/a	†	n/a	See Figure 0-4.
Natural Gas Buses	-	-	n/a	-	Female-headed households are more intensive users of public transit, and thus stand to benefit more from cleaner tailpipe emissions at bus stations. Investments in public transport may also open up employment options and improve safety for female-headed households that do not own vehicles.
Net Billing	-/-	n/a	n/a	n/a	Lower income female-headed households may be less able to take advantage of net billing opportunities if they require substantial capital investment. However, net billing can also provide participating households with a small income stream.
Public and Commercial LED Lighting	n/a	-	n/a	n/a	Due to their decreased maintenance requirements, LEDs have the potential to increase lighting reliability in public and commercial facilities, which in turn can promote safety. Many commercial subsectors in Jamaica employ more women than men (although the public sector is more balanced).
Reduced Electricity Losses	n/a	-	n/a	n/a	Reducing non-technical losses and improving JPS's account management could increase the security of female-headed households by eliminating dependencies on neighbours or other individuals for electricity connections.

Mitigation Action	Employment and Income	Security	Afford-ability	Health	Explanation
Reduced Water Distribution Losses (Kingston and National)	n/a	-	-	-	Although not represented in the Consultancy LEAP model, upgrading the water supply system could lower the price of water in the long run through a reduced need for storage tanks (Kebede 2015) and other savings. Improving water access could also decrease women's dependence on "dons," whom they may be forced to support in order to obtain clean water (National Gender Task Force 2009). Reduced water service interruptions promote public health by ensuring regular access to clean water for consumption and sanitation.
Residential LED Lighting	n/a	n/a	-	-	LED bulbs are a cost-effective way to reduce household energy expenditures. Indoor air quality improvements can occur if LED lamps displace emergency kerosene lighting, which is more prevalent in female-headed households (Planning Institute of Jamaica and Statistical Institute of Jamaica 2007).
Run-of-river Hydropower	n/a	n/a	-†	n/a	See Figure 0-4.
Smart LED Street Lighting	n/a	-	n/a	n/a	Pedestrian-aware street lighting could increase women's safety by deterring violent crime in public spaces. See also Public and Commercial LED Lighting.
Solar Hot Water	-	n/a	-	-	Many economically disadvantaged women rely on charcoal production for income, which could be displaced by solar water heating (National Gender Task Force 2009). Solar water heaters are also expensive, and may therefore be less available to lower income female-headed households. However, shifting to solar energy could improve indoor air quality in female-headed homes, which tend to use more biomass and liquid fuels compared to male-headed homes.
T8 Fluorescent Lighting in Schools and Hospitals	n/a	-	n/a	-	Improved colour quality can reduce preventable errors in healthcare industries (National Grid n.d.), while reliable lighting on school and hospital campuses increases public safety. Both schools and hospitals employ substantially more women than men.
Utility-scale Solar PV Power	-	n/a	-†	n/a	Wind and solar power are growing in Jamaica and require the development of a technically skilled workforce. With their larger share of post-secondary degrees, women may be well-positioned to take advantage of employment opportunities in these industries – particularly if supported with enabling programs such as affirmative hiring practices. See also Figure 0-4.
Utility-scale Wind Power	-	n/a	-†	n/a	See Utility-scale solar PV Power.

The † superscript in Table 0-28 identifies mitigation actions with a significant potential to impact household energy costs. Given gendered disparities in income and household poverty, changing household energy costs could disproportionately affect women.

Figure O-4 illustrates possibilities for electricity, showing the impact on electricity production costs of mitigation actions that target the power sector. Each action is compared individually to the baseline (i.e., using the partial approach). Though electricity is not the only fuel that households purchase, with electrical access at nearly 100% it is a major component of household energy bills in Jamaica.

Figure O-4: Indexed Real Cost of Electricity Production for Major Power-sector Mitigation Actions



Utility-scale Wind Power, Utility-scale Solar PV Power, and Run-of-river Hydropower all show potential to decrease production costs, while MSW Incineration Power increases costs due to its high investment requirements. By making energy more affordable and providing new employment opportunities for highly skilled female workers, wind, solar, and hydro could contribute to meeting both national mitigation and gender equity objectives.

4.5 Mitigation Pathways

4.5.1 Actions Selected for UNDC and CNDC Pathways

Mitigation actions were selected for the UNDC and CNDC pathway scenarios in order of retrospective abatement cost (Error! Reference source not found.). Actions were added one-by-one to a combined mitigation scenario until the relevant NDC targets in 2025 and 2030 were met (within a tolerance of a few percent). This method produced pathways with the following measures:

UNDC pathway

- Smart LED Street Lighting
- Residential LED Lighting
- Increased Cogeneration Efficiency
- Reduced Electricity Losses
- T8 Fluorescent Lighting in Schools and Hospitals
- Natural Gas Buses
- Utility-scale Wind Power[114]
- Run-of-river Hydropower

CNDC pathway

- All actions in UNDC pathway
- Reduced Water Distribution Losses (National)
- Net Billing
- Utility-scale Solar PV Power

While this approach to building up the UNDC and CNDC scenarios is conceptually clear and is appealing from a cost standpoint, it should be noted that the selected actions are by no means the only way Jamaica could achieve its NDC objectives. Multiple other UNDC and CNDC pathways are possible with the actions evaluated in the Consultancy. Expanding the set of potential actions to new measures not covered in the Consultancy could further increase the options.

4.5.2 Pathway Projections

Table 0.29 shows annual abatement potentials and cumulative abatement costs for the three pathway scenarios. As in Table 27, the costs are the NPV of the scenarios during 2017-2055 divided by the cumulative abatement in the same period. Both costs and abatement are relative to the baseline scenario. Annual abatement results are shown by decade and for 2025, the interim target year in Jamaica's NDC. Since none of the mitigation actions in the pathway scenarios affects non-energy emissions, the numbers shown in Table 0-29 for 2025 and 2030 are directly comparable with the NDC targets (which also exclude non-energy emissions)

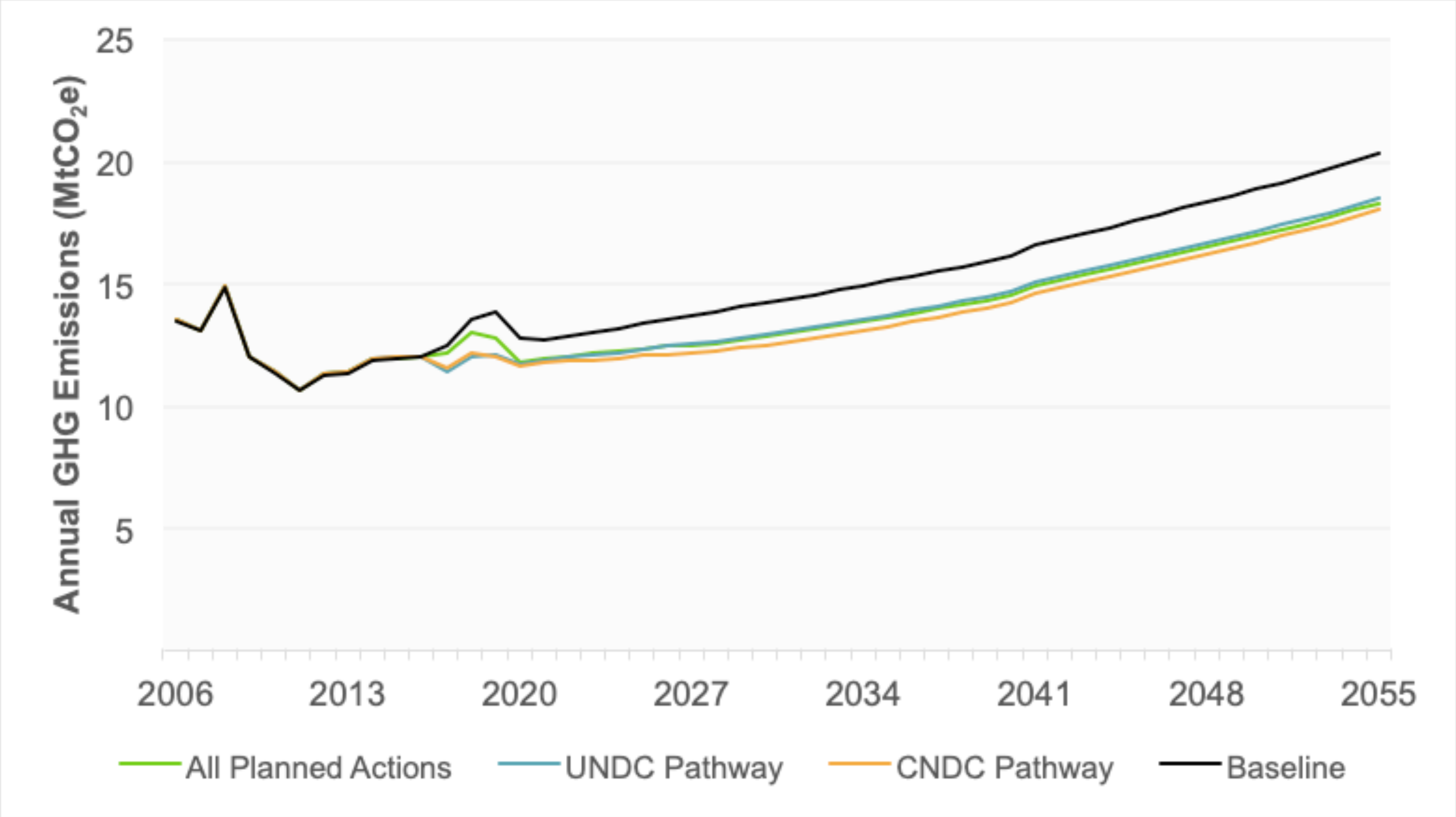
Table 0-29: GHG Abatement Potential and Abatement Costs of Mitigation Pathway Scenarios

Pathway Scenario	Annual Abatement Potential for Selected Years (ktCO_2e/year)					Abatement Cost (cumulative discounted USD/ tCO_2e)
	2020	2025	2030	2040	2050	
All Planned Actions	970	1,034	1,408	1,636	1,914	-41.96
UNDC Pathway	1,087	1,038	1,342	1,510	1,740	-88.39
CNDC Pathway	1,142	1,338	1,756	1,971	2,204	-75.86

Annual emissions over time for each pathway scenario are graphed in Figure 0-5.

114 *The utility-scale wind option included in the UNDC pathway is the same as in* **Error! Reference source not found.**. *It ensures only enough renewable electricity to meet 20% of generation requirements by 2030.*

Figure 0-5: GHG Emissions in Mitigation Pathway Scenarios115



4.5.3 Key Messages and Discussion

A number of conclusions can be drawn from the analysis presented in the preceding sections. First, while none of the modelled mitigation pathways decouples economic growth from increasing GHG emissions, significant no-direct-cost or low-direct-cost abatement potential is available. From 2017 to 2055, the three pathway scenarios lower emissions by between 56 and 70 MtCO2e at a direct cost savings exceeding 40 USD/tCO2e. As Table 0-30 shows, implementing actions with an abatement cost below USD 10/tCO2e increases the cumulative abatement through 2055 to approximately 150 MtCO2e.

Although the pathway scenarios look qualitatively similar in Figure 05, there are important differences between them. For example, the All Planned Actions scenario and the UNDC pathway have comparable emissions, but very different average abatement costs (Error! Reference source not found.). Cumulative abatement between 2017 and 2055 is 56.9 MtCO2e for All Planned Actions and 55.9 MtCO2e for the UNDC pathway, but their abatement costs of -41.96 and -88.39 mean that far greater savings to society are realized by pursuing the UNDC pathway. Meanwhile, even greater abatement is unlocked in the CNDC pathway for only a small reduction in cost savings.

A substantial amount of the total abatement potential identified in this study is not exploited in any of the mitigation pathway scenarios. Relative to the baseline trajectory, total abatement from all mitigation actions is 243.8 MtCO2e during 2017-2055. This is a considerable fraction of baseline emissions – more than 38% over the same period. About half (117.4 MtCO2e) of this abatement is negative direct cost (i.e., the associated actions provide a net cost savings for society on implementation). Emission reductions for this "negative cost" pathway exceed what is realized even in the CNDC scenario. Table 030 shows the magnitude of the differences in the key NDC years 2025 and 2030 (abatements in the table are measured relative to the LEAP model's baseline scenario).

115 The "bump" in emissions in all of the scenarios in 2018/2019 is due to the re-opening of the Alpart alumina refinery. This is expected to increase total production capacity by 1.673 million tonnes of alumina per year (Rusal 2016a), giving rise to a proportional increase in energy consumption and emissions from alumina production. The decrease in emissions in 2020 is caused by the commissioning of the Old Harbour gas plant – and a corresponding shift away from oil for electricity generation.

Table 030: Comparison of CNDC with Potential Emission Reductions That Could Be Achieved at No Additional Direct Social Cost

Target or Pathway	Annual Abatement Potential (ktCO_2e/year)		Annual % Abatement	
	2025	2030	2025	2030
CNDC Targets	1,344	1,449	10.0%	10.2%
CNDC Pathway	1,338	1,756	10.0%	12.3%
"Negative Cost" Pathway	2,730	4,046	20.4%	28.4%

These results suggest that Jamaica's mitigation ambition could be increased without additional direct costs to society as a whole.

Non-energy GHG mitigation opportunities are significant and could help justify increased mitigation targets. Two of the non-energy mitigation actions analysed in the Consultancy – LFG Power and Animal Waste Digestion Power – by themselves offer over 60 MtCO2e of abatement potential between 2017 and 2055). Their discounted net social cost is essentially zero, meaning their direct costs and benefits offset each other. For each of these measures, abatement is divided between energy and non-energy sources. In the energy sector, mitigation arises from substituting LFG or biogas for fossil fuels in electricity generation; on the non-energy side, abatement comes from avoided methane and nitrous oxide emissions at farms and landfills. In each case, the dominant share of abatement – well over 90% – is from non-energy sources. The potential role of non-energy mitigation could be even more salient if additional non-energy mitigation actions were defined.

The cost-effectiveness of certain mitigation actions depends on the time horizon considered. Cumulative results are based on abatement and NPV from 2017 to 2055. However, restricting the analysis to a shorter period changes the outlook for two options: biodiesel blending and reduced water distribution losses. These actions show a negative NPV (net social cost savings) when evaluated through 2055, but a positive NPV (net social cost) over shorter periods. Figure 06 and Figure 07 illustrate this dynamic, graphing the NPV of each action (calculated using the retrospective approach) by end year for the period covered by the NPV.

Figure 06: NPV of B20 Blending Mitigation Action

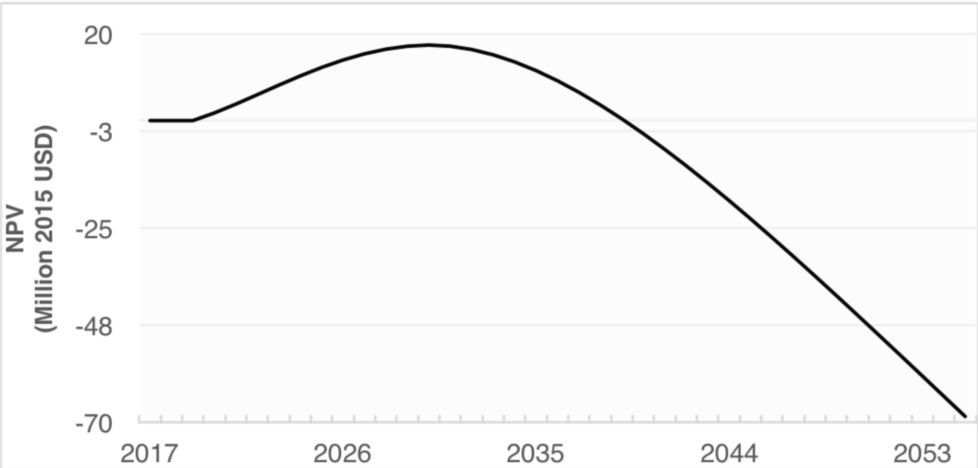
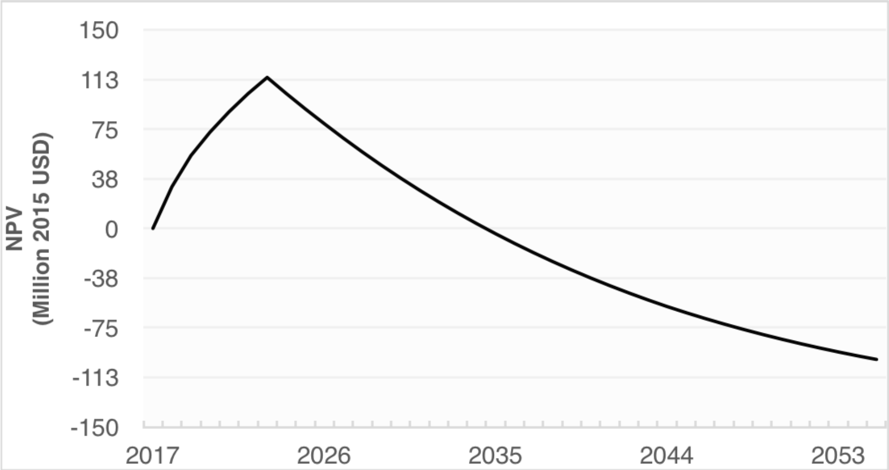


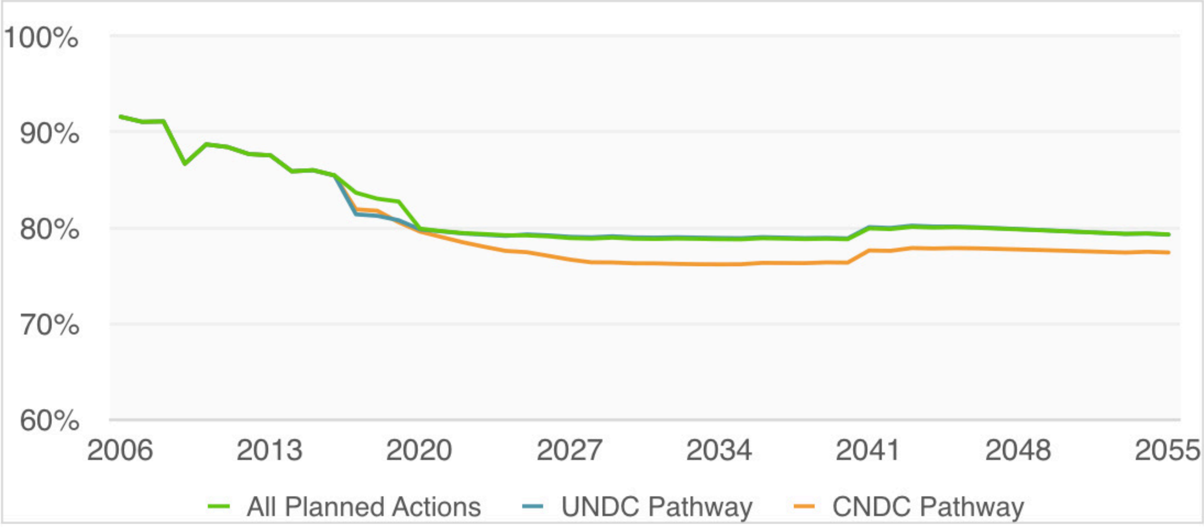
Figure 07: NPV of Reduced Water Distribution Losses (National) Mitigation Action



In each of these cases, there are clear points where the NPV stops growing, and where it changes from positive to negative. These effects are ultimately linked to fuel cost savings. For the water distribution measure, accumulating fuel cost savings eventually overwhelm the incremental capital costs of implementation. For biodiesel blending, changes in the relative costs of diesel and biodiesel drive the shape of the NPV curve. This analysis supports taking a longer-term view of these two mitigation actions – in particular, taking into account their substantial cost benefits after the NDC's end year of 2030.

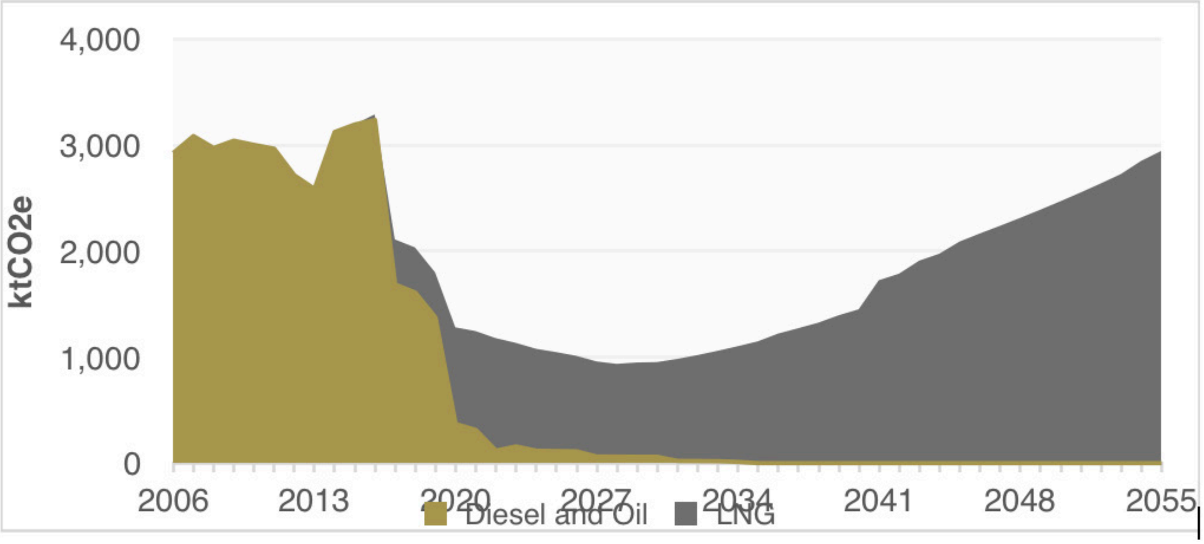
Modeling results indicate that pathways consistent with Jamaica's NDC targets involve incremental – rather than radical – changes toward a low-carbon society. In each of the modelled pathway scenarios, national GHG emissions grow by 2030 (5%-12% versus 2017) and by 2055 (46%-57% versus 2017). Non-energy emissions advance 4% and 20% over the same periods, and fossil-fuel dependency in transport and industry remains high. The overall share of fossil fuels in the total primary energy supply drops only slightly over the long term (Figure 08).

Figure 08: Share of Fossil Fuels in Total Primary Energy Supply in Mitigation Pathway Scenarios



Some emission benefits are realized in the pathway scenarios by switching from oil to LNG, particularly in the electricity sector, but growth in energy requirements ultimately pushes GHG emissions upward. Electricity sector emissions in the CNDC scenario are shown in Figure 09 as an example.

Figure 09: Electricity Sector GHG Emissions in CNDC Pathway Scenario



Taking a higher-level view, the GHG intensity of both energy and GDP show modest decreases from their historical levels (Figure 010 and Figure 011, again using the CNDC pathway as an example).

Figure 010: GHG Intensity of Total Primary Energy Supply in CNDC Pathway Scenario

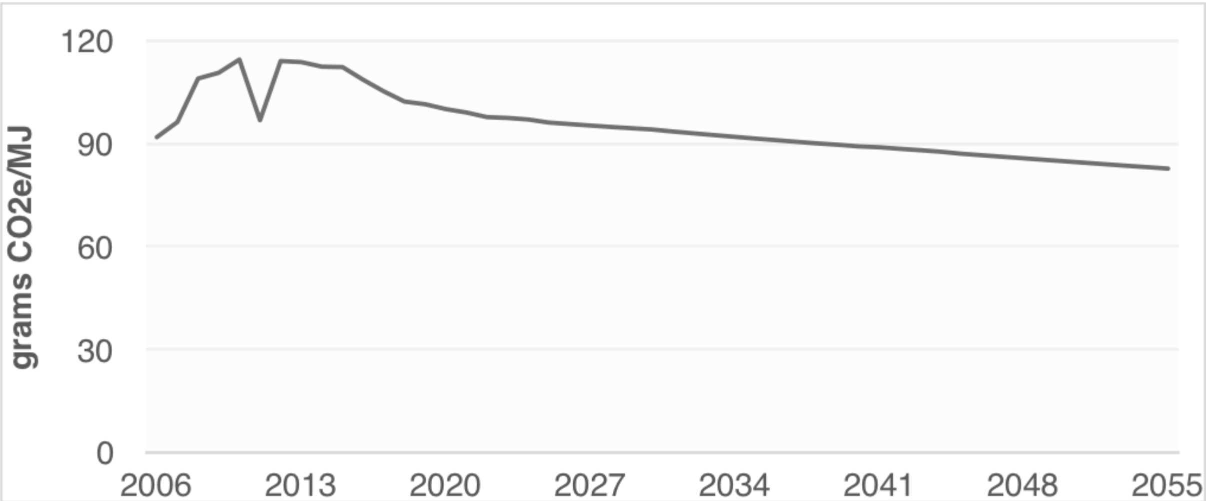
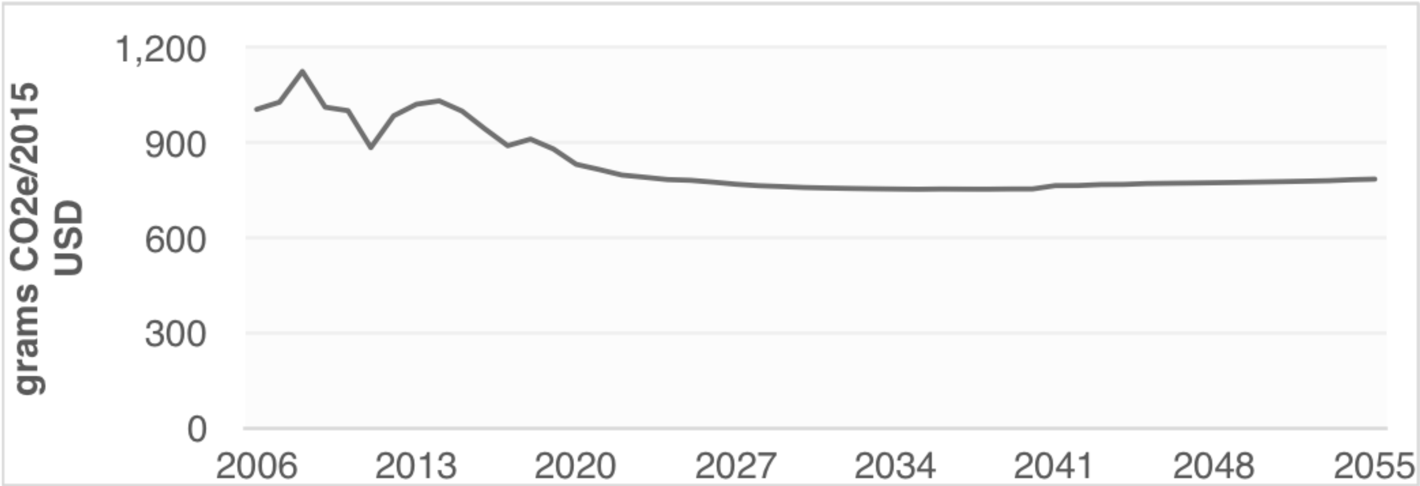


Figure 011: GHG Intensity of GDP in CNDC Pathway Scenario



These findings suggest that the current NDC can be realized without deeply transformative changes in the Jamaican economy and energy system.

4.6 Financial, Technical, and Capacity Development Needs Related to National Mitigation Objectives

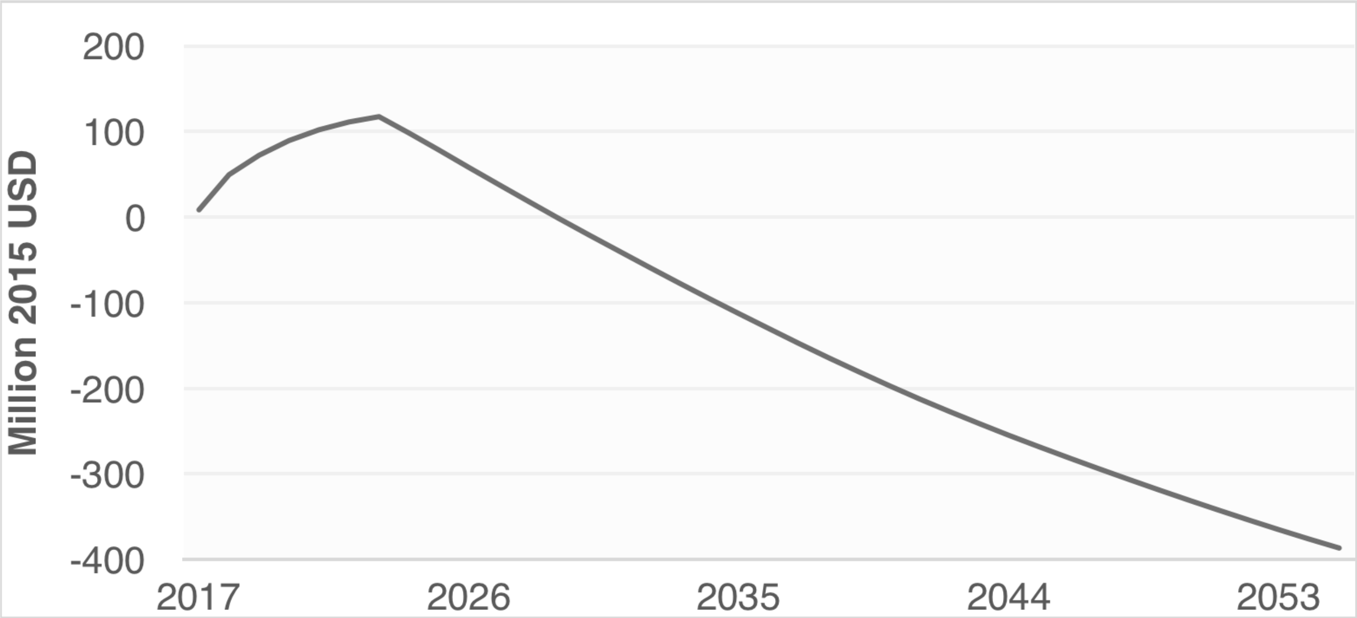
Implementing Jamaica's NDC will require a concerted mobilization of financial, technical, and human resources. This is true even for pathways that offer a net direct cost savings, such as the UNDC and CNDC scenarios examined in this report. This section provides a few perspectives on resource requirements related to the NDC pathways and other mitigation options studied in the Consultancy. It focuses on financial, technical, and capacity development needs identified through the Consultancy's modelling and SEI's interactions with project stakeholders.

4.6.1 Financial Needs

The financial support needed to implement a mitigation option can be evaluated in various ways, with assumptions about baseline conditions, mitigation ambition, time horizons, and other factors all affecting the results. To provide a sense of the possibilities in the context of the Consultancy analysis, SEI examined financial needs from three different standpoints. The first explores social cost differences between the UNDC and CNDC pathway scenarios. This assessment quantifies additional social costs that could be incurred in taking on the conditional commitment. The estimated costs could serve as a first-order approximation of international financial support required for the CNDC.

Figure 012 plots the cumulative social cost differences between the UNDC and CNDC scenarios during 2017-2055. Costs in the UNDC scenario are subtracted from those in the CNDC scenario. As the figure shows, the conditional pathway has lower cumulative costs in the long run but costs more in the shorter term. Through 2025, for instance, the extra cost associated with the CNDC scenario is 78 million USD. Overall, the results suggest that short-term financial support of up to approximately 120 million USD (in net present value terms) may be needed to shift from the UNDC pathway to the CNDC pathway.

Figure 012: Cumulative Discounted Social Cost Differences Between UNDC and CNDC Scenarios (CNDC – UNDC)



The second approach looks at differences in the cost of mitigation from the perspective of investors versus the perspective of society as a whole. As noted earlier, the direct costs and benefits quantified in the LEAP model are figured from the perspective of society as a whole, and discounted costs are calculated using a 5% social discount rate. The costs of mitigation may differ from the standpoint of investors, however, in particular because of transaction costs of mitigation investments and differences between investors' hurdle rates and the social discount rate (NERA Economic Consulting, Bloomberg New Energy Finance 2011). An exploration of the transaction costs of each mitigation action is beyond the scope of the Consultancy, but the effect of varying the discount rate is readily analysed with the LEAP model.

Figure 014 compares the NPVs for the mitigation pathway scenarios at discount rates between 6% and 20% to their respective NPVs at the 5% social discount rate. The 5% NPV is subtracted from the higher-rate NPVs. The difference illustrates the gap between the social value of each mitigation pathway (assuming a 5% social discount rate) and the value that could be perceived by investors. For example, at a 12% discount rate – similar to the electricity sector WACC in Office of Utilities Regulation (2010) – the UNDC pathway is worth 3.2 billion USD less to a notional investor (i.e., it costs more), and the CNDC pathway 3.5 billion USD less. If transaction costs were included, the discrepancy would be even larger, and the NPV of the mitigation pathways could be positive (representing a net cost) at typical hurdle rates. International financial support can help bridge the divide between the investor's perspective and society's perspective and ensure a rate of return that is sufficient to mobilize investment. A full analysis of transaction costs and actual investors' hurdle rates in Jamaica could enable an estimate of the level of support needed for this purpose.

Figure 013 shows the change in NPV for the three mitigation pathway scenarios (compared to the baseline scenario) at various discount rates. The NPV is for the 2017-2055 period; costs relative to the baseline are positive, and cost savings are negative. As the discount rate rises, the present value of each mitigation portfolio does as well, indicating the set of mitigation actions is becoming less cost-compelling.

Figure 014 compares the NPVs for the mitigation pathway scenarios at discount rates between 6% and 20% to their respective NPVs at the 5% social discount rate. The 5% NPV is subtracted from the higher-rate NPVs. The difference illustrates the gap between the social value of each mitigation pathway (assuming a 5% social discount rate) and the value that could be perceived by investors. For example, at a 12% discount rate – similar to the electricity sector WACC in Office of Utilities Regulation (2010) – the UNDC pathway is worth 3.2 billion USD less to a notional investor (i.e., it costs more), and the CNDC pathway 3.5 billion USD less. If transaction costs were included, the discrepancy would be even larger, and the NPV of the mitigation pathways could be positive (representing a net cost) at typical hurdle rates. International financial support can help bridge the divide between the investor's perspective and society's perspective and ensure a rate of return that is sufficient to mobilize investment. A full analysis of transaction costs and actual investors' hurdle rates in Jamaica could enable an estimate of the level of support needed for this purpose.

Figure 013: NPV of Mitigation Pathway Scenarios (Relative to Baseline) During 2017-2055

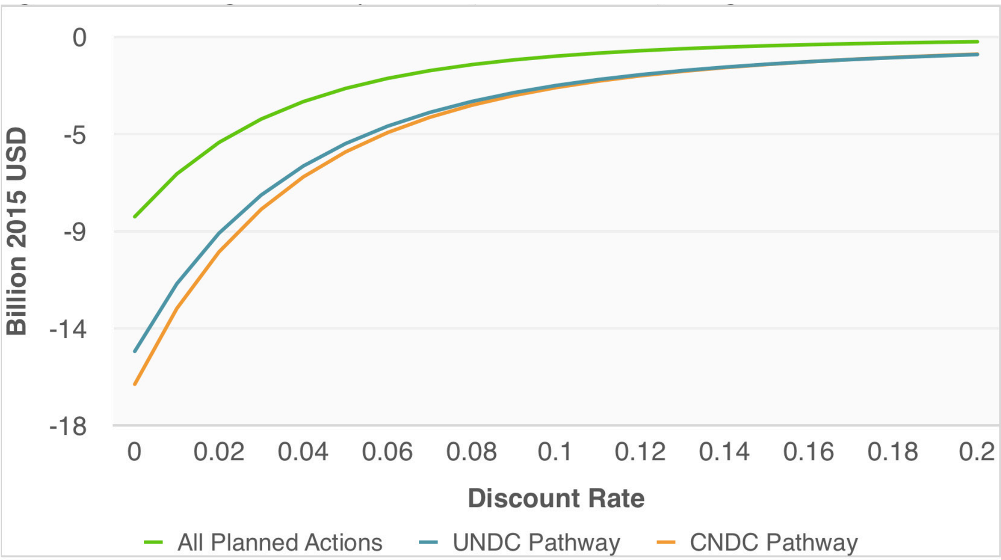
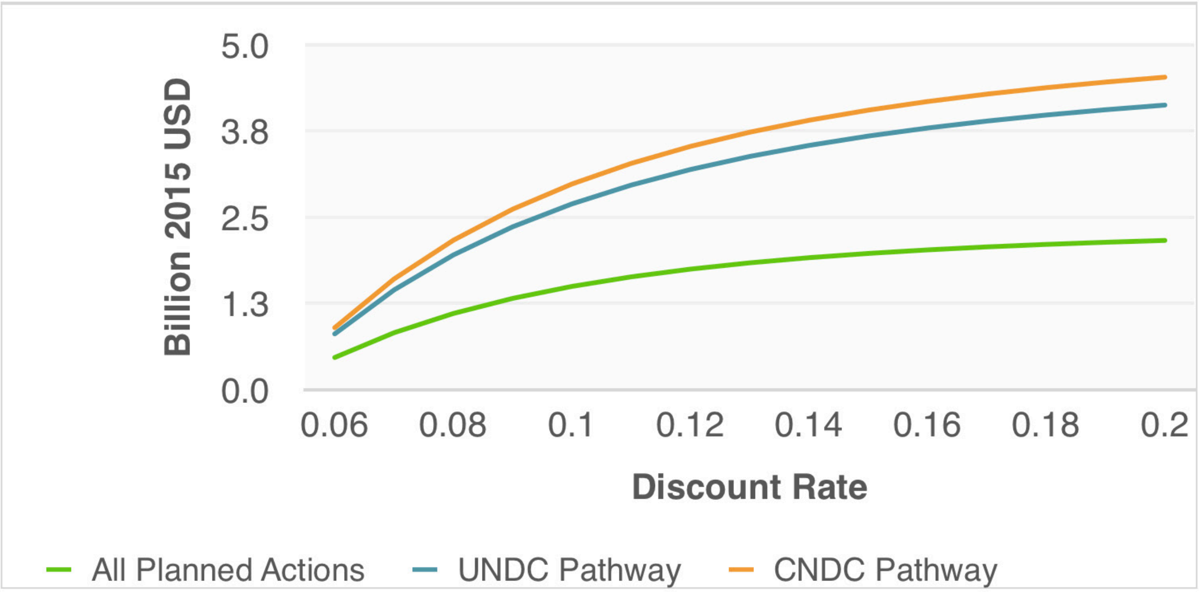


Figure 014: NPV of Mitigation Pathway Scenarios (Relative to Baseline) During 2017-2055 Minus NPV at 5% Discount Rate



The third technique considers the social costs of implementing particular mitigation actions. Table 0-1 shows that several mitigation actions have net positive social costs after accounting for interactions with other measures. Each is a potential action, and none are part of the UNDC or CNDC pathway scenario. Nonetheless, these actions represent an opportunity for Jamaica to reduce its GHG emissions beyond the NDC targets – a step that could be contemplated, for example, in the next revision of the NDC.Table 031 lays out the incremental discounted social costs of these actions. The costs are cumulated over 2017-2055 and are calculated as marginal costs after adding each option into the retrospective analysis. They provide an estimate of the additional costs to society imposed by these measures, costs that could be met by mobilizing financial support. As suggested by the preceding discussion of investors' perspectives, the costs would likely be higher in investors' view, and the need for support could be greater[116].

116 *It is worth noting that this is equally true of the cost difference between the UNDC pathway and CNDC pathway, explored earlier.*

Table 031: Cumulative Marginal Social Cost (2017-2055) of Positive-Cost Mitigation Actions

Mitigation Action	Cumulative Marginal Social Cost(Million Discounted 2015 USD)
Animal Waste Digestion Power	9.7
LNG for Alumina Production	483.0
E85 Blending	4,751.9
Solar Hot Water	56.8
MSW Incineration Power	189.1

The analysis in Section 0 also highlights two mitigation actions that offer a net social cost savings in the long run but have a positive-cost NPV over shorter periods – Reduced Water Distribution Losses (National) and B20 Blending. This result indicates that short- or medium-term financial support could be key to realizing these actions. The NPV of Reduced Water Distribution Losses (National) reaches 114 million USD in the early 2020s (Figure 07), while the maximum NPV of B20 Blending is about 18 million USD by 2030 (Figure 06). Again, these net costs could be larger if figured from the standpoint of investors.

4.6.2 Technical and Capacity Development Needs

Technical and capacity development needs for mitigation can span a number of areas, from education and training to technology access, intellectual property, and legal and regulatory frameworks. While carrying out the Consultancy, SEI noted technical and capacity development needs in two main categories: mitigation action implementation and mitigation planning. Both are relevant to Jamaica's mitigation objectives, although the issues differ in each case. The needs that SEI identified are by no means exhaustive, and reflect instead potential focus areas that stood out in the Consultancy's mitigation analyses and stakeholder interactions.

4.6.3 Mitigation Action Implementation

Needs in this category centre on mitigation actions involving technologies, applications of technologies, or approaches that are new or nascent in Jamaica. Some of the actions are planned actions and/or part of an NDC pathway scenario, suggesting their associated needs may be higher priority.

Table 032: Key Technical and Capacity Development Needs Related to Mitigation Action Implementation

Mitigation Action	Planned	UNDC or CNDC Pathway	Technical and Capacity Needs
B5 Blending	•		While Petroleum Corporation of Jamaica has been testing the performance of B5 blends – and has recently deepened its commitment to biodiesel through a research partnership with the University of Technology (Kennedy 2017) – local production of biodiesel at scale has yet to be demonstrated. This will require both assuring a reliable supply of feed stocks and constructing and operating biodiesel production facilities. Additionally, to move to a B20 standard, further testing of blend options and performance will be necessary. Access to appropriate biodiesel manufacturing technology and developing the engineering expertise to operate and maintain production equipment are important potential needs. Educating end users about the benefits of biodiesel will also be essential.
B20 Blending			

LNG for Alumina Production	•(at Alpart)		As of the writing of this report, it had just been announced that the Alpart refinery would switch to using LNG, not coal (Jamaica Gleaner 2017). This comes at a time when the adoption of LNG is accelerating across the country. Within the alumina industry, introducing LNG may require developing new staff competencies in using and maintaining gas-powered equipment and gas fuelling infrastructure. In addition, the significant role international companies are playing in supplying LNG in Jamaica underscores the importance of transferring related skills and knowledge to national actors. This potential need encompasses designing, constructing, and operating LNG terminal and distribution facilities.
E10 Blending With Domestic Production	•		Potential technical and capacity building needs related to the ethanol mitigation actions are similar to those for biodiesel. Developing a domestic supply of ethanol requires access to production technology and cultivating associated engineering and operational expertise. To enable an E85 standard, E85-capable vehicles and other equipment must be available and supported by qualified maintenance providers. Testing and quality control procedures for high-content ethanol blends must be put in place, and the public should be informed about the implications of shifting to ethanol.
E85 Blending			
LFG Power			Neither of these waste-to-energy technologies has been implemented in Jamaica, so their initial deployment will probably require international technical support. This should be accompanied by training and capacity development for local plant engineers and operators. Focus areas may include using and maintaining LFG collection and processing systems, combustion equipment, and emission controls (particularly for MSW incineration); as well as best practices for sorting and preparing MSW feedstock and managing incinerator ash. Enhanced emission monitoring and public outreach may also be needed to address concerns about air quality impacts from waste-to-energy.
MSW Incineration Power			
Natural Gas Buses	•	•	JUTC is studying the feasibility of LNG bus technology with an eye toward eventual large-scale adoption (Linton 2017). Making this switch will require procuring LNG buses themselves and the necessary fuelling equipment, as well as training personnel on equipment safety, operation, and maintenance. Lessons learned may facilitate the deployment of LNG in other vehicle fleets, such as the police force's (Jamaica Observer 2017b).
Reduced Water Distribution Losses	•(in Kingston)	•	This mitigation action is already underway in the Kingston area (Smith-Edwards 2015), where a loss-reduction program is being implemented by NWC and an international partner. Given the reliance on international experts, knowledge transfer and capacity building for Jamaican participants are critical. Important topics include efficiency audits, system monitoring and leak detection, and equipment repair and replacement.
Utility-scale Solar PV Power		•	To date, utility-scale solar projects in Jamaica have been implemented by international partners (WRB Enterprises built the Content facility, and Eight Rivers Energy Company is constructing Paradise Park). The existing projects demonstrate the availability of solar technology in Jamaica, but here again the dependence on international expertise indicates a potential need for capacity development. Enhancing local capacity for system design and engineering, construction, and maintenance could help accelerate solar uptake in Jamaica and decrease implementation costs.

4.6.4 Mitigation Planning

As noted in Section 1, the Government of Jamaica is actively engaged in mitigation planning and international mitigation processes. CCD plays a key role in these activities, coordinating climate policy and initiatives with multiple governmental and non-governmental stakeholders. CCD is Jamaica's liaison to UNFCCC and is responsible for the country's obligations under the Convention and Paris Agreement (Ministry of Economic Growth and Job Creation 2016).

The Consultancy highlighted one facet of long-term mitigation planning in Jamaica where capacity development could materially enhance future outcomes: mitigation modelling. The Government of Jamaica regularly requires modelling to project long-term GHG emissions and analyse mitigation potential. This work is necessary both for domestic policymaking and to fulfil international commitments, including national communications and updates to UNFCCC and maintaining and updating Jamaica's NDC. It will also be essential if Jamaica elects to prepare a long-term low greenhouse gas emission development strategy as urged in the Paris Agreement (United Nations 2015; UNFCCC Secretariat 2016).

For a number of years, the government has relied on international experts for mitigation modelling. The most recent example is the Mitigation Consultancy itself, but other cases include modelling to inform Jamaica's INDC in 2015 and for the Second National Communication in 2010-2011. Developing local expertise in mitigation modelling could have several benefits, however. It could promote continuity in mitigation analyses and save the administrative costs of recruiting international consultants. It could also allow for more regular updates of national modelling, making national projections more responsive to ongoing policy, market, and other changes in Jamaica.Discussions with stakeholders at MEJC and CCD during the Consultancy established that a productive way forward in this area could be to build modelling capacity simultaneously at CCD/MEGJC and academic partners. Staff at CCD/MEGJC would focus on running and interpreting mitigation models, while academic practitioners (such as at the University of the West Indies) would develop and update the models. Government staff would collaborate with academic partners on defining scenarios, identifying data and assumptions, and validating model results. Coursework on mitigation modelling could be introduced at academic institutions to support ongoing modelling efforts and to train the next generation of practitioners.

The mitigation model submitted with this report could seed a program along these lines. The LEAP software is available free-of-charge to government and academic users in Jamaica (Stockholm Environment Institute 2017), and CCD could share the model with academic collaborators. A variety of LEAP training materials are available through the LEAP website[117], which also supports an active online community where users can find assistance. SEI can provide guidance on developing advanced mitigation modelling capabilities with LEAP and on integrating modelling topics in academic courses. Leveraging the Consultancy's modelling in this way – to enhance Jamaica's national modelling capacity – could ultimately be the most important outcome of the project. Although the potential cost of investing in national modelling capabilities is not explicitly included in the earlier analysis of financial needs for mitigation, it would likely be very small relative to mitigation action implementation costs (i.e., measured in thousands of USD in total).

117 *https://www.energycommunity.org/*

4.7 Conclusion

The Mitigation Consultancy component of the Third National Communication and First BUR to the UNFCCC project produced a new GHG and energy system model for Jamaica and applied it to a study of climate mitigation actions and scenarios through 2055. Mitigation potential, costs, and other impacts in multiple sectors were explored, and pathways to meeting Jamaica's NDC objectives were assessed. Financial, technical, and capacity development needs related to national mitigation goals were characterized from several perspectives.

This report documents the Consultancy's model and analytic results. The model shows significant mitigation opportunities in Jamaica, including multiple low-cost ways of realizing the NDC. When compared to the NDC's targets, the total quantified abatement potential implies that Jamaican decision makers have a range of options at their disposal as they chart a course for NDC implementation. Different options have varying implications for costs; gender equality; and national needs for financial, technical, and capacity building support.

The Consultancy's findings highlight several potentially useful next steps in Jamaican climate planning. As noted above, SEI was not able to identify quantifiable mitigation actions in the forestry sector, and found enough information to model only a few actions for transport, buildings, and other non-energy sectors. Further work to develop data and to define plans and programs in these areas could help illuminate deeper mitigation pathways for Jamaica. In the same vein, grid integration studies examining renewable electricity shares above 30% are needed.

Notwithstanding the opportunities to define additional mitigation options, the Consultancy modelling provides evidence that the NDC's ambition could be increased at low direct social cost. The available low or no-cost abatement potential is at least twice what is required for the current CNDC. An important fraction of the potential is from non-energy sources, suggesting a revised NDC might incorporate both energy and non-energy sectors.

Regardless of NDC goals and plans, strengthening mitigation modelling capabilities in Jamaica would pay a number of dividends. Capacity to develop and use mitigation models should be enhanced at both government agencies and academic partners, and joint teams should be constituted to carry forward the modelling required for domestic policymaking and international negotiations. The results of the Consultancy – especially the Consultancy model itself (Annex 1) – could be a key input to such efforts.

5.0 APPENDIX 1: EMISSION ESTIMATE TABLE (CRF FORMAT)

The following tables present emissions of direct and indirect GHGs for each year of the time series (with the exception of 2012, which is presented in the main body of the report, in Section 2).

Inventory Year:	2006								HFCs (Gg CO2 EQ)			PFCs (Gg CO2 EQ)		
Greenhouse gas source and sink categories	CO2 Emissions (Gg)	CO2 Removals (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)	HFC - 23	HFC - 134	Other	CF4	C2F6	Other
Total National Emissions and Removals	9519.77		38.97	12.48	99.88	64.77	32.01	18.71	0	44.32	34.75	0	0	0
1 - Energy	10615.51		1.66	0.30	85.21	58.56	12.42	18.69						
1A - Fuel Combustion Activities	10614.32		1.66	0.30	85.21	58.56	12.42	18.69						
1A1 - Energy Industries	3003.85		0.12	0.02	0.58	4.81	0.07	14.28						
1A2 - Manufacturing Industries and Construction (ISIC)	4961.00		0.32	0.06	14.37	32.94	2.98	3.90						
1A3 - Transport	2110.20		0.61	0.21	56.93	18.82	8.03	0.32						
1A4 - Other Sectors	539.27		0.62	0.01	13.33	1.99	1.34	0.20						
1A5 - Other	NO		NO	NO	NO	NO	NO	NO						
1B - Fugitive Emissions from Fuels	1.19		0.00	0.00	0.00	0.00	0.00	0.00						
1B1 - Solid Fuels	NO		NO	NO	NO	NO	NO	NO						
1B2 - Oil and Natural Gas	1.19		0.00	0.00	0.00	0.00	0.00	0.00						
2 - Industrial Processes	543.95		0.00	0.00	0.00	0.00	3.13	0.00	0	44.32	34.75	0	0	0
2A - Mineral Products	542.02		NA	NA	NA	NA	NA	NA						
2B - Chemical Industry	NO		NO	NO	NO	NO	NO	NO						
2C - Metal Production	NO		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2D - Other Production	1.94		NO	NO	NO	NO	NO	NO						
2E - Production of Halocarbons and Sulphur Hexafluoride					NA	NA	NA	NA	NO	NO	NO	NO	NO	NO
2F - Consumption of Halocarbons and Sulphur Hexafluoride					NA	NA	NA	NA	NO	44.32	34.75	NO	NO	NO
2G - Other (please specify)	NO		NO	NO	NO	NO	3.13	NO						
3 - Solvent and Other Product Use	0.00		0.00	0.00	0.00	0.00	14.25	0.00						
4 - Agriculture			12.87	12.03	8.61	5.86	1.07	0.00						
4A - Enteric Fermentation			8.26		NA	NA	NA	NA						
4B - Manure Management			4.36	3.97	NA	IE	1.01	NA						
4C - Rice Cultivation			0.00		NA	NA	NA	NA						
4D - Agricultural Soils				4.19	NA	5.62	0.06	NA						
4E - Prescribed Burning of Savannas			NO	NO	NO	NO	NO	NO						
4F - Field Burning of Agricultural Residues			0.25	0.01	8.61	0.23	NE	NE						
4G - Other (please specify)	1.07		NO	3.87	NO	NO	NO	NO						
5 - Land-Use Change & Forestry	-1685.19			0.00	0.00	0.00	0.00	0.00						
5A - Changes in Forest and Other Woody Biomass Stocks	-1834				NA	NA	NA	NA						
5B - Forest and Grassland Conversion	86				NA	NA	NA	NA						
5E - Other (please specify)	62				NA	NA	NA	NA						
6 - Waste	44.43		24.44	0.15	6.06	0.35	1.13	0.01						
6A - Solid Waste Disposal on Land			19.05		0.00	0.00	0.98	0.00						
6B - Wastewater Handling			4.68	0.13	0.00	0.00	0.00	0.00						
6C - Waste Incineration	6		0.00	0.00	0.00	0.01	0.02	0.00						
6D - Other (open bruning and biological treatment)	39		0.71	0.02	6.06	0.34	0.13	0.01						
7 - Other (please specify)	0.00		0.00	0.00	0.00	0.00	0.00	0.00	NO	NO	NO	NO	NO	NO
									NO	NO	NO	NO	NO	NO
Memo Items														
International Bunkers	2284.83		0.14	0.06	4.09	41.71	1.40	9.91						
1A3a1 - International Aviation	769.02		0.01	0.02	0.51	3.42	0.09	0.24						
1A3d1 - International Marine (Bunkers)	1515.81		0.14	0.04	3.58	38.29	1.31	9.67						
CO2 emissions from biomass	586.92													

Inventory Year:	2007								HFCs (Gg CO2 EQ)			PFCs (Gg CO2 EQ)		
Greenhouse gas source and sink categories	CO2 Emissions (Gg)	CO2 Removals (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)	HFC - 23	HFC - 134	Other	CF4	C2F6	Other
Total National Emissions and Removals	8218.83		39.75	16.08	93.11	55.40	31.24	19.05	0	49.14	38.22	0	0	0
1 - Energy	9331.21		1.57	0.28	78.19	47.48	11.13	19.04						
1A - Fuel Combustion Activities	9330.18		1.57	0.28	78.19	47.48	11.13	19.04						
1A1 - Energy Industries	3171.01		0.12	0.02	0.61	5.10	0.08	15.17						
1A2 - Manufacturing Industries and Construction (ISIC)	3421.23		0.26	0.05	14.15	22.72	2.54	3.27						
1A3 - Transport	2034.69		0.55	0.20	50.60	16.72	7.15	0.28						
1A4 - Other Sectors	703.25		0.64	0.01	12.83	2.94	1.37	0.32						
1A5 - Other	NO		NO	NO	NO	NO	NO	NO						
1B - Fugitive Emissions from Fuels	1.02		0.00	0.00	0.00	0.00	0.00	0.00						
1B1 - Solid Fuels	NO		NO	NO	NO	NO	NO	NO						
1B2 - Oil and Natural Gas	1.02		0.00	0.00	0.00	0.00	0.00	0.00						
2 - Industrial Processes	479.73		0.00	0.00	0.00	0.00	3.28	0.00	0	49.14	38.22	0	0	0
2A - Mineral Products	477.79		NA	NA	NA	NA	NA	NA						
2B - Chemical Industry	NO		NO	NO	NO	NO	NO	NO						
2C - Metal Production	NO		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2D - Other Production	1.94		NO	NO	NO	NO	NO	NO						
2E - Production of Halocarbons and Sulphur Hexafluoride					NA	NA	NA	NA	NO	NO	NO	NO	NO	NO
2F - Consumption of Halocarbons and Sulphur Hexafluoride					NA	NA	NA	NA	NO	49.14	38.22	NO	NO	NO
2G - Other (please specify)	NO		NO	NO	NO	NO	3.28	NO						
3 - Solvent and Other Product Use	0.00		0.00	0.00	0.00	0.00	14.40	0.00						
4 - Agriculture			13.69	15.65	8.84	7.57	1.34	0.00						
4A - Enteric Fermentation			8.63		NA	NA	NA	NA						
4B - Manure Management			4.80	5.18	NA	IE	1.28	NA						
4C - Rice Cultivation			0.01		NA	NA	NA	NA						
4D - Agricultural Soils				5.24	NA	7.33	0.06	NA						
4E - Prescribed Burning of Savannas			NO	NO	NO	NO	NO	NO						
4F - Field Burning of Agricultural Residues			0.26	0.01	8.84	0.24	NE	NE						
4G - Other (please specify)	2.10		NO	5.22	NO	NO	NO	NO						
5 - Land-Use Change & Forestry	-1638.39			0.00	0.00	0.00	0.00	0.00						
5A - Changes in Forest and Other Woody Biomass Stocks	-1786				NA	NA	NA	NA						
5B - Forest and Grassland Conversion	85				NA	NA	NA	NA						
5E - Other (please specify)	63				NA	NA	NA	NA						
6 - Waste	44.19		24.49	0.15	6.08	0.35	1.10	0.01						
6A - Solid Waste Disposal on Land			19.64		0.00	0.00	0.95	0.00						
6B - Wastewater Handling			4.14	0.13	0.00	0.00	0.00	0.00						
6C - Waste Incineration	5		0.00	0.00	0.00	0.01	0.02	0.00						
6D - Other (open bruning and biological treatment)	39		0.71	0.02	6.08	0.35	0.13	0.01						
7 - Other (please specify)	0.00		0.00	0.00	0.00	0.00	0.00	0.00	NO	NO	NO	NO	NO	NO
									NO	NO	NO	NO	NO	NO
Memo Items														
International Bunkers	2583.28		0.17	0.07	4.79	49.27	1.65	11.81						
1A3a1 - International Aviation	770.58		0.01	0.02	0.51	3.43	0.09	0.24						
1A3d1 - International Marine (Bunkers)	1812.70		0.16	0.05	4.28	45.85	1.56	11.57						
CO2 emissions from biomass	586.92													

Inventory Year:	2008								HFCs (Gg CO2 EQ)			PFCs (Gg CO2 EQ)		
Greenhouse gas source and sink categories	CO2 Emissions (Gg)	CO2 Removals (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)	HFC - 23	HFC - 134	Other	CF4	C2F6	Other
Total National Emissions and Removals	9026.33		40.03	22.17	96.05	66.57	32.38	18.63	0	52.22	40.27	0	0	0
1 - Energy	10069.95		1.67	0.29	80.58	55.76	11.96	18.62						
1A - Fuel Combustion Activities	10069.59		1.67	0.29	80.58	55.76	11.96	18.62						
1A1 - Energy Industries	3061.88		0.12	0.02	0.59	4.91	0.07	14.51						
1A2 - Manufacturing Industries and Construction (ISIC)	4718.59		0.31	0.07	14.41	32.09	3.03	3.69						
1A3 - Transport	1928.02		0.56	0.19	51.89	17.26	7.40	0.27						
1A4 - Other Sectors	361.09		0.68	0.01	13.68	1.50	1.46	0.14						
1A5 - Other	NO		NO	NO	NO	NO	NO	NO						
1B - Fugitive Emissions from Fuels	0.36		0.00	0.00	0.00	0.00	0.00	0.00						
1B1 - Solid Fuels	NO		NO	NO	NO	NO	NO	NO						
1B2 - Oil and Natural Gas	0.36		0.00	0.00	0.00	0.00	0.00	0.00						
2 - Industrial Processes	537.03		0.00	0.00	0.00	0.00	3.11	0.00	0	52.22	40.27	0	0	0
2A - Mineral Products	535.10		NA	NA	NA	NA	NA	NA						
2B - Chemical Industry	NO		NO	NO	NO	NO	NO	NO						
2C - Metal Production	NO		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2D - Other Production	1.94		NO	NO	NO	NO	NO	NO						
2E - Production of Halocarbons and Sulphur Hexafluoride					NA	NA	NA	NA	NO	NO	NO	NO	NO	NO
2F - Consumption of Halocarbons and Sulphur Hexafluoride					NA	NA	NA	NA	NO	52.22	40.27	NO	NO	NO
2G - Other (please specify)	NO		NO	NO	NO	NO	3.11	NO						
3 - Solvent and Other Product Use	0.00		0.00	0.00	0.00	0.00	14.28	0.00						
4 - Agriculture			13.66	21.73	8.58	10.42	1.73	0.00						
4A - Enteric Fermentation			8.31		NA	NA	NA	NA						
4B - Manure Management			5.10	7.24	NA	IE	1.68	NA						
4C - Rice Cultivation			0.01		NA	NA	NA	NA						
4D - Agricultural Soils				6.95	NA	10.18	0.06	NA						
4E - Prescribed Burning of Savannas			NO	NO	NO	NO	NO	NO						
4F - Field Burning of Agricultural Residues			0.25	0.01	8.58	0.23	NE	NE						
4G - Other (please specify)	1.60		NO	7.54	NO	NO	NO	NO						
5 - Land-Use Change & Forestry	-1631.47			0.00	0.00	0.00	0.00	0.00						
5A - Changes in Forest and Other Woody Biomass Stocks	-1779				NA	NA	NA	NA						
5B - Forest and Grassland Conversion	83				NA	NA	NA	NA						
5E - Other (please specify)	64				NA	NA	NA	NA						
6 - Waste	49.22		24.70	0.15	6.88	0.40	1.30	0.01						
6A - Solid Waste Disposal on Land			20.11		0.00	0.00	1.13	0.00						
6B - Wastewater Handling			3.79	0.13	0.00	0.00	0.00	0.00						
6C - Waste Incineration	5		0.00	0.00	0.00	0.01	0.02	0.00						
6D - Other (open bruning and biological treatment)	44		0.80	0.02	6.88	0.39	0.15	0.01						
7 - Other (please specify)	0.00		0.00	0.00	0.00	0.00	0.00	0.00	NO	NO	NO	NO	NO	NO
									NO	NO	NO	NO	NO	NO
Memo Items														
International Bunkers	2450.58		0.16	0.07	4.47	45.74	1.53	10.91						
1A3a1 - International Aviation	778.95		0.01	0.02	0.52	3.47	0.09	0.25						
1A3d1 - International Marine (Bunkers)	1671.63		0.15	0.04	3.95	42.27	1.44	10.67						
CO2 emissions from biomass	586.92													

Inventory Year:	2009								HFCs (Gg CO2 EQ)			PFCs (Gg CO2 EQ)		
Greenhouse gas source and sink categories	CO2 Emissions (Gg)	CO2 Removals (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)	HFC - 23	HFC - 134	Other	CF4	C2F6	Other
Total National Emissions and Removals	6296.01		40.82	21.49	91.11	46.36	31.57	17.34	0	53.82	41.12	0	0	0
1 - Energy	7388.45		1.63	0.28	77.47	35.99	11.56	17.33						
1A - Fuel Combustion Activities	7386.72		1.63	0.28	77.47	35.98	11.56	17.33						
1A1 - Energy Industries	3129.61		0.12	0.02	0.60	5.02	0.08	14.87						
1A2 - Manufacturing Industries and Construction (ISIC)	1940.10		0.28	0.05	13.12	13.33	2.86	2.20						
1A3 - Transport	1997.88		0.55	0.20	50.42	16.38	7.20	0.15						
1A4 - Other Sectors	319.14		0.68	0.01	13.32	1.26	1.43	0.12						
1A5 - Other	NO		NO	NO	NO	NO	NO	NO						
1B - Fugitive Emissions from Fuels	1.72		0.00	0.00	0.00	0.00	0.00	0.00						
1B1 - Solid Fuels	NO		NO	NO	NO	NO	NO	NO						
1B2 - Oil and Natural Gas	1.72		0.00	0.00	0.00	0.00	0.00	0.00						
2 - Industrial Processes	484.17		0.00	0.00	0.00	0.00	2.96	0.00	0	53.82	41.12	0	0	0
2A - Mineral Products	482.24		NA	NA	NA	NA	NA	NA						
2B - Chemical Industry	NO		NO	NO	NO	NO	NO	NO						
2C - Metal Production	NO		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2D - Other Production	1.94		NO	NO	NO	NO	NO	NO						
2E - Production of Halocarbons and Sulphur Hexafluoride					NA	NA	NA	NA	NO	NO	NO	NO	NO	NO
2F - Consumption of Halocarbons and Sulphur Hexafluoride					NA	NA	NA	NA	NO	53.82	41.12	NO	NO	NO
2G - Other (please specify)	NO		NO	NO	NO	NO	2.96	NO						
3 - Solvent and Other Product Use	0.00		0.00	0.00	0.00	0.00	14.19	0.00						
4 - Agriculture			13.10	21.07	7.52	10.02	1.69	0.00						
4A - Enteric Fermentation			7.98		NA	NA	NA	NA						
4B - Manure Management			4.89	7.02	NA	IE	1.63	NA						
4C - Rice Cultivation			0.01		NA	NA	NA	NA						
4D - Agricultural Soils				6.70	NA	9.82	0.06	NA						
4E - Prescribed Burning of Savannas			NO	NO	NO	NO	NO	NO						
4F - Field Burning of Agricultural Residues			0.22	0.01	7.52	0.20	NE	NE						
4G - Other (please specify)	0.74		NO	7.34	NO	NO	NO	NO						
5 - Land-Use Change & Forestry	-1621.56			0.00	0.00	0.00	0.00	0.00						
5A - Changes in Forest and Other Woody Biomass Stocks	-1770				NA	NA	NA	NA						
5B - Forest and Grassland Conversion	83				NA	NA	NA	NA						
5E - Other (please specify)	65				NA	NA	NA	NA						
6 - Waste	44.22		26.09	0.15	6.12	0.35	1.17	0.01						
6A - Solid Waste Disposal on Land			21.71		0.00	0.00	1.01	0.00						
6B - Wastewater Handling			3.67	0.13	0.00	0.00	0.00	0.00						
6C - Waste Incineration	5		0.00	0.00	0.00	0.01	0.02	0.00						
6D - Other (open bruning and biological treatment)	39		0.71	0.02	6.12	0.35	0.13	0.01						
7 - Other (please specify)	0.00		0.00	0.00	0.00	0.00	0.00	0.00	NO	NO	NO	NO	NO	NO
									NO	NO	NO	NO	NO	NO
Memo Items														
International Bunkers	1640.88		0.09	0.04	2.70	27.04	0.90	6.26						
1A3a1 - International Aviation	694.47		0.00	0.02	0.46	3.09	0.08	0.22						
1A3d1 - International Marine (Bunkers)	946.41		0.09	0.02	2.24	23.95	0.82	6.04						
CO2 emissions from biomass	586.92													

Inventory Year:	2010								HFCs (Gg CO2 EQ)			PFCs (Gg CO2 EQ)		
Greenhouse gas source and sink categories	CO2 Emissions (Gg)	CO2 Removals (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)	HFC - 23	HFC - 134	Other	CF4	C2F6	Other
Total National Emissions and Removals	5666.64		40.36	21.43	83.17	42.23	29.26	16.65	0	54.15	40.94	0	0	0
1 - Energy	6829.01		1.46	0.25	69.95	31.86	9.73	16.63						
1A - Fuel Combustion Activities	6827.92		1.46	0.25	69.95	31.86	9.73	16.63						
1A1 - Energy Industries	3093.20		0.12	0.02	0.60	4.99	0.08	14.84						
1A2 - Manufacturing Industries and Construction (ISIC)	1502.57		0.15	0.03	9.48	10.17	1.50	1.51						
1A3 - Transport	1910.67		0.52	0.18	47.16	15.48	6.74	0.18						
1A4 - Other Sectors	321.48		0.67	0.01	12.71	1.22	1.42	0.11						
1A5 - Other	NO		NO	NO	NO	NO	NO	NO						
1B - Fugitive Emissions from Fuels	1.09		0.00	0.00	0.00	0.00	0.00	0.00						
1B1 - Solid Fuels	NO		NO	NO	NO	NO	NO	NO						
1B2 - Oil and Natural Gas	1.09		0.00	0.00	0.00	0.00	0.00	0.00						
2 - Industrial Processes	415.60		0.00	0.00	0.00	0.00	2.90	0.00	0	54.15	40.94	0	0	0
2A - Mineral Products	413.67		NA	NA	NA	NA	NA	NA						
2B - Chemical Industry	NO		NO	NO	NO	NO	NO	NO						
2C - Metal Production	NO		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2D - Other Production	1.94		NO	NO	NO	NO	NO	NO						
2E - Production of Halocarbons and Sulphur Hexafluoride					NA	NA	NA	NA	NO	NO	NO	NO	NO	NO
2F - Consumption of Halocarbons and Sulphur Hexafluoride					NA	NA	NA	NA	NO	54.15	40.94	NO	NO	NO
2G - Other (please specify)	NO		NO	NO	NO	NO	2.90	NO						
3 - Solvent and Other Product Use	0.00		0.00	0.00	0.00	0.00	13.89	0.00						
4 - Agriculture			12.63	21.04	7.92	10.06	1.67	0.00						
4A - Enteric Fermentation			7.66		NA	NA	NA	NA						
4B - Manure Management			4.72	6.98	NA	IE	1.61	NA						
4C - Rice Cultivation			0.01		NA	NA	NA	NA						
4D - Agricultural Soils				6.69	NA	9.85	0.06	NA						
4E - Prescribed Burning of Savannas			NO	NO	NO	NO	NO	NO						
4F - Field Burning of Agricultural Residues			0.23	0.01	7.92	0.22	NE	NE						
4G - Other (please specify)	1.10		NO	7.36	NO	NO	NO	NO						
5 - Land-Use Change & Forestry	-1617.95			0.00	0.00	0.00	0.00	0.00						
5A - Changes in Forest and Other Woody Biomass Stocks	-1767				NA	NA	NA	NA						
5B - Forest and Grassland Conversion	83				NA	NA	NA	NA						
5E - Other (please specify)	66				NA	NA	NA	NA						
6 - Waste	38.87		26.27	0.15	5.30	0.31	1.07	0.01						
6A - Solid Waste Disposal on Land			22.30		0.00	0.00	0.93	0.00						
6B - Wastewater Handling			3.35	0.13	0.00	0.00	0.00	0.00						
6C - Waste Incineration	5		0.00	0.00	0.00	0.01	0.02	0.00						
6D - Other (open bruning and biological treatment)	34		0.62	0.01	5.30	0.30	0.12	0.01						
7 - Other (please specify)	0.00		0.00	0.00	0.00	0.00	0.00	0.00	NO	NO	NO	NO	NO	NO
									NO	NO	NO	NO	NO	NO
Memo Items														
International Bunkers	1687.69		0.09	0.05	2.73	27.30	0.90	6.30						
1A3a1 - International Aviation	737.47		0.01	0.02	0.49	3.28	0.08	0.23						
1A3d1 - International Marine (Bunkers)	950.22		0.09	0.02	2.24	24.02	0.82	6.06						
CO2 emissions from biomass	586.92													

6.0 APPENDIX 2: CROP PRODUCTION & HARVESTED AREAS

6.1 Crop Production

TABLE 0.1: PRODUCTION. TONNES

PRODUCTION (TONNES)							
Crop	2006	2007	2008	2009	2010	2011	2012
Broad Bean	156	133	125	171	178	211	224
Sugar Bean	145	115	111	125	116	135	146
Cow Pea	229	246	222	206	199	232	253
Gungo Pea	934	868	668	847	749	965	951
Red pea	622	554	506	768	682	905	986
Peanut	3,413	3,728	2,825	2,704	2,007	2,643	2,701
Total Pulses	5,499	5,644	4,457	4,821	3,931	5,091	5,261
Beetroot	1,038	1,025	1,392	1,650	1,661	1,853	1,541
Broccoli	550	550	475	688	647	817	988
Cabbage	25,676	22,110	20,648	25,896	24,515	33,046	32,687
Callaloo	13,708	12,192	11,184	12,938	12,886	15,693	16,607
Carrot	22,887	19,365	18,925	25,437	21,026	32,004	29,528
Cauliflower	1,545	1,490	1,204	1,279	787	1,301	1,063
Celery	101	48	95	193	160	174	203
Chocho	3,032	2,534	2,596	3,162	3,876	4,691	5,394
Cucumber	12,967	11,252	11,217	11,428	11,681	16,025	16,617
Egg Plant	317	423	311	404	817	391	361
Lettuce (iceberg)	5,723	5,682	5,364	6,125	6,234	9,607	8,845
Lettuce (other)	682	618	647	1,200	969	1,578	1,527
Okra	3,652	3,379	3,432	4,377	4,202	5,513	6,344
Pak Choi	8,337	7,099	6,803	9,101	9,197	12,339	12,454
Pumpkin	36,484	33,749	32,927	39,785	39,292	49,432	52,170
Squash	886	886	1,192	1,016	1,538	1,631	1,521
String Bean	6,205	5,596	5,446	6,322	5,621	8,717	8,068
Tomato	23,090	19,576	19,387	21,190	19,006	26,950	26,526
Turnip	1,608	1,419	1,311	1,340	1,297	1,713	1,618
Other Vegetables	70	180	41	59	44	73	68

PRODUCTION (TONNES)							
Crop	2006	2007	2008	2009	2010	2011	2012
Total Vegetables	168,558	149,173	144,597	173,590	165,456	223,548	224,130
Escallion	11,037	10,840	10,190	10,181	11,194	13,908	14,142
Ginger	259	241	298	459	486	444	1,082
Onion	234	215	455	721	555	1,015	1,088
Hot Pepper	7,440	6,596	5,338	10,565	11,206	13,293	14,263
Sweet Pepper	9,240	8,556	7,869	10,804	10,017	14,998	15,154
Thyme	1,878	2,423	2,131	1,584	1,249	1,053	1,124
Total Condiments	30,088	28,871	26,281	34,314	34,707	44,711	46,853
Canteloupe	2,743	2,743	2,520	2,337	2,333	2,624	3,243
Papaya	11,300	9,201	7,156	10,671	5,314	5,846	6,455
Pineapple	20,533	18,102	20,351	21,368	19,749	17,607	19,757
Watermelon	14,056	9,573	12,230	12,393	10,606	12,666	15,569
Total Fruits	48,632	39,619	42,257	46,769	38,002	38,743	45,024
Hybrid Corn	630	587	784	1,236	1,344	1,564	1,606
Ordinary Corn	1,259	1,080	1,107	1,114	1,017	1,159	1,192
Sweet Corn	5	7	6	9	2	11	24
Rice	2	65	100	150	264	235	299
Total Cereals	1,896	1,739	1,997	2,509	2,627	2,969	3,121
Horse Plantain	17,219	14,900	11,345	18,792	23,519	27,509	27,381
Other Plantain	4,768	4,187	3,690	5,829	6,307	7,826	8,822
Total Plantain	21,987	19,087	15,035	24,621	29,826	35,335	36,203
Irish Potato	8,559	7,477	4,929	8,708	11,222	15,333	15,396
Sweet Potato	27,468	26,055	25,797	34,229	34,512	42,091	42,165
Total Potatoes	36,027	33,532	30,726	42,937	45,734	57,424	57,561
Lucea	9,831	10,306	10,542	9,609	10,744	9,138	9,412
Negro	12,654	11,217	11,075	15,289	15,163	16,311	15,632
Renta	7,956	8,006	6,662	8,253	9,444	9,892	10,017
St. Vincent	2,717	2,323	2,026	2,443	2,902	2,801	2,420
Sweet	6,275	5,186	3,765	4,411	3,907	3,291	2,609
Tau	2,913	2,588	2,150	2,245	2,442	2,507	2,675
Yellow	78,571	71,863	64,374	80,531	89,944	88,601	100,325
Other	2,088	1,636	1,689	1,735	2,240	2,079	1,971
Total Yams	123,005	113,125	102,283	124,516	136,786	134,620	145,061
Bitter Cassava	7,710	8,299	6,741	5,764	6,426	7,522	6,036
Sweet Cassava	10,001	10,220	8,250	8,231	12,064	13,011	11,984
Coco	6,921	6,485	5,464	6,635	7,494	9,432	9,805
Dasheen	10,993	10,830	11,416	14,305	16,196	18,493	17,888
Other Tubers	35,625	35,834	31,871	34,935	42,180	48,458	45,713

PRODUCTION (TONNES)							
Crop	2006	2007	2008	2009	2010	2011	2012
Sorrel	738	749	708	811	1,057	1,212	1,213
Sugar Cane	141,200	158,000	140,400	126,000	116,500	137,800	130,700
Banana	35,649	36,200	36,200	45,334	53,649	46,660	47,473
Citrus	120,092	124,553	122,291	128,241	117,440	106,922	97,072
Coffee	12,390	15,117	9,035	12,456	9,121	8,099	6,687
Cocoa	595	1,915	1,015	1,108	1,368	499	1,393
Coconut	19,240	19,080	19,060	19,000	19,060	19,120	19,280

6.2 Harvested Areas

TABLE 0.2 HARVEST AREAS (HECTARES)

HARVESTED AREAS (HECTARES)							
Crop	2006	2007	2008	2009	2010	2011	2012
Broad Bean	146	128	124	163	185	202	209
Sugar Bean	137	108	104	119	116	128	141
Cow Pea	215	228	210	195	196	222	244
Gungo Pea	785	725	565	746	723	830	796
Red Pea	569	516	468	678	630	792	865
Peanut	2,459	2,729	1,950	1,916	1,751	2,013	2,125
Total Pulses	4,311	4,434	3,421	3,817	3,601	4,187	4,380
Beetroot	103	106	155	172	189	190	150
Broccoli	70	70	64	80	85	89	108
Cabbage	1,459	1,295	1,208	1,469	1,495	1,865	1,904
Callaloo	797	717	668	781	807	937	973
Carrot	1,568	1,349	1,277	1,627	1,480	1,983	1,907
Cauliflower	125	125	114	113	84	115	97
Celery	10	5	10	17	16	28	20
Chocho	213	179	187	219	255	318	351
Cucumber	877	792	821	848	887	1,111	1,115
Egg Plant	27	36	27	34	34	33	31
Lettuce (iceberg)	406	402	379	432	463	632	608
Lettuce (other)	54	47	50	77	71	136	130
Okra	404	369	385	474	480	559	634
Pak choi	559	497	490	639	656	830	858
Pumpkin	2,035	1,897	1,873	2,186	2,238	2,630	2,787
Squash	82	82	78	85	117	119	108
String bean	546	486	463	584	552	763	730
Tomato	1,350	1,165	1,155	1,278	1,281	1,595	1,668
Turnip	129	123	112	113	118	134	131
Other vegetables	12	12	8	13	12	8	14
Total Vegetables	10,826	9,754	9,524	11,241	11,320	14,075	14,324
Escallion	767	787	795	863	989	1,003	1,065
Ginger	107	105	106	149	148	162	219
Onion	30	26	50	59	59	95	104
Hot Pepper	738	659	526	877	952	923	1,069
Sweet Pepper	721	688	635	801	828	964	1,126
Thyme	260	332	317	214	201	176	196
Total Condiments	2,623	2,597	2,429	2,963	3,177	3,323	3,779

HARVESTED AREAS (HECTARES)							
Crop	2006	2007	2008	2009	2010	2011	2012
Canteloupe	213	213	245	213	235	203	247
Papaya	499	430	325	421	258	274	331
Pineapple	921	807	910	1,029	1,061	979	1,075
Watermelon	760	646	810	776	727	665	880
Total Fruits	2,393	2,096	2,290	2,439	2,281	2,121	2,533
Hybrid Corn	506	489	609	939	1,077	1,165	1,273
Ordinary Corn	1,030	906	900	925	938	974	1,079
Sweet Corn	5	4	5	6	2	5	20
Rice	1	22	30	37	56	44	61
Total Cereals	1,542	1,421	1,544	1,907	2,073	2,188	2,433
Horse Plantain	1,000	876	675	1,031	1,258	1,367	1,552
Other Plantain	256	223	200	294	326	365	459
Total Plantain	1,256	1,099	875	1,325	1,584	1,732	2,011
Irish Potato	513	455	299	514	788	806	931
Sweet Potato	1,653	1,576	1,533	2,004	2,122	2,306	2,468
Total Potatoes	2,166	2,031	1,832	2,518	2,910	3,112	3,399
Lucea	615	665	680	596	661	554	626
Negro	790	793	726	875	870	929	914
Renta	463	459	397	471	536	544	557
St. Vincent	173	148	130	152	181	169	147
Sweet	440	360	264	292	261	215	173
Tau	163	151	125	126	141	139	155
Yellow	4,672	4,559	4,245	4,838	5,359	5,659	5,800
Other	115	99	101	97	128	114	109
Total Yams	7,431	7,234	6,668	7,447	8,137	8,323	8,481
Bitter Cassava	389	429	340	288	345	397	315
Sweet Cassava	562	563	466	463	653	690	639
Coco	456	427	358	420	483	578	610
Dasheen	568	588	599	695	832	938	954
Other Tubers	1,975	2,007	1,763	1,866	2,313	2,603	2,518
Sorrel	564	519	464	570	610	717	750
Sugar Cane	30,000	30,800	29,900	26,200	27,600	27,900	28,100
Banana	2,228	2,263	2,263	2,833	3,353	2,916	2,967
Citrus	1,501	1,557	1,529	1,603	1,468	1,337	1,213
Coffee	1,033	1,260	753	1,038	760	675	557
Cocoa	20	64	34	37	46	17	46
Coconut	175	173	173	173	173	174	175

7.0 APPENDIX 3: DETAILED EXPLANATION OF LAND USE AREAS & LAND USE CHANGES

7.1 Land Use Area Definitions

In Volume 1, Section 1.5 of the 2006 IPCC Guidelines, an inventory compiler is advised that futureGHG inventories should be based on previous inventories. Therefore, an iterative process should be developed which builds on previous inventories and consequently leads to improvements of the new inventory. It further states that when a new inventory is compiled, the estimates for each year should be reviewed for consistency and updated, integrating any feasible improvements where necessary. This is the procedure that this LULUCF inventory followed.

The 2006 IPCC Guidelines also provide comprehensive documentation on how to proceed with the estimation of the emissions by sources and removals by sinks of GHG gases.

The 2006 IPCC Guidelines require reporting on emissions and removals of CO_2 and non-CO_2 greenhouse gases for six key land-use categories for the LULUCF Sector. These categories are as follows:1)

Forest Land - This category includes all land with woody vegetation consistent with thresholds used to define Forest Land in the national greenhouse gas inventory. It also includes systems with a vegetation structure that currently falls below, but in situ could potentially reach the threshold values used by a country to define the Forest Land category.Reporting is required for the following: Forest Land Remaining Forest Land (FF) and Land Converted to Forest Land (LF).2)

Cropland - This category includes arable and tillable land, rice fields and agroforestry systems where the vegetation structure falls below the thresholds used for the Forest Land category, and is not expected to exceed those thresholds at a later time. Cropland includes all annual and before being cultivated again). Annual crops include cereals, oils seeds, vegetables, root crops and forages. Perennial crops include trees and shrubs, in combination with herbaceous crops (e.g., agroforestry) or orchards, vineyards and plantations, such as cocoa, coffee, tea, oil palm, coconut, rubber trees and bananas, except where these lands meet the criteria for categorisation as Forest Land. Arable land, which is normally used for cultivation of annual crops but which is temporarily used for forage crops or grazing as part of an annual crop-pasture rotation (mixed system), is included under cropland.Reporting is required for the following: Cropland Remaining Cropland (CC) and Land Converted to Cropland (LC).3)

Grassland - this category includes rangelands and pasture land that are not considered Cropland. It also includes systems with woody vegetation and other non-grass vegetation, such as herbs and brushes that fall below the threshold values used in the Forest Land category. This category also includes all grassland from wild lands to recreational areas as well as agricultural and silvopastoral systems, consistent with national definitions.Reporting is required for the following: Grassland Remaining Grassland (GG) and Land Converted to Grassland (LG).4)

Wetlands - This category includes any land that is covered or saturated by water for all or part of the year and which does not fall into the Forest Land, Cropland or Grassland categories.Managed wetlands will be restricted to wetlands where the water table is artificially changed(e.g., drained or raised) or those created through human activity (e.g. damming a river).Emissions from unmanaged wetlands are not estimated. Methodologies are provided for peatlands cleared and drained for production of peat for energy, horticultural and other uses.Methodologies are also provided for reservoirs or impoundments, for energy production, irrigation, navigation or recreation.Reporting is required for the following: Wetlands Remaining Wetlands (WW) and Land Converted to Wetlands (LW).5)

Settlements - this category includes all developed land, i.e., residential, transportation, commercial, and production (commercial, manufacturing) infrastructure of any size, unless it is already included under other land-use categories. The land-use category "Settlements" includes soils, herbaceous perennial vegetation, such as turf grass and garden plants, trees in rural settlements, homestead gardens and urban areas.Reporting is required for the following: Settlements Remaining Settlements (SS) and Land Converted to Settlements (LS).6)

Other Land - this category includes bare soil, rock and all land areas that do not fall into any of the other five categories. "Other Land" is often unmanaged and in that case, changes in carbon stocks and non-CO_2 emissions and removals are not estimated.Reporting is required for the following: Other Land Remaining Other Land (OO) and LandConverted to Other Land (LO).

7.2 Relating Country-Specific Data to the IPCC Land Use Categories

A systematic data gathering process, started in the year 2000 after a critical analysis of the existing land use/cover and land classification systems in Jamaica, was done by the Forestry Department (Camirand and Evelyn, 2003). This analysis determined that none of the systems that had been developed had the characteristics or capability of classifying forests for forest management, conservation or the evaluation for forest development in the island. A standardised broad classification system was therefore developed for use with satellite imagery and aerial photograph interpretation. An aerial photo interpretation manual was also prepared which provides guidelines for interpretation of the various land use types on aerial photographs (Forestry Department, 2002) and by extension, satellite imagery. The process is a hierarchical stratified system and is shown in Figure 13.1 below.

Evelyn and Camirand (2003) used this classification system for reporting, among other things, details of deforestation and land use/cover changes in Jamaica between 1989 and 1998. They reported that the annual rate of loss in forest cover during that period was 0.1%. A land-use conversion matrix showing the area changes from one land use/cover to another during that period was also reported (See Table 13.2).

The IPCC land-use categories are not dissimilar to Jamaica's national land-use classes. For theNational Forest Inventory Report 2003 (Camirand and Evelyn, 2004), the island's land uses were determined using 1992 colour aerial photographs following the procedures outlined in the ForestryDepartment Aerial Interpretation Manual (Forestry Department, 2002). The "Forest" and the"Mixed" Land/Use Cover classes were then aggregated to ten (10) broad categories. These categories can be aligned to the six key IPCC GHG land-use categories, as shown in Table 13.1.

The area of forest land and cropland for the year 2005 as reported in Jamaica's second National Greenhouse Gas (GHG) emissions by sources and removal by sinks inventory (Davis et al., 2008) was 498, 834 hectares and 84,880 hectares respectively. However, after a review, errors were found in the calculations of both of these figures. Therefore, the figures had to be adjusted to 499,604 hectares and 81,715 hectares respectively. These are the benchmark figures on which the 2006-2012 GHG Inventory are built.

All of the forested lands in Jamaica can be classified as managed forests. This is so because anthropogenic activities such as extraction of wood and non-wood forest products are continuously taking place in almost all the forests. About 34% of this forest area has been designated as Forest Reserves and other protected areas and are under continuous management as stipulated by the Forest Act, 1996 (Section 8,1) and the Natural Resources Conservation Authority Act, 1991.

It is to be noted that the area of forest land on the island being reported in Table 13.1 will differ from those reported elsewhere. This is because of the low resolution of the LandsatTM imagery that was used for the 1998 land use/cover study which did not allow for separation of the forested areas in the "mixed" categories. Estimates of these mixed forest areas were done for the 2000-2005 GHG inventory (Davis et al., 2008) and are again being estimated for this compilation because they represent a significant amount of carbon.

TABLE 0.1 JAMAICAN AND IPCC LAND USE/COVER TYPES

LAND USE/COVER TYPES**						
Code	Jamaica National Land Use Classes		Definitions		GHG Inventory Land Use Categories	Area (ha)
Forests (1)						334,170
PF	Closed Broadleaf		Closed primary forest with broadleaf trees at least 5m tall and crown interlocking, with minimal human disturbance		Forest Land	87,853
SF	Disturbed Broadleaf		Disturbed broadleaf forest with trees at least 5m tall and species-indicators of disturbance such as Ceropia peltata (trumpet tree)		Forest Land	172,756
WL	Tall Open Dry		Open natural woodland or forest with trees at least 5 m tall and crown not in contact, in drier parts of Jamaica with species-indicators such as Bursera simaruba (Red Birch)		Forest Land	41,899

LAND USE/COVER TYPES**						
Code	Jamaica National Land Use Classes		Definitions		GHG Inventory Land Use Categories	Area (ha)
SL	Short Open Dry		Open scrub, shrub, bush or brushland with trees or shrubs 1-5 m tall and crowns not in contact, in drier parts of Jamaica with species-indicators such as Prosopis juliflora (cashew) or Stenocereus hystrix (columnar cactus)		Forest Land	12,120
SW	Riparian/Swamp		Edaphic forest (soil waterlogging) with a single tree storey with species-indicators such as Symphonia globulifera (Hog Plum) and Roystonea princeps (Royal Palm)		Forest Land	2,161
MG	Mangrove		Edaphic forest (areas with brackish water) composed of trees with stilt roots or pneumatopores, species indicators, such as Rhizophora mangle (Red Mangrove)		Forest Land	9,715
PP	Carib Pine Plantation		Forest plantation with Pinus caribaea		Forest Land	3,767
HP	Other Species Plantation		Forest plantation with other species such as Hibiscus elatus (Blue Mahoe), Swietenia macrophylia (Honduras mahogany), Tectona grandis (Teak), Eucalyptus saligna, Cedrela odorata (cedar), etc.		Forest Land	3,900
Mixed						331,086
SC	Disturbed Broadleaf Forest &	>50% Disturbed Broadleaf Forest;		75%	Forest Land	124,540
	Non-Forest Land Use	>25% Non-Forest Land Use (2)		25%	Other Land	41,317
CS	Non-Forest Land Use &	>50% Non-Forest Land Use (2);		75%	80% Grassland	93,829
					20% Otherland	30,506
	Disturbed Broadleaf Forest	>25% Disturbed Broadleaf Forest		25%	Forest Land	40,894
Non-Forest (3)						431,160
	Non-Forest Land Use	Non-Forest Land Use		20%	Cropland	81,715
				65%	Grassland	275,493
				3%	Wetlands	12,446
				12%	Settlements	52,534
				1%	Other Land	8,972

(1) Forest land use/cover > 75%; minimum unit: 25 hectares.
(2) Fields (herbaceous crops, fallow, cultivated grass/legumes); bamboo, bauxite extraction.
(3) Trees/shrub crops (sugar cane, bananas, citrus, coconuts); fields (herbaceous crops, fallow, cultivated grass/legumes); herbaceous wetland; buildings and other infrastructure; surface mining/bauxite; bare sand/rock; small islands; lakes and rivers.

A spatially explicit land use conversion matrix for land use change in Jamaica was reported in Evelyn and Camirand, 2003. A modified version of this matrix is reproduced below in Table 13.2.It should be noted that several of the forest land use classes are degraded to a lower class. For example, 396 ha from Closed broadleaf forest (PF) (194m^3/ha) was degraded to Disturbed broadleaf forest (SF) (165m3/ha) and 2018ha from Disturbed broadleaf forest (SF) was degraded to Disturbed broadleaf forest and Mixed-forest (SC) (94m^3/ha). However, it is difficult to accurately account for this loss because, as was stated above, net average annual increments (m^3 ha^{-1} yr^{-1}) for these country-specific vegetation types are not available.

Table 13.3 below shows the estimates of annual removals. Figures for the wood removals from public lands are well documented in records at the Forestry Department. However, figures for private lands are unknown. An assumption is therefore made that removals from privately owned lands are in accordance with the ratio of publicly owned lands to privately owned lands in Jamaica.

The figure for annual fuelwood use in Jamaica is also unknown. However, FAOSTAT has estimates these quantities using a statistical model, which relates wood fuel and charcoal consumption to several variables, such as income, climate, forest cover, land area, and percentage of population living in urban areas. FAOSTAT estimates for Jamaica are not considered reliable, however, because when they are related to area cleared, it is evident that the figures are grossly overestimated. For example, the estimated area of fuelwood cleared using the FAOSTAT volume for the year 2006, is 6,128 hectares (the m^3/ha used is 105 m^3, the average of all the volumes, except Pine and Hardwoods. This is 18 times the annual rate of deforestation in Jamaica that was estimated by Evelyn and Camirand (2003). It could be argued that some of this volume is coming from the degradation of the forests for yam sticks that is taking place in Jamaican forests, which is unquantified. However, nothing of this magnitude has been observed. An adjustment was therefore made to the estimated FAOSTAT figures by applying the ratio between fuelwood and round wood removal, which was also estimated by FAOSTAT, to the actual round wood removal figures from the Forestry Department records. When this was done, the derived estimated area of land harvested for fuelwood in 2006 was approximately 167 ha, or less than half the area of deforestation estimated by Evelyn and Camirand (2003). This area is regarded as reasonable. Estimates of the annual total losses from removals, such as logging, are included in Table 13.3 above.

Table 13.4 below summarises the annual losses and gains by land use class and Table 13.5 shows a derived conversion matrix by GHG classes from the matrix in Table 13.2.

FIGURE 13.1 HIERARCHICAL LAND USE/COVER FRAMEWORK IN JAMAICA

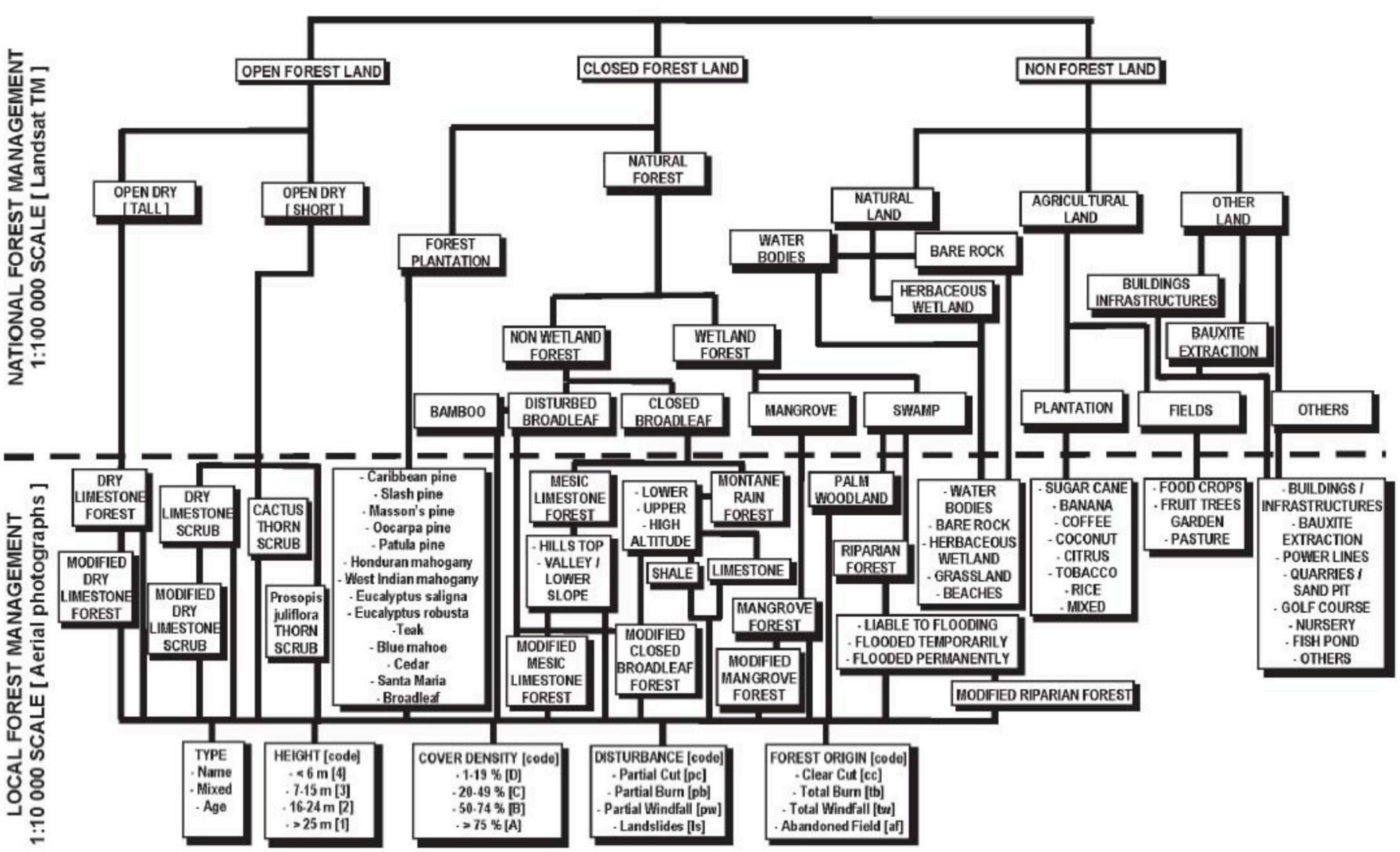


TABLE 0.2 MATRIX OF LAND USE CHANGES

To \ From			GHG Class	Total Land use/cover Change (Ha)																						Total Gain (ha)	Net Loss/Gain
				Forest							Mixed						Non-forest										
				PF	SF	WL	SL	SW	MG	PP & HP	BB	BC	BF	BS	CS	SC	BA	BE	BR	FC	HW	PC	WA	SI			
Land use/cover 1998	Forest	PF	Forest Land																							0	-486
		SF	Forest Land	396						7					106					62						571	-2531
		WL	Forest Land																				6			6	-127
		SL	Forest Land																			227				227	20
		SW	Forest Land																							0	-111
		MG	Forest Land													1							40			41	-21
		PP&HP	Forest Land																							0	-669
	Mixed	BB	Forestland		3							139				46										188	188
		BC	75% Forestland, 25% GrassLand							16			193							90						299	-773
		BF	Forest Land		241					172		156														569	376
		BS	75% Other Land, 25% Forest Land		229										230	911										1370	1370
		CS	Mixed: 75% 80% Grassland, 20% OtherLand / 25% Forest Land		359	28				385		378				1301	1			30			60			0	-3473
		SC	75% Forest Land, 25% OtherLand	90	2018										357					101			8			2574	-882
	Non-Forest	BA	Settlement Land		85	105	31					27			76					29						353	352
		BE	Other Land												1725	250				1754						3729	3729
		BR	Other Land				67																			67	67
		FC	Grass Land		167		109	111	62	89		372			979	947						657				3493	1304
		HW	Wetland																							0	0
		PC	Crop Land																	123			3			126	-805
		WA	Wetland																			47				47	-70
		SI	Other Land																							0	0
			Total loss (ha)	486	3102	133	207	111	62	669	0	1072	193	0	3473	3456	1	0	0	2189	0	931	117	0		16202	0

TABLE 0.3 WOOD REMOVALS

Wood Removal - on Forest Reserves & Public Lands														
	Total Volume (m3 vob)							Estinated Area (Ha)						
Year	2006	2007	2008	2009	2010	2011	2012	2006	2007	2008	2009	2010	2011	2012
Species	**Carib pine plantations**							**Carib pine plantations**						
Public	3583.1	1005.7	662.3	270.0	251.7	26.3	237.3	30.00	8.42	5.55	2.26	2.11	0.22	1.99
Private	1992.5	559.3	368.3	150.1	139.9	14.6	132.0	16.68	4.68	3.08	1.26	1.17	0.12	1.11
Sub-total	**5575.6**	**1565.0**	**1030.7**	**420.1**	**391.6**	**41.0**	**369.3**	**46.68**	**13.10**	**8.63**	**3.52**	**3.28**	**0.34**	**3.09**
Species	**Hardwoods - natural forest & plantation**							**Hardwoods**						
Public	1172.5	183.0	164.8	80.8	48.7	262.3	650.6	7.93	1.24	1.12	0.55	0.33	1.77	4.40
Private	2045.5	319.2	287.6	140.9	84.9	457.6	1134.9	13.84	2.16	1.95	0.95	0.57	3.10	7.68
Sub-total	**3218.0**	**502.1**	**452.4**	**221.7**	**133.5**	**719.9**	**1785.5**	**21.77**	**3.40**	**3.06**	**1.50**	**0.90**	**4.87**	**12.08**
Species	**Fuelwood* - public and private**							**Fuelwood* - public and private**						
FAOSTAT	~~643414~~	~~639170~~	~~635030~~	~~630925~~	~~626808~~	~~626808~~	~~626808~~	~~6128~~	~~6087~~	~~6048~~	~~6009~~	~~5970~~	~~5970~~	~~5970~~
Adjusted	17563	4095	2926	1260	1818	2712	7644	167.26	39.00	27.87	12.00	17.32	25.83	72.80

TABLE 0.4 ANNUAL LOSSES/GAINS BY LAND USE CLASS

Land use Class				Total loss/transfer (ha)	Gain (ha)		Net loss/gain (ha)
					From other land use	From transfers	
1	2	3		4	5	6.0	7
Forest	PF	Forest Land		-54.0	0.0	0.0	-54.0
	SF	Forest Land		-344.7	15.7	47.7	-281.2
	WL	Forest Land		-14.8	0.7	0.0	-14.1
	SL	Forest Land		-23.0	25.2	0.0	2.2
	SW	Forest Land		-12.3	0.0	0.0	-12.3
	MG	Forest Land		-6.9	4.5	0.1	-2.3
	PP	Forest Land		-74.3	0.0	0.0	-74.3
	HP	Forest Land		0.0	0.0	0.0	0.0
			Sub-total	**-530.0**	**46.1**	**47.8**	**-436.1**
Mixed	SC	75% Forest Land		-288.0	40.9	257.7	10.6
		25% Otherland		-96.0	70.0	1.5	-24.5
	CS	75%	80% Grassland	-261.3	167.0	10.8	-83.5
			20% Otherland	-57.9	129.3	27.3	98.7
		25%	Forest Land	-207.3	32.8	100.8	-73.7
			Sub-total	**-910.4**	**439.9**	**398.1**	**-72.4**
Non-Forest	Mixed	20% Cropland		-103.4	14.0	0.0	-89.4
		65% Grassland		-243.2	312.5	75.6	144.9
		3% Wetlands		-13.0	5.2	0.0	-7.8
		12% Settlements		-0.1	39.2	0.0	39.1
		1% Otherland			386.1	35.7	421.8
			Sub-total	**-359.8**	**757.0**	**111.3**	**508.6**
			GRAND TOTAL	**-1800.2**	**1243.0**	**557.2**	**0.0**

Figures in column 4 of Table 13.4 above are derived from the losses in Table 13.2. For example, for PF, the total loss for that Class in Table 3 is divided by 9 (486 ha/9 years =54 ha) and for SF, the total is also divided by 9 (3102 ha/9 years = 344.7 ha).Figures in column 5 are also derived from the Gains in Table 13.2. For example, for SF, 75% of the figure for CS (since 25% is already forest) is added to the figure for FC ((106*0.75) + 62)/9 = 15.7 ha. For the transfers in column 6, the figures are also derived from the gains (transfers) in Table 13.2. For example, for SF, the figures from the forest types PF, PP and 25% of CS are added together (396+7 + (106*0.25))/9 = 47.7 ha.

TABLE 0.5 CONVERSION MATRIX – ANNUAL CONVERSION BY GHG LAND USE CLASS

Annual Land-use Conversion (Ha)							
To \ From	Forest Land	CropLand	GrassLand	WetLands	Settlement	Other Lands	Total
Forest Land		25.2	63.2	7.4	0.03	23.9	**119.8**
CropLand			13.7	0.3			**14.0**
GrassLand	338.1	73.0		4.0	0.07	64.3	**479.5**
WetLands		5.2					**5.2**
Settlement	28.9		9.0			1.3	**39.2**
Other Lands	251.9		332.2	1.2	0.02		**585.4**
Total	**618.9**	**103.4**	**418.1**	**13.0**	**0.1**	**89.4**	**1243.0**

TABLE 0.6 SUMMARY OF TOTAL ANNUAL LAND USE AREAS FROM COUNTRY-SPECIFIC DATA

Forest Types - Areas and Land use/cover change in Jamaica											
Code	National class		GHG Inventory Classes	Area (ha)							
				Based Year	Estimations Based on Extrapolation						
				2005	2006	2007	2008	2009	2010	2011	2012
Forests land use											
PF	Closed broadleaf		Forest Land	87853	87799	87745	87691	87637	87583	87529	87475
SF	Disturbed		Forest Land	172756	172475	172194	171913	171632	171350	171069	170788
WL	Tall open dry		Forest Land	41899	41885	41871	41857	41843	41829	41815	41800
SL	Short open dry		Forest Land	12120	12122	12124	12126	12128	12131	12133	12135
SW	Swamp		Forest Land	2161	2148	2136	2124	2111	2099	2087	2074
MG	Mangrove		Forest Land	9715	9712	9710	9708	9705	9703	9701	9698
PP	Pine plantation		Forest Land	3767	3692	3618	3544	3469	3395	3321	3246
HP	Other Species Plantation		Forest Land	3900	3900	3900	3900	3900	3900	3900	3900
			SUB-TOTAL	**334170**	**333734**	**333298**	**332862**	**332426**	**331990**	**331554**	**331117**
Mixed Land Use											
SC	Disturbed Broadleaf Forest &	75%	Forest Land	124540	124550	124561	124572	124582	124593	124603	124614
	Non-Forest land Use	25%	Otherland	41317	41293	41268	41244	41219	41195	41170	41146
CS	Non-Forest land Use &	75%	80% Grassland	93829	93746	93662	93579	93495	93412	93328	93245
			20% Otherland	30506	30604	30703	30802	30900	30999	31097	31196
	Disturbed Broadleaf Forest	25%	Forest Land	40894	40820	40747	40673	40599	40526	40452	40378
			SUB-TOTAL	**331086**	**331013**	**330941**	**330869**	**330796**	**330724**	**330651**	**330579**
Non-Forest land use											
	Non-Forest land use	20%	Cropland	81715	81625	81536	81447	81357	81268	81178	81089
		65%	Grassland	275493	275638	275783	275928	276073	276218	276363	276507
		3%	Wetlands	12446	12438	12430	12422	12414	12407	12399	12391
		12%	Settlements	52534	52573	52612	52651	52690	52729	52768	52808
		1%	Otherland	8972	9394	9816	10238	10660	11081	11503	11925
			SUB-TOTAL	**431160**	**431668**	**432177**	**432686**	**433194**	**433703**	**434211**	**434720**
			TOTAL	**1096416**	**1096416**	**1096416**	**1096416**	**1096416**	**1096416**	**1096416**	**1096416**

Table 13.6 summarises the land use areas total net loss/gain for each year without taking into account the areas in transition in Table 13.4, Column 5. For example, the 2005 figure for PF in Table 13.6 is added to the Total Net Loss/Gain figure for PF in column 7 of Table 13.4 to derive the 2006 figure for PF in Table 13.6 (i.e. 87853 + (-54) = 87799).

The IPCC Guidelines advise that the default limit to account for "Lands Converted to Forest Land" is 20 years. This corresponds to the age limit for late secondary/ successional stage forests in Jamaica (Camirand and Evelyn, 2003). Lands being converted to forests land since 1989 were reported in Evelyn and Camirand (2003) and up to 2013, the Forestry Department observed this trend continuing in other areas of the country.

For the years 1989-2008, these areas in transition were in the early secondary/successional stage of forest development (Camirand and Evelyn, 2003) and are therefore outside the 20 years IPCC Guidelines. However, in 2009, the 20-year threshold would have been reached. Therefore, the areas that were converted to forests since 1989 would have become well-stocked forests and will be accounted for in this inventory.

Table 13.7 shows the calculations when the areas in transition from forest lands are accounted for. For example, for the year 2006, the accumulated area of forest land in transition (land converted to FL) is subtracted from the Forest land total in Table 13.6 (i.e. 499105-2156=496949 ha).

Note however that after the year 2008 when the 20 year threshold is reached, there is no more accumulation on the 2395 ha. Therefore, the area subtracted remains constant.

TABLE 0.7 SUMMARY OF LAND TRANSITIONS, BY IPCC CLASSES

GHG Inventory Classes	Area (ha)							
	2005	2006	2007	2008	2009	2010	2011	2012
FL remaining FL	497568	496949	496330	495711	495212	494713	494214	493715
PF	87853	87799	87745	87691	87637	87583	87529	87475
SF	172489	172192	171895	171598	171317	171036	170755	170473
WL	41888	41873	41858	41844	41829	41815	41801	41787
SL	11691	11668	11645	11622	11624	11626	11628	11631
SW	2161	2148	2136	2124	2111	2099	2087	2074
MG	9639	9632	9625	9618	9616	9614	9611	9609
PP	3767	3692	3618	3544	3469	3395	3321	3246
HP	3900	3900	3900	3900	3900	3900	3900	3900
SC	123845	123815	123785	123754	123765	123775	123786	123797
CS	40336	40230	40123	40017	39943	39870	39796	39722
Land converted to FL	2036	2156	2275	2395	2395	2395	2395	2395
CL remaining CL	81701	81611	81522	81433	81343	81254	81164	81075
Land converted to CL	14	14	14	14	14	14	14	14
GL remaining GL	368843	368905	368966	369027	369089	369150	369211	369273
Land converted to GL	479	479	479	479	479	479	479	479
WL remaining WL	12440	12433	12425	12417	12409	12401	12394	12386
Land converted to WL	5	5	5	5	5	5	5	5
SL remaining SL	52495	52534	52573	52612	52651	52690	52729	52768
Land converted to SL	39	39	39	39	39	39	39	39
OL remaining OL	80210	80706	81202	81697	82193	82689	83185	83681
Land converted to OL	585	585	585	585	585	585	585	585
TOTAL	**1096416**	**1096416**	**1096416**	**1096416**	**1096416**	**1096416**	**1096416**	**1096416**

Country-specific land use areas are reported by Holdridge Life Zones in Camirand and Evelyn (2004). These zones are converted to GHG inventory ecological zones and shown as percentage of the relevant land use they affect in Table 13.7.

Table 13.9 gives an example of how the calculations are derived for each year using the percentages from Table 13.8 and the figures for year 2006 from Tables 13.6 and 13.7. These zones are used as the sub categories in the carbon calculations.

TABLE 0.8 AREA (%) OF JAMAICA BY LAND USE, HOLDRIDGE LIFE ZONES AND GHG ECOLOGICAL CLASSES

Area (%) of Jamaica by land use class and Holdridge life (ecoligical) zone														Area (%) GHG Inventory Classes sub-categories				
Code	National class	GHG Inventory Classes		TROPICAL				PREMONTANE			LOWER MONTANE		GRAND TOTAL	Tropical rain forest	Tropical moist deciduous forest	Tropical dry forest	Tropical mountain systems	TOTAL
				TVDF	TDF	TMF	TWF	PMF	PWF	PRF	LWF	LRF						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Forests land use																		
PF	Closed broadleaf	Forest Land		0.00	0.25	0.99	0.01	1.93	2.91	1.66	0.22	0.07	8.04	3.21	0.99	0.25	3.59	8.04
SF	Disturbed broadleaf	Forest Land		0.08	6.61	3.42	0.04	3.49	2.13	0.16	0.01	0.00	15.94	2.18	3.42	6.69	3.65	15.94
WL	Tall open dry	Forest Land		1.33	2.22	0.08	0.00	0.19	0.02	0.00	0.00	0.00	3.84	0.02	0.08	3.55	0.19	3.84
SL	Short open dry	Forest Land		0.71	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.00	0.00	1.11	0.00	1.11
SW	Swamp	Forest Land		0.06	0.14	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.01	0.20	0.00	0.21
MG	Mangrove	Forest Land		0.65	0.21	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.00	0.02	0.86	0.00	0.88
PP	Pine plantation	Forest Land		0.00	0.00	0.02	0.02	0.01	0.31	0.03	0.00	0.00	0.39	0.33	0.02	0.00	0.04	0.39
HP	Other Species Plantation	Forest Land		0.00	0.00	0.10	0.01	0.14	0.08	0.02	0.00	0.00	0.35	0.09	0.10	0.00	0.16	0.35
		SUB-TOTAL		**2.83**	**9.83**	**4.64**	**0.08**	**5.76**	**5.45**	**1.87**	**0.23**	**0.07**	**30.76**	**5.83**	**4.64**	**12.66**	**7.63**	**30.76**
Mixed Land Use																		
SC	Disturbed Broadleaf Forest &	75% Forest Land		0.04	4.40	1.88	0.05	4.00	0.90	0.09	0.00	0.00	11.36	0.95	1.88	4.43	4.09	11.36
	Non-Forest land Use	25% Otherland		0.01	1.47	0.63	0.02	1.33	0.30	0.03	0.00	0.00	3.79	0.32	0.63	1.48	1.36	3.79
CS	Non-Forest land Use &	75%	Otherland	0.02	2.84	2.06	0.39	2.35	0.71	0.23	0.00	0.00	8.62	1.10	2.06	2.87	2.59	8.62
			Grassland	0.01	0.90	0.65	0.12	0.74	0.22	0.07	0.00	0.00	2.72	0.35	0.65	0.91	0.82	2.72
	Disturbed Broadleaf Forest	25% Forest Land		0.01	1.25	0.91	0.17	1.03	0.31	0.10	0.00	0.00	3.78	0.48	0.91	1.26	1.14	3.78
		SUB-TOTAL		**0.09**	**10.85**	**6.13**	**0.76**	**9.46**	**2.44**	**0.53**	**0.00**	**0.00**	**30.26**	**3.20**	**6.13**	**10.94**	**9.99**	**30.26**
Non-Forest land use																		
	Non-Forest land use	20% Cropland		0.57	3.66	1.00	0.03	1.85	0.67	0.01	0.00	0.00	7.80	0.71	1.00	4.23	1.86	7.80
		64% Grassland		1.81	11.72	3.21	0.10	5.93	2.16	0.02	0.00	0.00	24.95	2.26	3.21	13.53	5.95	24.95
		3% Wetlands		0.08	0.55	0.15	0.00	0.28	0.10	0.00	0.00	0.00	1.17	0.11	0.15	0.63	0.28	1.17
		12% Settlements		0.34	2.20	0.60	0.02	1.11	0.40	0.00	0.00	0.00	4.68	0.42	0.60	2.54	1.12	4.68
		1% Otherland		0.03	0.18	0.05	0.00	0.09	0.03	0.00	0.00	0.00	0.39	0.04	0.05	0.21	0.09	0.39
		SUB-TOTAL		**2.83**	**18.31**	**5.02**	**0.16**	**9.27**	**3.37**	**0.03**	**0.00**	**0.00**	**38.99**	**3.53**	**5.02**	**21.14**	**9.30**	**38.99**
		TOTAL		**5.8**	**39.0**	**15.8**	**1.0**	**24.5**	**11.3**	**2.4**	**0.2**	**0.1**	**100.0**	**12.6**	**15.8**	**44.7**	**26.9**	**100.0**

TVDF - Tropical life zone (T > 24 oC) – Very dry forest (R = 50-100 cm)
TDF - Tropical life zone (T > 24 oC) – Dry forest (R = 100-200 cm)
TMF - Tropical life zone (T > 24 oC) – Moist forest (R = 200-400 cm)
TWF - Tropical life zone (T > 24 oC) – Wet forest (R = 400-800 cm)
PMF - Premontane life zone (T = 24-18 oC) – Moist forest (R = 100-200 cm)
PWF - Premontane life zone (T = 24-18 oC) – Wet forest (R = 200-400 cm)
PRF - Premontane life zone (T = 24-18 oC) – Rain forest (R = 400-800 cm)
LWF - Lower montane life zone (T < 18 oC) – Wet forest (R = 200-400 cm)
LRF - Lower montane life zone (T < 18 oC) – Rain forest (R = 400-800 cm)
T = Mean bio-temperature; R = Mean annual rainfall.

Tropical rain forest = TWF+PWF+ LWF+LRF   Tropical moist deciduous forest = TMF   Tropical dry forest = TVDF+TDF   Tropical mountain systems = PMF+PRF

TABLE 0.9 EXAMPLE AREA CALCULATIONS BY GHG INVENTORY CLASS SUBCATEGORIES

Area (%) of Jamaica by land use class and Holdridge life (ecoligical) zone													GHG Inventory Classes sub-categories				
Code	National class	GHG Inventory Classes	TROPICAL				PREMONTANE			LOWER MONTANE		GRAND TOTAL	Tropical rain forest	Tropical moist deciduous forest	Tropical dry forest	Tropical mountain systems	TOTAL
			TVDF	TDF	TMF	TWF	PMF	PWF	PRF	LWF	LRF						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2006																	
Forests land use																	
PF	Closed broadleaf	Forest Land	0	2730	10811	109	21076	31778	18128	2402	764	87799	35054	10811	2730	39204	87799
SF	Disturbed broadleaf	Forest Land	864	71405	36945	432	37701	23009	1728	108	0	172192	23550	36945	72269	39429	172192
WL	Tall open dry	Forest Land	14503	24208	872	0	2072	218	0	0	0	41873	218	872	38711	2072	41873
SL	Short open dry	Forest Land	7463	4205	0	0	0	0	0	0	0	11668	0	0	11668	0	11668
SW	Swamp	Forest Land	614	1432	102	0	0	0	0	0	0	2148	0	102	2046	0	2148
MG	Mangrove	Forest Land	7114	2299	219	0	0	0	0	0	0	9632	0	219	9413	0	9632
PP	Pine plantation	Forest Land	0	0	189	189	95	2935	284	0	0	3692	3124	189	0	379	3692
HP	Other Species Plantation	Forest Land	0	0	1114	111	1560	891	223	0	0	3900	1003	1114	0	1783	3900
		SUB-TOTAL	**30569**	**108278**	**60253**	**842**	**62503**	**58832**	**20383**	**2510**	**784**	**332806**	**62849**	**60253**	**138837**	**82868**	**332806**
Mixed Land Use																	
SC	Disturbed Broadleaf Forest &	75% Forest Land	409	47923	20527	572	43589	9814	981	0	0	123815	10386	20527	48332	44570	123815
	Non-Forest land Use	25% Otherland	136	15982	6846	191	14537	3273	327	0	0	41293	3464	6846	16119	14864	41293
CS	Non-Forest land Use &	75% 80% Grassland	248	30939	22444	4278	25607	7688	2542	0	0	93746	11966	22444	31187	28149	93746
		20% Otherland	81	10100	7327	1397	8359	2510	830	0	0	30604	3906	7327	10181	9189	30604
	Disturbed Broadleaf Forest	25% Forest Land	106	13277	9632	1836	10989	3299	1091	0	0	40230	5135	9632	13383	12080	40230
		SUB-TOTAL	**981**	**118221**	**66776**	**8274**	**103080**	**26684**	**6771**	**0**	**0**	**329687**	**34868**	**66776**	**119202**	**108862**	**329687**
Non-Forest land use																	
	Non-Forest land use	20% Cropland	5925	38332	10509	335	19407	7055	63	0	0	81625	7390	10509	44257	19470	81625
		65% Grassland	20007	129442	35489	1131	65534	23824	212	0	0	275638	24955	35489	149448	65746	275638
		3% Wetlands	903	5841	1601	51	2957	1075	10	0	0	12438	1126	1601	6744	2967	12438
		12% Settlements	3816	24689	6769	216	12499	4544	40	0	0	52573	4760	6769	28505	12540	52573
		1% Otherland	682	4412	1210	39	2234	812	7	0	0	9394	851	1210	5093	2241	9394
		SUB-TOTAL	**31332**	**202716**	**55578**	**1771**	**102631**	**37310**	**332**	**0**	**0**	**431668**	**38082**	**55578**	**234048**	**102963**	**431668**
		TOTAL	**62871**	**427214**	**172607**	**10887**	**268214**	**122726**	**28487**	**2610**	**784**	**1094260**	**138888**	**172607**	**490086**	**294681**	**1094260**

Summary - 2006	Tropical rain forest	Tropical moist deciduous forest	Tropical dry forest	Tropical mountain systems	TOTAL
Forest Land	78470	80411	198552	139516	496949
CropLand	7390	10509	44257	19470	81625
GrassLand	28862	42816	159629	74935	306242
WetLands	1126	1601	6744	2967	12438
Settlement	4760	6769	28505	12540	52573
Other Lands	16281	30500	52399	45254	144433
GRAND TOTAL	138888	172607	490086	294681	1094260

The calculations in Table 13.9 are fairly straightforward. For example, for the calculation of the area of Closed Broadleaf (35054 ha), which is classified as Tropical Rain Forest (Column 14), the percentage from Column 15 in Table 13.8 is divided by the total in Column 19 and then multiplied by the area of Closed Broadleaf Forest (PF) for the year 2006 in Table 8 (i.e. ((3.21/8.04)* 87799) = 35054.

National calculations of total aboveground biomass (over-storey living biomass, not including roots, litter, dead wood and under-storey) per hectare were done following the methodology proposed by Brown (1997). Table 13.10 below shows the estimates for 1998 from Camirand and Evelyn, (2004). Please note that the biomass estimates were incorrectly calculated in the source and are therefore corrected in Table 13.10. Brown (1997) does not use average net annual increment (m3 ha^{-1} yr^{-1}) for specific vegetation type to estimate biomass density as is required by the IPCC guidelines. Instead, volume over bark (VOB/ha) is used. This is convenient for countries, such as Jamaica which lack data on mean annual increment (MAI) for non-plantation forests. Jamaica is currently establishing a network of Permanent Sample Plots (PSPs) in all the forest types. Therefore, average net annual biomass increments for each forest type will be available in the future.

TABLE 0.10 TOTAL VOLUME AND ABOVEGROUND LIVING BIOMASS BY FOREST TYPE

Code	National class	GHG Inventory Classes	Area (ha) 1998	Volume over bark (VOB) (m^3/ha)	weighted average wood density (WD)	BV (t/ha)	BEF	Total Volume (,000 m^3)	Total Aboveground Living Biomass (,000 t)
1	2	3	4	5				6	7
Forests land use									
PF	Closed broadleaf	Forest Land	88231.0	194	0.60	116.21	2.24	17088.5	22974
SF	Disturbed broadleaf	Forest Land	174725.0	165	0.60	99.28	2.43	28909.9	42090
WL	Tall open dry	Forest Land	41998.0	38	0.60	22.66	5.12	1585.9	4876
SL	Short open dry	Forest Land	12104.0	23	0.60	13.68	6.62	275.9	1095
SW	Swamp	Forest Land	2247.0	181	0.60	108.76	2.32	407.3	566
MG	Mangrove	Forest Land	9731.0	79	0.60	47.18	3.54	765.1	1623
PP	CaribbeanPine plantation	Forest Land	4287.0	119	0.51	60.91	1.30	512.0	339
HP	Other Species Plantation	Forest Land	3900.0	148	0.60	88.69	2.57	576.5	889
		SUB-TOTAL	337223.0					50121.1	74453.2
Mixed Land Use									
SC	Disturbed Broadleaf Forest & 75%	Forest Land	124465.5	94	0.60	56.17	3.54	15534.9	30173
	Non-Forest land Use 25%	Otherland	41488.5						
CS	Non-Forest land Use & 75%	80% Grassland	94414.2	66	0.60	39.83	3.54	10996.8	25414
		20% Otherland	29815.0						
	Disturbed Broadleaf Forest 25%	Forest Land	41409.8						
		SUB-TOTAL	331593.0					26531.7	55587.0
Non-Forest land use									
	Non-Forest land use	20% Cropland 65% Grassland 3% Wetlands 12% Settlements 1% Otherland	427600.0						
		SUB-TOTAL	427600.0						
		TOTAL	1096416					76653	130040

8.0 Annex 4: Mitigation Consultancy LEAP Model

The LEAP model developed during the Consultancy was submitted with this report as "Jamaica TNC 1.2.leap" (a LEAP model file). It is compatible with version 2017.0.11.0 of the LEAP software, which can be downloaded at: ***ftp://ftp.energycommunity.org/LEAP/LEAP2017.0.11.exe***

The model can be opened and reviewed with the LEAP software, but calculating or recalculating scenarios requires an additional software component and a LEAP license. The additional component enables advanced optimization features in LEAP, including functionality to model energy storage. It can be installed by unzipping "Optimization Extensions Installer.zip," which was also submitted with this report, and by running the extracted program "setup.exe." A LEAP license can be obtained at the LEAP website: ***https://www.energycommunity.org/default.asp?action=license***

Licenses for government, non-profit, and academic users in Jamaica are free-of-charge.

8.1 Baseline Input

This annex catalogues major exogenous data inputs used in the LEAP model's baseline scenario. SEI obtained historical values for these inputs from the sources listed in this section, and developed future projections using published forecasts, historical trends, and other simple techniques. Exogenous data inputs enter the LEAP model's calculations in many ways – for example, they may be used as drivers of final energy demands and non-energy emissions, to control the production characteristics of different energy supply processes, or to quantify the costs of energy-sector activities.

The inputs are divided into three thematic categories below and are organized into tables. The tables document sources and available years of historical data, projection methods, and sample values from the modelling period. A full set of values for each input and the mathematical formulation of input projections are provided in the LEAP model itself (Annex 1).

8.3 Demographic Assumptions

Major demographic inputs include Jamaica's national population and the number of dwellings in the country.

TABLE 01: KEY DEMOGRAPHIC INPUTS, BASELINE SCENARIO

Input	Historical Data	Projections	Values		
			2015	2035	2055
Population(thousands of people)	2006-2016 (Statistical Institute of Jamaica 2016b)	2017-2055 (United Nations Department of Economic and Social Affairs 2017b), medium variant, calibrated to historical 2016 population	2,727.3	2,765.3	2,478.5
Dwellings(thousands of units)	2011 data used for all years (Statistical Institute of Jamaica 2011b), from 3.17 persons per dwelling	Annual changes indexed to population	861.0	873.0	782.5

8.4 Cross-Cutting Economic Assumptions

Several economic inputs are used in the modelling of multiple sectors or sources of GHG emissions. They include national economic indicators such as GDP and value added, commodity prices required for the estimation of energy demands, and fuel prices. Prices of all fuels except electricity are specified exogenously in the model. The exogenous prices are market prices and are assumed to represent the social cost of supplying the fuels. In the case of electricity, the model provides a bottom-up estimate of production costs, including generation, storage, and T&D costs. The total production cost is used in social cost-benefit calculations involving electricity. Cost inputs for electricity modelling (except for input fuel prices) are covered in the next section.

TABLE 02: KEY NATIONAL ECONOMIC INPUTS, BASELINE SCENARIO

Input	Historical Data	Projections	Values		
			2015	2035	2055
GDP(billion USD)	2006-2016 (Statistical Institute of Jamaica 2016a)	2017-2022 (International Monetary Fund 2017)2023-2055, from 2000-2022 average growth rate of 1.25%	13.40	19.41	24.89
Average income(thousand USD/person)	Ratio of GDP and population	Based on GDP and population projections	4.91	7.02	10.04
Value added from transport, storage and communication(million USD)	2006-2016 (Statistical Institute of Jamaica 2016a)	Annual change indexed to GDP	969.5	1,350.8	1,731.8
Value added from industry(million USD)	2006-2016 (Statistical Institute of Jamaica 2016a), sum of mining and quarry, manufacturing and construction value-added	Annual change indexed to GDP	2,130.1	3,201.9	4,105.0
Value added from construction (million USD)	2006-2016 (Statistical Institute of Jamaica 2016a)	Annual change indexed to GDP	851.3	1,287.9	1,651.2
Value added from manufacturing (million USD)	2006-2016 (Statistical Institute of Jamaica 2016a)	Annual change indexed to GDP	1,103.2	1,558.2	1,997.7
Value added from other services (million USD)	2006-2016 (Statistical Institute of Jamaica 2016a)	Annual change indexed to GDP	754.3	1,065.5	1,366.0
Value added from agriculture and forestry (million USD)	2006-2016 (Statistical Institute of Jamaica 2016a)	Annual change indexed to GDP	812.9	1,250.8	1,603.6

TABLE 03: KEY COMMODITY PRICE INPUTS, BASELINE SCENARIO

Input	Historical Data	Projections	Values		
			2015	2035	2055
Cement price(USD/t)	2006-2015 (United States Geological Survey 2017a)	2016-2055 (United States Geological Survey 2017a), average growth rate 1980-2015 of -1.2%	101.3	79.55	62.48
Aluminium price(USD/t)	2006-2016 (The World Bank 2017c)	2017-2030 (The World Bank 2017b)2031-2055, from 2017-2030 average growth rate of -0.35%	1,853.1	1,937.9	1,806.7
Sugar price(USD/t)	2006-2016 (The World Bank 2017c)	2017-2030 (The World Bank 2017b)2031-2055, from 2017-2030 average growth rate of -2.7%	329.8	297.1	171.8

TABLE 04: KEY FUEL PRICE INPUTS, BASELINE SCENARIO

Input	Historical Data	Projections	Values		
			2015	2035	2055
Crude oil(USD/gigajoule [GJ])	2006-2016 (The World Bank 2017c), world average	2017-2030 (The World Bank 2017b)2031-2055, from 2017-2030 average growth rate of 1.0%	9.7	13.0	15.8
Bituminous coal(USD/GJ)	2006-2016 (The World Bank 2017c), Australian coal	2017-2030 (The World Bank 2017b)2031-2055, from 2017-2030 average growth rate of -3.0%	2.4	1.7	0.9
Jet kerosene(USD/GJ)	Equal to kerosene price	Equal to kerosene price	12.8	13.4	16.4
Residual fuel oil(USD/GJ)	2015-2017 (Petrojam 2017), average annual ex refinery price	2018-2055, annual changes indexed to crude oil price	8.5	13.0	15.9
Diesel(USD/GJ)	2006-2017 (Petrojam 2017), average annual ex refinery price	2018-2055, annual changes indexed to crude oil price	21.5	26.0	31.8
LPG(USD/GJ)	2006-2017 (Petrojam 2017), mean of annual ex refinery price for propane and butane	2018-2055, annual changes indexed to crude oil price	10.0	13.2	16.1
Kerosene(USD/GJ)	2006-2017 (Petrojam 2017), average annual ex refinery price	2018-2055, annual changes indexed to crude oil price	12.9	13.6	16.6
Charcoal(USD/GJ)	2006 (Planning Institute of Jamaica and Statistical Institute of Jamaica 2007), weighted average of all purchase sizes used for all years	No change	16.6	16.6	16.6
LNG(USD/GJ)	2014-2016 (Jamaica Public Service Company 2014; US EIA 2017b), assuming 9 USD greater than Henry Hub price and adjusting to include ex tax delivery costs	2018 (US EIA 2017a)2019-2030, annual changes indexed to Japanese LNG cost (The World Bank 2017b)2031-2055, from 2019-2030 average growth rate of 0.6%	11.9	14.0	15.7
Biodiesel(USD/GJ)	2012 (International Renewable Energy Agency 2013), average from Malaysian palm oil biodiesel, subtracting difference cost between palm and jatropha feed stocks	2013-2055 (OECD 2017), average forecasted growth rate for German rapeseed biodiesel of -1.05%	27.9	22.6	18.3
Bioethanol(USD/GJ)	2012 (International Renewable Energy Agency 2013), from Brazilian cane ethanol, subtracting the value of electricity cogenerated during ethanol production	2013-2055 (OECD 2017), average forecasted growth rate for Brazilian cane ethanol of 0.27%	30.2	31.9	33.6
Gasoline(USD/GJ)	2006-2017 (Petrojam 2017), average annual ex refinery price for gasoline 90	2018-2055, annual changes indexed to crude oil price	16.0	19.0	23.1

8.5 Electricity Production Assumptions

As outlined inputs to the modelling of electricity production comprise a range of technical and cost parameters for generation and storage resources. These variables are profiled below (additional inputs for modelling electricity T&D are documented directly in Section Error! Reference source not found.). Most of the parameters are covered in Table 05, which lists technical and cost inputs for each existing production facility, planned production facility, and candidate production technology in the model. Sample availability profiles for hydro, wind, and solar are provided after the table. The model includes individualized availability profiles for existing and planned hydro, wind, and solar facilities, as well as averaged profiles for the candidate hydro, wind, and solar technologies. The latter are presented here as an example (the others are available in the model itself). The profiles show attainable capacity factors over the 576 time slices in the electricity model.

TABLE 05: KEY TECHNICAL AND COST INPUTS FOR MODELING ELECTRICITY GENERATION AND STORAGE, BASELINE SCENARIO

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
BMR wind	Feedstock		Wind	
	Capacity (MW)	(Ministry of Science, Energy and Technology 2017b), capacity assumed to retire in 2041	36.3	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)			
	Unplanned outage rate (% of year)			
	Capacity credit (% of capacity)	(Ministry of Science, Energy and Technology 2017b; Jamaica Observer 2016; Worldwatch Institute 2013), based on availability at time of peak load	46.4	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Fixed O&M cost (thousand USD/MW)	Assumed same value as for Wigton wind	0.0	
	Variable O&M cost (USD/MWh)	Assumed same value as for Wigton wind	10.3	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Bogue combined cycle BOCC	Feedstock	Historical diesel consumption before 2017 is also modelled	LNG	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2027	120.0	0.0
	Gross heat rate (mega joules [MJ]/kWh)	(Rowe 2017)	8.9	
	Own use rate (% of gross generation)	(Rowe 2017)	3.0	
	Planned outage rate (% of year)	(Rowe 2017)	18.0	
	Unplanned outage rate (% of year)	(Rowe 2017)	1.0	
	Capacity credit (% of capacity)	Based on availability at time of peak load	78.6	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Fixed O&M cost (thousand USD/MW)	(Rowe 2017)	12.4	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	0.0	
Bogue combustion turbine GT3	Feedstock		Diesel	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2023	21.5	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	18.0	
	Own use rate (% of gross generation)	(Rowe 2017)	0.2	
	Planned outage rate (% of year)	(Rowe 2017)	0.6	
	Unplanned outage rate (% of year)	(Rowe 2017)	0.3	
	Capacity credit (% of capacity)	Based on availability at time of peak load	98.9	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Fixed O&M cost (thousand USD/MW)	(Rowe 2017)	12.4	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	0.0	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Bogue combustion turbine GT6	Feedstock		Diesel	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2040	18.0	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	19.3	
	Own use rate (% of gross generation)	(Rowe 2017)	1.6	
	Planned outage rate (% of year)	(Rowe 2017)	0.2	
	Unplanned outage rate (% of year)	(Rowe 2017)	0.0	
	Capacity credit (% of capacity)	Based on availability at time of peak load	98.2	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Fixed O&M cost (thousand USD/MW)	(Rowe 2017)	12.4	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	0.0	
Bogue combustion turbine GT7	Feedstock		Diesel	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2040	18.0	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	21.3	
	Own use rate (% of gross generation)	(Rowe 2017)	2.8	
	Planned outage rate (% of year)	(Rowe 2017)	13.3	
	Unplanned outage rate (% of year)	(Rowe 2017)	14.6	
	Capacity credit (% of capacity)	Based on availability at time of peak load	70.1	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Fixed O&M cost (thousand USD/MW)	(Rowe 2017)	12.4	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	0.0	
Bogue combustion turbine GT8	Feedstock		Diesel	
	Capacity (MW)	(Rowe 2017), capacity assumed to be out of service	18.0	0.0
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Bogue combustion turbine GT9	Feedstock		Diesel	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2042	20.0	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	23.5	
	Own use rate (% of gross generation)	(Rowe 2017)	1.4	
	Planned outage rate (% of year)	(Rowe 2017)	0.1	
	Unplanned outage rate (% of year)	(Rowe 2017)	14.9	
	Capacity credit (% of capacity)	Based on availability at time of peak load	83.7	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Fixed O&M cost (thousand USD/MW)	(Rowe 2017)	12.4	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	0.0	
Bogue combustion turbine GT11	Feedstock		Diesel	
	Capacity (MW)	(Rowe 2017), capacity assumed to be out of service	20.0	0.0
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
Constant Spring hydro	Feedstock		Hydro	
	Capacity (MW)	(Ministry of Science, Energy and Technology 2017b), capacity assumed to retire in 2028	0.8	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)	Captured in availability profile		
	Unplanned outage rate (% of year)	Captured in availability profile		
	Capacity credit (% of capacity)	(Ministry of Science, Technology, Energy and Mining 2013), based on availability at time of peak load	60.4	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	40	
	Fixed O&M cost (thousand USD/MW)	(Ministry of Science, Technology, Energy and Mining 2013)	36.8	
	Variable O&M cost (USD/MWh)	(Ministry of Science, Technology, Energy and Mining 2013)	12.6	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
EAL Jamaica Broilers steam	Feedstock		Residual fuel oil	
	Capacity (MW)	(Ministry of Science, Energy and Technology 2017b), capacity assumed to retire in 2033	12.1	0.0
	Gross heat rate (MJ/kWh)	Assumed same value as for Halse Hall steam JAMALCO	9.5	
	Own use rate (% of gross generation)	Average of available values for other oil steam units	5.7	
	Planned outage rate (% of year)	Assumed same value as for Halse Hall steam JAMALCO	5.2	
	Unplanned outage rate (% of year)	Assumed same value as for Halse Hall steam JAMALCO	5.0	
	Capacity credit (% of capacity)	Based on availability at time of peak load	84.7	
	Lifetime (years)	(Office of Utilities Regulation 2010)	35	
	Fixed O&M cost (thousand USD/ MW)	(Ministry of Science, Technology, Energy and Mining 2013)	19.0	
	Variable O&M cost (USD/MWh)	(Ministry of Science, Technology, Energy and Mining 2013)	22.4	
Halse Hall steam JAMALCO	Feedstock		Residual fuel oil	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2034	11.0	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	9.5	
	Own use rate (% of gross generation)	Average of available values for other oil steam units	5.7	
	Planned outage rate (% of year)	(Office of Utilities Regulation 2010)	5.2	
	Unplanned outage rate (% of year)	(Office of Utilities Regulation 2010)	5.0	
	Capacity credit (% of capacity)	Based on availability at time of peak load	84.7	
	Lifetime (years)	(Office of Utilities Regulation 2010)	35	
	Fixed O&M cost (thousand USD/ MW)	(Rowe 2017)	149.1	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	14.0	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Hunt's Bay combustion turbine GT5	Feedstock		Diesel	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2024	21.5	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	17.3	
	Own use rate (% of gross generation)	(Rowe 2017)	0.5	
	Planned outage rate (% of year)	(Rowe 2017)	1.3	
	Unplanned outage rate (% of year)	(Rowe 2017)	7.7	
	Capacity credit (% of capacity)	Based on availability at time of peak load	90.6	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Fixed O&M cost (thousand USD/MW)	(Rowe 2017)	12.4	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	0.0	
Hunt's Bay combustion turbine GT10	Feedstock		Diesel	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2018	32.5	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	17.4	
	Own use rate (% of gross generation)	(Rowe 2017)	1.3	
	Planned outage rate (% of year)	(Rowe 2017)	1.2	
	Unplanned outage rate (% of year)	(Rowe 2017)	8.0	
	Capacity credit (% of capacity)	Based on availability at time of peak load	89.6	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Fixed O&M cost (thousand USD/MW)	(Rowe 2017)	12.4	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	0.0	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Hunt's Bay steam HB6	Feedstock		Residual fuel oil	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2046	68.5	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	12.0	
	Own use rate (% of gross generation)	(Rowe 2017)	6.8	
	Planned outage rate (% of year)	(Rowe 2017)	2.7	
	Unplanned outage rate (% of year)	(Rowe 2017)	1.9	
	Capacity credit (% of capacity)	Based on availability at time of peak load	88.9	
	Lifetime (years)	(Office of Utilities Regulation 2010)	35	
	Fixed O&M cost (thousand USD/MW)	(Rowe 2017)	20.1	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	0.0	
Lower White River hydro	Feedstock		Hydro	
	Capacity (MW)	(Ministry of Science, Energy and Technology 2017b), capacity assumed to retire in 2032	4.8	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)			
	Unplanned outage rate (% of year)			
	Capacity credit (% of capacity)	(Ministry of Science, Technology, Energy and Mining 2013), based on availability at time of peak load	61.0	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	40	
	Fixed O&M cost (thousand USD/MW)	(Ministry of Science, Technology, Energy and Mining 2013)	36.8	
	Variable O&M cost (USD/MWh)	(Ministry of Science, Technology, Energy and Mining 2013)	3.4	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Maggotty hydro	Feedstock		Hydro	
	Capacity (MW)	(Ministry of Science, Energy and Technology 2017b), capacity assumed to retire in 2039	6.0	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)			
	Unplanned outage rate (% of year)			
	Capacity credit (% of capacity)	(Ministry of Science, Technology, Energy and Mining 2013), based on availability at time of peak load	61.0	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	40	
	Fixed O&M cost (thousand USD/MW)	(Ministry of Science, Technology, Energy and Mining 2013)	36.8	
	Variable O&M cost (USD/MWh)	(Ministry of Science, Technology, Energy and Mining 2013)	3.1	
Maggotty B hydro	Feedstock		Hydro	
	Capacity (MW)	(Ministry of Science, Energy and Technology 2017b), capacity assumed to retire in 2054	7.2	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)			
	Unplanned outage rate (% of year)			
	Capacity credit (% of capacity)	(Ministry of Science, Technology, Energy and Mining 2013), based on availability at time of peak load	61.0	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	40	
	Fixed O&M cost (thousand USD/MW)	Assumed same value as for Maggotty hydro	36.8	
	Variable O&M cost (USD/MWh)	Assumed same value as for Maggotty hydro	3.1	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Munro wind	Feedstock		Wind	
	Capacity (MW)	(Ministry of Science, Energy and Technology 2017b), capacity assumed to retire in 2035	3.0	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)			
	Unplanned outage rate (% of year)			
	Capacity credit (% of capacity)	(Ministry of Science, Technology, Energy and Mining 2013; Worldwatch Institute 2013), based on availability at time of peak load	26.9	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Fixed O&M cost (thousand USD/ MW)	(Ministry of Science, Technology, Energy and Mining 2013)	0.0	
	Variable O&M cost (USD/MWh)	(Ministry of Science, Technology, Energy and Mining 2013)	10.3	
Old Harbour medium speed oil JEP	Feedstock		Residual fuel oil	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2020	124.0	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	8.6	
	Own use rate (% of gross generation)	Assumed same value as for Rockfort oil steam RF1	2.8	
	Planned outage rate (% of year)	(Rowe 2017)	3.8	
	Unplanned outage rate (% of year)	(Rowe 2017)	4.9	
	Capacity credit (% of capacity)	Based on availability at time of peak load	88.7	
	Lifetime (years)	(Office of Utilities Regulation 2010)	25	
	Fixed O&M cost (thousand USD/ MW)	(Rowe 2017)	213.7	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	22.2	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Old Harbour steam OH2	Feedstock		Residual fuel oil	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2020	60.0	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	14.0	
	Own use rate (% of gross generation)	(Rowe 2017)	4.8	
	Planned outage rate (% of year)	(Rowe 2017)	7.1	
	Unplanned outage rate (% of year)	(Rowe 2017)	19.8	
	Capacity credit (% of capacity)	Based on availability at time of peak load	69.6	
	Lifetime (years)	(Office of Utilities Regulation 2010)	35	
	Fixed O&M cost (thousand USD/ MW)	(Rowe 2017)	20.1	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	0.0	
Old Harbour steam OH3	Feedstock		Residual fuel oil	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2020	65.0	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	12.9	
	Own use rate (% of gross generation)	(Rowe 2017)	5.4	
	Planned outage rate (% of year)	(Rowe 2017)	4.9	
	Unplanned outage rate (% of year)	(Rowe 2017)	22.8	
	Capacity credit (% of capacity)	Based on availability at time of peak load	68.3	
	Lifetime (years)	(Office of Utilities Regulation 2010)	35	
	Fixed O&M cost (thousand USD/ MW)	(Rowe 2017)	20.1	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	0.0	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Old Harbour steam OH4	Feedstock		Residual fuel oil	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2020	68.5	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	12.4	
	Own use rate (% of gross generation)	(Rowe 2017)	5.6	
	Planned outage rate (% of year)	(Rowe 2017)	5.5	
	Unplanned outage rate (% of year)	(Rowe 2017)	5.8	
	Capacity credit (% of capacity)	Based on availability at time of peak load	83.8	
	Lifetime (years)	(Office of Utilities Regulation 2010)	35	
	Fixed O&M cost (thousand USD/MW)	(Rowe 2017)	20.1	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	0.0	
Ram's Horn hydro	Feedstock		Hydro	
	Capacity (MW)	(Ministry of Science, Energy and Technology 2017b), capacity assumed to retire in 2028	1.1	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)			
	Unplanned outage rate (% of year)			
	Capacity credit (% of capacity)	(Ministry of Science, Technology, Energy and Mining 2013), based on availability at time of peak load	60.3	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	40	
	Fixed O&M cost (thousand USD/MW)	(Ministry of Science, Technology, Energy and Mining 2013)	36.8	
	Variable O&M cost (USD/MWh)	(Ministry of Science, Technology, Energy and Mining 2013)	12.6	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Rio Bueno A hydro	Feedstock		Hydro	
	Capacity (MW)	(Ministry of Science, Energy and Technology 2017b), capacity assumed to retire in 2046	2.5	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)			
	Unplanned outage rate (% of year)			
	Capacity credit (% of capacity)	(Ministry of Science, Technology, Energy and Mining 2013), based on availability at time of peak load	61.0	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	40	
	Fixed O&M cost (thousand USD/MW)	(Ministry of Science, Technology, Energy and Mining 2013)	36.8	
	Variable O&M cost (USD/MWh)	(Ministry of Science, Technology, Energy and Mining 2013)	9.3	
Rio Bueno B hydro	Feedstock		Hydro	
	Capacity (MW)	(Ministry of Science, Technology, Energy and Mining 2013), capacity assumed to retire in 2028	1.1	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)			
	Unplanned outage rate (% of year)			
	Capacity credit (% of capacity)	Assumed same value as for Rio Bueno A	61.0	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	40	
	Fixed O&M cost (thousand USD/MW)	(Ministry of Science, Technology, Energy and Mining 2013)	36.8	
	Variable O&M cost (USD/MWh)	(Ministry of Science, Technology, Energy and Mining 2013)	9.3	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Roaring River hydro	Feedstock		Hydro	
	Capacity (MW)	(Ministry of Science, Energy and Technology 2017b), capacity assumed to retire in 2029	3.8	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)			
	Unplanned outage rate (% of year)			
	Capacity credit (% of capacity)	(Ministry of Science, Technology, Energy and Mining 2013), based on availability at time of peak load	61.0	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	40	
	Fixed O&M cost (thousand USD/MW)	(Ministry of Science, Technology, Energy and Mining 2013)	36.8	
	Variable O&M cost (USD/MWh)	(Ministry of Science, Technology, Energy and Mining 2013)	1.7	
Rockfort oil steam RF1	Feedstock		Residual fuel oil	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2020	20.0	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	9.4	
	Own use rate (% of gross generation)	(Rowe 2017)	2.8	
	Planned outage rate (% of year)	(Rowe 2017)	3.9	
	Unplanned outage rate (% of year)	(Rowe 2017)	8.0	
	Capacity credit (% of capacity)	Based on availability at time of peak load	85.7	
	Lifetime (years)	(Office of Utilities Regulation 2010)	35	
	Fixed O&M cost (thousand USD/MW)	(Rowe 2017)	54.2	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	0.0	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Rockfort slow speed oil RF2	Feedstock		Residual fuel oil	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2035	20.0	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	9.3	
	Own use rate (% of gross generation)	(Rowe 2017)	2.8	
	Planned outage rate (% of year)	(Rowe 2017)	13.1	
	Unplanned outage rate (% of year)	(Rowe 2017)	5.0	
	Capacity credit (% of capacity)	Based on availability at time of peak load	79.6	
	Lifetime (years)	(Office of Utilities Regulation 2010)	25	
	Fixed O&M cost (thousand USD/MW)	(Rowe 2017)	54.2	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	0.0	
Rockfort slow speed oil JPPC	Feedstock		Residual fuel oil	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2022	60.0	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	8.0	
	Own use rate (% of gross generation)	Assumed same value as for Rockfort oil steam RF1	2.8	
	Planned outage rate (% of year)	(Rowe 2017)	6.3	
	Unplanned outage rate (% of year)	(Rowe 2017)	17.5	
	Capacity credit (% of capacity)	Based on availability at time of peak load	74.0	
	Lifetime (years)	(Office of Utilities Regulation 2010)	25	
	Fixed O&M cost (thousand USD/MW)	(Rowe 2017)	214.0	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	10.2	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Upper White River hydro	Feedstock		Hydro	
	Capacity (MW)	(Ministry of Science, Energy and Technology 2017b), capacity assumed to retire in 2025	3.1	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)			
	Unplanned outage rate (% of year)			
	Capacity credit (% of capacity)	(Ministry of Science, Technology, Energy and Mining 2013), based on availability at time of peak load	61.0	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	40	
	Fixed O&M cost (thousand USD/MW)	(Ministry of Science, Technology, Energy and Mining 2013)	36.8	
	Variable O&M cost (USD/MWh)	(Ministry of Science, Technology, Energy and Mining 2013)	3.4	
West Kingston medium speed oil WKPP	Feedstock		Residual fuel oil	
	Capacity (MW)	(Rowe 2017), capacity assumed to retire in 2031	65.0	0.0
	Gross heat rate (MJ/kWh)	(Rowe 2017)	8.6	
	Own use rate (% of gross generation)	Assumed same value as for Rockfort oil steam RF1	2.8	
	Planned outage rate (% of year)	(Rowe 2017)	7.2	
	Unplanned outage rate (% of year)	(Rowe 2017)	3.2	
	Capacity credit (% of capacity)	Based on availability at time of peak load	87.0	
	Lifetime (years)	(Office of Utilities Regulation 2010)	25	
	Fixed O&M cost (thousand USD/MW)	(Rowe 2017)	312.9	
	Variable O&M cost (USD/MWh)	(Rowe 2017)	13.9	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Wigton 1 wind	Feedstock		Wind	
	Capacity (MW)	(Ministry of Science, Energy and Technology 2017b), capacity assumed to retire in 2029	20.0	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)			
	Unplanned outage rate (% of year)			
	Capacity credit (% of capacity)	(Ministry of Science, Technology, Energy and Mining 2013; Worldwatch Institute 2013), based on availability at time of peak load	28.3	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Fixed O&M cost (thousand USD/MW)	(Ministry of Science, Technology, Energy and Mining 2013)	0.0	
	Variable O&M cost (USD/MWh)	(Ministry of Science, Technology, Energy and Mining 2013)	10.3	
Wigton 2 wind	Feedstock		Wind	
	Capacity (MW)	(Ministry of Science, Energy and Technology 2017b), capacity assumed to retire in 2036	18.0	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)			
	Unplanned outage rate (% of year)			
	Capacity credit (% of capacity)	(Ministry of Science, Technology, Energy and Mining 2013; Worldwatch Institute 2013), based on availability at time of peak load	35.4	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Fixed O&M cost (thousand USD/MW)	(Ministry of Science, Technology, Energy and Mining 2013)	0.0	
	Variable O&M cost (USD/MWh)	(Ministry of Science, Technology, Energy and Mining 2013)	10.3	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Wigton 3 wind	Feedstock		Wind	
	Capacity (MW)	(Ministry of Science, Energy and Technology 2017b), capacity assumed to retire in 2041	24.0	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)			
	Unplanned outage rate (% of year)			
	Capacity credit (% of capacity)	(Ministry of Science, Technology, Energy and Mining 2013; Worldwatch Institute 2013), based on availability at time of peak load	35.4	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Fixed O&M cost (thousand USD/MW)	(Ministry of Science, Technology, Energy and Mining 2013)	0.0	
	Variable O&M cost (USD/MWh)	Assumed same value as for Wigton 1 wind and Wigton 2 wind	10.3	
WRB Content solar	Feedstock		Solar	
	Capacity (MW)	(Ministry of Science, Energy and Technology 2017b), capacity assumed to retire in 2041	20.0	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)			
	Unplanned outage rate (% of year)			
	Capacity credit (% of capacity)	(Ministry of Science, Energy and Technology 2017b; Worldwatch Institute 2013), based on availability at time of peak load	0.0	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Fixed O&M cost (thousand USD/MW)	(National Renewable Energy Laboratory 2016b)	16.9	
	Variable O&M cost (USD/MWh)	(National Renewable Energy Laboratory 2016b)	0.0	
Planned Facilities				

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Hunt's Bay storage	Charging / discharging capacity (MW)	24.5 MW deployed in 2019 (Jamaica Public Service Company 2017d)	0.0	0.0
	Full load hours	(Lazard 2016)	8.0	
	Round-trip efficiency (%)	(Lazard 2016)	92.5	
	Planned outage rate (% of year)	(Lazard 2016)	2.1	
	Unplanned outage rate (% of year)	(Lazard 2016)	2.1	
	Capacity credit (% of capacity)	Based on availability at time of peak load	95.9	
	Lifetime (years)	(Lazard 2016)	20	
	Overnight capital cost (million USD/MW)	(Lazard 2016), includes estimated grid connection costs	6.4	
	WACC (%)	(Office of Utilities Regulation 2010)	11.95	
	Construction loan period (years)	SEI assumption	10	
	Fixed O&M cost (thousand USD/MW)	(Lazard 2016)	67.5	
	Variable O&M cost (USD/MWh)	(Lazard 2016)	0.0	
Old Harbour gas	Feedstock		LNG	
	Capacity (MW)	190 MW deployed in 2020 (Jamaica Public Service Company 2017b)	0.0	0.0
	Gross heat rate (MJ/kWh)	(National Renewable Energy Laboratory 2016b)	7.0	
	Own use rate (% of gross generation)	Assumed same value as for Bogue combined cycle BOCC	3.0	
	Planned outage rate (% of year)	(National Renewable Energy Laboratory 2016b)	6.0	
	Unplanned outage rate (% of year)	(National Renewable Energy Laboratory 2016b)	4.0	
	Capacity credit (% of capacity)	Based on availability at time of peak load	87.3	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Overnight capital cost (million USD/MW)	(Jamaica Public Service Company 2017b), includes estimated grid connection costs	1.7	
	WACC (%)	(Office of Utilities Regulation 2010)	11.95	
	Construction loan period (years)	SEI assumption	10	
	Fixed O&M cost (thousand USD/MW)	(National Renewable Energy Laboratory 2016b)	14.6	
	Variable O&M cost (USD/MWh)	(National Renewable Energy Laboratory 2016b)	3.5	

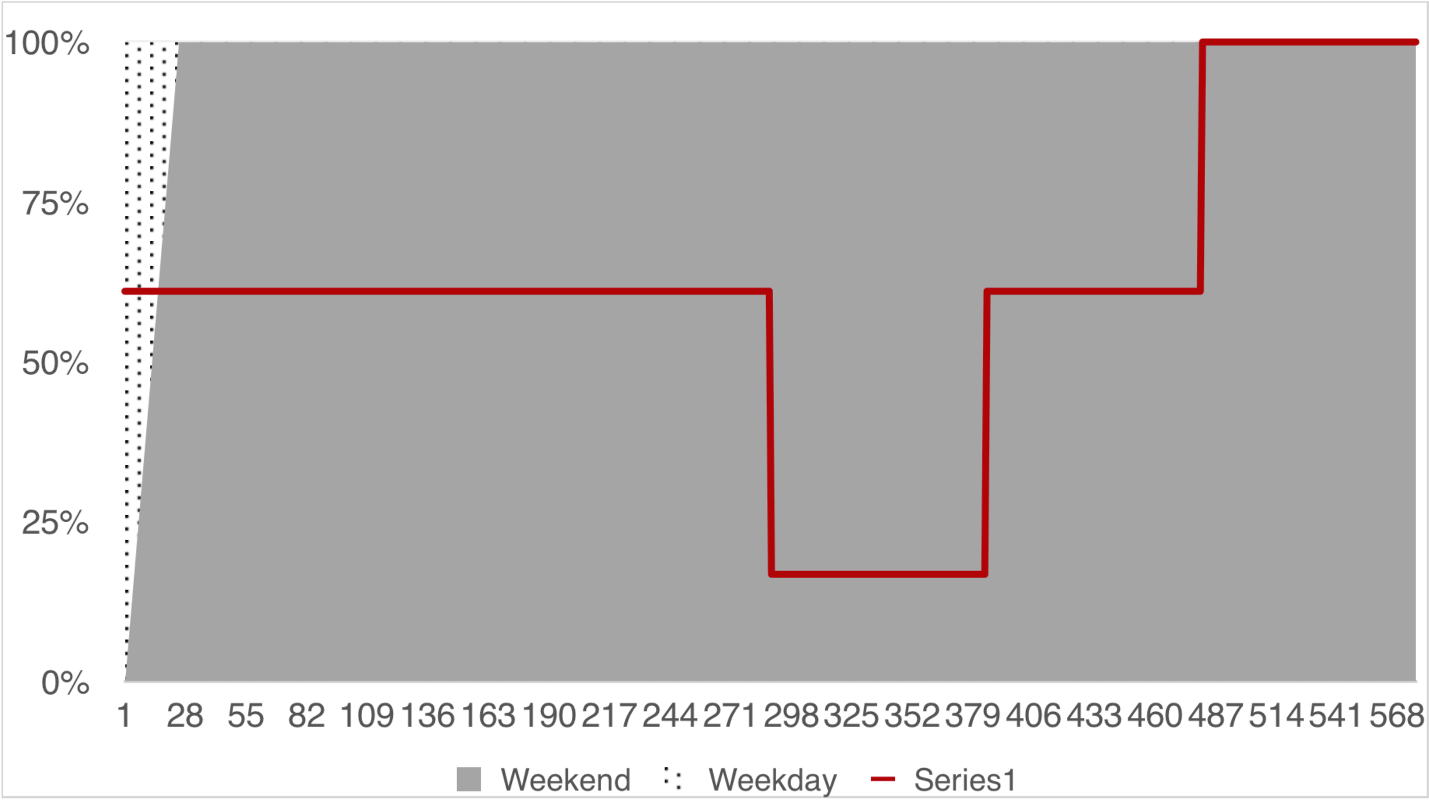
Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Paradise Park solar	Feedstock		Solar	
	Capacity (MW)	37 MW deployed in 2018 (Jamaica Public Service Company 2017c)	0.0	0.0
	Own use rate (% of gross generation)	Captured in availability profile		
	Planned outage rate (% of year)			
	Unplanned outage rate (% of year)			
	Capacity credit (% of capacity)	(Ministry of Science, Technology, Energy and Mining 2013; Worldwatch Institute 2013), based on availability at time of peak load	0.0	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Overnight capital cost (million USD/MW)	(Jamaica Information Service 2016), includes estimated grid connection costs	1.5	
	WACC (%)	(Office of Utilities Regulation 2010)	11.95	
	Construction loan period (years)	SEI assumption	10	
	Fixed O&M cost (thousand USD/ MW)	(National Renewable Energy Laboratory 2016b)	15.1	
	Variable O&M cost (USD/MWh)	(National Renewable Energy Laboratory 2016b)	0.0	
Candidate Technologies				
Combined cycle gas	Feedstock		LNG	
	Gross heat rate (MJ/kWh)	(Office of Utilities Regulation 2010)	7.4	
	Own use rate (% of gross generation)	Assumed same value as for Bogue combined cycle BOCC	3.0	
	Planned outage rate (% of year)	(Office of Utilities Regulation 2010)	7.1	
	Unplanned outage rate (% of year)	(Office of Utilities Regulation 2010)	3.0	
	Capacity credit (% of capacity)	Based on availability at time of peak load	87.1	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Overnight capital cost (million USD/MW)	(Office of Utilities Regulation 2010), includes estimated grid connection costs	1.4	
	WACC (%)	(Office of Utilities Regulation 2010)	11.95	
	Construction loan period (years)	SEI assumption	10	
	Fixed O&M cost (thousand USD/ MW)	(Office of Utilities Regulation 2010)	14.0	
	Variable O&M cost (USD/MWh)	(Office of Utilities Regulation 2010)	2.7	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Combustion turbine diesel	Feedstock		Diesel	
	Gross heat rate (MJ/kWh)	(Office of Utilities Regulation 2010)	10.5	
	Own use rate (% of gross generation)	Average value for existing combustion turbine units	1.3	
	Planned outage rate (% of year)	(Office of Utilities Regulation 2010)	4.9	
	Unplanned outage rate (% of year)	(Office of Utilities Regulation 2010)	3.0	
	Capacity credit (% of capacity)	Based on availability at time of peak load	90.9	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Overnight capital cost (million USD/MW)	(Office of Utilities Regulation 2010), includes estimated grid connection costs	0.9	
	WACC (%)	(Office of Utilities Regulation 2010)	11.95	
	Construction loan period (years)	SEI assumption	10	
	Fixed O&M cost (thousand USD/MW)	(Office of Utilities Regulation 2010)	13.6	
	Variable O&M cost (USD/MWh)	(Office of Utilities Regulation 2010)	4.0	
Combustion turbine gas	Feedstock		LNG	
	Gross heat rate (MJ/kWh)	(Office of Utilities Regulation 2010)	10.5	
	Own use rate (% of gross generation)	Average value for existing combustion turbine units	1.3	
	Planned outage rate (% of year)	(Office of Utilities Regulation 2010)	4.9	
	Unplanned outage rate (% of year)	(Office of Utilities Regulation 2010)	3.0	
	Capacity credit (% of capacity)	Based on availability at time of peak load	90.9	
	Lifetime (years)	(Ministry of Science, Technology, Energy and Mining 2013)	25	
	Overnight capital cost (million USD/MW)	(Office of Utilities Regulation 2010), includes estimated grid connection costs	0.9	
	WACC (%)	(Office of Utilities Regulation 2010)	11.95	
	Construction loan period (years)	SEI assumption	10	
	Fixed O&M cost (thousand USD/MW)	(Office of Utilities Regulation 2010)	13.6	
	Variable O&M cost (USD/MWh)	(Office of Utilities Regulation 2010)	4.0	

Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Lithium ion batteries	Full load hours	(Lazard 2016)	8.0	
	Round-trip efficiency (%)	(Lazard 2016)	92.5	
	Planned outage rate (% of year)	(Lazard 2016)	2.1	
	Unplanned outage rate (% of year)	(Lazard 2016)	2.1	
	Capacity credit (% of capacity)	Based on availability at time of peak load	95.9	
	Lifetime (years)	(Lazard 2016)	20	
	Overnight capital cost (million USD/MW)	(Lazard 2016), includes estimated grid connection costs	6.4	4.0
	WACC (%)	(Office of Utilities Regulation 2010)	11.95	
	Construction loan period (years)	SEI assumption	10	
	Fixed O&M cost (thousand USD/MW)	(Lazard 2016)	67.5	41.8
	Variable O&M cost (USD/MWh)	(Lazard 2016)	0.0	
Medium speed ICE oil	Feedstock		Residual fuel oil	
	Gross heat rate (MJ/kWh)	(Office of Utilities Regulation 2010)	8.3	
	Own use rate (% of gross generation)	Assumed same value as for Rockfort oil steam RF1	2.8	
	Planned outage rate (% of year)	(Office of Utilities Regulation 2010)	4.9	
	Unplanned outage rate (% of year)	(Office of Utilities Regulation 2010)	4.0	
	Capacity credit (% of capacity)	Based on availability at time of peak load	88.5	
	Lifetime (years)	(Office of Utilities Regulation 2010)	25	
	Overnight capital cost (million USD/MW)	(Office of Utilities Regulation 2010), includes estimated grid connection costs	1.8	
	WACC (%)	(Office of Utilities Regulation 2010)	11.95	
	Construction loan period (years)	SEI assumption	10	
	Fixed O&M cost (thousand USD/MW)	(Office of Utilities Regulation 2010)	78.9	
	Variable O&M cost (USD/MWh)	(Office of Utilities Regulation 2010)	14.8	

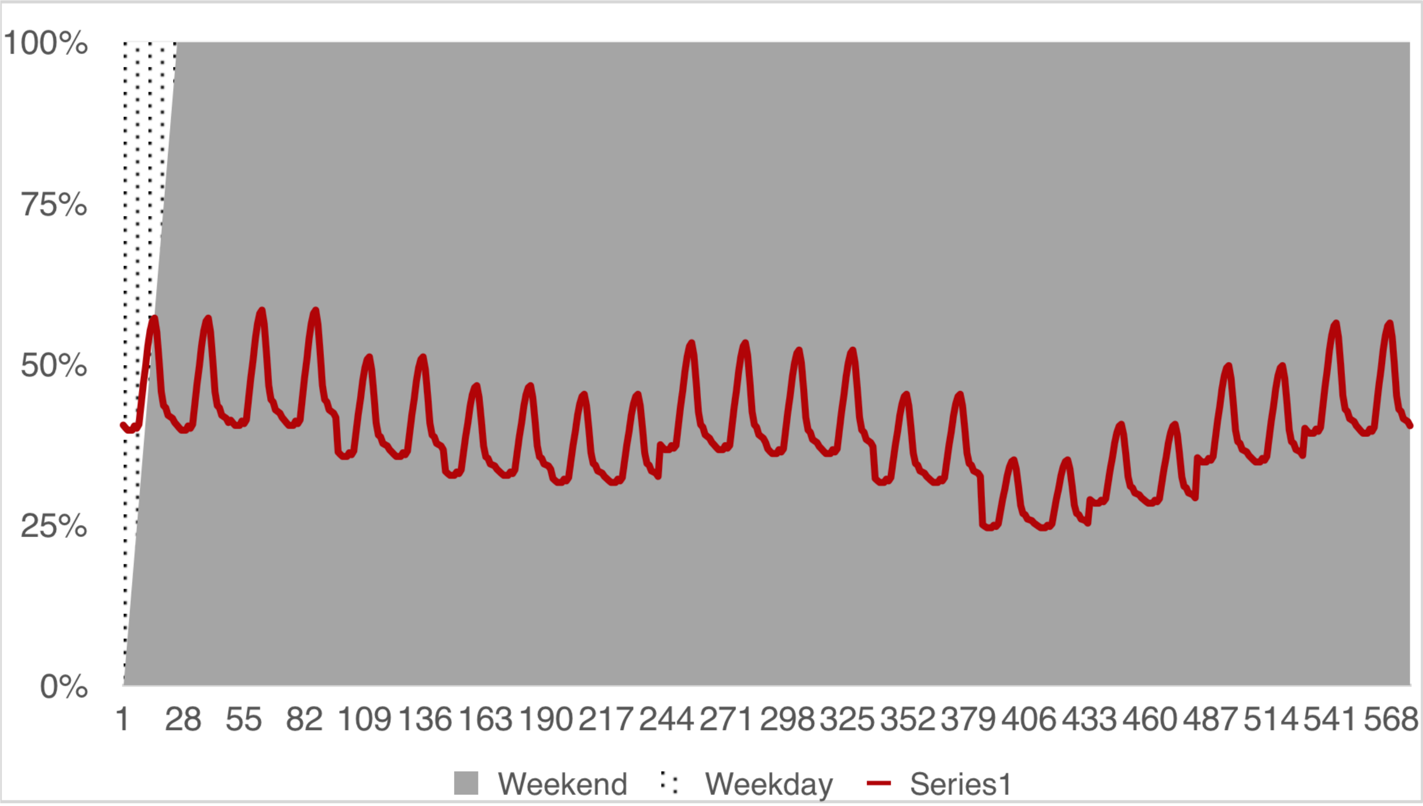
Facility or Technology	Input	Sources and Notes	Values	
			2017	2055
Existing Facilities				
Slow speed ICE oil	Feedstock		Residual fuel oil	
	Gross heat rate (MJ/kWh)	(Office of Utilities Regulation 2010)	7.4	
	Own use rate (% of gross generation)	Assumed same value as for Rockfort oil steam RF1	2.8	
	Planned outage rate (% of year)	(Office of Utilities Regulation 2010)	4.9	
	Unplanned outage rate (% of year)	(Office of Utilities Regulation 2010)	4.0	
	Capacity credit (% of capacity)	Based on availability at time of peak load	88.5	
	Lifetime (years)	(Office of Utilities Regulation 2010)	25	
	Overnight capital cost (million USD/MW)	(Office of Utilities Regulation 2010), includes estimated grid connection costs	2.6	
	WACC (%)	(Office of Utilities Regulation 2010)	11.95	
	Construction loan period (years)	SEI assumption	10	
	Fixed O&M cost (thousand USD/MW)	(Office of Utilities Regulation 2010)	91.3	
	Variable O&M cost (USD/MWh)	(Office of Utilities Regulation 2010)	9.2	

FIGURE 01: AVAILABILITY PROFILE FOR CANDIDATE SMALL HYDRO, BASELINE SCENARIO



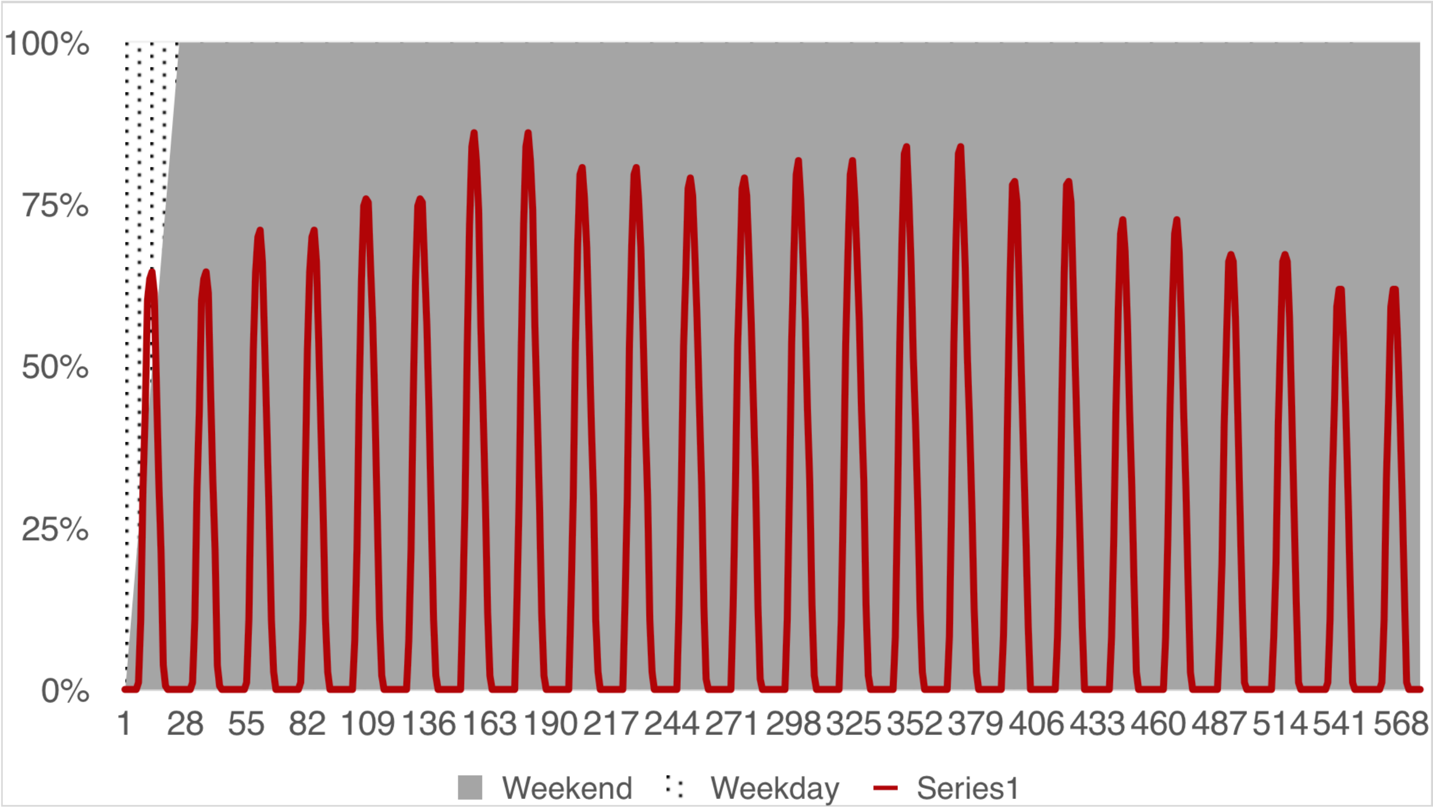
Source: (Ministry of Science, Technology, Energy and Mining 2013)

FIGURE 02: AVAILABILITY PROFILE FOR CANDIDATE ONSHORE WIND, BASELINE SCENARIO



Source: (Ministry of Science, Technology, Energy and Mining 2013; Worldwatch Institute 2013)

FIGURE 03: AVAILABILITY PROFILE FOR CANDIDATE SOLAR PV, BASELINE SCENARIO



Source: (Ministry of Science, Technology, Energy and Mining 2013; Worldwatch Institute 2013; aleo solar AG 2010)

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